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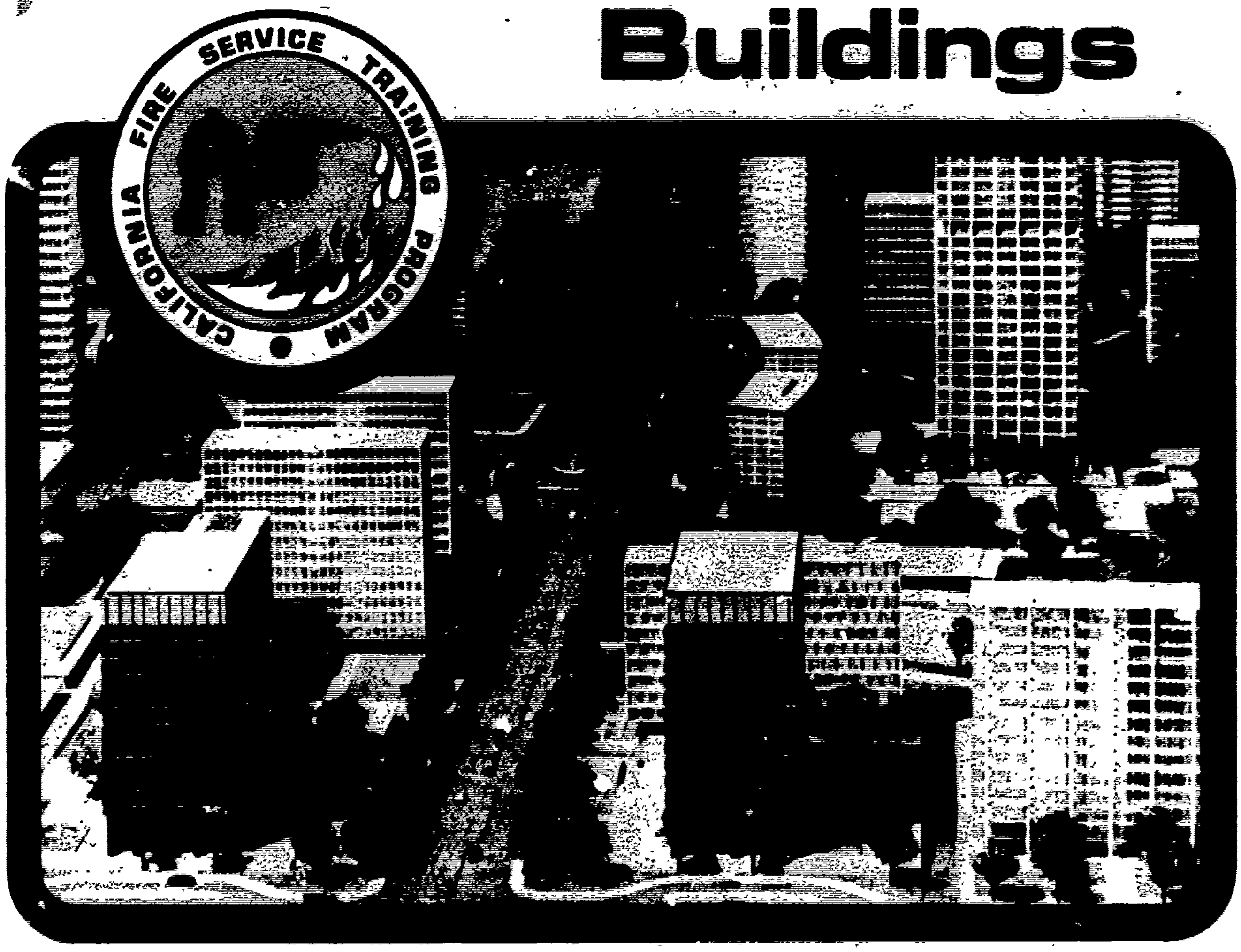
ABSTRACT

Resulting from a conference concerned with high-rise fire problems, this manual has been prepared as a fire department training manual and as a reference for students enrolled in fire service training courses. Information is provided for topics dealing with: (1) Typical Fire Problems in High-Rise Buildings, (2) Heat, (3) Smoke and Fire Gases, (4) Life Hazards, (5) Exposure Problems, (6) Water Supplies, (7) Access Problems, (8) Logistics Problems, (9) Coordination Problems, (10) Communications Problems, (11) Salvage and Overhaul, (12) Loss of Electrical Power, (13) Smokeproof Stairways, and (14) Special Problems. A tactical checklist and glossary are appended. (SB)

Fire Problems in High-Rise Buildings



CALIFORNIA STATE DEPARTMENT OF EDUCATION, Wilson Riles, Superintendent of Public Instruction, Sacramento, 1971

Fire Problems in High-Rise Buildings

CALIFORNIA FIRE SERVICE TRAINING PROGRAM

Prepared by
BUREAU OF INDUSTRIAL EDUCATION
Fire Service Training Staff

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FOREWORD

One meaning of the word education is training by formal instruction and supervised practice, especially in a trade, skill, or profession. This is the kind of education that is being provided by the California Fire Service Training Program. Through this program fire fighters in California are continuing to acquire the knowledge and skills required by their profession.

Cooperation makes this training program work. The Department of Education, which provides instructional materials and supervision for the program, cannot do the job alone. The success of the program comes from the cooperation of everyone involved: supervisors, teachers, and participants.

An important part of a fire fighter's training in protecting life and property from destructive fires is knowing how to combat fires in high-rise buildings, the subject of this publication. As high-rise buildings become more numerous in our urban areas, the unique problems associated with fires in these buildings demand more attention. The intent of this publication is to provide fire fighters with the information they need to cope with these problems.

Wilson Riles

Superintendent of Public Instruction

PREFACE

This manual, *Fire Problems in High-Rise Buildings,* is another in a series of publications prepared by the California Fire Service Program staff for use as (1) a fire department training manual, and (2) a reference for students enrolled in fire service training courses.

The basic content of this manual was determined at the Conference on High-Rise Fire Problems, which was held as part of the Fire Training Officers' Workshop, Group V, conducted in Fresno in 1967. Assistant Chief Benjamin F. Renfro, Los Angeles City Fire Department, was later asked to develop the basic ideas proposed at the conference. This publication is the result of his work.

Chief Renfro is a division commander in an industrial, manufacturing, commercial, and residential area of 88 square miles and a million inhabitants. He has responsibility for fire suppression in the congested high-value district in the City of Los Angeles and the many high-rise buildings located in Hollywood. He has developed fire tactics and strategy that have been used effectively in combating many fires in high-rise buildings. Since 1964 he has conducted numerous large-scale training exercises for fire fighters in buildings 20 or more stories high. Chief Renfro has also been instrumental in developing legislation designed to solve some of the problems encountered when fires occur in high-rise buildings.

Other contributors to this publication include Fireman Ernie Bilsland, who created the cartoon illustrations, and the Los Angeles City Fire Department, which supplied the photographs. Direction for the publication was provided by Carlton H. Williams, Instructor of Fire Service Training, California State Department of Education.

More is being learned continually about problems associated with fires in high-rise buildings. The fire fighter who wants to keep informed about these problems should supplement study of this publication with other activities.

He should read articles dealing with fires in high-rise buildings, and he should pay close attention to the high-rise buildings in the area in which he works. He should notice innovations in construction and new materials being used. Only by such study and observation can the modern fire fighter keep up with developments that affect fire prevention and control.

EUGENE GONZALES
Associate Superintendent of Public Instruction; and Chief, Division of Instruction

JAMES A. HERMAN
Chief, Bureau of Industrial Education

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Supervisor of Fire Service Training

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Introduction

The term "high-rise" is a newspaper term coined to describe buildings taller than those that people are accustomed to seeing. As buildings grow taller, the parking needs of tenants and guests require more space underground. Service facilities for tenants and shops for building maintenance are also placed in basements.

In most areas buildings are considered to be high-rise structures if they contain special fire-protection devices such as dry, wet, or combination standpipes that are built into the buildings for fire department use. In some cities additional fire-protection systems are built into buildings taller than 150 feet. A wet standpipe system, automatically pressurized by a fire pump upon demand, is generally included within the structure; it is commonly called a combination standpipe. Some fire departments designate only those buildings equipped with combination standpipes as high-rise buildings.

The banking industry defines a high-rise building as one with a minimum height of five floors above ground and a building permit valuation of $500,000 or more per structure. Under this definition the following figures show the tremendous growth of high-rise buildings completed in southern California from 1960 to 1969:[1]

Number of stories	*Number of buildings*
5 to 9	448
10 to 19	183
20 to 29	31
30 or more	8
Total	670

The 670 buildings were valued at more than $2,400,000,000.

Additional growth in the form of multistory buildings has taken place in many other California counties not included in the survey. The economics of land use dictates that this growth in the construction of tall buildings will continue throughout the state. Apparently, no fire department in any county, community, or incorporated city in a growth area can escape being involved with fire problems in high-rise buildings. Involvement with fire problems in tall buildings can occur either within a fire department's own jurisdiction or in another jurisdiction by reason of mutual-aid agreements.

A common definition for high-rise buildings is needed. Generally speaking, the buildings in California that have extra protection in the form of standpipes are those four stories in height and above. For the purpose of this manual, therefore, the term "high-rise" refers to any building containing four or more stories above ground level.

[1]The source of these figures is the 1960-69 survey conducted by the Economic Research Department, Security Pacific National Bank, Los Angeles.

TOPIC 1

Typical Fire Problems in High-Rise Buildings

This topic, "Typical Fire Problems in High-Rise Buildings," is planned to provide answers to the following questions:

- What are some of the difficulties involved in locating fires in high-rise buildings?
- What are some things to be considered in gaining access to fires in high-rise buildings?
- What are the effects of smoke on interior fire-fighting operations in high-rise buildings?
- How may the time factor affect fire-fighting operations in high-rise buildings?

High-rise buildings create fire-fighting problems that are unique. Activities that are relatively simple when fires in small structures are being dealt with – locating the fire, getting into the building, and conducting operations – become more difficult when the fires are located in high-rise buildings. Fire behavior, smoke-spread characteristics, and the extra time required to conduct every phase of fire fighting are also significant factors to be reckoned with.

Locating the Fire

The first problem that fire fighters encounter on their arrival at an alarm in a high-rise building is locating the fire. In smaller structures the fire is usually readily visible. As the size of a structure increases, however, sources of information other than sight become significant; the larger the building, the greater becomes the probability that informat on may be misleading or incomplete.

Human Error

Information received regarding the location of the fire may be inaccurate. For example, a person who rides an elevator to a given floor and encounters smoke when the elevator door opens is most likely to report a fire on that floor. The actual fire may be several floors away from the location he reports.

Mechanical Error

Mechanical devices such as supervised heat-actuated devices (HAD) may operate on a floor high above the fire where heat accumulates and thus transmit a false fire-floor location. This transmission can occur before alarm devices are activated on the fire floor. Similarly, because most tall buildings are occupied by many tenants, some floors may be protected by HAD while others may not be protected by an alarm or detection system. In the event a fire is reported only by an automatic device, therefore, a false location signal may be transmitted.

Physical Evidence

Physical evidence of a fire does not necessarily mean that the fire started on a given floor or that it is contained on that floor. It may have spread from floors below through concealed spaces such as vertical ducting or improperly sealed "poke-through construction," to be discussed later in this topic. A minor fire discovered on one floor may be the only visible evidence of a major fire on a lower floor. Smoke pouring from a ventilating or air-conditioning outlet on any given floor does not necessarily indicate that the fire is on that floor, and smoke emitting from such an outlet should not lead the fire fighter to the assumption that the fire is contained within system ducting.

Getting into the Building

Gaining access to fires is so important a concern that an entire topic (Topic 7) in this publication is devoted to a discussion of access problems and solutions. This section, however, deals only with getting into the fire building.

Normal Access

External access to high-rise structures can be very limited. Building setbacks, landscaped areas, reflecting pools, and weak structures covering underground parking and service areas can severely limit an approach to a building by aerial-ladder trucks. Sealed windows may have to be broken, and the breakage can create a hazard for firemen in the area.

Unless the fire floor can be readily reached by fire department ladders, access through the lobby or basement to the interior stairways and elevators is the most practical approach. The storefront-type, tempered-glass double doors that are commonly used in lobby entrances should not be broken if the building is locked and there is no other means of access. These doors are very expensive to replace, and a minimum of three weeks is required to get them from the manufacturer. A better procedure is to break out a large plate-glass window (see Fig. 1-1).

Fig. 1-1. Large plate-glass window that may be broken to enter

Access to Basements

Most high-rise buildings have an exterior stairway that leads from basement areas to the outside at grade level. It is separate from all other stairways and is generally remotely located; the entrance may be as far as 150 feet from the face of the building. Access to this basement stairway shaft is comparatively simple (see Fig. 1-2). It is generally protected by an easily opened, plain-wood door since codes do not require "rated" fire doors on this type of remote building exit. Once inside the basement, access to the entire building via elevators and interior stairways is relatively easy.

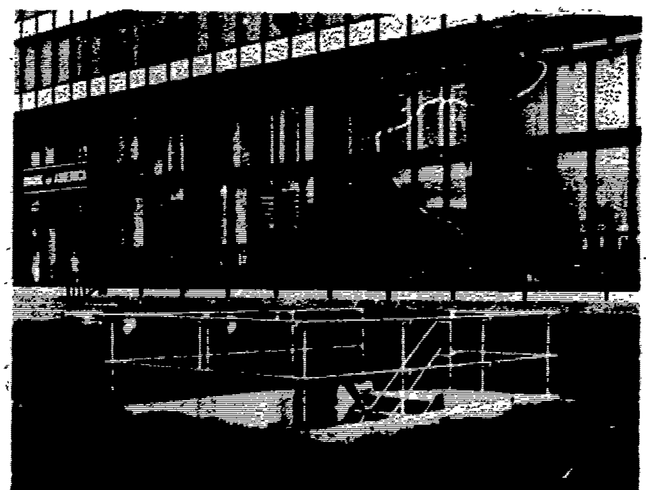

Fig. 1-2. Exterior stairway leading into basement

Getting to the Fire Floor

In some cases gaining access to individual floors may be just as difficult as gaining access to the building.

One-Way Doors

Required exit doors must be capable of being opened from the inside without the use of a key or any special knowledge or effort. In most cases, however, they are locked on the outside. In multiple-occupancy buildings access into the interior of any floor from stair-shafts requires a key. Tenants are issued keys that permit access only to their particular floors. Therefore, doors may be keyed differently on each floor. Access to various floors by firemen may be gained, therefore, only by the use of master stairway keys or by forcible entry to each floor where access is required. Master keys are sometimes available from maintenance personnel who may be on the scene.

A lock-stop device has been developed in Los Angeles and other cities that allows fire fighters the two-way use of locked stairshaft doors once they have been opened. These lock-stop rubbers, applied over the door knobs, prevent the engagement of the locking device (see Fig. 1-3). Fire fighters usually carry the rubbers in the pockets of their turnout coats.

Fig. 1-3. Lock-stop rubber fastened to knob of stairway door

If keys are not immediately available, a forcible entry can easily be made by using a radial saw to cut off the locking latch. Generally, the latch can be cut without damage to the door.

Partial Stairways

Partial stairways are those that serve only certain floors rather than an entire building. They are generally unlabeled and may dead-end on any floor. Therefore, knowing which stairways reach to the desired floor and knowing how to get from one stairway to another are necessary requirements for effective fire-fighting operations.

Scissor Stairways

The scissor stairway, a new architectural development designed to provide more usable space, sometimes has an intricate, repetitive stair pattern that can severely complicate fire-fighting and rescue operations (see Fig. 1-4). In some instances scissor stairways do not serve each floor but only alternate floors. Thus, access to the fire floor via a scissor-stairway system may be impossible.

Some stairways that start out as conventional stairways high in a building become scissor-type at lower levels as the accumulative occupant load requires additional exit width to evacuate people. In other types of scissor-stairway installations, each floor is served. A common landing space used between floors is the space-saving device. Unless the doors or landings of every type of stairway are numbered, occupants and firemen cannot readily determine the height of the floor on which they are located.

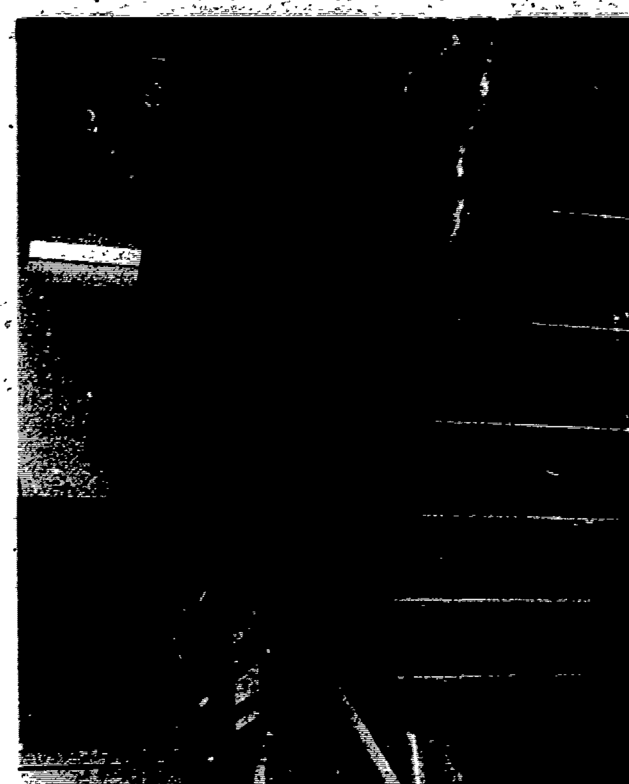

Fig. 1-4. Typical scissor stairways

Blank Elevator Shafts

Blank elevator shafts (those that do not have openings on every floor) are found in many tall buildings. Some elevators in this type of construction may serve only the first ten floors; others may serve the eleventh through the twentieth floors, the twentieth through the thirtieth floors, and so on.

Many buildings are not provided with signs in the lobby indicating which floors are served by various elevators. Accurate information regarding which elevators to use to reach various floors is vitally necessary during fire operations. Fire fighters should be trained to check the indicator panels inside each elevator to determine which floors it serves. Arriving at the wrong location on programmed elevators not only wastes valuable time but also may expose fire fighters to unnecessary danger.

Operating in the Building

After access has been gained to the building and fire floor, still other unique problems can occur in fighting fires in high-rise buildings.

Ordinary Buildings

In ordinary buildings having windows that can be opened, some smoke leakage can usually be seen from the outside of the building. This leakage generally aids the officer in charge when he sizes up the fire problem. The fire floor and other areas where the smoke is accumulating can be spotted quickly.

Dense smoke, which affects operating visibility, can be reduced rather easily by proper ventilation tactics in this type of building. When smoldering fires are being dealt with in which the heat level has not built up sufficiently to create a stack effect, cross ventilation of smoky floor areas is expedited by the opening of windows. Ventilation tactics should take advantage of any natural breeze.

Buildings with Sealed Windows

A building with sealed windows (like windshields on automobiles) contains all the products of combustion until fire fighters do something to release them. Although no exterior leakage occurs through sealed windows, leakage does occur from floor to floor within the building.

As smoke increases, visibility decreases. Because smoke is trapped within a sealed building, visibility during a smouldering fire may be reduced to a few feet even though strong lights are used. Finding the fire under these conditions is extremely difficult. Men operating in teams and wearing self-contained breathing apparatus are required to locate the fire floor and the fire.

Windowless Buildings

Windo[illegible] [illegible]ings create the same problems as [illegible]gs with sealed windows. In addition, windowless buildings shut out natural light. Fire fighters must, therefore, use artificial lights for all fire-fighting activities, from finding the fire floor and fire through completing salvage and overhaul operations.

Concealed Areas

Pipe and duct shafts, spaces housing plumbing or electrical runs, and various other ducting systems are difficult to locate under fire conditions. They also contribute to smoke and fire spread. Prefire planning is necessary to gain knowledge of the construction of buildings. Many modern buildings contain on each floor, above a hanging ceiling, concealed space equal in area to the entire surface of the floor. In this concealed space all electrical, plumbing, and ducting systems for a particular floor are placed above a hanging ceiling (see Fig. 1-5). The aver-

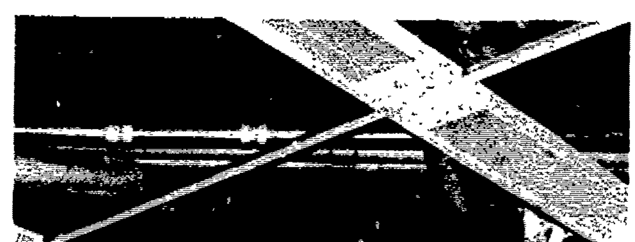

Fig. 1-5. Concealed space above hanging ceiling

age depth of the concealed space is 30 inches. In many cases this enclosed area is used as a return-air plenum for air-conditioning systems. In most buildings a small utility room on each floor provides space for the ducting systems ser[illegible]d floor to be connected to the master system. These rooms are positioned one above the other and, therefore, are in the same area on every floor.

Combating Smoke Spread

Smoke threatens the lives of occupants in a fire building and hinders fire-fighting operations. Firemen must know how smoke spreads and what effects it has on building occupants.

Vertical Spread

Since heated smoke rises, vertical distribution of smoke through any opening must be anticipated. Open-stair shafts, elevator shafts, and floor-to-floor air-conditioning systems are the main channels that carry smoke. The newest type of construction, in which attic spaces on each floor hide the utility services for the floor above, has created new exposure problems for the fire service. In theory each floor acts as a concrete barrier to fire from every other floor. Holes (generally five inches in diameter) are cut through floors as various utilities are connected. In this manner utilities are let in on any given floor from the concealed space below.

Voids around piping and ducting installed in "poke-through construction" holes generally are required to be sealed with concrete. In practice, however, much of this concrete resealing is left undone (see Fig. 1-6). As a result many fire-resistive buildings are literally punched full of holes. Improperly sealed "poke-through" construction also permits passage of smoke from floor to floor. In sealed buildings, where there is no possible leakage to the outside, experience has shown that smoke will be found on at least three floors even when only a minor fire on one floor is in progress. After many floors have become smoke-filled, finding the fire floor becomes a major operation.

Horizontal Spread

In addition to traveling through hallways, smoke may spread horizontally through connecting ducts, concealed spaces, and, in modern buildings, through air-conditioning systems. Some modern air-conditioning systems use common attic spaces as return-air plenums; the spread of smoke horizontally through these plenums is very rapid. The reason for the rapidity of the smoke spread is that the smoke, cooled by the air-conditioning system, does not rise as it normally does but instead spreads horizontally.

Effects of Drafts

Heating and air-conditioning systems form natural channels for the distribution of smoke. The forced drafts developed within such systems may spread the smoke from floor to floor throughout the building (see Fig. 1-7). The systems must be shut down quickly to prevent the rapid spread of smoke.

Fig. 1-6. Unsealed voids around piping

Fig. 1-7. Forced drafts spreading smoke

Effects of Smoke

Heavy smoke may delay certain necessary operations. Smoke is a problem because it is toxic and reduces visibility. Rapid ventilation is not possible in modern buildings. Rescue operations by properly equipped firemen must be conducted quickly, and as much ventilation as possible must be provided to reduce the hazard to life. If manpower is sufficient, these operations should be carried out in conjunction with the attempt to locate and extinguish the fire.

Regardless of its temperature, smoke increases the urgency of rescue operations. Building occupants who are trapped within an area of the building because of lack of visibility will succumb unless rescued promptly.[1] The problem of smoke toxicity is magnified in sealed buildings because there is no natural ventilation.

Dealing with Time

Time is the most important element that the fire service must deal with. Experience has shown that fires in high-rise buildings require somewhat abnormal manpower and equipment commitments. In fact, a National Fire Protection Association (NFPA) study of 50 fires in high-rise buildings without sprinklers revealed that a force of 60 to 90 men was required.[2] The extra time necessary to get this quantity of manpower and the necessary supportive equipment to the scene and into operation on upper floors can be a serious factor. The fire commander who neglects to anticipate what the fire will do and where it will go during the time between his arrival at the scene and the start of a coordinated effort to cope with the fire will make an inadequate estimate of the situation. As a result. his strategy in handling the fire will be faulty, and a higher fire loss will occur.

Manpower Requirements

The extent of fire loss is determined by the time required to locate a fire and to begin combating it. Fire departments may be severely taxed to supply the number of men needed to search a smoke-filled multistory building quickly and to commence fire-fighting operations. As buildings grow taller, the manpower requirements become more critical. Since in many areas fire departments have not been able to keep up with the growth of their community, the development of mutual-aid agreements to supply the manpower needed to cope with an expected fire problem may be a vital necessity.

Equipment Requirements

The availability of equipment such as self-contained breathing apparatus, forcible-entry tools, and lights, together with sufficient reserve air supplies and power sources, must be evaluated (see Fig. 1-8 and Fig. 1-9). The time element is critical (1) in obtaining the necessary

[1]See *Operation School Burning* [No. 1]. Prepared by the Los Angeles Fire Department. Boston: National Fire Protection Association, 1959, pp. 28-31. See also *Operation School Burning No. 2.* Prepared by the Los Angeles Fire Department. Boston: National Fire Protection Association, 1961, pp. 25-35.

[2]See Horatio Bond, "Sprinkler Protection for High-Rise Buildings," *Fire Journal* (November, 1968), 3-10.

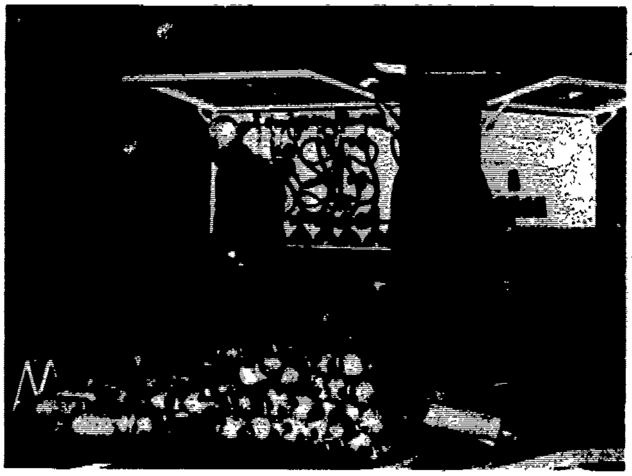

Fig. 1-8. Reserve tanks for breathing apparatus

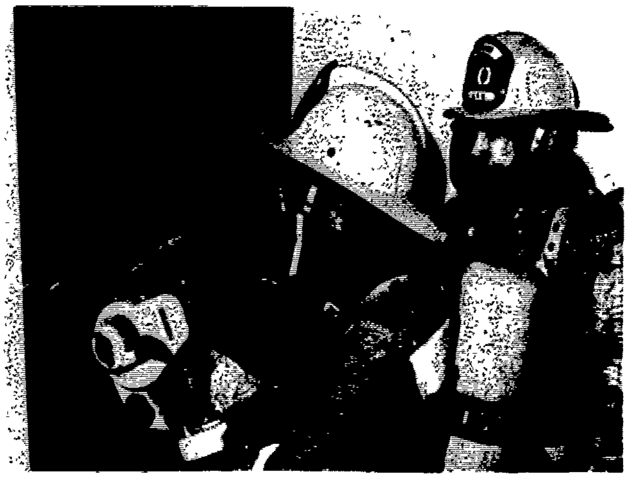

Fig. 1-9. Forcible entry made with power saw

equipment and transporting it to the upper floors; and (2) in obtaining replacements necessary to keep the men effectively equipped and supplied. Fire fighters who are equipped improperly or inadequately are unnecessarily handicapped in the performance of their duties.

TOPIC 2

Heat

This topic, "Heat," is planned to provide answers to the following questions:

- How does heat build up in high-rise buildings?
- What exposure problems are caused by heat?
- What are the effects of heat on life safety?
- What effect does heat have on fire-fighting operations?
- How does heat affect building materials?

Heat and Heat Transfer

Heat and heat transfer are responsible for the start, spread, and eventual extinguishment of most fires. Heat also contributes to the number of deaths as a result of fire. Accurate statistics are not available regarding fire deaths; however, available records show that more fire fatalities are caused by the inhalation of hot fire gases and hot air than by all other causes combined.[1]

Confinement of Heat

There is practically no leakage of heat from sealed buildings under fire conditions. On the other hand, there is some leakage in older structures with windows that can be opened. This leakage, however, serves to dissipate heat only during the early stages of a fire. Once the rate of heat evolution exceeds the leakage rate, controlled ventilation must be utilized in buildings of all types to reduce the problems created by accumulated heat.

Mushrooming Process

Heat rises because heated gases expand and weigh less than normal atmospheres. Fires, therefore, develop thermal columns. Within buildings, heat and products of combustion rise through interior openings and spread out at the highest level to which they have access. A process called "mushrooming" thus begins. Unless ventilation is accomplished, accumulated heat will bank down and fill floor after floor with smoke and heated fire gases. Entire buildings have become filled with heat and fire gases by this mushrooming process.

Residual Heat

After a fire has been extinguished and the building ventilated, any residual heat accumulated in structural assemblies and contents will be given off. Controlled ventilation of residual heat is necessary to prevent damage in areas not previously exposed. During salvage and overhaul operations, unnecessary losses have been caused by residual heat when fire fighters have opened doorways between heated and previously unexposed areas.

Back-Draft Potential

When sufficient heat is confined in an area, the temperatures of combustible materials are raised to their ignition point. The materials will not ignite, however, unless sufficient oxygen is available to support combustion. In this situation, a very dangerous condition exists. Top ventilation must be provided to release superheated fire gases and smoke. Since it is axiomatic that fire intensity is always controlled by the rate of air supply, the admittance of an air supply (which provides the necessary oxygen) is all that is needed to change the overheated area into an inferno. This sudden ignition is often referred to as a smoke explosion or back draft.

Fire fighters must be aware of this explosion potential and must proceed cautiously in areas where excessive amounts of heat have accumulated. During fire-fighting or rescue operations,

[1] *Fire Protection Handbook* (Thirteenth edition). Edited by George H. Tryon and Gordon P. McKinnon. Boston: National Fire Protection Association, 1969, pp. 1-6 and 1-7.

doors should be opened slightly and carefully so they may be closed quickly, if necessary, to shut off the air supply to extremely hot areas. Before top ventilation is attained in sealed buildings, overheated areas may be partially cooled by the use of spray streams operated through small holes cut in doors.

Flashover Potential

In areas that are not hot enough to result in a back draft, other flash-fire problems may exist. Acoustical tile, hardwood paneling, and similar materials located near the ceiling may be raised to their ignition temperatures before the rest of the combustible materials in the area become hot enough to burn. This flash-fire potential exists even though materials may carry a low flame-spread rating. When preheating occurs, the material is gradually raised to its ignition temperature; the low flame-spread rating of the material is thus nullified. If sufficient air is available, a flash fire or flashover occurs across the entire overheated surface. Whenever temperatures at shoulder level are uncomfortable for fire fighters, a flashover potential may exist. Ceiling areas should be immediately cooled with spray streams to reduce this potential.

Exposure Potential

In most accidental fires, fortunately, convected heat is visible because of the smoke particles it carries. As fire fighters deal with the smoke problem, they automatically reduce the convected-heat problem. Such is not the case with the other two problem areas of heat transfer – conduction and radiation.

In theory, multistory buildings are built so that each floor forms a compartment. These floors may be further divided into smaller compartments or cubes. Heat can be transferred from a fire-involved cubicle in six directions by one or more methods of heat transfer: convection, conduction, and radiation (see Fig. 2-1). Heat transfer by conduction and radiation can be a serious consideration in this case, and the fire-resistive integrity of each compartment must be evaluated.

The extension of heat into adjacent taller structures must be prevented. Convected and radiated heat may expose other buildings when fire fighters ventilate the fire building. Windows must be closed to stop convected heat, and water curtains may be necessary to reduce the effects of radiated heat. Hose lines, laid inside exposed buildings, may be required to prevent fire spread or extinguish fires caused by the extension of heat.

Floor-to-floor extension of heat can occur when windows on the fire floor are open and windows on floors above are open or unprotected by hose streams. Even when flames do not lap from floor to floor, heat and smoke damage may still occur.

Effects of Heat on Operations

Heat generated in the fire building seriously affects the entire fire-fighting operation.

Fatigue

In heated atmospheres men tire much more quickly. Reserve personnel must be available to relieve fatigued men at frequent intervals.

Steam

Condensing water vapors (steam) decrease visibility and create high humidity. Unless prompt ventilation is accomplished, this hot, humid condition will exist for long periods of time in sealed buildings. Since heated atmospheres are much more of a health hazard when moisture is present, fire fighters must not work in hot, humid atmospheres without self-contained breathing apparatus and protective clothing.

Smoke and Fire Gases

Until overheated combustible materials cool, they will continue to generate smoke and fire gases. Overheated areas must be ventilated to reduce the effects of distillation of trapped heat.

Access

Heat can prevent access to various floors or compartments of a multistory building. In most cases access to the seat of fire in superheated structures must be delayed until ventilation is accomplished. During such a delay the situation within the building continues to become more dangerous.

Rescue Operations

Life-threatening problems on upper floors are caused by the mushrooming effect of convected heat. In sealed buildings heat can build up on

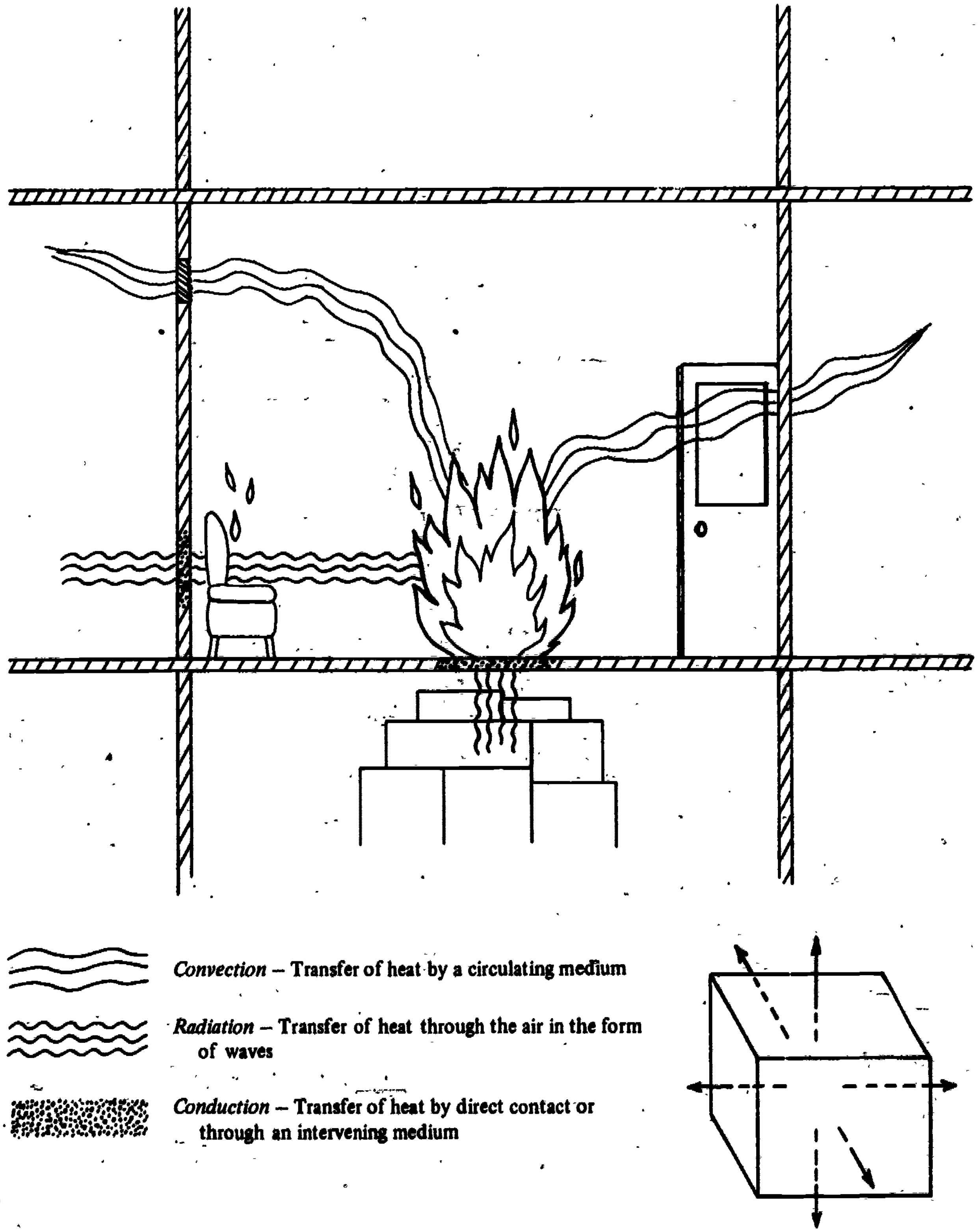

Fig. 2-1. Kinds of heat transfer

upper floors to a point where life cannot exist. Various professional estimates place the survival point between 105 degrees and 300 degrees F. if the air is dry, and within a much narrower range when there is moisture in the atmosphere.[2] Human beings cannot inhale more than one or two breaths of hot, moisture-saturated air without serious consequences. What is essential is quick ventilation to rid the building of the heat before it becomes dangerous to life.

Life Hazard

Various studies suggest that firemen should not enter atmospheres exceeding 120 to 130 degrees F. without special protective clothing and breathing apparatus.[3] However, fire fighters in self-contained breathing apparatus and full protective clothing can tolerate higher levels of heat for short periods of time.

Time Factor

Operations in multistory buildings take longer than the same operations performed at ground level. The time required to get into operation in such buildings compounds the heat problem. Heat is continually being generated by the fire. If heat is confined in the building, smoke and fire gases are being distilled out of combustibles. Thus, more and more areas are exposed, and more materials become preheated. Under these conditions fire losses increase rapidly during the time required to reach and control the fire.

Heat Damage

Heat damage can occur in areas remote from the fire. This damage usually occurs on floors above the fire floor or in the top of the building when mushrooming develops. Heat accumulations have caused automatic sprinklers to release on floors above the fire floor, thereby causing widespread water damage and salvage problems on intervening floors.

Heat accumulations have caused heat-actuated fire-alarm systems to report false locations for the real fire. It is extremely hazardous to respond to an alarm on a floor high above the actual fire floor before control of the vertical passageways in the building has been established. Vertical passageways may be controlled by ventilation, closed doors, and the use of hose streams to prevent flames, heat, smoke, and fire gases from extending into the passageways. Pre-fire planning should include identification of the areas protected by automatic fire alarms and consideration of the possibility of false messages.

Structural Damage

Structural damage caused by heat includes distortion of structural components, partial or complete structural collapse, and concrete spalling.

Distortion of structural components. The distortion of unprotected metals exposed to excessive heat is well known. Little is known, however, about the behavior of steel members protected by lightweight insulation. This is a new type of insulation, blown into place with pressure guns. Unless applied carefully, voids or "holidays" can develop in the protective covering. Some of the materials used are easily chipped out or damaged during construction and alteration operations. Distortion of steel components, thus exposed, can occur under fire conditions. Building inspectors should be encouraged to insist on complete coverage of structural steel as specified in building codes when buildings are under construction or alteration.

Collapse of structures. If a fire occurs while a building is under construction, collapse of the structure (partial or complete) may occur. Large fire losses have occurred because of the failure of exposed structural steel. Unless the steel members are cooled, this failure can occur in less than 15 minutes.[4] Collapse of prestressed concrete members in which a relaxation in reinforcing steel has taken place is also possible. The failure, however, is generally preceded by a noticeable sag in the affected members.

Concrete spalling. Spalling occurs when heat turns into steam the minute quantities of water contained in concrete. The expansion ratio of water to steam (about 1 to 1,700) causes minor explosions to occur within the concrete. Chips of concrete are then dislodged with enough

[2]See William D. Claudy, M.D., *Respiratory Hazards of the Fire Service.* Boston: National Fire Protection Association, 1957, pp. 116-17.

[3]*Ibid.*

[4]*Fire Protection Handbook, op. cit.*, p. 8-118.

force to create a hazard to nearby personnel. Cooling extremely hot areas with fog or spray streams can prevent spalling of concrete and reduce the hazard to personnel and structural damage as well.

Failure of Nonferrous Pipe

Water flowing through copper piping carries away the heat that would otherwise melt soldered joints. However, when the water does not flow, pipes frequently separate during a fire. Nonferrous piping is frequently installed in walls, and a hidden separation can occur. Generally, the first indication of pipe failure is a disproportionate amount of water accumulating on floors below the fire.

Glass Failure

Nonwired or plain glass checks and cracks under moderate heat conditions (1,000 to 1,200 degrees F.) and becomes easily dislodged from its frame. When window panes are dislodged, uncontrolled ventilation channels are formed. Fire fighters should be aware of the problems, such as life hazard, fire spread, and heat damage, that can be caused by uncontrolled channels through which fire, heat, and smoke may travel.

Failure of Accessory Supports

Numerous accessories may be installed on the exterior of high-rise buildings. In most cases such accessories require supports of some kind that are generally composed of unprotected steel. Many are anchored in wooden trim boards or in wooden plugs driven into exterior walls. Experience has shown that supports and anchors are subject to early failure under fire conditions. Common accessories that can be hazardous under fire conditions are window air conditioners, exterior signs, and sunscreens.

Window air conditioners. Window air conditioners are installed in many older buildings that have been modernized. These heavy units are hung outside the building and are anchored inside. This type of installation is easily spotted by the trained fire fighter either on prefire planning inspections or at fires. In the past, window air conditioners have crashed to the street from floors high above the ground. All persons on the street below these window-hung units should be moved out of the danger zone to prevent serious injury or death.

Exterior signs. Exterior signs can create hazards similar to those created by air conditioners. Such hazards to fire fighters and onlookers are readily apparent when the possibility of the failure of the sign supports is considered. It is important to cool the metal supports when they are severely exposed and to keep clear the areas below exterior signs.

Sunscreens. Unlike exterior signs, sunscreens give the impression that they are as solid as the building itself. Many are very solid and are joined from floor to floor so that one area, even if damaged, will not fall away from the entire assembly. Others are individually attached on each floor. Prefire planning inspections should make efforts to discover sunscreens that can be a hazard under fire conditions.

Electrical Failures

Electrical insulation materials break down under heat. Short circuits then develop, and a progressive electrical system failure occurs. Furthermore, hot air provides less resistance to the passage of electricity than does cool air. Under fire conditions, therefore, more electrical arcing and additional shorting can be anticipated.

Damage to Contents and Finishes

The exposure potential of heat is not generally understood. Heat (without flame) can cause high fire losses to both buildings and contents. Damage to interior finishes and contents must be counted as fire loss. The actual destruction of materials having a low melting point occurs frequently wherever heat is trapped. Such damage may occur in areas remote from the fire floor.

The preheating of combustible materials on other floors adds to the rapid fire-spread potential. For instance, cotton cloth, which is considered to be safe or slow-burning at normal temperatures, may burn at a dangerously high rate when first heated to above-normal temperatures.

Deposits created by relatively cool smoke can be easily washed off. Heat damage, however, is generally permanent whether it occurs in building finishes or building contents. Experience has shown that whenever heat exceeding 300 degrees F. collects in a building, a chargeable fire loss occurs.

Heat damage on floors remote from the fire floor frequently equals or exceeds the fire loss on the fire floor. Prompt containment and controlled ventilation of areas where heat is collecting is necessary to reduce these large losses.

TOPIC 3

Smoke and Fire Gases

This topic, "Smoke and Fire Gases," is planned to provide answers to the following questions:

- How do smoke and fire gases affect fire-fighting operations?
- How do smoke and fire gases spread in high-rise buildings?
- What ventilation procedures are necessary in high-rise buildings?
- What are the effects of heat on smoke and gas problems in high-rise buildings?

Effects of Smoke and Fire Gases

The school-fire tests conducted in Los Angeles in 1959 identified numerous hazards created by smoke and fire gases in multistory buildings. These findings were published under the title *Operation School Burning.*[1]

Smoke and gases confined in buildings during fires interfere with size-up as well as with access and visibility for rescue and fire-fighting operations. Hot, unburned products of combustion that have accumulated in a building can ignite explosively when a supply of oxygen is suddenly made available. Buildings must be ventilated quickly to prevent smoke explosions.

Lack of Visibility

During the early stages of a fire, smoke and fire gases are not a serious problem. Even in sealed buildings numerous areas are available into which smoke can be dissipated. Visibility thus remains at a workable level. As the fire increases in size, however, the areas into which the smoke has expanded will become more densely filled. Thus, visibility is gradually and continuously reduced until ventilation is accomplished. Lack of visibility can trap persons in a smoke-filled building, especially when elevators become inoperative.

Toxicity of Gases

Sealed buildings are capable of retaining all smoke and fire gases until they are ventilated. Other types of buildings generally retain sufficient products of combustion to be considered hazardous.

Fires produce numerous toxic gases, the most common gas being carbon monoxide. A person exposed to concentrations of carbon monoxide as low as 1.3 percent in air may become unconscious after two or three breaths and will probably die within one to three minutes.[2]

Additionally, smoke and fire gases displace oxygen within a structure. The insidious effect of an oxygen deficiency is not generally understood. Short exposures to atmospheres where oxygen content has been reduced from the normal 21 percent to about 15 percent will impair the physical performance of fire fighters and seriously affect their judgment.[3] Loss of judgment under these conditions is rarely obvious to the fire fighters themselves. Documented cases exist in which fire fighters actually endangered their lives unknowingly after short exposures to oxygen-deficient atmospheres. In each case the fire fighters believed they were performing in a very normal manner without excessive risk, but their judgment was faulty.

Breathing apparatus for men exposed to smoke and fire gases is absolutely necessary to protect their health and provide for adequate performance. The day of the "hearty smoke

[1]See *Operation School Burning* [No. 1]. Prepared by the Los Angeles Fire Department. Boston: National Fire Protection Association, 1959.

[2]*Fire Protection Handbook* (Thirteenth edition). Edited by George H. Tryon and Gordon P. McKinnon. Boston: National Fire Protection Association, 1969, p. 4-33.

[3]*Ibid.*, see pp. 4-36 and 4-37.

eater" is gone. There is no room in a modern fire department for men who refuse to wear breathing apparatus when available.

Heat Transfer

Heat is transported to other parts of a structure by smoke and fire gases. The quantity of heat transported by this method is directly related to (1) the length of time the heat is being generated; and (2) the distance it must travel before being trapped on an upper floor. Heat carried by particles and vapors is absorbed by the air, by the building, and by the contents as the particles and vapors are convected within the structure.

Heat-actuated fire-protection devices do not prevent fire gas and smoke spread since these devices generally do not operate quickly enough to close doors and dampers in order to block the passage of smoke and fire gases. This shortcoming is especially true in multistory buildings, in which smoke and fire gases can travel great distances and transfer the heat necessary to activate such devices to building contents and components in the process.

Travel of Smoke and Fire Gases

Smoke and fire gases can travel in the fire building by means of convection and by means of heating and air-conditioning systems.

Convection Within a Building

The circulation of heated air through a room, floor, or building creates heat transfer by convection. Heated air expands and rises. Heat transfer by convection occurs naturally, therefore, in an upward direction. However, natural or artificial air currents can carry heat by convection in any direction.

Vertical travel of heat, smoke, and fire gases is aided by various openings, stairways, shafts, ductwork, and shaftways that pierce floors. While open stairways are prime extension channels, vertical travel may also occur as follows:

1. Through laundry and trash chutes. Laundry and trash chutes may carry smoke to a number of upper floors. Dangerous smoke leakage occurs when chute doors are not self-closing and tightly fitted.
2. Through elevator shafts. Shaftways are ideal smokestacks. Many elevator doors are designed or installed in such a manner that they permit leakage of smoke on upper floors remote from the fire area. Additionally, when shaftways become smoke-filled. the opening of doors to load or unload passengers allows smoke to spread on other floors.
3. Through dumbwaiter shafts. The problem of smoke travel in dumbwaiter shafts is similar to that found in laundry and trash chutes.
4. Through mail chutes. Mail chutes frequently are not equipped with self-closing doors but are instead slotted to receive mail on each floor. A passageway for smoke and fire gases is, therefore, present in this type of installation.

Until a "stack effect" is built up through some vertical opening, the horizontal spread of smoke and fire gases is very rapid. Even though smoke rises from floor to floor, rapid horizontal travel occurs on each floor as the smoke loses heat to its surroundings. Open passageways, such as halls, attic spaces, and ductwork, aid horizontal travel.

Poke-through construction, through which utilities are led in from the attic space of the floor below, frequently creates unprotected vertical openings in multistory buildings. Failure to seal these openings in floor assemblies nullifies fire-protective construction in modern buildings. Under these floor conditions the rapid spread of smoke and fire gases, both vertically and horizontally, can be expected throughout the building.

Heating and Air-Conditioning Systems

Mechanical heating and air-conditioning systems provide both passageways and air currents for the travel of smoke and fire gases.

Dampers installed in duct systems and controlled by heat-activated devices usually cannot prevent the rapid spread of smoke through the areas served by the heating system. Air-conditioning systems are plagued by a similar problem with the heat-activated damper control. Additionally, many air-conditioning systems are designed to use the common attic space on each floor as a return-air plenum. The development of heavy concentrations of smoke and fire gases on individual floors through this arrangement must be expected. The heat concentration required to activate dampers takes longer to accumulate in a common air-plenum system than it does in a fully ducted system because of the greater area available for heat dissipation.

Stratification of Smoke and Fire Gases

The creation of layers of smoke and fire gases on floors below the top floor of sealed multistory buildings is a new phenomenon. Since no normal leakage occurs, all of the smoke and fire gases produced will accumulate at various levels until the building is ventilated. Prefire planning should include tactics and strategy that can cope with the ventilation, fire-loss damage, and life-hazard problems inherent in stratified smoke.

Loss of Heat

Heat is given up to its environment as smoke and fire gases travel through a building. The products of combustion rise through any vertical opening until their temperature is reduced to the temperature of the surrounding air. When this stabilization of temperature occurs, the smoke and fire gases form layers or clouds within the building.

Experience has shown that these dense smoke clouds form at a level below the top floor. A classic example of this formation occurred in a 17-story sealed building in the city of Los Angeles. The fire was in the second-level basement, and the dense smoke clouds formed on the tenth, eleventh, and twelfth floors. The fire was extinguished before sufficient heat had built up to move the stratified smoke to the top floor. Ventilating this cooled smoke out of the top of the building was accomplished by creating controlled currents of air up the stairshafts and across the smoke-filled floors.

The mushrooming effect, which is usually expected on top floors, does not occur in tall buildings until sufficient heat is built up to move, in an upward direction, the stratified smoke and fire gas clouds that have gathered on lower floors.

Life Hazard

Although it is well known that fatalities caused by the inhalation of hot fire gases and hot air are far more common than fire deaths from all other causes combined,[4] little thought is generally given to the toxicity of cool smoke and fire gases. Stratified smoke and fire gases have lost only their heat factor; deadly carbon monoxide and other toxic gases are still present Since temperature does not affect toxicity, cool gases are as hazardous as those that are heated.

Occupants of areas of buildings where smoke is stratifying must be evacuated quickly. Fire fighters must be protected by self-contained breathing apparatus when working in smoky areas.

Smoke Damage

Property loss is high in areas where smoke has stratified. The small particles of carbon and tar that make smoke visible are deposited on all exposed surfaces of the building and its contents. The longer that smoke is allowed to remain in the building, the greater will be the deposit of particles. Additionally, the condensation of water vapors causes damaging stains. Rapid ventilation is the only solution to the problem.

In Sealed Buildings

The fire-loss potential in sealed buildings is directly related to the time that smoke and fire gases remain in the building. Since relatively no leakage occurs in these buildings, an unventilated fire can fill every floor of the building with smoke. Smoke that is stratified in the first stages of a fire may be moved mechanically by air-conditioning systems into other areas of the building. Additionally, as the heat level builds up, more areas are affected by stratification, and the air-conditioning systems further spread the newly stratified smoke.

Eventually, as the heat builds up and the top floors become involved, the familiar mushrooming condition completes the process of filling the building with smoke and fire gases. Because of the total containment of smoke within the building, severe losses occur from smoke damage alone.

Smoke-damage exposure must be anticipated on every floor of a sealed high-rise building. Strategy must be developed with this idea in mind since normal ventilation tactics are generally not possible in sealed buildings. Windows that cannot be opened must not be broken out if this tactic may create a "flying-guillotine" hazard to men working below.

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[4]See *Fire Protection Handbook, op. cit.*, pp. 1-6 and 1-7.

Breaking out plate-glass windows high above the ground creates a situation where heavy shards of glass can seriously injure or kill persons on the street below. Tests conducted in the city of Los Angeles have shown that glass broken on the twentieth floor on a relatively calm day will travel as far as 75 feet from the face of a building. This "flying-guillotine" hazard must not be minimized in planning fire strategy.

Street-level areas where persons are endangered by falling glass must be cleared before glass is broken on upper floors. This tactic requires close coordination with the police and proper timing to prevent serious injury or death.

In Older Buildings

Smoke damage within older multistory buildings that lack central air conditioning and sealed windows is much easier to control. The normal leakage of smoke and fire gases aids greatly in reducing the problem. After the arrival of fire fighters, cross ventilation on upper floors where smoke may be stratifying is easily accomplished by opening windows and operating smoke ejectors as necessary.

Panic Hazard

Fear is the main cause of panic. Fatalities caused by panic have occurred when occupants of a building were led to believe that there was a fire when no fire existed. Smoke in a multistory building can create this belief and cause fear. Panic is contagious, and the greater the number of occupants in a building, the greater is the potential for panic. Since modern tall buildings frequently contain a daily occupant load of 100 or more persons per floor, the panic hazard under fire or smoke conditions is very real.

Most persons know only one way into and out of the tall buildings where they work or live. Access is generally through the lobby, up the elevator, through a hall, and into their offices or apartments. Egress is generally accomplished by the same route. Under fire conditions other means of exit are usually unknown or overlooked.

As long as people can keep moving toward a recognized place of safety, there is little danger of panic. When the orderly movement is stopped by any interference, panic can develop. Interference with this orderly movement can be caused by heavy smoke, heat, decreased visibility, excessive waiting for elevators, delays in opening d ors, and so forth. When panic starts, people do not behave logically. The resultant push of people to use known exits may quickly block those exits and trap all persons within that particular area.

Prefire planning should include methods of introducing occupants of buildings to alternate means of exit. Exit drills for occupants and mimeographed sheets showing alternate exits have been used to advantage in tall buildings in some cities.

Ventilation Operations

Smoke and fire-gas ventilation from buildings with windows that can be opened has become a generally understood tactic. Top ventilation is used to remove the superheated smoke. Cross ventilation to remove the cooler smoke not involved in the "stack effect" is then accomplished by opening windows and operating smoke ejectors.

Ventilation in Sealed Buildings

Top ventilation in modern tall buildings must be preplanned. In many buildings only one stairshaft pierces the roof. Necessarily, then, this vertical "chimney" must be used to ventilate smoke, heat, and fire gases from various floors. Before the doorways on the fire floors are opened and the stairshaft is ventilated, the penthouse door must be removed from its hinges or blocked open in a very secure manner. Removal of the door at the top of the shaft is preferred so that the door cannot close after ventilating tactics are started (see Fig. 3-1). Otherwise, the door may close, and the shaft may become filled with superheated gases. Fire fighters would have no way, then, of reopening the door except from the roof side. During ventilation, occupants and firemen must not enter this deadly chimney above the fire floor.

Prior knowledge of stairway layout is imperative. Improper ventilation through a dead-end stairshaft can only delay seriously the extinguishment of the fire and increase the fire damage. Usually, the common cross-ventilation procedure is impossible in newer buildings because the windows cannot be opened. Forced ventilation up a stairshaft, across a smoke-filled

Fig. 3-1. Stairshaft door removed to protect persons inside

floor, and out through the roof by way of another stairshaft is the usual ventilation tactic in sealed buildings.

Internal and External Exposures

Fire commanders using ventilation to rid buildings of smoke and fire gases, hot or cooled, must consider internal and external exposures. The path of ventilation can generally be controlled to protect exposures. Unnecessarily heavy losses can occur when improper ventilation tactics channel smoke into previously unexposed areas.

Exposures to other buildings as a result of top ventilation must be considered. Adjacent taller structures must be protected so that heat, smoke, and fire gases do not penetrate through exposed windows and other openings. Hose lines may be required inside adjacent buildings to provide the necessary protection. These lines must be in position prior to ventilation of the involved structure.

Timing and coordination of tactics are most important. Occupants of buildings and fire fighters can be dangerously exposed to smoke and fire gases during ventilation procedures. Ventilation up the one stairshaft that pierces the roof must necessarily be delayed until all occupants above the fire floor are either evacuated or warned to stay out of the chimney.

Explosion Potential

Until buildings are ventilated, hot, unburned products of combustion accumulate on various levels. The explosion hazard created by such an accumulation is more acute in sealed buildings. If smoke and fire gases are above their ignition temperatures, they will ignite explosively when a supply of oxygen is suddenly made available. If smoke explosions occur, windows will probably be broken, and an ample supply of oxygen will then be available to accelerate and spread the fire. Close coordination of confinement, ventilation, and extinguishing tactics are required to prevent smoke explosions.

Weather

Weather factors (temperature and relative humidity) affect ventilation tactics and the spread of smoke inside buildings. On warm, dry days smoke tends to rise rapidly and move away from the involved structure and exposures. On the other hand, cool temperatures and high humidity may prevent smoke from rising naturally. It may "hang" within and around the involved structure.

Time

Time, which works so detrimentally against the fire service, must be considered when dealing with smoke and fire gases. The longer the fire burns before extinguishment, the more heat, smoke, and fire gases are generated. The longer smoke is generated in a confined space, the more dense it becomes, thus reducing visibility and increasing the hazards to life. The longer smoke stays in the building, the greater will be the fire loss. In many instances rapid control and ventilation of smoke and fire gases must be accomplished before actual extinguishment of the fire is attempted. This rapid control and ventilation is particularly important in tall sealed buildings because all the products of combustion are contained within the building.

TOPIC 4

Life Hazards

This topic, "Life Hazards," is planned to provide answers to the following questions:

- What determines the seriousness of the life-hazard problem in fires occurring in high-rise buildings?
- What problems are encountered in evacuating occupants from high-rise buildings?
- What are the means of egress in high-rise buildings?
- How may exits best be used in performing rescue operations?

Building Occupancy

The occupancy of any building determines the seriousness of the life-hazard problem in the event of fire at that building. Most tall commercial buildings have mixed occupancies. Generally, high-rise buildings are planned and constructed prior to the time when occupants sign leases. Upon completion of the building, space in varying amounts is rented to a number of different tenants. Internal walls, furniture, and fixtures for the various types of occupants are then installed.

Onsite prefire inspections must be made to determine the layout, occupancies, uses, and fire and occupant load on any given floor (see Fig. 4-1). The age and physical condition of the occupants must also be evaluated to determine how much fire department help and guidance would be necessary to evacuate people to a place of safety.

Some buildings are a serious life-hazard problem in the daytime only; others present more serious problems at night. Buildings with floors beyond the reach of normal fire ladders are serious life-hazard risks when they are occupied. The life-hazard problem is related to the use of the building and is directly proportional to building height, fire load, and the number of occupants. The occupant load in many high-rise buildings is seriously underestimated. It is not uncommon to have at least 100 or more persons on each floor of a commercial high-rise structure. If the building exceeds 25 stories, the occupant load in that particular building can exceed the population of many communities. A fire in a high-rise structure can, therefore, be considered a fire in a vertical city insofar as total population is concerned.

Rescue Problems

Rescue problems commonly faced by firemen are evacuation of occupants, occupant control, establishment of safe-refuge areas, and lack of time.

Evacuation of Occupants

People must be moved out of dangerous areas. Higher buildings and more people, of course, tend to make this job more difficult. Additionally, the complexity of the problem is directly related to whether the persons are ambulatory or nonambulatory.

Ambulatory persons are those who are able without assistance to leave a building during

Fig. 4-1. Group instruction at site of high-rise building

emergency conditions.[1] During a fire, however, they may require guidance from fire department personnel to reach a place of safety. Nonambulatory persons are "those persons unable to leave a building unassisted under emergency conditions and may include those persons who depend upon mechancial aids such as canes, crutches, walkers, and wheelchairs, and may also include blind or deaf persons."[2]

From a practical standpoint, persons temporarily incapacitated by acute sickness or the excessive use of alcohol or drugs and persons confined for security reasons must also be considered nonambulatory. Top priority must be given to rescuing nonambulatory persons; this effort may require a large complement of fire department manpower.

Occupant Control

Persons being evacuated must be under control during and after their removal to a safe area. They must not be allowed to reenter a hazardous area or to venture into other areas of danger once they have been moved to a safe place. Posting of guards at strategic places on various floors within the building may be required to control people being evacuated. Otherwise, panic and interference with fire department operations are real possibilities.

Establishment of Safe-Refuge Areas

Two reasons why it may be impossible to evacuate occupants to street level are (1) that valuable fire department manpower can be used for other purposes; and (2) that many persons are physically incapable of walking down numerous flights of stairs.

If a fire is located high in a modern building, safe-refuge areas can usually be established in any location at least three floors below the fire floor or on the roof (see Fig. 4-2). The risk of exposing occupants to inclement weather in safe-refuge areas on roofs is much less than the risk of exposing them to the hazards of fire, smoke, and fire gases in attempting to evacuate them downward past the fire. Additionally, evacuation of occupants from roofs by means of helicopters is not recommended unless the occupants are in imminent danger. Usually, occupants can safely remain on roofs for a long period of time if they are not exposed to smoke or severe weather conditions and are under the supervision of fire department personnel.

Lack of Time

Time is the most important factor in any rescue operation. Most other fire department operations must be postponed until people are safely out of danger areas. The time required for fire department personnel to transport people to the ground floor by making long round trips from upper floors is too costly. A shuttle service over shorter distances

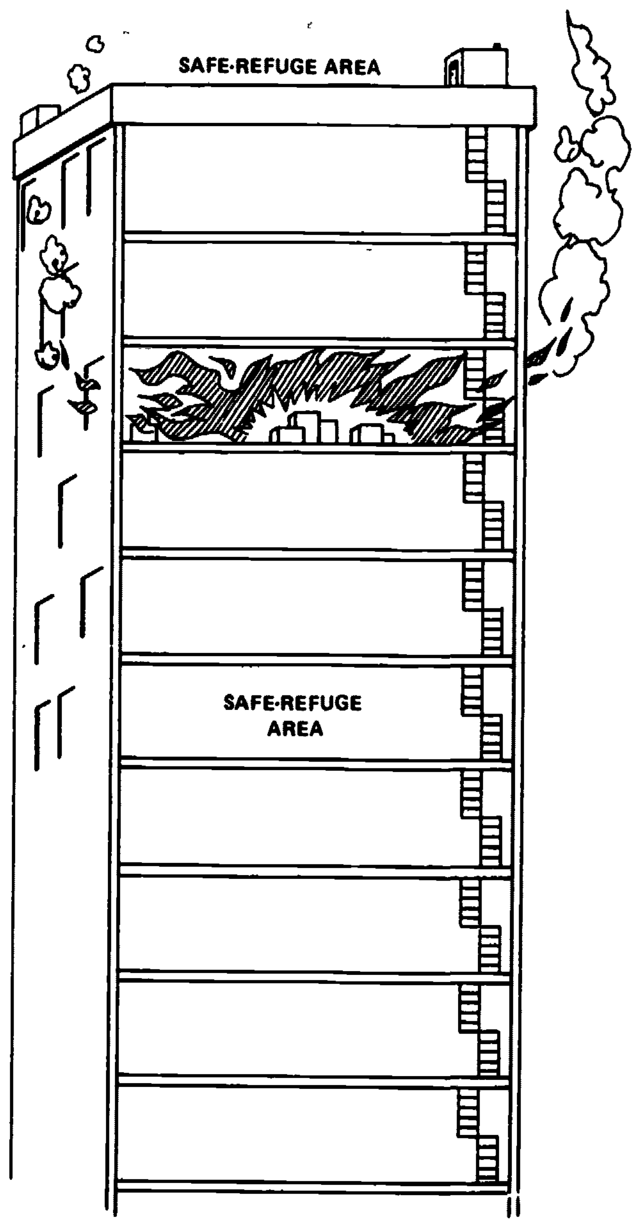

Fig. 4-2. Safe-refuge areas in fire building

[1] California Administrative Code, Title 19, Public Safety, Section 4.15(e).

[2] *Ibid.*

to safe-refuge areas on floors below the fire or on the roof must be established to save precious time.

Use of Exits

It should be remembered that most persons are unaware of the various exits available in a given building. Occupants frequently enter the elevator from the lobby, ride to a particular floor, and walk along a known path to their apartment or office. They usually make no effort to discover other ways to get out of the building. If the elevator service is interrupted and the lights are out in any interior hallway, the occupants cannot be expected to find the exit stairways. Smoke trapped in interior hallways creates a similar problem. The panic potential under these conditions is very real. Education of occupants regarding the types and locations of exits available is a necessary fire department function.

Capacity of Exits

The exit capacity of a given floor may be divided into several stairways. Some stairways exist only on lower floors in a building to serve the additional occupant load from upper floors. Many stairways do not reach the roof but stop at the top floor. Many stairway doors are unmarked and cannot be distinguished from other doors. During prefire planning surveys, efforts should be directed toward convincing owners and occupants of the necessity of marking all stairway doors.

Terminal Points

Knowledge of the location and terminal points of all stairways serving each floor is vital for occupants and firemen. Stairway-door markings that show whether the stairshaft exits at the street level only or at the street and roof levels can facilitate egress from areas within the building. Unfamiliarity with the alternate exits available is a serious problem for building occupants. Access to known exits may be blocked by heavy smoke, heat, movement of people, and locked doors.

Other Means of Egress

Freight elevators may be located in separate shafts remote from regularly used passenger elevators. Occupants frequently are unaware of the location of these elevators and the method of operating them.

Building codes require that certain stairways must be installed in high-rise structures for the use of occupants. Additionally, nonrequired stairways may be installed for the primary use of building employees to connect several floors near an engineering or service floor. These stairways may be used by occupants to gain access to less hazardous areas of the building and can be valuable aids in fire-fighting operations.

Ladders may be used to evacuate people from lower floors. The limits of reach of all standard fire department ladders available for use should be established for every high-rise building. Such planning can prevent tactical errors when rescue work is being carried on or access is being provided for fire department personnel.

Access for Rescue

Too little thought has been given to fire department access for rescue operations in high-rise buildings. It is generally assumed that fire fighters can get in anywhere to rescue people. Firemen, however, are human and are therefore subject to human limitations. Access for fire fighters involved in rescue operations may be restricted by building height, vehicular traffic, movement of people, blocked doorways or exits, sunscreens, landscaping, heavy smoke, and heat.

Fire department control of the vertical transportation channels (elevators and stairways) must be established before rescue operations can be accomplished above the fire. When such channels are in use, every possible means must be exercised to maintain them in a safe, tenable manner.

TOPIC 5

Exposure Problems

This topic, "Exposure Problems," is planned to provide answers to the following questions:

- How do weather conditions affect exposure problems?
- How do building construction features affect exposure problems?
- What are some of the exterior exposures in high-rise buildings?
- What are some of the interior exposures in high-rise buildings?

Generally, exposure problems vary directly in proportion to the height and size of a building.[1] All of the products of fire – flames, heat, smoke, and toxic gases – can create exposure problems.

Types of Exposure Problems

Exposure problems are typically divided into exterior exposures and interior exposures.

Exterior Exposures

Exterior-exposure problems are magnified by lack of fire department access if the fire is above the level where normal (ground-based) fire-fighting operations can be employed. In areas where multistory buildings almost adjoin one another, additional manpower and equipment must be committed to protect exposed buildings. These commitments can deplete the fire-fighting force available to combat the main fire and may reduce that force to an ineffective level.

In many cities the fire-fighting force is too small to cope with problems presented by large multistory buildings. Adequate planning to devise methods of providing necessary men and equipment becomes part of the overall fire strategy. The manpower shortage may be overcome to a certain extent by mutual-aid agreements, effective methods to recall off-duty platoons, and the establishment of a roster of trained call or volunteer firemen. Mutual-aid agreements can include provisions for recalling off-duty and volunteer members from other jurisdictions. Any method to supplement available on-duty manpower is worth consideration when high-rise construction presents problems of exposure protection.

It is probable that a fire located high in a building will break out of the fire floor to the outside and reenter the building on floors above the fire (see Fig. 5-1). Fire fighters must be placed on floors above the fire floor to prevent flames

Fig. 5-1. Results of fire lapping in older building

[1] *Fire Protection Handbook* (Thirteenth edition). Edited by George H. Tryon and Gordon P. McKinnon. Boston: National Fire Protection Association, 1969, p. 8-208.

from reentering the building should the breakout occur. This "fire lapping" from floor to floor, which causes serious fire problems and severe losses, has occurred in many cities. Modern buildings, which have no projections between floors to protect glass building faces, are also vulnerable to this phenomenon (see Fig. 5-2). In older buildings the reentry of heat and heavy smoke into upper floors through open windows, even though there is no fire lapping, can also cause serious losses. Closely akin to fire lapping is the problem of fire, heat, and smoke entering exposed buildings. Preparation for the prevention of fire spread to exterior exposures must be included in size-up and overall strategy.

Interior Exposures

Property loss due to interior exposures is often underestimated. In older buildings with open stairways, the probability of heavy losses from heat and smoke damage is very great. Even though the fire is confined to one floor, heat and smoke losses can occur in other parts of the building. Prompt and effective tactics to rid the building of this heat and smoke is the only way to minimize the problem. The effectiveness of ventilation operations will directly affect the total fire loss.

Interior-exposure problems are also magnified when the fire is above the level of normal ground-based fire-fighting operations. Again, men must be placed above the fire to establish and control ventilation channels. Self-contained breathing apparatus, protective hose lines, good judgment, and a team effort are all necessary if this strategy is to be used. Team efforts must be carefully coordinated and directed by the officer in charge.

In modern sealed buildings the interior-exposure problem is compounded because all of the products of combustion are contained within the building. Generally, heat and smoke do not leak to the outside. The ease with which heat and smoke travel through horizontal and vertical channels adds to the total loss. Heat and smoke frequently accumulate on the top floor and then "mushroom" down to other floors. Fire loss on upper floors exposed to this phenomenon can be as great as the loss on the fire floor itself. Ventilation by way of the stairshaft that pierces the roof must be accomplished quickly to reduce top-floor fire losses.

The potential life-exposure hazard is also often underestimated. This hazard increases directly according to the size of the occupant load in the building and the distance occupants must travel to reach a safe-refuge area. This problem is particularly acute in buildings with sealed windows. The life-hazard problem inherent in ventilating through stairshafts that must be used to evacuate occupants will of necessity delay fire-fighting operations until all exposed persons above the fire floor have been guided to safety.

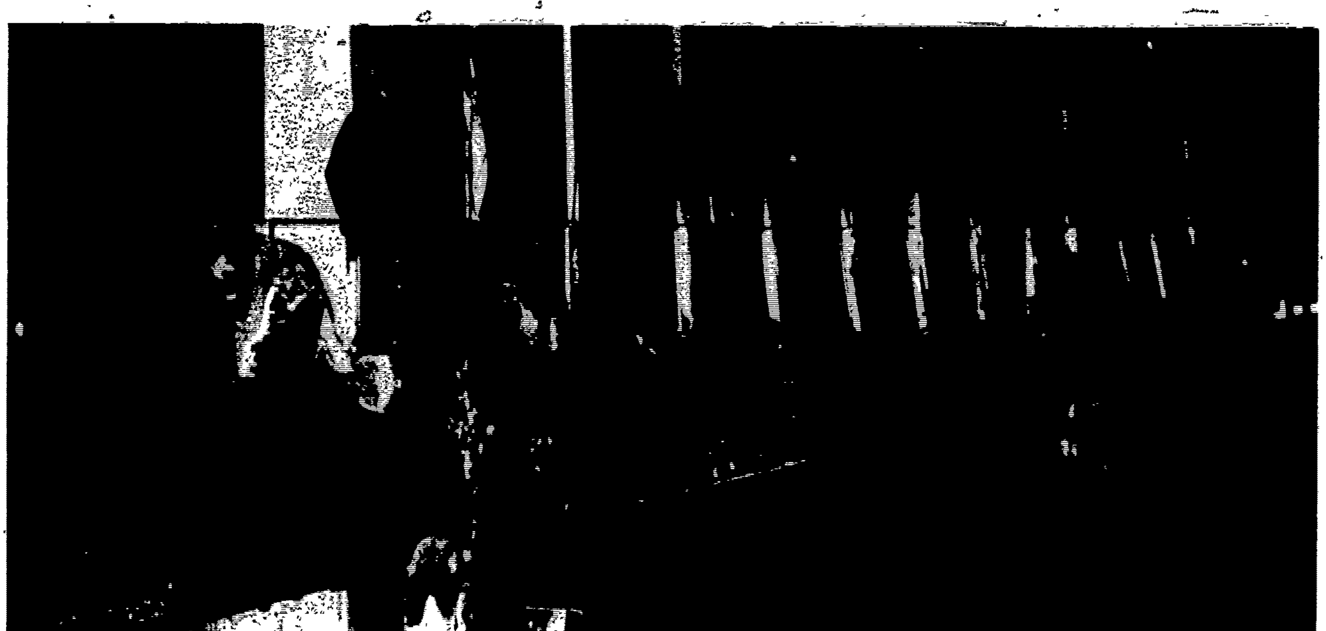

Fig. 5-2. Results of fire lapping in modern building

Effects of Weather

Weather has a great influence on exposure problems. Obviously, the exterior-exposure hazard is much less during cold and rainy weather than during hot and dry weather. Fires are apt to be undiscovered for longer periods, however, during cold, rainy weather, especially at night. Fires located far up in high-rise buildings are frequently undiscovered until they become serious. People rarely look up at buildings unless there is a reason to do so. Frequently, rainy, windy, or cold weather, which keeps pedestrians off the streets and windows closed in tall buildings, can delay discovery of fires until they break out of the building and can be seen from a distance (see Fig. 5-3). In some areas of California, a temperature-inversion problem occurs on certain days; visibility outside of the fire building may, therefore, be obscured. Additionally, inversion layers cause clouds of smoke to accumulate at ground level, making ventilation of the fire building more difficult to accomplish. Forced drafts created by smoke ejectors may be necessary to solve the problem. Methods to keep this heavy and relatively cool smoke out of exposed buildings must also be considered.

During extended periods of hot, dry weather, the increased readiness of all combustible materials to burn is a well-known problem. Both internal and external exposures become more susceptible to fire spread. Heavy commitments of equipment and manpower during these periods may be necessary to control large fires. Prefire planning activities must include provisions for increasing responses to fires in high-rise areas to protect exposures adequately.

Effects of Height Differentials

Height differentials of buildings cause severe exposure problems. In many cases the problem can be solved by the use of water curtains and heavy streams of water or by the placement of manned hose lines inside the exposed buildings to prevent the extension of fire into endangered floors. Smoke and heat must also be prevented from entering exposed building areas above and adjacent to the actual fire building. This problem can be particularly acute if a wind is driving the heat and smoke into the adjacent building. Additional manpower must be committed quickly to close and protect windows that provide a way for fire, heat, and smoke to enter exposed buildings.

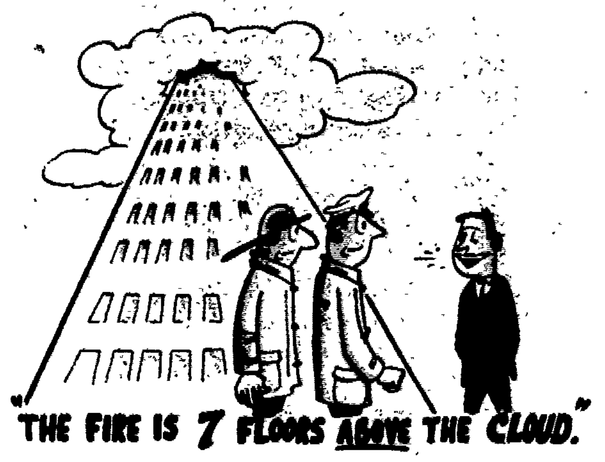

Fig. 5-3. Late discovery of fire in high-rise building

In modern buildings the external-exposure problem is generally less because the windows are sealed. Such windows, while intact, provide a barrier against smoke and convected heat. Height differentials may result, however, in direct exposure to flame or concentrations of radiated heat, and this factor may require the commitment of additional manpower on certain floors inside an exposed building with sealed windows.

Effects of Construction Differences

The type of construction, the age, the condition, and the fire load of the fire building all affect the course of the fire.

Type of Construction

The exposure problems caused by unprotected vertical openings such as open elevator shafts and stairways in older buildings are well known. Heat, smoke, and flames are carried upward in these vertical channels to expose the upper floors. Property losses during serious fires are usually very high in this type of building; some of America's greatest fire disasters have occurred in buildings that contained unprotected vertical openings.[2] Prompt control of flame, smoke, and heat travel must be gained by coordinated ventilation tactics and the use of hose streams inside the building to prevent extension of the fire and ensuing large losses.

Improperly sealed "poke-through" construction can create a serious internal-exposure problem

[2] *Ibid.*, see p. 8-158.

between floors. Tests by Underwriters Laboratories have shown that when the space surrounding utility lead-ins is not refilled, such construction can reduce the fire resistance of a concrete floor from two hours to about seven minutes.[3]

Age of Building

The age of a building can create many exposure problems. Older buildings generally do not incorporate the fire-protection features found in more modern buildings. The fire-protection features they do incorporate may not function properly because of age, alterations, and lack of maintenance. Additionally, older buildings usually attract occupants and occupancies that tend to increase the possibility of fires and the rapid spread of fires once they start.

Attempts to modernize older buildings have created some special problems for fire fighters. Development of concealed spaces through the addition of false ceilings, new building facings, and interior paneling is common. Spaces created by the installation of false ceilings are channels through which fire spread can be both rapid and hidden. The covering of combustible structural materials with noncombustible facings creates areas where creeping fires can exist.

Condition of Building

The overall condition of a building must be considered in determining the total exposure problem, particularly from a life-hazard standpoint. Window-mounted air conditioners, ancient advertising-sign assemblies, and old installations of fire escape balconies and ladder assemblies should always be considered as life hazards. Mounting brackets, bracing supports, and anchoring devices may fail because of fire exposure or fire-fighting activities. Such failures may cause externally mounted facilities to fall to the street below.

Determining the condition of all assemblies and facilities attached to building faces or windows is a very important part of prefire planning inspections. Proper maintenance of all building attachments to prevent their falling during fire-fighting operations should be required.

[3]See Richard E. Stevens, "Maintaining Fire Resistance in Floor Assemblies," *Fire Journal* (March, 1966), 45.

Modern construction that encloses stairways and other vertical openings has solved many fire-fighting problems. Fires in modern buildings should be more easily confined to fewer floors than fires in older buildings that have open stairways.

The use of materials to retard flame spread has helped reduce fire losses. However, the substitution of slow-burning plastics for other more flammable building materials has caused a new, more difficult fire-fighting problem. These plastics create large amounts of dense, heavy, toxic smoke. Such smoke creates a severe life hazard, hampers fire-fighting operations, and causes larger fire losses.

Fire Load

The severity of most fires can be estimated by determining the fire load contained within the building. Occupancies have long been classified with regard to fire loading. Light-hazard occupancies contain zero to 13 pounds of combustibles per square foot, medium-hazard occupancies contain 13 to 25 pounds, and high-hazard occupancies contain over 25 pounds.[4] Prefire planning inspections should be made to determine the fire loading on each floor. An estimate of the fire problem that may be encountered and plans to deal with it can then be made.

Fire problems in sealed, climate-controlled buildings that contain only light-hazard occupancies have generally been underestimated. Heat and all of the other products of combustion are contained within the building. In cases of smoldering fires or fires that go undiscovered for a long period of time, the buildup of heat raises most common combustibles above their ignition temperatures. Under these conditions the mere addition of enough air instantly creates a hot fire. This type of fire has occurred repeatedly in new buildings.

Experience has also shown that when materials with low flame-spread characteristics are preheated to near their ignition temperatures before being exposed to fire, the materials flash and burn as rapidly as comparable materials with high flame-spread reatings. Entire ceilings of material with low flame-spread characteristics have flashed and burned rapidly under these preheating conditions.

[4]*Fire Protection Handbook, op. cit.*, see pp. 8-9 to 8-11.

TOPIC 6

Water Supplies

This topic, "Water Supplies," has been developed to provide answers to the following questions:

- What basic problem exists in every fire-fighting situation?
- What fire-protection systems may exist in high-rise buildings?
- For what reasons may fire-protection systems fail to operate effectively?
- What preplanning is necessary regarding water supplies?

One basic problem exists in every fire-fighting operation in which ordinary combustible materials are involved. A sufficient quantity of water must be applied to reduce the quantity of heat being produced so that the fire can be controlled. Locating an adequate source of water and transporting it to necessary places in a high-rise building can be an extensive operation. An adequate and reliable source of water should exist in street mains adjacent to buildings. Information on the street-main system, and particularly its potential inadequacies, is an essential part of prefire planning.

Transporting water to desired locations within a building usually involves the use of hose lines in conjunction with permanent fire-protection systems. Every high-rise building incorporates one or more fire-protection systems, including wet standpipe systems, dry standpipe systems, combination wet and dry standpipe systems, and automatic-sprinkler systems. A properly engineered fire-protection system will provide a sufficient amount of water throughout a high-rise building. Such systems depend for their supply of water, however, on sources outside the building (see Fig. 6-1).

Inadequate Fire Flows

Fire fighters may encounter water-supply problems while combating fires in high-rise buildings. This problem of inadequate fire flows to multistory buildings is more prevalent than most fire department officers realize. It is usually caused by inadequate street mains, closed or partially closed street valves, and standpipe systems that are not cross-connected.

Street mains that are too small or are not properly cross-connected are common problems. Such conditions develop gradually in a city unless an active program exists to prevent them. The provision of adequate fire flows should be a requisite for granting building permits. Correction of any existing fire-flow problems should become a part of every fire department's planning program.

Adequate fire flows through proper-sized mains and hydrants can be nullified at large fires by closed or partially closed street valves. A representative from the water utility should be available at every large fire to overcome this problem. Where large fire flows may be required, a hydrant-flow testing program can serve to locate areas where flows are being reduced by closed valves.

Fig. 6-1. Water to fight fires contained in modern high-rise buildings

Cross-connecting of standpipes should be encouraged for older buildings and required by law for new buildings. More than one source of water under pressure is thus available for each standpipe. Where standpipes are not cross-connected, fire fighters on an upper floor have occasionally hooked hose lines into a standpipe different from the one into which a pumper is connected at street level. The potential disaster created by hooking hose lines to the wrong standpipe on upper floors and waiting for water that will not arrive can be eliminated by cross-connections.

Long hose lays to deliver necessary water supplies may be required to combat fires in multistory buildings. In areas where the available fire flow is questionable or is known to be deficient, prefire planning should include provisions for relay pumping from strong hydrants in adjacent areas.

Fire-Protection Systems

Since overall fire strategy for tall buildings depends to such a degree on fire-protection systems, a thorough knowledge of the problems that may exist in such systems is essential.

Deteriorated Systems

Many older systems may not have been properly maintained. They may be in such poor condition and so unreliable that they are worse than no system at all. Prefire planning inspections of multistory buildings that incorporate fixed piping systems should include tests to determine that reliable water supplies will be available when needed. Standpipes, automatic-sprinkler systems, and water mains should all be inspected.

Standpipes. Wet and dry standpipes that have been neglected cannot be depended upon for fire-fighting operations. Damaged threads, inoperative valves, rusted pipes, and inoperative clapper valves are visible signs of serious deterioration. Very costly delay can be caused when fire fighters hook into a standpipe system, start operations, and then discover that the system is inoperative. Men and units must then be regrouped and another water source developed. Meanwhile, the fire intensifies, and more serious exposures of life and property occur.

Automatic-sprinkler system. Any automatic sprinkler system that has not been correctly maintained will fail to function as it should. Pipes and joints may leak when fire department pumpers are attached and fire-fighting pressures are produced. These shortcomings can prevent an adequate water supply from reaching the fire area and can cause excessive water damage in areas where no fire exists. Pipes may be blocked so solidly with rust and scale that no water can be delivered to the fire area.

Water mains. The problems caused by deteriorated water mains, both private and public, are well known. Close coordination with the local water utility and knowledge of the fire flows available to multistory buildings are basic components of prefire planning.

Altered Systems

Fire-fighting systems may be altered as buildings are remodeled. Such alterations can create unsuspected water-supply problems in modified and refaced buildings and in building additions.

Modified buildings. Unless buildings being modernized or remodeled are closely inspected during construction, the basic engineering in standpipe and sprinkler systems may be so altered as to make them inefficient, ineffective, or inoperative. Excessively long runs of small piping, newly created dead ends, changes in cross-connections, disconnected portions of systems, and piping blocked with various construction materials have been found in modified buildings.

The National Fire Protection Association suggests numerous standards that can be adopted by local jurisdictions as fire-protection laws or ordinances. The suggested standards for fire-protection systems in high-rise buildings include provisions for engineering, materials to be used, specifications, tests, and inspections. The standards also provide for notification of the fire department when systems are out of service or under repair (see Fig. 6-2). Appropriate standards should be adopted and enforced on a local basis.

Refaced buildings. A common problem in refaced buildings is failure to install longer pipes to compensate for increased wall thickness. This practice results in too few threads holding parts of the fire-protection system together. Failure of these weak connections to withstand necessary water pressures have occurred during fire-fighting operations. The delay caused by interruption of the water supply is costly in terms of fire loss and seriously endangers the lives of fire fighters and occupants. Fire-fighting strategy and tactics must undergo a drastic change when this problem develops. Fire department inspections of standpipe systems during building remodeling operations should, therefore, be required. If possible, standpipes should be tested after any building remodeling or modernization takes place.

Additions to buildings. Additions to buildings may create problems similar to those created by alterations. The failure of existing water supplies to supply the new areas adequately is common. Failure to extend fire-protection systems to new areas may also occur. Proper engineering should be required prior to the issuance of a building permit. If this procedure is impossible, fire-flow tests and thorough building inspections should be made during and following construction.

Inoperative Systems

Inoperative private systems cause many costly delays. Since fire fighters do not knowingly commit themselves to an inoperative water-supply system, any condition interfering with getting water where it is needed steals valuable time and energy. Failure to receive water as expected is generally the only indication that the system is inoperative. Correction of the problem, if it can be located, or developing another supply is most time-consuming and multiplies the loss. Prefire planning and regular building inspections should reduce the possibility of inoperative systems. Inspections should include looking for such things as the following:

1. Missing or disconnected standpipe outlet caps

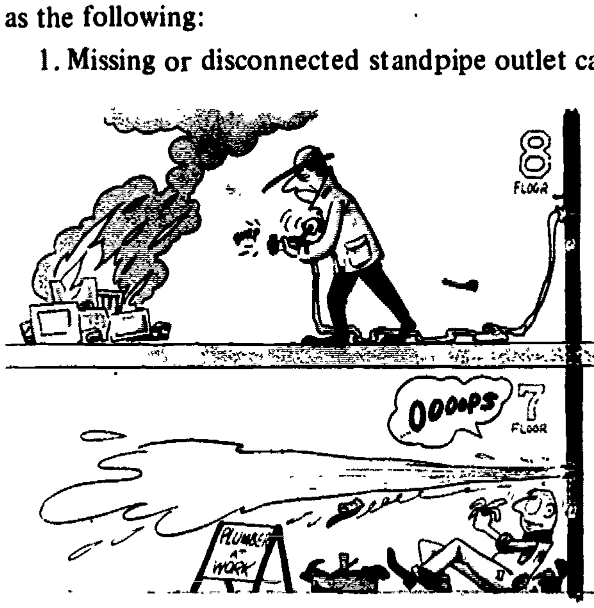

Fig. 6-2. Inoperative fire-protection system

2. Debris in the system, which is generally found near fire department inlets and at standpipe outlets
3. Open standpipe outlet valves that prevent water from reaching upper floors and cause great water damage on intermediate floors
4. Damaged fire department connections (The fire plan should include use of standpipe outlets on other floors as inlets to the system.)
5. Closed outside screw-and-yoke (O S and Y) or post-indicator (P-I) valves, a problem most commonly encountered and easiest to correct
6. Lack of access to fire department connections, a condition easily corrected before fires begin but most difficult to overcome quickly during a fire

Inoperative Fire Pumps

That private fire pumps sometimes are inoperative must be anticipated, and alternate plans must be developed to provide for this situation. The private system may be properly designed and yet fail to function for various reasons. Local or citywide power failure is always a possibility. Standby power systems to operate pumps in the event of blackout or power failure should be encouraged if these systems are not required by law. Workmen who do maintenance work on the pump system may inadvertently leave water-supply valves closed. This action negates the entire system. Regular building inspections should include checking for closed valves.

Well-designed systems that are not properly maintained will sometimes nullify the cooperative efforts of architects, builders, and advisors on fire protection. Unfortunately, as buildings grow older, the fire problems become greater. As fire-pump systems grow older, therefore, increasingly greater attention must be paid to proper maintenance if the pumps are to help solve the fire problem. Regular testing of fire pumps should be encouraged if not required by law, and legal requirements should be enforced.

Unidentified Systems

Unidentified systems, which pose problems of locating inlets and outlets for necessary water supply, exist in some multistory buildings. Prefire planning inspections should provide a knowledge of various fire department connections, the systems they serve, and the building areas that each system protects. Identification of various systems and areas they serve should be encouraged or required by law. If such a law exists, it should be enforced.

Excessively Pressurized Systems

Unless maximum pressures are specified by law and controlled on various levels of multistory buildings, excessive pressures can exist. Frequently, calibrated washers are installed at each standpipe outlet to limit flow and, in turn, water pressure. In some installations a hole as small as ½ inch in a 2½-inch outlet washer will supply a working 2½-inch line. Generally, calibrated washers are not permanently installed and may be easily removed. Their presence in the valve outlet should be checked on regular building inspections. Missing washers will always create hose-handling problems because of excessive pressures. Additionally, if the nozzle is closed on a line working from a system outlet, whether or not the calibrated washer is in place, hose rupture from the excessive static pressure is possible. To prevent hose-handling problems and unnecessary water damage, outlet valves rather than nozzles should be used to control water flow and pressure.

TOPIC 7

Access Problems

This topic, "Access Problems," is planned to provide answers to the following questions:

- What are the problems involved in responding to a fire in a high-rise building?
- What are the hazards involved in gaining access to a high-rise building with fire apparatus?
- How may access to the interiors of high-rise buildings best be gained?
- How may prefire planning reduce access problems?

The problems involved in gaining access to high-rise buildings are often underestimated. Unless prefire planning includes ways of getting to the fire address, getting to the fire building, and gaining access to the fire floor, much valuable time can be lost.

Getting to the Fire Address

Response to a fire alarm with fire apparatus is complicated by many things that can delay arrival at the fire scene, such as one-way streets, raised dividers, and traffic congestion.

One-Way Streets

One-way streets pose special response problems. Drivers of fire apparatus must know very thoroughly their response routes, including any patterns of one-way streets. Most drivers learn the layout of their district by using their own fire station as a reference point. This type of training is insufficient, however, because of problems the drivers may encounter after they leave the station. For example, the address given may be inaccurate, or resposes may have to be made frequently from other than assigned fire stations.

The driver of a fire apparatus must be capable of rerouting his apparatus over the shortest distance in the least possible time. Driver-training drills should be developed through the use of different reference points for responses to target hazards.

Raised Dividers

Raised street dividers are intended to channel traffic and improve normal traffic flow. They can, however, create delays in responses to fire calls. Motorists traveling in traffic lanes rarely move over to the curb when they hear sirens. Usually, they stop within their own lanes. Unless traffic is very light, these stopped automobiles effectively block the street from the curb to the raised center divider. Opening a passage through an area where cars are parked in every lane is time-consuming. Motorists, unsure of what to do when they realize that they are blocking passage of fire equipment, become difficult to direct. The public-address feature of some electronic siren systems can be used to direct stopped motorists and to clear blocked traffic lanes.

Raised dividers prevent crossing to the wrong side of the street to negotiate an intersection jammed with traffic and make the proper spotting of aerial trucks at a fire building more difficult. Room to maneuver trucks may be limited or totally absent.

Painted traffic lines, used as dividers to channel traffic, do not interfere with fire department emergency responses and operations. The use of painted-line dividers rather than raised dividers should be encouraged by fire department administrators. Fire department response and fire-ground operation problems can be reduced when entire streets are available for movement of apparatus.

Traffic Congestion

Traffic congestion around tall buildings must be expected to delay responses during normal business hours. Here are a few of the problems to be considered:

1. *Vehicles.* Since traffic congestion during peak traffic hours can cause serious delays, response routes mapped out to avoid trouble

areas should be developed if alternate routes are reasonably available.

The increased use of heaters in winter and air conditioners in summer reduces the effective warning distances of sirens and air horns since more and more motorists are driving with their car windows closed. Loud radios and stereo tape sound systems in cars also complicate fire department response problems by reducing the advance warning time. Therefore, the time available to clear streets and intersections in advance of responding fire apparatus is shortened.

2. *Pedestrians.* At peak hours pedestrians generally follow set patterns in walking to or from their means of transportation to work. A little study of traffic-congestion problems caused by pedestrians can pay big dividends in response time saved. Heavily congested pedestrian intersections should be avoided during peak traffic hours.
3. *Fire equipment.* With a little thought fire apparatus on the scene can be parked or positioned so that it will not interfere with the functions of other incoming units. Pieces of apparatus stripped of their men and equipment and not actually needed for some fire-fighting operations (pumping or laddering) should be moved to a separate parking area. This action will reduce congestion at the fire building. A knowledgeable fireman or apparatus operator is sometimes designated as a street control officer to supervise apparatus movement and parking.
4. *Parking.* Private automobiles parked along streets in front of multistory buildings can prevent close access to the fire building and can interfere with hose line and ladder operations. Fortunately for the fire service, newer high-rise construction usually includes several levels of basement parking. Where basement parking is available, street parking is generally prohibited. In areas where parked vehicles can interfere with fire fighting, prefire planning should include alternate methods of operation.

Getting to the Fire Building

Numerous obstacles are often encountered by fire fighters in their attempts to get to the fire building as soon as possible after they arrive at the scene of the fire.

Setbacks

Building setbacks can prevent the use of aerial ladders from the street. Many buildings, in fact, are set back so far from the street that a 100-foot aerial ladder, fully extended, could not reach from the street to the main entrance at ground level. Sometimes, aerial-ladder trucks can be brought close enough to the setback building so that some of the lower floors can be reached by ladder. The location, accessibility, and suitability of ornamental driveways, paved parking areas, and service roads should be considered in prefire planning for access to high-rise buildings set back from the street.

Landscaping and Pools

Landscaping may prevent normal fire-fighting operations. In addition to lawns and other landscaped areas, trees and shrubs must be evaluated to determine whether they would obstruct or impede normal fire-fighting operations, such as making the size-up, laddering buildings, rescuing occupants, leading in hose lines, and protecting exposures.

Reflection and other ornamental water pools may impede and obstruct access. Their bottom surfaces are frequently so slippery from plant growth and moss that men cannot walk safely through them.

Ornamental Walls and Statues

Ornamental walls and statues are frequently in the wrong places as far as fire department ladder and hose operations are concerned. Sometimes one side of a building is completely inaccessible for fire-fighting and rescue purposes. Alternate methods should be developed to overcome these access handicaps.

Sunscreens

Sunscreens are devices used to restrict direct sunlight and yet allow reflected light to enter building windows. Certain types of these screens can seriously hamper access to buildings.

Limiting type. Sunscreens that limit access to windows may be made of metal, plastic, brick, or concrete. They may be self-supporting, separate structures or an ornamental part of the building itself. The ornamental type either has holes too small for men to pass through or is installed too close to building faces to permit normal fire-fighting operations (see Fig. 7-1). Sometimes it is possible to pull off the screens in certain areas to provide window access. Prefire planning should take into consideration different ways to penetrate or remove limiting-type sunscreens.

Nonlimiting type. Nonlimiting sunscreens are those that have holes large enough for men to pass through or that are not so close to the building faces that they interfere with normal fire fighting (see Fig. 7-2). Even nonlimiting, freestanding, or self-supporting sunscreens can hamper access to the building. Ladders may have to be carried around the ends of long screens to reach desired locations; thus, fire-fighting operations are delayed and manpower energy is wasted.

Limited-Load Areas

Areas adjacent to structures incapable of supporting the weight of fire apparatus are a relatively new problem for the fire service (see Fig. 7-3). New-type construction, which incorporates special service and storage facilities, creates apparently safe areas on which normal fire-ground operations may be hazardous, impractical, or impossible.

Underground parking. Underground parking areas generally extend to property lines. The roofs of underground parking areas may be covered with landscaping, ornamental driveways, paved parking slabs, or reflection pools. In any event, most surface areas above underground parking garages will not support the weight of fire apparatus. Some areas are designed to support heavy trucks no closer than 30 feet apart, approximately the distance between the supporting arches and pillars. When heavy apparatus is improperly positioned above underground parking areas, it is possible for a fire truck and its entire crew to crash through several layers of parking. Building engineers or design architects should be contacted to determine safe-load limits over all parts of underground parking areas. Weights of various pieces of apparatus must also be considered in prefire planning.

Tunnels. The area over tunnels installed for utilities or as access for deliveries into basements may not support the gross vehicle weight of a fire truck. Prefire planning must include knowledge of front and rear axle weights of apparatus as well as load limits for various tunnels.

Above-ground parking. Above-ground parking areas are sometimes constructed over underground parking garages. Since these areas are primarily

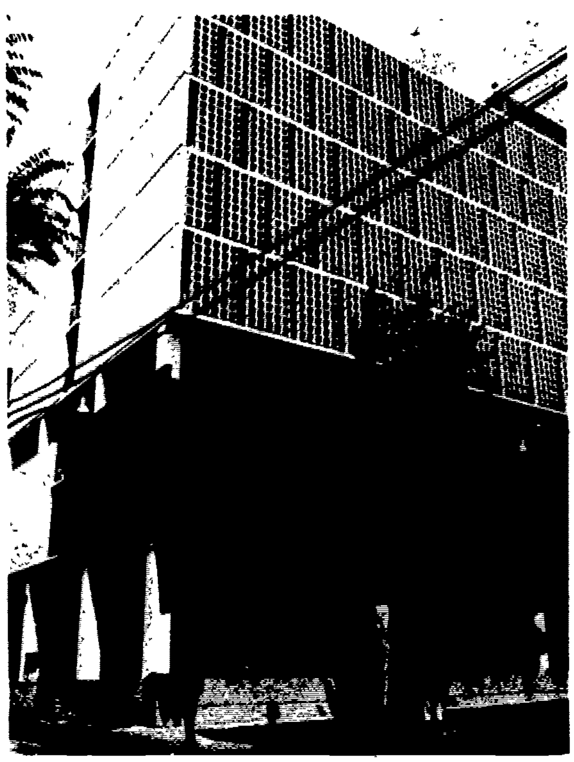

Fig. 7-1. Access hindered by limiting-type sunscreens

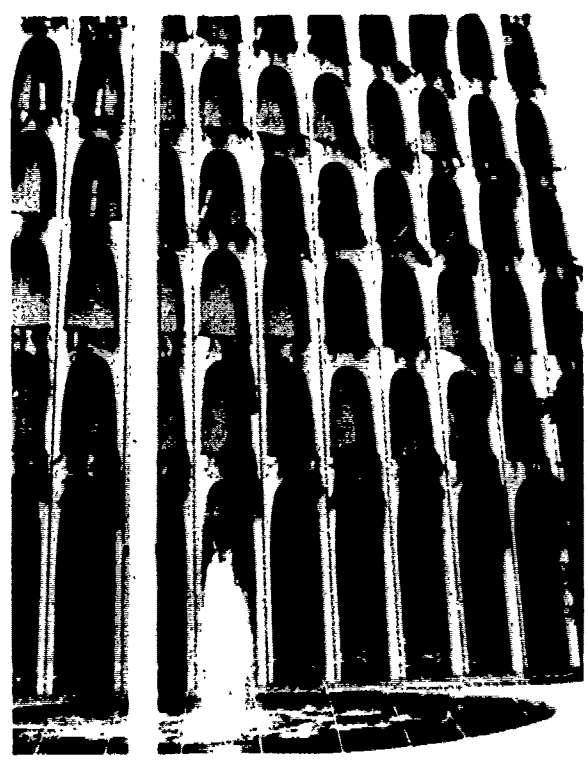

Fig. 7-2. Access allowed by nonlimiting-type sunscreens

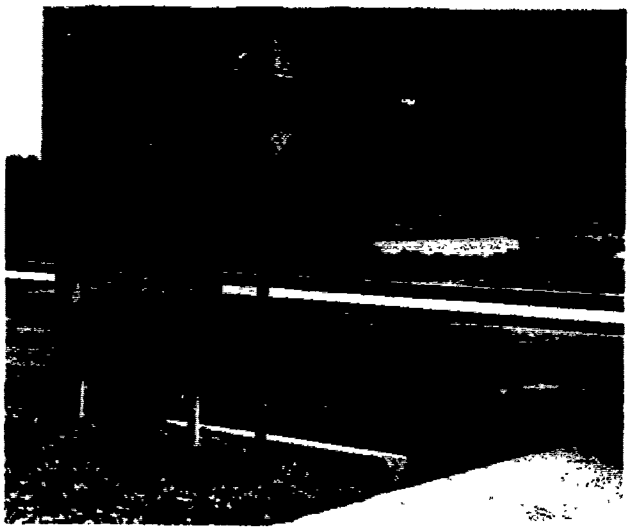

Fig. 7-3. Unsafe entrance for heavy fire apparatus

designed for automobiles, in most cases they will not support heavy fire apparatus.

Separate decks accessible by ramped driveways may also be built to increase available parking space. Parking decks often present an inviting alternative to long hand-laid hose lines. Ramps and parking-deck structures are, however, designed primarily for automobile use. They should never be used in fire-fighting operations involving heavy apparatus unless the ability of the ramp or parking structure to support such apparatus is known in advance (see Fig. 7-4). At second and third parking levels, sufficient headroom for apparatus may not be available even though the structure will support the weight of the apparatus (see Fig. 7-5). Lightweight apparatus such as rescue, salvage, squad, and ambulance vehicles may generally be driven on single-roof decks.

Driveways. Driveways may not support heavy apparatus. Unnecessary damage such as cracking, breaking, or depressing the driveway material can be caused by using inadequate driveways for access to the fire building. This damage potential must be weighed against the total loss potential when the fire commander considers the time that may be saved by the use of such driveways. He must also be aware of the fact that driveways may be installed over underground parking garages. In operations of this kind, therefore, he must consider hazards to personnel and apparatus.

Pedestrian walks. Although they may appear to offer access for apparatus, pedestrian walks present the same problem as driveways. These walks should not be used unless they are capable of withstanding the weight of apparatus or unless a greater loss will accrue if they are not used.

Getting to the Fire Floor

The design of a building frequently interferes with normal access for fire-fighting operations. Two of the more common design problems are created by windowless buildings and offsets.

Fig. 7-4. Heavy fire apparatus prohibited on roof

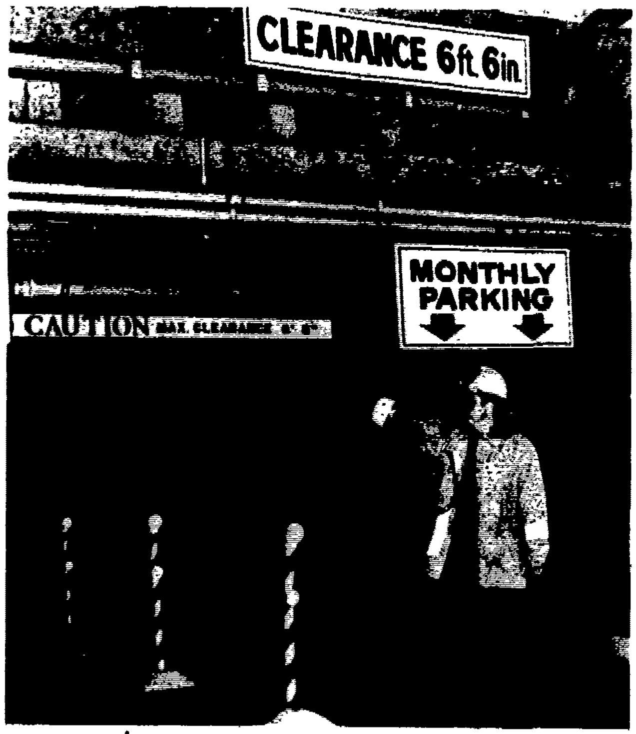

Fig. 7-5. Limited clearance available

Windowless Buildings

Windowless buildings obviously reduce means of access to interior areas. Rescue operations are also made more difficult by the lack of windows. In addition to planning for evacuation of windowless buildings, unique methods of getting men and equipment to proper locations must be developed.

Building Offsets

Building offsets can prevent laddering and rescue operations on upper floors. Building areas that could generally be reached by aerial ladders operating from the street become inaccessible on the second, third, or fourth floors. Double-laddering operations are sometimes possible in this situation. The roof of an accessible part of the building is reached by one ladder, and a second ladder is used to reach from that point to higher floors. Prefire planning must include alternate means of access to buildings with offset areas.

Prefire Planning for Access

Prefire planning for access is extremely important, including planning for possible fires in buildings under construction and planning for inadequate vertical clearances.

Buildings Under Construction

Buildings under construction present continually changing problems of access (see Fig. 7-6). Prefire plans developed today will have to be changed next month, next week, or tomorrow. A brief daily inspection by a fire department member should be a regular part of prefire planning for high-rise construction projects.

Screens. Temporary protective screens installed during construction impede access. Ways to remove portions of them or to bypass them during fire-fighting operations should be considered.

Excavations. Excavations prevent the placement of fire apparatus close to unfinished buildings and magnify the problems normally presented in rescue, hose, and ladder operations (see Fig. 7-7). An entire side of a fire building may be totally inaccessible for ground-based operations. Partially completed concrete structures and steel work laid in excavations further complicate access. Men carrying equipment may be forced to climb into and out of the excavation on their way to the fire building.

Heavy equipment. Temporarily installed heavy equipment, used during construction, can prevent access and increase structural failure hazards to fire

Fig. 7-6. Uncertain means of access to fire in unfinished building

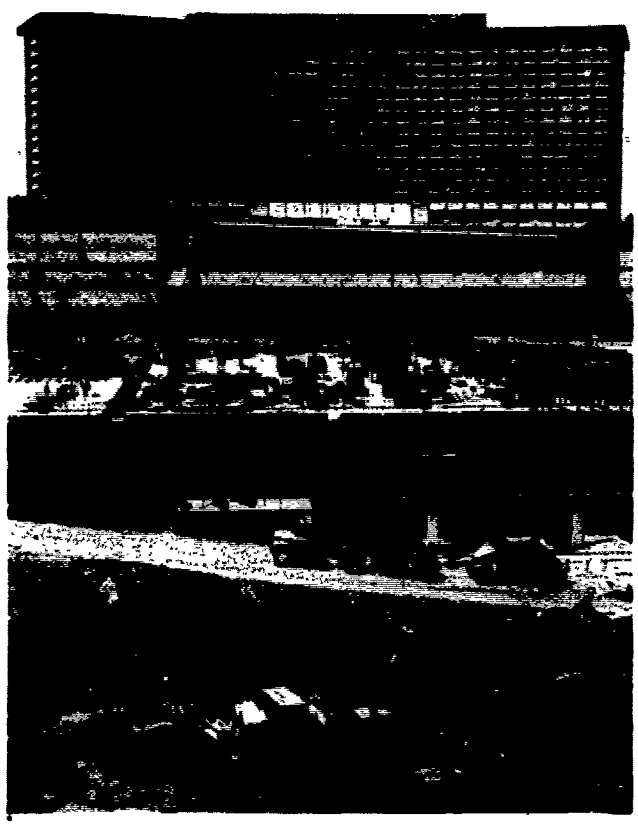

Fig. 7-7. Serious obstacles caused by excavation

fighters. Frequently, heavy equipment is also temporarily stored in hallways, stairway landings, basements, and on roofs. These kinds of problems will not be present when the building is completed.

Missing stairways. Missing stairways between certain floors prevent prompt access to the upper floors. The completion of stairways depends on construction scheduling. Access to the upper floors for regular workmen is generally by way of construction elevators.

Missing floors. Portions of floors may be missing for the same reason that some stairways are missing. Although critical-path scheduling results in an early completion date and keeps construction crews from interfering with each other, this type of scheduling does not create ideal conditions for fire fighters.

Material storage. Storage of building materials may block certain doors, stairways, and floors. Heavy storage may be present only on certain floors while other areas are clear. Inspection of material storage areas inside and outside buildings must be done on a regular basis.

Scaffolding. Scaffolding used by the various crafts sometimes completely blocks portions of stairways and floor areas. As building construction proceeds, scaffolding is moved from one area to another.

Inadequate Vertical Clearance

Inadequate vertical clearance presents access problems in some areas of new-style construction. Ornamental arches and breezeways over driveways may prevent use of driveways and surface roads even though the road's surface is structurally strong enough to support heavy apparatus. Lack of apparatus headroom in parking structures above ground and in many floors of underground parking basements can prevent driving fire apparatus to the fire level. Long hose lays, stretched by hand, become necessary under these conditions. Prefire planning should include the actual trial use of driveways to determine whether proper vertical clearance exists for different types of apparatus.

TOPIC 8

Logistics Problems

This topic, "Logistics Problems," is planned to provide answers to the following questions:

- What are some of the factors that complicate the logistics of dealing with fires in high-rise buildings?
- What role does time play in fires of this kind?
- What do many fire department officers seriously underestimate in dealing with these fires?
- What can be done to reduce the time required to transport men and equipment to upper floors?
- What unique manpower needs should be considered in dealing with fires in high-rise buildings?
- How should equipment used in combating these fires be handled?

General Problems

Generally, the problems inherent in moving men and equipment up and down in multistory buildings vary directly in proportion to the height of the building. These problems are compounded by such factors as unidentified floors and levels, scissor stairways, and partial stairways.

Unidentified Levels

Unless each of the levels in a high-rise structure is clearly marked with a floor number or by a designated name, fire fighters will have difficulty in orienting themselves. All doors and floor landings look alike when viewed from the interior stairways of tall buildings. Fire fighters should be trained to mark with chalk all doors and levels leading to areas where fire-fighting operations are being conducted. These "road signs" can eliminate costly delays and prevent duplication of efforts, such as checking floors for occupants and smoke or water damage (see Fig. 8-1). The identification of all stairway doors is required in some cities.

Fig. 8-1. Checking indicated by chalk marks

Scissor Stairways

In addition to causing the problem of unmarked floor levels, scissor stairways present other orientation problems. Some of these stairways may serve only every other floor; they are then criss-crossed by other stairways that serve the alternate floors. In some cases there is no means of access from one stairway to the other. In other cases a common landing between floors serves both of the scissor stairways (see Fig. 8-2). Prefire planning inspections and orientation signs (either permanent, or temporary during fire-fighting operations) are the answers to the problems caused by scissor stairways.

Partial Stairways

Partial stairways that serve only a few floors in a multistory building add to the fire fighter's problems. These stairways may serve from two to ten or 15 floors and then become dead ends. If access beyond these dead-end points is desired or needed, other stairways must be found. Under fire conditions, however, finding alternate stairways may be extremely difficult. Prefire planning inspections to discover these access traps are necessary. Owners of buildings should be asked to label each stairway door clearly so that users will know which floors are served by each stairway (see Fig. 8-3).

Time Factors

In tall buildings time has numerous influences on operations. The time required to perform various tasks in these surroundings is frequently seriously underestimated.

Time of Day

The time of day must be considered when fire-fighting tactics are being planned. This factor will influence the number of men who must be assigned to the most important operation, that of rescue, and will have an effect on all other operations.

Building occupants can interfere with and seriously delay the movement of men and equipment

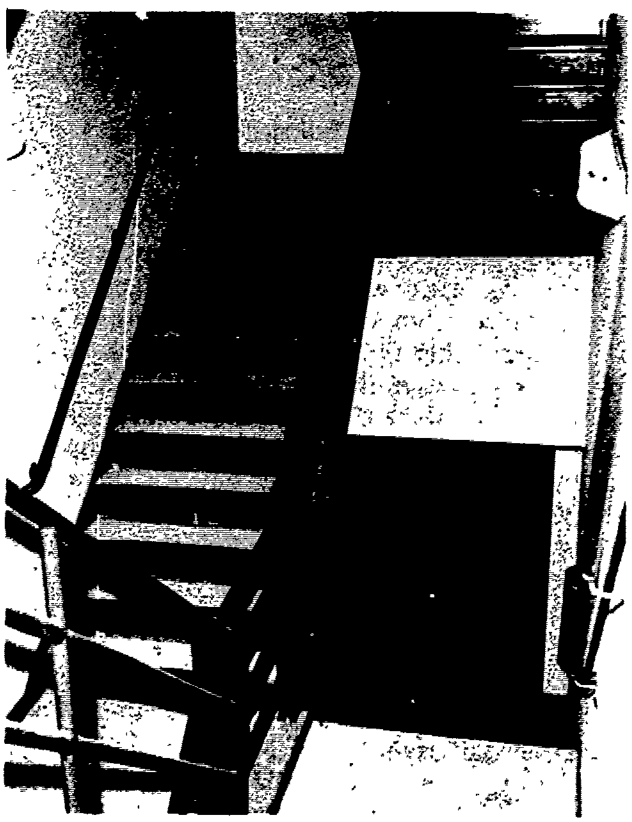

Fig. 8-2. Common landing for scissor stairways

to upper floors. Demands on automatically programmed elevators and the flow of pedestrian traffic down stairways are two factors that must be considered during periods of heavy building use. Traffic problems may exist both during the day and at night since some buildings are heavily occupied at night.

In buildings that are occupied primarily during the daytime, the programming of elevators at night introduces the "sleeping-elevator" delay in operations. Precious minutes may be lost unless fire department personnel have the means to switch elevators from automatic to manual control.

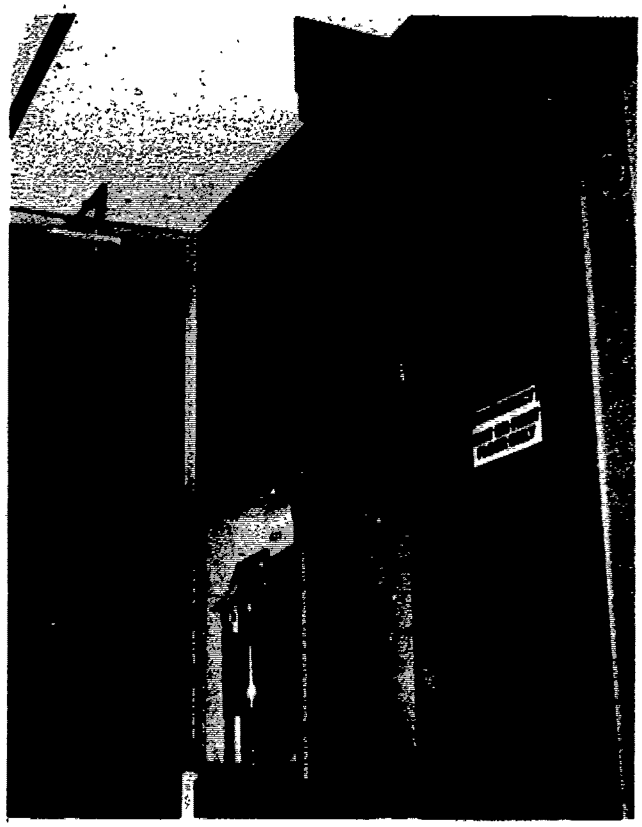

Fig. 8-3. Exit floor indicated by sign

Time for Necessary Tasks

The time required to do most fire-fighting jobs usually increases in direct proportion to the height of the building. Many fire officers seriously underestimate the time required to accomplish the basic operation of putting water on a fire in a tall building. It often happens that fire fighters require more time to reach the fire floor of a high-rise building than to get from the fire station to the fire building.

Ventilation, salvage, and overhaul also take much longer because of the number of floors that may be involved in the problem or because of the large number of floors between the fire and street level. Coordination and a total team effort are required to reduce the time needed to accomplish fire-fighting jobs in tall buildings.

Time for Transportation

Vertical transportation of required manpower and equipment by elevator is more time-consuming than horizontal transportation. Since elevators have weight limits, it is not unusual to have loads waiting for elevators. On the other hand, the time required to transport material from the street to the lotby may create a situation where elevators are waiting for loads. For the purpose of saving time, at least two elevators should be placed on manual control for fire department use, and the operators of these elevators should be suitably instructed.

A "home station" to which each elevator returns after making a transport trip should be designated. At the beginning of operations, a home station is designated at the street or other fire department access level. Later, a home station may be established high in the building so that one elevator may be based at the command-post or resource-pool floor to transport relief crews and reserve equipment. Still later, home stations may be designated at various levels to expedite salvage and overhaul operations.

Where elevators are inoperative, the transportation of men and equipment to upper floors by stairway is a most serious situation. The time lost in transportation by this method will compound every problem created by the fire.

Manpower Considerations

Manpower is the most important fire department resource. Proper utilization of manpower always requires extensive planning. Fire planning for high-rise buildings must include consideration of fatigue, coordination, and the ever-present problem of inadequate manpower.

Fatigue

Fatigue occurs early among those fighting fires in high-rise buildings. Fire fighting is hard work at street level; when the fire is located high in a building, the workoad is probably at least doubled. Such things as climbing stairways when wearing protective clothing, carrying necessary equipment into the building, and getting equipment to the fire floor all contribute to early fatigue. When the use of breathing apparatus is necessary, the additional weight carried by the fire fighters takes an early toll.

Salvage and ventilation operations must usually be conducted on several floors. Access to necessary floors, even if men have been transported to the fire area by elevator, is generally made by connecting stairways. Tired crews on the fire floor are much less efficient, are less alert, and, therefore, are more accident-prone. Of necessity men must be trained to pace themselves and conserve energy whenever possible.

Coordination

The team effort necessary to achieve a common objective should be uppermost in the minds of all firemen and officers present at a fire (see Fig. 8-4). This attitude is particularly important at fires in multistory buildings. Vertical separations and distances between crews complicate the coordination of effort. Traditional rivalry between fire-fighting units must be transposed from How do I make my company look good? to How do I make the department look good? Rescue work, fire fighting, salvage work, and overhaul work are all linked together at fires. The final goal can be attained more easily through consideration of the team's job, through awareness of one's individual role, and through open communication with one's fellow fire fighters.

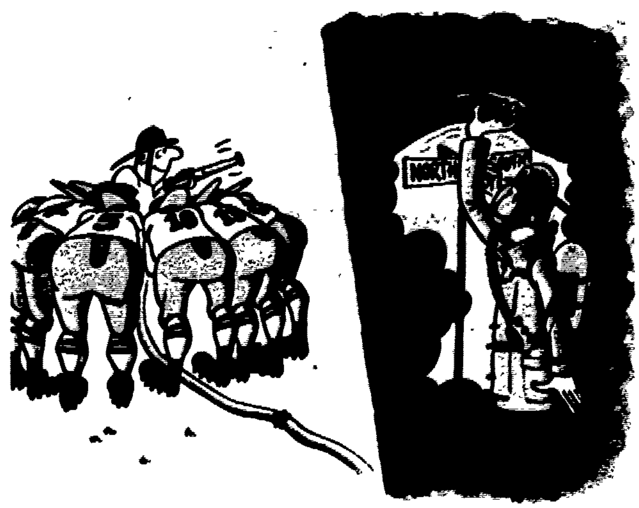

Fig. 8-4. Cooperation – key to successful fire fighting

Manpower should be rotated fairly often when relief crews are available. If no relief crews are available, crews that have been taking a beating should be exchanged with crews which have had easier jobs to perform.

All fire officers must understand the strategy developed by the fire commander. They must then communicate the part their unit will play in the total picture to the members of their respective commands. With complete understanding of the total and final objectives, much wasted effort can be eliminated.

Insufficient Manpower

Insufficient manpower creates greater fire losses. Fire operations in multistory buildings require more manpower than is generally available on the scene. This problem requires the most efficient utilization of available manpower. Prefire planning, sound strategy, effective coordination, and close supervision all contribute to effective utilization of manpower.

Even when relatively small fires in sealed buildings are being dealt with, the full first-alarm assignment should be kept at the scene of the fire until ventilation and overhaul are completed. Until all smoke, water, and debris are out of the building or properly controlled, fire-damage losses continue to accrue. A commonly heard radio message goes as follows: "We have a small fire on the seventh floor. One engine and one truck can handle." Such a response does not provide for the most effective use of the resources responding to the fire. The workload should be shared with as many units as possible. Companies not totally committed can be dispatched to other emergencies with very little delay. Meanwhile, they can contribute greatly to reducing the total fire loss.

Equipment

Transportation of equipment to be used when combating fires in multistory buildings presents new problems to the fire service. Every piece of equipment must be carried into the building and then transported vertically to the floor level where it is needed (see Fig. 8-5). No fire fighter should, therefore, enter the fire building empty-handed. The simple function of placing equipment where it is wanted requires much manpower, time, and proper planning.

Resource pools can be established to expedite transportation and use of equipment. As fire operations commence, fire fighters should carry spare breathing-apparatus bottles, hose packs, forcible-entry tools, spare lights, sawdust, salvage covers, and so forth into the lobby of a tall building. The lobby thus becomes an equipment resource pool closer to the fire floor and a relay point from which resource pools on upper floors may fill their equipment needs more quickly. Air bottles and lights must be carefully controlled. Empty air bottles must be kept separate from full bottles, and discharged lights must be kept separate from charged lights.

Manpower resource pools are frequently established to expedite relief of tired crews, to give units a place to report to when jobs are completed, and to expedite and control the exchange of breathing apparatus, air bottles, and other equipment in equipment resource pools.

Fig. 8-5. Problems caused by height of fire floor

TOPIC 9

Coordination Problems

This topic, "Coordination Problems," is planned to provide answers to the following questions:

- Why is coordination of equipment and manpower so important in combating fires in high-rise buildings?
- How can the coordination of these fire-fighting operations be improved?
- Why must a command post be established to coordinate operations?
- What are resource pools?

Coordination is the key to any successful fire-ground strategy. Fires in high-rise buildings require more prefire planning, more men, more equipment, and more active direction by the fire commander than do fires in buildings of ordinary size (see Fig. 9-1).

Reduction of Time Lapse

No element works against the fire service as detrimentally as does time. The old saying that "the first five minutes at any fire is more important to the fire department than the next five hours" is certainly true regarding fires in multi-story buildings. The taller the building, the greater will be the potential for fire loss because the internal exposure to flames, heat, and smoke becomes greater. The time required to control the flames, heat, and smoke must be reduced to an absolute minimum. Fire strategy must be developed with swiftness and with a definite plan and purpose in mind. Well-trained fire companies, following a prefire plan for a given building, are essential in reducing fire losses.

After their arrival at the scene of a fire in a high-rise building, fire fighters may need more time to reach the fire floor than they needed to travel from the fire station to the front of the fire building. Delay caused by lack of access up to or into the fire floor adds substantially to the loss potential.

A total fire plan, actively directed, which places men and equipment in suitable positions to perform all necessary fire-fighting operations, must be developed quickly by the officer in charge. The elements needed to develop a sound fire strategy are (1) a good knowledge of the building, men, equipment, and water supply available; (2) the size of the fire problem; (3) the external and internal exposures; and (4) a continuous size-up of the rapidly changing situation. Fire losses vary geometrically rather than directly according to the time the fire burns, as demonstrated by the Standard Time-Temperature Curve.[1] Time delays caused by lack of coordination of effort, duplication or omissions of work to be done, and false starts or unnecessary work accomplished cause greatly increased fire losses.

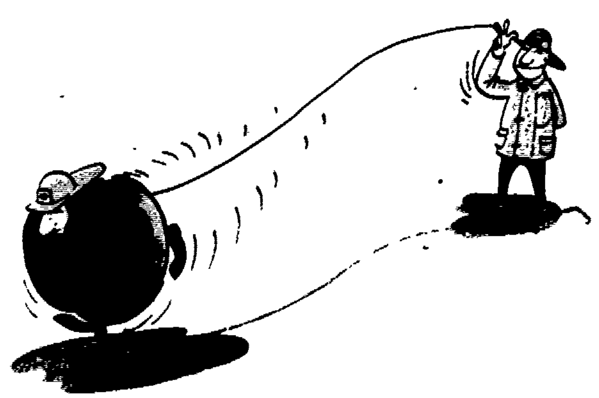

Fig. 9-1. Fire fighters directed by fire commander

Improvement of Communications

Much time can be lost through uncoordinated efforts in communications. Fire-ground communi-

[1] *Fire Protection Handbook* (Thirteenth edition). Edited by George H. Tryon and Gordon P. McKinnon. Boston: National Fire Protection Association, 1969, p. 8-6.

cations must be accomplished in a different manner than ordinary communications. Absolute understanding by the sender and the receiver are requisites for emergency messages. Rules to be observed are as follows:

1. The message should be well thought out before it is sent so that its meaning will be clear.
2. The message must be received and understood.
3. The message must be acknowledged so that the sender knows he got through and will not have to repeat the message.
4. The sender should be questioned by the receiver until understanding is complete.

Coordination of Mutual-Aid Companies

Mutual-aid companies pose special problems in coordinate fire-ground practices. The time required for mutual-aid companies to arrive at the fire scene must be considered in light of the expected progress of the fire during the same time period. Assistance should be requested as soon as the officer in charge determines that mutual-aid companies might be needed. If it is later decided that they are not needed, they can be sent back. Too often, mutual-aid companies have been called too late to reduce the loss; their assistance was limited to overhauling and wetting down the already ruined building.

Complete understanding of the part these companies play in the overall fire strategy must be established between fire commanders and mutual-aid officers before the companies are committed to specific operations. More time is required to brief mutual-aid companies than to brief one's own companies. Mutual-aid companies generally will not be familiar with one's exposure problems, individual company tactics, and fire-ground strategy.

Different radio frequencies can cause significant problems in working with mutual-aid companies unless advance plans are made. Such plans should include developing mutual-aid communications systems and carrying out communications exercises together with mutual-aid companies.

Although most fire departments now use standard hose fittings, other nonstandard equipment and fittings may be a problem. What is considered standard in one's own department may not be considered standard by mutual-aid companies. Among the most critical equipment to consider is self-contained breathing apparatus. Air cylinders and oxygen cylinders are definitely not interchangeable. An explosion hazard may be created by impurities or oils in the air systems. Air must be used with air equipment and oxygen with oxygen equipment. Manpower from mutual-aid companies is of little value in smoky buildings once their original air or oxygen supply has been used unless provisions have been made to replenish such supplies.

A comparison of equipment and fittings should be made with all mutual-aid companies. Adapters for air systems and noninterchangeable adapters for oxygen systems should be developed wherever possible.

Establishment of Command Posts

Important items to be considered in the establishment of command posts are their location, staffing, and equipment.

Location

Command posts must be established with the greatest possible utility of function in mind. Since they are centers for information, strategy development, and decision making, command posts must be located close enough to the fire scene to make effective communications possible. Locations of resource pools also must be considered when command posts are being established. Resource pools should not interfere with command-post operations but should readily provide the tools needed by the fire commander.

An excessive number of persons in the command post will interfere with fire-command operations. Only necessary personnel should be used at the command post; the rest should be assigned to resource pools at secondary command posts.

Inside of buildings. Secondary command posts (subcommand posts) located inside of buildings may become a necessity in dealing with fires in tall structures. If adequate space is available, secondary command posts should be located two or more floors below the fire floor. This location leaves the intervening floors open for water control and salvage work (see Fig. 9-2). Secondary command posts so located are close enough to provide necessary communication to and from fire areas. At the same time they are away from the turmoil, congestion, and noise of the streets below. If, however, adequate space is not available on upper floors, secondary command posts should be located in the lobby of the fire building.

Outside of buildings. Command posts located outside of buildings should be selected with care. Command-post operation is a separate and most important function. Interference with its function from any source must be avoided. Roping off of the area around the command post has proved effective in reducing the number of unneeded persons in the command post. All persons, including fire fighters who are not essential to the operation of the command post, must stay out of the area. Police assistance may be required to maintain security.

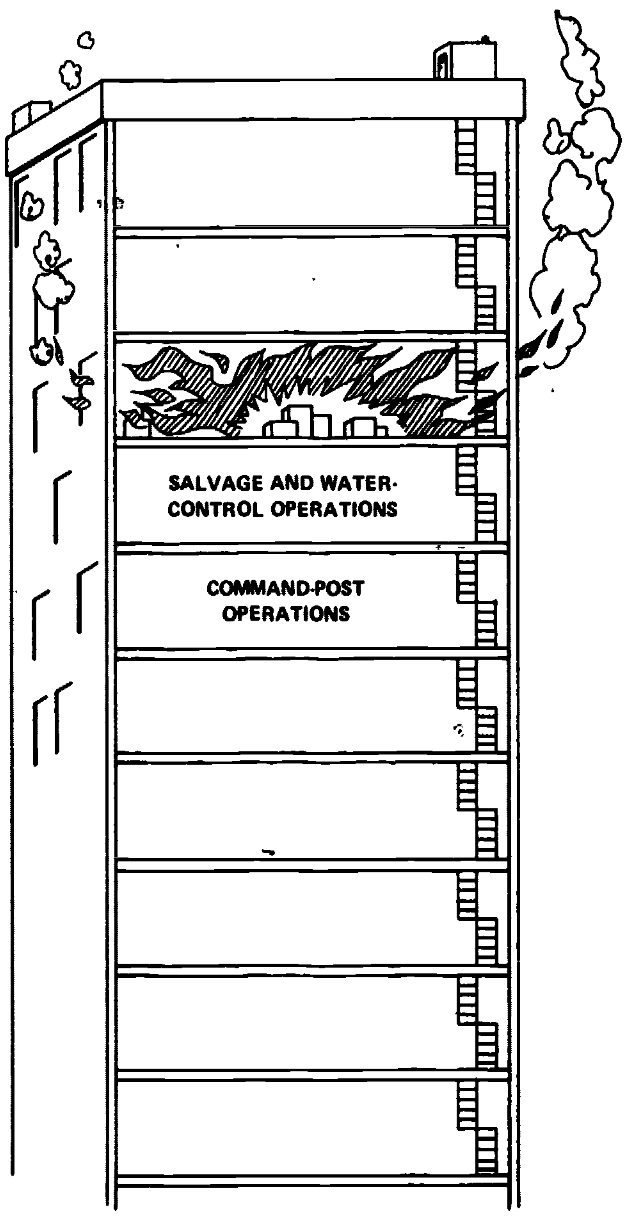

Fig. 9-2. Command-post operations in fire building

All but necessary radios should be silenced, engines should be shut off when they are not needed, and other methods of reducing noise should be used to minimize the confusion in the area of the command post.

Aides

Aides are a primary requirement at command posts. The aides should be used to develop situation maps or drawings, record locations of units working, keep track of relief units available, and receive and send messages by whatever means available. Generally, at least two aides are needed whenever a serious fire is present in a multistory building. The number of aides required to handle fire-ground details for the fire commander grows in direct proportion to the size of the fire problem. The fire commander must not be involved in minor details of the fire; he must instead be free to make decisions based on all of the information and details collected and recorded by his aides. He must see the total picture of events and actions on the fire ground. Strong leadership, definite delegation of responsibility for jobs to be done, and a determination not be become involved with details being handled by other persons are requisites for the fire commander.

Command Structure

At major fires in high-rise buildings, a preplanned method of expanding the command structure is necessary. As the number of fire fighters at the fire scene increases, higher-ranking chief officers should assume command according to procedures already established. When a senior chief officer arrives and assumes overall command, the chief officers on the scene may be assigned to command fire sectors or resource pools.

Other Requirements

Previously developed attack plans, good lighting, and basic materials for constructing charts and recording information are essential and should be carried in command cars.

Information Facility

A public information officer should be designated during all large fires. The news media are eager to get information and meet deadlines, and it is most important that the fire department cooperate with them. The public is entitled to know what its fire department is doing, what its problems are, and how effectively it is solving those problems. In addition, a capable person who has no other job to do but to keep the news media informed can improve command-post operations by allowing other command personnel to work without interruption.

Resource Pools

Resource pools are depots for temporary storage of fire-fighting assets (see Fig. 9-3). Manpower, equipment, and apparatus pools will probably be necessary at large fires in multistory buildings.

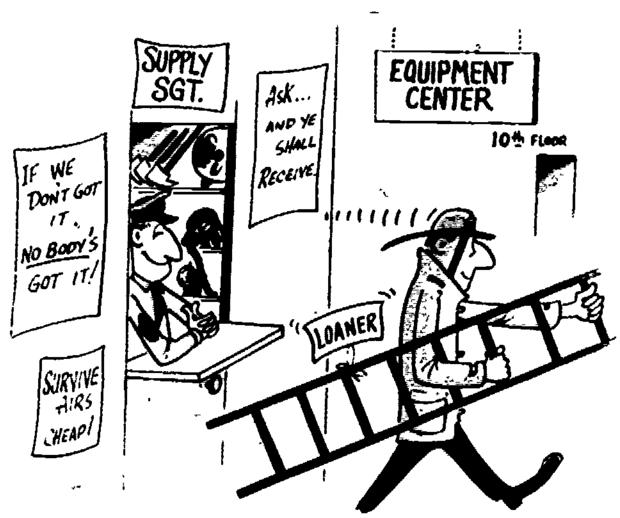

Fig. 9-3. Fire-fighting operations simplified by use of resource pool

Location

Locations of resource pools should be carefully chosen. They should be established close enough to the fire scene to permit an easy flow of men, apparatus, and equipment in and out of the pool. Resource pools should not, however, be allowed to interfere with command-post operations. All personnel not actually working on the fire or in the command post should be assigned to the resource pool.

Inside of buildings. Manpower and equipment pools inside of buildings should be set up as close to the fire floor as possible. The logistics involved in transporting men and equipment in tall buildings determines the locations of resource pools. Men and equipment in resource pools close to the fire floor are more readily available. When the floor on which the secondary command post is located is of sufficient size, the resource pool may be located there; otherwise, the floor below the command post is recommended for the resource pool.

Building lobbies, basement parking areas, and commercial delivery tunnels have been used to good advantage as space for resource pools. Proximity to elevators that can transport men and equipment aloft is one good reason for considering these locations. Another very good reason for using an inside location is good public relations. Few people understand the complexity of fire-ground operations. When fire fighters are observed standing idle while a raging fire is in progress, a very adverse public reaction is created.

Outside of buildings. Apparatus resource pools outside of the fire building should be located where there is ample space to park. The pools should be close enough to the building so that equipment can be carried in quickly. Finding such an ideal situation will be difficult at most fire grounds, but the effort must be made so that the transportation of fire-fighting equipment into the building can be expedited. Long lines of men carrying fire hose, spare breathing apparatus, bottles, lights, smoke ejectors, forcible-entry tools, small ladders, and so forth waste manpower energy and precious time.

The complete blocking of streets without adequate police traffic control is to be discouraged. A better method of operation is to use nearby parking lots or not more than one-half of the available street area. This procedure allows incoming companies to reach the fire building more quickly.

TOPIC 10

Communications Problems

This topic, "Communications Problems," is planned to provide answers to the following questions:

- What communications facilities may be available in a high-rise building?
- What communications facilities are needed at fires in high-rise buildings?
- Why may auxiliary communications facilities be necessary?

Fire-ground communications are much more difficult in tall buildings than in ordinary buildings. Since visual communications, such as arm signals or flashlight signals, are practically impossible to use, they should not be relied on. If firemen and fire companies are forced to use visual signals, advance planning is necessary so that the receiver of the message will be watching a particular location for the messages that are to be sent. Sometimes at least one man must be assigned the specific duty of watching for and answering visual messages.

External and Internal Communications

External communications at street level are easier to achieve than communications between those outside and those inside high-rise buildings. Visual signals such as lights, audible signals such as apparatus horns, and message runners may be used to supplement two-way radio communications. When radio traffic is heavy, supplementary methods should be developed to permit critical or command messages to be transmitted and acknowledged by radio. Communications teamwork that uses other means of communications and does not clutter frequencies with unnecessary or routine messages should be a part of the total prefire plan.

Internal communications are most difficult to establish. Men and companies separated by partitions, floors, and roofs obviously cannot use visual or audible signals.

Methods of Communication

Methods of communication at the fire ground include the use of shortwave radios, telephones, voice amplifiers, message runners, and radio relays.

Shortwave Radios

Until the shortwave radio becomes a part of every fireman's personal equipment, the fire service will continue to have massive communications problems. Methods of making the best possible use of those portable radios available on the fire scene must be developed. Companies and men that are not radio-equipped should be assigned near others that are so equipped. Each man should know the location of his radio link at all times. Reports of changing situations are expedited by proper joint use of available radios. The fire commander must know as soon as possible (1) when companies have completed a particular job; (2) when they are available for another assignment; (3) when there is a need for assistance; and (4) when relief crews are needed and where they should be sent.

Telephones

Telephone command posts improve communications; they may be established in some buildings. Switchboard operators in hotels and large apartments (or single-occupancy commercial buildings) can be instructed to give all command-post calls to a fireman stationed at a particular extension. Other firemen on various floors of the building merely pick up a telephone and ask for the fire command post. A radio relay can be established at this command post to keep in contact with the dispatching center and with fire department units in the street.

Firemen may also commandeer telephones in buildings not equipped with a switchboard. They can call a predesignated telephone number at the command post from any other telephone. Training in the use of "call director" and other new types of telephones is necessary if this procedure is to be used.

Voice Amplifiers

Bullhorns and other voice amplifiers may be used to advantage in long enclosed stairshafts. The tendency of the message sender to shout must be overcome. Speaking in a normal voice and letting the electronic speaker do the work is the best technique.

Message Runners

Message runners may become necessary to augment other means of communication. This procedure uses manpower that, in the opinion of some fire service authorities, may be used to better advantage elsewhere. The assignment of men for this vital purpose should, however, receive top priority. Extra men who would otherwise be standing by in fire stations may have to be called.

Radio Relays

The relaying of radio messages to expedite communications should be a regular part of fire department training. Messages sent by one unit may not be heard by the intended receiver. Units that are in a position to hear unacknowledged messages should repeat the message exactly as sent. A good rule is to relay any message heard that has not been acknowledged. Firemen who are not radio-equipped may use a telephone in the building to call their dispatching center and thus have messages relayed by land-station radio. The same procedure can be followed by radio-equipped firemen when they find themselves in areas of buildings where portable radios will not transmit effectively.

Operation of Two-Way Radios

The two-way radio is the best means of communication under normal conditions. Complete understanding between sender and receiver can be achieved quickly when location, weather factors, and traffic volume permit.

Dead Spots

Dead spots from which mobile or portable radio units cannot operate efficiently will be encountered inside and outside some tall buildings. Moving the unit a few feet, especially to locations near windows and elevator shafts, sometimes solves the problem. Frequently, portable radios cannot transmit from within elevator cages. However, land-station messages will generally be received by all mobile units because the output power is greater. Persons with mobile units should remember to relay messages that are sent but not acknowledged. Improper use of portable radios has created more dead-spot areas than actually exist in tall buildings; proper training in the use of these radios is absolutely necessary. A knowledge of the weaknesses, functions, and theory of built-in antenna systems will eliminate many of the so-called dead spots.

Traffic Volume

Excessive radio traffic can seriously restrict the use of radios. Each message sent is usually important to the sender. However, in the excitement surrounding a major fire, many messages that are either too long or actually unnecessary use much of the available air time. Other important messages may be kept off the air or may be interrupted during transmission. Repeating of interrupted messages uses twice the air time that should be used. Training in the proper use of air time should include (1) deciding whether the message is really necessary; (2) thinking through the wording of the message before sending; (3) keeping the message as short as possible; and (4) listening before sending so as not to interrupt another message. This training should be given to all fire department personnel.

Some priority must be established for the proper use of air time. Generally, this type of priority is linked to rank. The reason for this procedure is that the more responsibility a fire department officer has, the more important his messages will be.

Alternate frequencies used as command channels for major emergencies can separate and simplify fire-ground communications.

Geographical Skips

Geographical skips occur under certain weather conditions. Broadcasts on the same frequency made from some other city will bounce off an ionized layer high in the sky and be received by other radios many miles away. Some fire departments in southern California regularly hear messages from Ohio, Alabama, and Washington. These broadcasts can and do interfere with emergency operations. It may be necessary, therefore, to switch to an alternate frequency, repeat messages, ask the skipping station to stand by, or use some other means of communications. A new development called "private line" is available to overcome "skip" problems.

Mutual-Aid Frequencies

Radio frequencies used by mutual-aid companies may be different from one's own frequencies. Where mutual-aid agreements are carried out on a day-to-day basis, certain command-car radios should be made to operate on all necessary frequencies. The cost of this arrangement is minor compared to the benefits that are possible in the event of a major fire in any of the cities involved. Some alternate methods are (1) loaning a portable radio on the proper frequency to the commander of the mutual-aid companies; or (2) stationing radio-equipped vehicles, one on each frequency, side by side to serve as a listening post and as a radio-relay point.

Operation of Telephones

Telephones can be used at the fire scene to more advantage than most fire officers realize. With the advancement of two-way radio, many fire departments have quit using telephones and have relied upon radios too heavily. It must be remembered that once a telephone connection is completed there is no interference from other messages; a two-way conversation can be had with complete understanding. Many buildings housing occupancies that take up several floors, such as hotels, hospitals, and large business enterprises, are equipped with "house phones." These local telephones, which terminate at a switchboard, provide a ready-made communications system for fire-ground operations.

Traffic Volume

Heavy telephone traffic on the receiving end of calls made from the fire ground to a communications center may delay communications. Alternate numbers may have to be set up to handle part of the volume. These alternate numbers can also be established to good advantage when no traffic problem exists. Certain officers or units (such as those assigned to salvage or water control) may be instructed to call an alternate or semiprivate number. Messages concerning certain fire-ground functions can thus be handled separately.

Inoperative Switchboards

Inoperative switchboards in fire buildings may prevent the use of extension telephones. An attempt to find someone in the building who is knowledgeable enough to connect certain telephones to outside lines should be made. Many firemen have this knowledge or can acquire it in a short training period.

Dead circuits may be created by a fire. In newer-type construction the problem of dead telephone circuits caused by fire has been minimized if not entirely eliminated. Telephone cables are led in by way of the basement and then up to each floor served. Thus, any telephone below the fire floor should be in working order.

Complicated Dial Systems

Complicated dial systems are being installed in many new buildings. New multipurpose telephones used by modern businesses are simple to operate once a person knows how. Fire department members should keep in close contact with local telephone representatives to determine what new types of telephones, attachments, and call directors are being installed. Training in the use of all new types of telephones should be a regular event if fire departments are to use them for communications. Local telephone offices will cooperate in this training program.

Use of Messengers

Messengers used to carry important fire-ground information may supplement or, at times, take the place of other means of communication. Positive understanding and acknowledgment of orders relayed by messengers are two good reasons for using messengers.

New tall buildings generally exceed 20,000 square feet per floor. These distances preclude normal voice communications. The simultaneous use of walkie-talkies on the same floor creates technical radio problems. A message runner employed to keep persons informed has been found to be a very effective alternate means of communication. This messenger need not be separated from his unit or from other duties except while delivering messages.

The height of a tall building may require messenger service. If radio transmission is technically difficult or the air is cluttered with messages and telephones are unavailable, the positive sending and receiving of important messages is assured by the use of message runners. However, the energy limitations of message runners must be considered. Climbing stairs in buildings and running between the message sender and receiver are hard work (see Fig. 10-1). Runners should be alternated to prevent excessive fatigue.

Coordination of messenger information is probably more difficult than coordination of information received from other sources. Fewer people are aware of the information carried. In order that no "secrets" exist, control of fire-ground information must be established if messengers are used. All information must come into the command post or an information relay point.

Fig. 10-1. Message runner: an important link

Use of Public-Address Systems

A public-address system can be used to inform many persons of new situations or changing events. The system will generally not interfere with other means of communication. When buildings are unoccupied except for fire department personnel, broadcasts on public-address systems are helpful in keeping all persons informed. Communications are thus established to report the progress of the fire and the fire-fighting strategy.

One hazard of using a public-address system is the panic potential in the event that the building is occupied by civilians. Building occupants who hear fire department messages may misinterpret meaning or intent. Persons who are in no danger from the fire may conclude that they are indeed in peril. It should be remembered that panic is contagious. Once started, panic will create many extra problems in addition to the fire problem.

Public-address systems may be inoperative because of fire damage. Fire department members with other means of communications who are in areas to which messages are being directed on the public-address system should be asked if they heard the message.

Portable public-address systems can be used to keep units informed and to direct operations of companies or units that are visible to the fire officers concerned. Portable systems used in buildings are subject to the same uses and limitations as permanent systems. Portable public-address systems and air speakers may be used to magnify and project voice orders. These means are particularly effective within stairshafts and on large floors. The volume of the speaker output must be controlled to prevent distortion of the message by the echo. Speaking in a normal tone of voice and letting the system do the work helps improve message clarity.

TOPIC 11

Salvage and Overhaul

This topic, "Salvage and Overhaul," is planned to provide answers to the following questions:

- Why are salvage operations so important in fire-fighting operations in high-rise buildings?
- How can water used to combat fire be removed from high-rise buildings?
- How can heat damage caused by fire be reduced in high-rise buildings?

General Observations

Salvage operations should not be delayed until the fire is extinguished but should be started as soon as manpower is available. Training of fire-fighters should include developing the capability to "think salvage" during fire-fighting operations. Losses are reduced and fire-ground operations are more effective when the salvage factor is included in overall fire strategy. Losses caused by improper forcible entry, uncoordinated ventilation, and indiscriminate use of water are familiar to all fire service personnel.

Other types of losses can occur in modern high-rise structures, and every effort must be made to prevent unnecessary damage. For example, costly damage has occurred to carpeted floors and wood-paneled walls; carpeting has been ruined by improper containment of wet debris prior to transporting it to and in the elevator; wood paneling has been scraped and damaged by debris; and breathing apparatus strapped to the back of fire fighters have caused damage to paneled elevators. Although damages such as these are chargeable to fire loss, they are mostly preventable.

Effects of Height on Operations

The height of the fire building has a substantial effect on salvage and overhaul operations.

Debris Removal

Debris removal from upper floors is most difficult. Elevators and stairways must be used since throwing debris from upper floors is hazardous (see Fig. 11-1). Broken windows, damaged signs and awnings, and a scattered mess on the street below have resulted from this practice. Debris should not normally be thrown from windows located above the third floor.

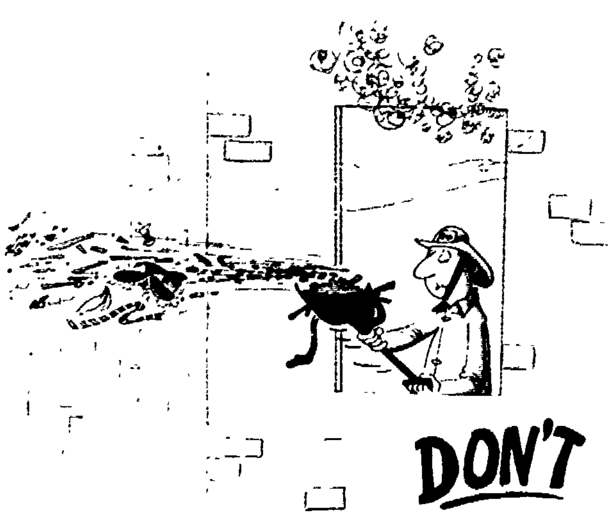

Fig. 11-1. Hazards caused by falling debris

In many instances properly overhauled debris may be left on the fire floor. However, glowing material must be completely extinguished, and water seepage from the debris must be controlled both horizontally and vertically. Storing debris on the fire floor is generally a good practice because it eliminates the need to find a safe and adequate storage area for the debris at street level and reduces damage that might be caused by transporting debris through the building. Generally, only debris that has no salvage value should be removed from the building. Fire-damaged business records especially should be retained in the building until the occupant or owner determines their value.

Manpower and Equipment Requirements

All salvage equipment (covers, sawdust, squeegees, and the like) must be carried into the building and transported to the floors of use. After use the process is reversed. Efficient salvage work requires the active movement of men and equipment from floor to floor. Men and equipment must be transported to positions where salvage operations are required and moved from time to time to stay ahead of the water that will descend from floor to floor until contained or controlled.

Ventilation of smoke-filled areas and the prevention of smoke buildup can also be classed as salvage work. Ventilation during salvage and overhaul operations requires additional men and equipment. Debris to be removed from the building must be loaded into rubbish carriers and elevators, then transported, rehandled, and overhauled at the storage site. Rubbish containers, bins, and dollies may be available at the fire building for use in removing debris.

When a serious fire occurs, salvage and overhaul operations should be actively directed by officers who are experienced in salvage work. They should be qualified to decide what materials should remain on the fire floor and what debris should be removed from the building.

Safety Hazards

Among safety hazards encountered by fire fighters in the fire building are structural collapse, failure of exterior assemblies, and respiratory problems.

Structural collapse. Fire streams that pour a ton of water (or more) per minute on various floors can quickly and significantly change the content load of a building. When fires involve older buildings, the weight of water applied for fire-fighting purposes can quickly exceed the structural-load limits of the building, perhaps causing entire floors to collapse. To prevent such collapse, fire fighters must channel water out of the building quickly by directing it to elevator shafts or stairways or, in extreme cases, by breaching floors and walls to provide drains. This tactic should not be delayed until the fire is under control but should be accomplished soon after streams begin working.

Fire-weakened floors may allow heavy equipment (such as safes, printing presses, extra-large filing cabinets, and the like) to break through and fall to the floor below. Once it starts falling, heavy equipment may crash through floor after floor until it finally stops in the basement. Prefire planning inspections will reveal those floors on which heavy equipment is located.

In some newer buildings prestressed concrete encases steel wires under tension. When exposed to high temperatures of a fire for a long enough period of time, the wires expand, relaxation takes place in the steel, and the affected member sags. When this sag occurs, the structure may not be able to carry its design load.

Failure of exterior assemblies. In some newer climate-controlled buildings the exterior walls do not support any of the building weight. This type of exterior wall is frequently constructed of glass and a lightweight framework with a low melting point (see Fig. 11-2). Failures of these exterior wall or window assemblies have occurred under fire conditions. When such failures occur, fire fighters are subjected to the hazard of falling from great heights (see Fig. 11-3). Extreme caution should be exercised by fire fighters who are working near exterior walls of lightweight construction.

Fig. 11-2. Lightweight construction of exterior wall

Respiratory problems. Fire fighters have a tendency to discard self-contained breathing apparatus too soon after a fire is under control and overhaul has started. Significant amounts of toxic fire gases may be present even though there is little or no smoke. Most fire gases are dangerous even in concentrations lower than one percent in air. Adequate ventilation, natural or forced, should be established before unprotected fire fighters are assigned to overhaul.

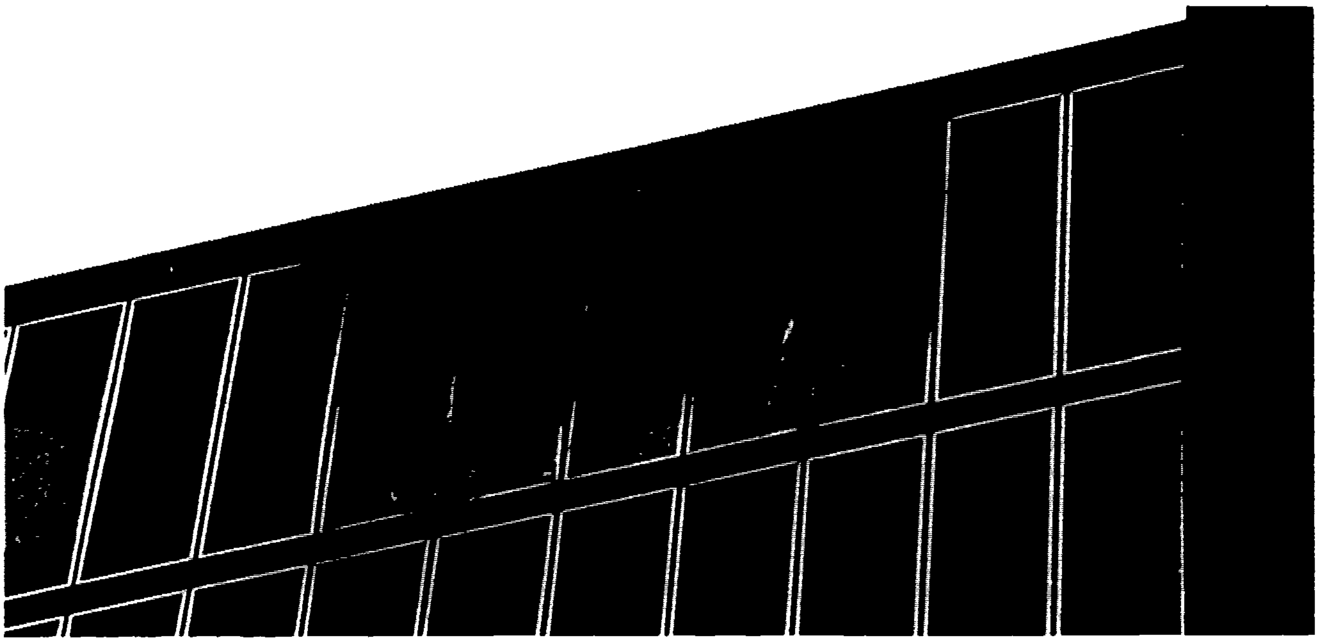

Fig. 11-3. Hazards caused by exterior walls of lightweight construction

Property Damage

Property damage can be increased by improper salvage and overhaul. Unnecessary exposure to water or smoke should be prevented wherever possible. Damage to contents and structural components should also be considered when debris is moved or transported.

Fatigue

Salvage and overhaul operations at ground level are hard work. In tall buildings the work load is at least doubled. Minimizing water damage and other damage requires fast-moving crews. Transporting equipment, handling debris, and traversing stairways to get the job done will tire men very quickly. In some cities relief crews are sent to the fire to do the remaining salvage and overhaul work after the initial assignment has the fire knocked down and under control.

Time

To date there is no substitute for hand labor during salvage and overhaul operations in multistory buildings. Time-saving equipment such as fork lifts, skiploaders, and bulldozers can be used on extensive overhaul jobs at ground level but cannot generally be transported and used above ground. Therefore, operations will take longer to complete.

Control of Water Damage

Water used for fire fighting and overhaul must be controlled and channelled out of the building. Final disposal of water that is traveling or dripping from floor to floor takes a great deal of time. Salvage covers and sawdust may have to be left on various floors for several days before the final cleanup is accomplished.

Poke-Through Construction

Poke-through construction that has not been properly sealed exposes every floor in the building to water damage. Water flows readily through the five-inch holes in each floor to the attic space below. The water then spreads out over hanging ceilings and flows downward. This process is repeated on each floor below the fire. The number of floors affected depends on the volume of water used and the length of time it is allowed to seek its own level. Every attempt should be made, therefore, to confine and control the water on the first floor below the fire.

Water Removal

The two general methods of water removal are vertical drainage and horizontal drainage.

Vertical drainage. Vertical removal of water is generally accomplished through the use of stairways for controlled channeling and the use of floor drains made by removing toilet bowls.

In some newer buildings carpeted hallways lead directly off each stairshaft. Generally, the only way to prevent unnecessary carpet damage when stairs are used to remove water is to construct sawdust dikes to seal stairway doors at each floor. The sealing must be accomplished before the water arrives at various levels.

In older buildings with windows that can be opened, a good tactic at times is to punch drain holes in floors to allow the water to drop to the floor below, where it is either more easily controlled or is rendered less damaging to contents and merchandise. Drains constructed to catch the water from the floor above and direct it out through a window should be used whenever possible.

Horizontal drainage. Horizontal removal of water from various floors is generally accomplished by using scuppers or by breaching small holes in outside walls where scuppers are absent. In some modern buildings the outside walls do not support any building weight. The structure is supported by columns which extend through the building. The exterior walls form a shell of glass and aluminum (or other lightweight material). This shell encloses the building and provides climate control. Areas directly under windows are composed of an exterior panel and an interior panel. Both panels are of lightweight material and the space between is generally filled with insulation. This assembly can easily be breached to remove excessive water that cannot be controlled in a less expensive manner.

Control of Heat Damage

Heat damage can be controlled through heat removal and through protection of exposed buildings.

Heat Removal

Heat can be removed from the fire building by means of vertical and horizontal ventilation.

Vertical ventilation. Vertical movement of heat out of the building is accomplished through vertical passageways. The stack effect draws the heat out of the areas being ventilated as soon as a top opening is provided.

Horizontal ventilation. Horizontal removal of damaging heat may be accomplished by cross-ventilation where windows that can be opened are available. In sealed buildings heat must be channeled both horizontally and vertically. Since heat is given up rapidly to the surroundings, this combined horizontal and vertical movement may have to be encouraged in tall buildings by the use of smoke ejectors.

Fire fighters should close off all possible avenues of heat travel and then develop ways of venting the heat through controlled passageways. Ordinary doors are amazingly effective in blocking dangerous convected heat. Exterior windows may be opened in isolated rooms to keep temperatures in those rooms at a safe level. In this case doors serving these areas are reclosed to prevent convected heat from passing through them. Property losses may also be materially reduced by the same techniques.

Exposure Protection

The passage of heat by convection and radiation into exposed buildings must be prevented. Unless severely exposed, standard glass windows that are closed will stop most convected heat. Regardless of their thickness, however, clear windows will not prevent the passage of radiated heat to materials on the other side of them. Secondary or exposure fires may start in adjacent buildings that receive radiant heat.

Buildings that have windows exposed to radiated heat or are severely exposed to convected heat will have to be protected. Water curtains must be developed outside to retard the flow of heat. If windows or walls fail, hose lines must be then operated inside exposed buildings to prevent passage of heat and flame through such openings.

Control of Smoke Damage

Generally, everything contacted by smoke is affected in some way. Even a smoke film deposited on a nonporous surface costs money to remove, adding to the total fire loss. In multistory buildings, therefore, every attempt should be made to control the movement of smoke until it no longer exposes life or property.

Smoke Removal

Controlled passageways that confine smoke to the smallest areas possible and provide a means to get it to the outside quickly should be a major objective during ventilation procedures. Smoke can be removed by means of vertical and horizontal ventilation.

Vertical ventilation. When smoke is hot enough to create a stack effect, ventilation is easily accomplished by the use of continuous vertical openings such as stairways and some types of elevator shafts. These vertical shafts must be prepared before smoke is ventilated through them. Doorways should be closed to prevent the horizontal spread of smoke on floors that have not yet suffered any fire loss.

Cooled smoke can be ventilated by establishing forced-air currents. Portable smoke ejectors may be used to move a column of air in from street level, up one stairway, across a smoke-filled floor, up another stairway, and out through the roof.

Horizontal ventilation. Horizontal movement of smoke should be as closely controlled as vertical movement. Lateral spread of smoke can be prevented by the quick closing of all openings leading to areas as yet unaffected. Firemen generally do not think of smoke damage control on the fire floor; yet losses at other than major fires may be substantially reduced by horizontal confinement of smoke prior to ventilation through controlled vertical passageways.

In older multistory buildings and in newer apartment buildings and hotels, quick confinement should be attempted. Horizontal ventilation of smoky areas through outside windows that can be opened is then the best tactic to keep smoke losses at a minimum. Portable smoke ejectors will be required to move the smoke horizontally.

Smoke Damage

Confinement and control of smoke are the keys to reduced interior smoke exposure. Smoke should be confined to as small an area as possible before it is ventilated through controlled passageways.

Smoke must be prevented from entering or damaging adjacent structures. Openings in exposed buildings, such as windows and air-conditioning intakes, should, if possible, be closed or protected by hose streams before horizontal or vertical ventilation is accomplished in the fire building.

Residual Odors

Residual smoke odors, even when no smoke damage is visible, may cause large losses at fires. This problem is particularly acute in sealed buildings. Confinement of smoke to as small an area as possible will reduce this problem.

Building Security

Buildings that have suffered a fire loss must be safeguarded from the effects of weather and from unauthorized entry.

Protection of Buildings

Building security can be restored in some cases. Windows can be covered with plywood or metal sheets, and doors can be refastened at the street level. When forcible entry into a fire building is required, some thought should be given to providing security for the building after the fire forces have left the premises. Alternate entries are possible at smaller fires, such as laddering and entering by a second-floor window or entering through a basement.

Damage caused by rain, snow, or wind entering a building through openings caused by fire-fighting operations are generally chargeable as secondary fire loss. Weather protection for roofs and window openings must, therefore, be provided. Tar paper and plastic sheeting have been used successfully for this purpose.

Protection of Contents

Valuable merchandise is easily recognized and usually provided with security. However, many other items, generally in the form of business records or documents, are of great value to the owner/occupant. These items, such as tax records, accounts receivable, business contracts, inventories, and other business records, must be secured from pilferage and additional damage.

Trade secrets such as formulas, processes, and business procedures are particularly vulnerable to theft after a fire. Unauthorized entry must be prohibited. In some cases, fire department or police department guards may be left to secure the premises until building owners or occupants can be contacted and private police protection provided. Proper security will then be provided for all occupants in the building.

Access for Operations

Fire fighters commonly face problems in the fire building that interfere with access needed for salvage and overhaul operations.

Concealed Spaces

Spaces in walls and ceilings, under stairways, and in other similar places may contain water that was used for fire fighting. Controlled draining of this entrapped water becomes an important salvage operation.

An active search for concealed spaces that may contain glowing embers must also be conducted during overhaul operations. Rekindled fires have occurred when this search was not made (see Fig. 11-4). In many instances walls enclosing concealed

Fig. 11-4. Serious consequences of hidden fires

spaces may be uncomfortably hot to the touch. Fire commanders must then decide whether such hot walls should be breached to check for a hidden fire. Assigning personnel to monitor the condition of the walls usually assists in making the decision. If the walls cool, it can be assumed that they were heated by an exterior fire. If they do not cool within a reasonable length of time, it can be assumed that they are being heated by a concealed fire. Opening them to search for and control the hidden fire is then the only alternative.

Stairway Access

Access for salvage and overhaul operations requires a good knowledge of the travel routes available. Prefire planning should include consideration of stairway use for salvage and overhaul work as well as for fire-fighting operations. Fire damage to stairways may change predetermined travel routes. Plans should include consideration of stairways that may be blocked with merchandise or debris; missing because of fire damage, remodeling, or new construction; incomplete because of remodeling or new construction; partial because of building design; or inaccessible because of locked doors serving stairwell enclosures.

Inoperative Elevators

As the result of fire damage, elevators may not be usable for salvage and overhaul work. Without elevators fire department men and apparatus may be needed at the fire for long periods of time. The restoring of inoperable elevators to service must, therefore, be accomplished as soon as possible.

In some cities that contain high-rise buildings, elevator service is available on a 24-hour basis. This service should be requested as soon as the need is apparent so that salvage and overhaul operations will be expedited and normal business transportation restored. Owners, managers, or occupants of fire buildings should be encouraged to arrange for restoration of service. If the fire department makes such arrangements directly, there may be a possibility of fire department liability for the repair charges.

TOPIC 12

Loss of Electrical Power

This topic, "Loss of Electrical Power," is planned to provide answers to the following questions:

- What problems occur when electrical power is lacking in a high-rise building?
- How does a loss of electrical power affect manpower requirements?
- How does a loss of electrical power affect rescue operations?

Since much fire department equipment and many operations are geared to electricity, a complete loss of electrical power in a building can seriously delay fire-fighting activities. This loss of power can occur during fires and may create problems in the involved building and in neighboring buildings that receive power from the same source.

Fires can occur in multistory buildings during a citywide or areawide blackout, such as the well-known blackout in New York City not long ago. Such a combination of events confronts fire departments with massive and unusual problems. Top-level prefire planning should be developed to cope with such potential events.

Elevator Problems

Elevators, an excellent aid to fire fighting, will not generally be available following a power failure. Therefore, all operations will be slower.

Evacuation of Occupants

Evacuation of occupants during power failures must be accomplished by using stairways. The added traffic and need for fire department supervision of building occupants will interfere with and delay other fire department operations. Therefore, the establishment of safe-refuge areas within reasonable walking distance is imperative under loss-of-power conditions. Portable lighting will be necessary in the evacuation of building occupants.

Transportation of Men and Equipment

Generally, fire fighters must walk up and down available stairways when elevators are inoperative. In tall buildings this procedure is slow and fatiguing. Fire fighters in the city of Los Angeles have been transported to the roofs of tall buildings by helicopters. When fires are high in the building and stairways can be used for the downward trip to the fire floor, both time and energy can be conserved by this airlift procedure. Many cities do not have fire department helicopters. Prefire planning should, therefore, include researching the availability of mutual-aid helicopters. Commercial helicopters may also be available for fires or other city emergency work under contractual arrangements. Prefire planning should determine whether the roof of a building can withstand the weight of a helicopter and whether a landing can be made safely.

Usually, a power failure necessitates a slow procession of men carrying needed equipment up available stairways. In buildings with windows that can be opened, aerial ladders and snorkels have been used to transport sling loads of small equipment to a relay point on the highest floor possible. Such a procedure can save valuable time and energy. Large sling loads of equipment can be airlifted to the roofs of tall buildings by helicopter to speed the transportation process.

Entrapment

Building occupants and fire fighters may be trapped in elevators between floors when the loss of power occurs. These people may or may not be in a hazardous area. They must be rescued or released as soon as possible. Blank elevator shafts (those without openings on all floors) can further complicate the problem. Walls may have to be breached to effect the rescue. When power is lost completely, emergency bells and alarms in the elevators may not operate. An active search must be made to locate each cage as soon as it is known that the power is gone.

If fire fighters are trapped between floors and have no means of communication, a help signal should be developed and understood by all. The standard lifeline tug code has been converted to audible signals and is being used successfully.[1] Instead of four tugs to signal that help is needed, four hammering noises are made in series. This signal should be repeated at intervals until acknowledged. Fire fighters should always work in pairs until a fire is under control. Each fireman can thus act as his "brother's keeper" in the event of trouble.

Fatigue

Obviously, much more energy will be required when elevators are out of service. Relief crews will be needed earlier and more often.

Lighting Problems

Portable generators or other auxiliary electrical power supplies must be available to provide a minimum level of lighting. Some fire departments have "light wagons" that, in effect, are rolling auxiliary light systems. Portable generators should be available in sufficient quantities to provide the emergency lighting and power needed for fire operations in the largest building in the community.

Lack of Visibility

Many modern buildings have a central hallway on each floor that surrounds the "elevator core" in the building. The central hallway leads to other hallways or directly to individual occupancies. Since there is no natural light in the central hallway, the hallway becomes completely dark when the lights go out.

Occupants who are unable to see where they are going are easily frightened. If their usual means of egress (the elevator) is inoperative when they do reach it in the dark, the mere smell of smoke can cause panic.

Fire service personnel are accustomed to fighting fires under adverse lighting conditions. After the fire has been controlled, however, some lighting is generally available for salvage and overhaul operations. Without the normal sources of power, new problems will exist.

[1]The code is explained as follows: 1. OK 2. Advance 3. Take up 4. Help.

Ventilation Problems

Modern air-conditioning systems depend upon a large power source to keep the air within buildings reasonably fresh. Eventually, an oxygen-deficient atmosphere can exist after a power failure. Therefore, some method of providing an air exchange must be devised.

Underground parking areas depend on forced ventilation to reduce the carbon monoxide hazards developed by automobiles. Underground service stations are common in new high-rise buildings. These service station areas also depend on forced ventilation to take flammable liquid vapors (which are heavier than air) out of the basement.

Fire-Pump Problems

Electrically powered fire pumps are installed in most high-rise buildings to supply standpipe systems. Many of these pumps have auxiliary power supplies; other pumps have power supplied from two separate power-line sources. The latter type will not operate during an areawide or citywide blackout. Standpipes can be supplied by fire department pumpers. The fire department then becomes the primary rather than the secondary source of water. Prefire planning should include pinpointing the buildings in which this problem can exist.

Use of Equipment

The complete loss of power in a building obviously renders all electrical equipment inoperative. Many fire departments now carry portable generators that can develop necessary sources of power. Other fire departments have large generators mounted on "light wagons" that can also supply power for electrically operated fire department equipment.

Power sources that are generally overlooked by fire departments exist in many cities; these sources can be called on in time of need. Public utility companies, construction contractors, municipal public works departments, and various public service companies frequently have high-output electric generators mounted on trucks or trailers. Top-level prefire planning should include studying these untapped resources and developing agreements for using such equipment and facilities.

Smoke Ejectors

Smoke ejectors may have to be operated with long, heavy-duty extension cords stretched to neighboring buildings or other sources of power.

Many fire departments now carry gasoline-operated ejectors to offset a complete loss of power.

Portable Lighting

Portable generators and light wagons should be included in prefire planning. Long, heavy-duty extension cords and flood lamps are needed in conjunction with portable generators. Large flood lights on hydraulically operated masts are used by some fire departments to light large areas. This type of apparatus may be privately owned and made available for fire department use if proper arrangements are made in advance of actual needs.

Air-Powered Tools

Some air-powered tools are now available. Compressors that supply fire truck air-brake systems can supply the necessary air on the fire ground. Long air-supply lines and the necessary adapters are available. Portable compressors may also be available from public agencies and private organizations for fire department use. This resource should be studied during prefire planning.

Communications Problems

The value of communicatons has long been recognized. Therefore, many systems have been designed with auxiliary power sources. Prefire planning activities should include seeking out those systems that can resonably be expected to operate without their regular sources of power.

Public-Address Systems

Generally, built-in public-address systems cannot be relied on.

Telephones

Public telephone companies have developed a high degree of reliability for performance. Telephone systems operate with well-engineered auxiliary power, "floating batteries," and separate circuits. Therefore, the single factor of power failure in a fire building, in a city, or in a metropolitan area will not affect the normal use of telephones.

Local Alarm Systems

Some types of local alarm systems have sources of auxiliary power and/or "floating batteries." Other types that do not have alternate power sources may cause building occupants to have a false sense of security. The result of this situation is that alarms can be seriously delayed when persons rely on such systems to report fires and the systems are inoperative because of a power failure.

Auxiliary Power

Many high-rise structures are provided with auxiliary power systems. Large generators powered by internal-combustion engines serve critical portions of the electrical system. These generators may start automatically following the failure of the normal power supply or may require manual starting.

Portable fire department generators and those from public utility companies have been used at major fires to offset the lack of power. Portable generators tied in to regular circuits and systems have been made to operate. These cross-connections should be made only by knowledgeable persons. This time-saving method of providing emergency electric power should be studied and planned well in advance of the need.

Since people are conditioned to rely on auxiliary systems in the event of power failure, inoperative systems can create panic problems, particularly as to exit lighting, emergency lighting, and local alarm systems.

Improper maintenance of properly engineered auxiliary power sources is a main cause of power failure. As electrical systems age, maintenance and testing become increasingly more important. Prefire planning inspections should include checking the maintenance and testing schedules for all auxiliary power systems.

TOPIC 13

Smokeproof Stairways

This topic, "Smokeproof Stairways," is planned to provide answers to the following questions:

- What is an entirely new concept in exit ways?
- What types of buildings may house pressurized smoke towers?
- What are the construction features of mechanically ventilated stairways?
- How do mechanically ventilated stairway systems work?
- What kinds of fire-fighting problems do pressurized stairway systems create?

Many modern high-rise buildings are now equipped with pressurized smoke towers in accordance with the provisions of Title 19 of the California Administrative Code. These smoke towers represent an entirely new concept in exit ways. In some cases buildings that are not currently required to incorporate this type of exit are being equipped with these mechanically ventilated smokeproof stairways so that at some future date public-assemblage occupancies may be allowed on upper stories in the building. This new type of smokeproof stairway is designed to provide a safe exit for occupants of the building and immediate access for fire fighters in the event of a fire.

When a fire occurs in isolated areas of a building, the movement of smoke into escape routes becomes a critical factor; therefore, the maintenance of good visibility levels in escape routes is necessary to prevent panic. A method of exhausting heat and noxious gases produced by combustion before they enter escape routes is vital. The pressurized smoke tower is designed to solve these problems.

Construction of Stairway

The smokeproof stairway, which is similar in construction to the nonpressurized stairway, is enclosed by walls of two-hour fire-resistive construction. The smokeproof stairway is entered by means of a vestibule located on each floor of the building. The vestibule has two automatic doors provided with approved magnetic hold-open devices. These devices are connected to a smoke-detection system that, when activated by smoke, releases the magnets and allows all the doors in the exit-way system to close (see Fig. 13-1).

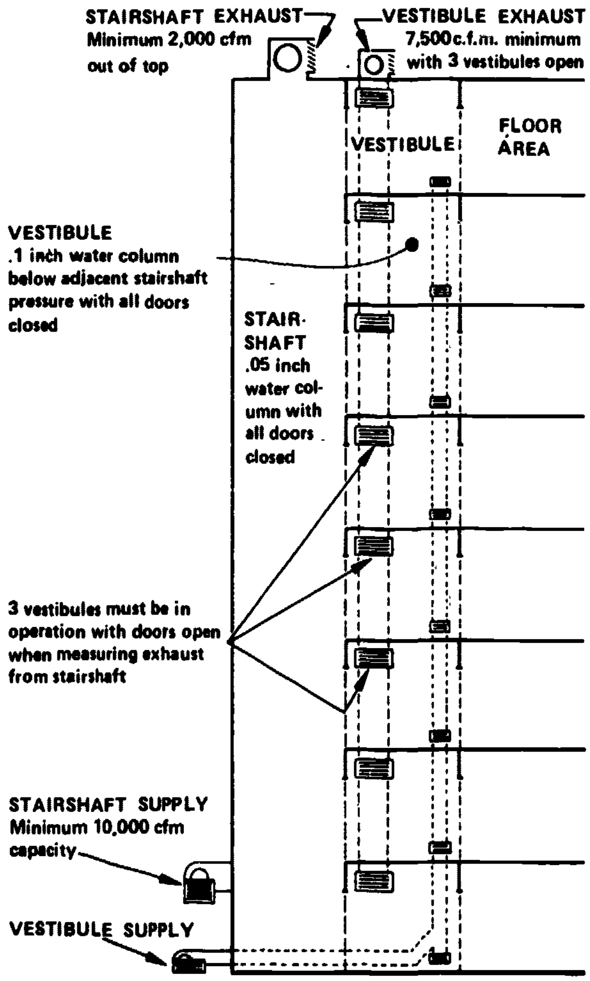

Fig. 13-1. Test requirements for mechanically ventilated smokeproof stairshaft

Ventilation of Stairway

The air at the base of the smokeproof stairway is provided by a fan capable of supplying 10,000 cubic feet of air per minute. The variable vortex damper for the air supply is automatically set by the air-pressure demand in the stairway. The exhaust system is controlled by a separate fan at the top of the stairway. The exhaust fan, which is capable of getting rid of 7,500 cubic feet of air per minute, is equipped with a variable vortex damper that automatically accommodates the exhaust to a maximum of 2,500 cubic feet per minute. Thus, it is readily apparent that when the system is in operation, a positive pressure is created within the stairway.

The vestibule exhaust system is separate from the stairway exhaust system (see Fig. 13-2). Although there is no air-supply fan at the base of the vestibule system, there is a separate vestibule air-supply duct. The exhaust fan for the vestibule system shaft supplies a minimum of 7,500 cubic feet per minute (2,500 cubic feet per minute from three vestibules on three separate floors simultaneously). A smoke-clearing draft is also developed within the vestibule system.

Smoke Detectors

Smoke detectors of the ionization type are pl_ed on the ceiling in line with the center of the vestibule doors and five feet from the wall on which the door is located. Additionally, detectors are placed in the air-supply ducts on the downstream side of the filters for the comfort air-conditioning system.

The purpose of the detectors is to cause a shutdown of the air-conditioning system when they are activated. As a back-up smoke-detection system, detectors are also placed in the return-air complex of the comfort air-conditioning system. If a detector fails on the fire floor, these back-up detectors will cause the same functions to be performed as would be caused by the activation of the primary detectors adjacent to the vestibule.

Auxiliary Power

Necessary auxiliary power is generally installed inside a room constructed with two-hour fire-resistive walls. The door opening is diked to prevent spilled fuel from leaving the equipment-room area. A large fuel-supply tank, usually with a capacity of 240 gallons, is provided. If a power failure occurs in the building, the auxiliary power system is designed to supply power not only for the stairway and vestibule ventilating systems but also for the exit-sign lights, the stairway lighting, the emergency elevator, and the fire pump supplying the combination standpipe system.

Operation of System

When smoke or heat activates any of the various detection devices, all doors to the vestibule and stairways close automatically. The stairway air-supply fan, the stairway exhaust fan, and the vestibule exhaust fan all start at the same time. This movement of air creates a positive pressure in the stairway and in the vestibule. Because of the positive pressure generated in these shafts, a force of approximately 25 pounds must be exerted to

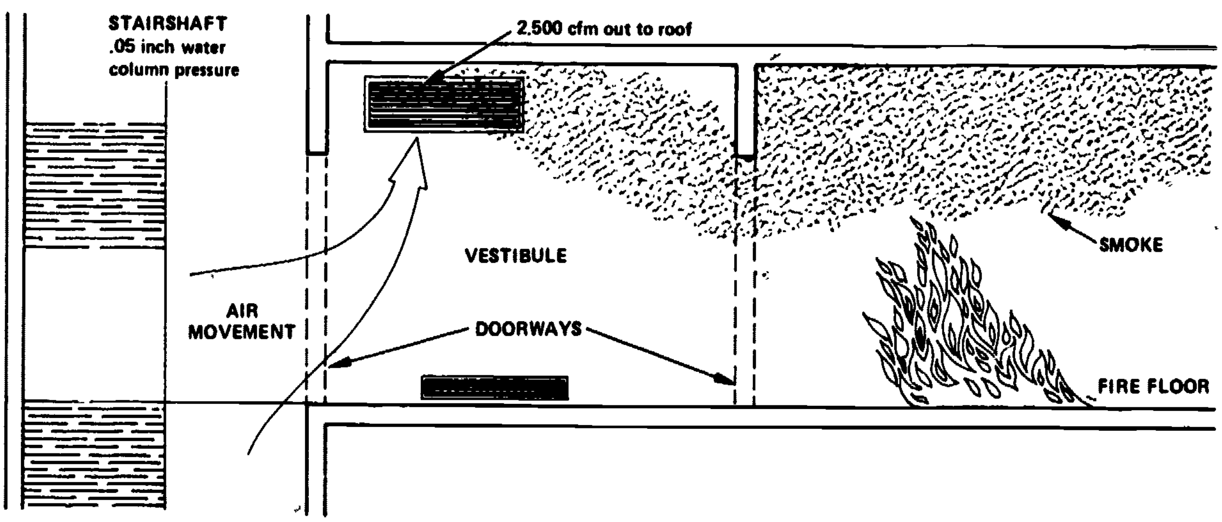

Fig. 13-2. Vestibule exhaust system in operation

open any exit door leading into the vestibule or stairshaft.

When a person enters the vestibule of the pressurized stairway from a smoke-filled floor, he allows smoke to enter the vestibule. However, the exhaust system in the vestibule, together with the positive pressure generated in the stairshaft, prevents smoke from entering the stairway. Building occupants and fire fighters thereby have a vertical transportation channel that will remain smoke-free.

Fire-Fighting Problems

Smoke may not be ventilated up and out of the stairway as previously described in material dealing with smoke and heat control. The vestibule exhaust system may be used to evacuate smoke from various floors by blocking open only the vestibule door and leaving the stairway door closed. If it becomes necessary to ventilate large amounts of smoke and fire gases that cannot be handled by the vestibule exhaust system, the stairway may be used in two ways. First, the entire pressure system must be shut down so that the stairway can be used as a ventilating chimney. Second, the stairway air-supply fan at the base of the stair may be shut off separately, the doors blocked open, and the exhaust fan left on at the top to aid in developing ventilation currents.

TOPIC 14

Special Problems

This topic, "Special Problems," is planned to provide answers to the following questions:

- What are special fire-fighting problems in high-rise buildings?
- What fire-fighting operations are necessary to cope with these special problems?
- How can prefire planning minimize special problems in high-rise buildings?

Thus far some typical fire-control problems in high-rise structures have been discussed. Many other fire-control problems can exist, however, and fire service personnel should be prepared to deal with any unusual situation. Continual prefire planning and training are the keys to handling any fire. Fires in high-rise structures require more prefire planning and training than those involving one-, two-, or three-story structures. One of the purposes of prefire planning and training is to prepare men to evaluate the fire problems created by related factors. Some of these related factors – or special fire-fighting problems – are discussed briefly in this topic.

Unusual Construction

Prefire planning should include consideration of (1) the absence of anticipated aids to fire fighting; (2) storage areas for building materials; and (3) missing building components that affect access, fire spread, and fire-fighting tactics.

Remodeling operations in a building usually create additional problems because of missing or inoperative first-aid fire-fighting appliances, altered access, and storage of building materials. Frequently, hidden spaces are created, particularly within walls and over ceilings. These hidden spaces can be the cause of the rapid spread of a fire.

Generally, access problems are more complicated in buildings of unusual construction. Fire behavior in such buildings has not been thoroughly researched or documented. Types of construction classified as unique include cantilevered; cable-suspended (see Fig. 14-1); needle-type, in which one problem is congestion in the transportation pathway (see Fig. 14-2); and air-rights structures, which may include exposures from below and difficult means of access.

Hanging ceilings may provide hidden fire areas, smoke channels, and unusual fire-spread potential. Movable partitions are installed in most new buildings. Floor plans and office design may change frequently on each floor. No two floors in new-style buildings are partitioned in the same manner.

Fig. 14-1. The Forum in Inglewood

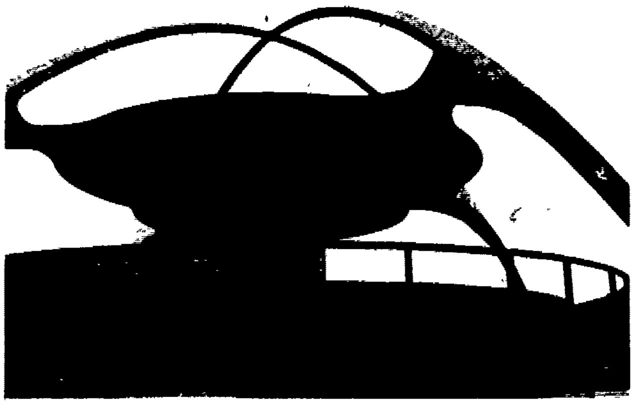

Fig. 14-2. Restaurant at the Los Angeles International Airport

Unusual Occupancies

Unusual occupancies of high-rise structures include the following:

1. Top-floor restaurants, which create rescue and exit problems
2. Multiple occupancies, which may be non-compatible, create unusual salvage problems, and suffer unusual ' siness interruption losses from fire
3. Underground service stations, which rely on engineered ventilating systems
4. Partially occupied structures that may be attractive nuisances and involve unusual housekeeping problems
5. Underground public assemblages, which create unusual rescue and ventilation problems (heat and smoke rising through exit ways)
6. Temperature- and humidity-controlled spaces in computer centers, scientific research areas, and production centers with controlled atmospheres for close tolerances
7. Maximum-security spaces in high-rise structures, which may house persons locked in because of mental deficiencies or criminal acts, or which may contain valuable storage
8. Areas where radioactive materials are stored or used, necessitating complete protective clothing and breathing apparatus (Even though men are fully protected for fire fighting, there is the problem of accumulative radioactive tolerance levels for fire fighters.)

Unusual Occurrences

Top-level prefire planning must be done to cope with these problems over which the fire service has no control. Specific plans should be developed to deal with unusual problems created by earthquakes, floods, aircraft crashes, explosions, riots, high winds, multiple fires, inclement weather, and total loss of electrical power.

Heliports and Helistops

The fire service should encourage the construction of heliports on the roofs of new buildings to provide bases for future operations. Model legislation is available from the National Fire Protection Association to prevent fire and life loss on these installations.

Special Fire Tactics

Response patterns must be studied for alternate approaches; operational procedures must be studied for alternate methods; logistics problems must be evaluated. Fire departments should assume that the worse possible conditions exist, and they must start from that point to develop methods to solve the problems.

The fire service is usually called on to provide emergency help when any problem is not clearly the responsibility of some other governmental department. When this event occurs, the fire service is in business by itself and is "the only game in town." Initiative must be encouraged at all levels in the fire service. Brainstorming sessions should be conducted to study problems, ponder ideas, and develop solutions.

APPENDIX A

Tactical Checklist

Fire commanders and company officers should refer to the tactical checklist intended for them as they carry out their duties at the fire scene:

Fire Commanders

Is the basic required equipment at hand, including the following:
- Portable radio?
- Large-scale emergency plans?[1]
- Clipboard with notemaking materials?
- Breathing apparatus (handled by an aide)?

Have requirements been met, including the following:
- Have building employees or firemen been assigned to operate manually controlled elevators?
- Has a command post been established and its location announced by radio?
- Has telephone contact been established with the dispatch center, if necessary, and has a fireman been assigned to maintain contact?

Has consideration been given to such matters as the following:
- Has a "red stairway" (the stairway that pierces the roof) been designated, if necessary, for ventilation purposes?[2]
- Has a manpower and equipment pool been established, if necessary, at or near the command post?
- Have responsibilities been assigned for the following activities:
  - Search and rescue?
  - Ventilation?
  - Determination of fire extension?
  - Extinguishment of fire?
  - Shutdown of air circulation system, if necessary?
  - Salvage operations (occupants' capabilities being considered)?
  - Overhaul?

Has the need been evaluated for the following:
- More staff?
- More smoke ejectors, walkie-talkies, bullhorns, sawdust, covers, and so forth?
- Air (bottle reserves)?
- Light utility (lighting)?
- Heavy utility (forcible-entry tools, cables, tow truck)?
- Service utility (lights, coffee)?
- Helicopter?
- Foam generator (high-expansion or protein)?
- First-aid station at command post, with resuscitators?
- Relief for tired crews?
- Police traffic control?
- Public information officer?
- Lobby control officer?
- Street control officer?
- Safe-refuge areas?

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[1]See especially *Emergency Operations Plan.* Sacramento: California State Department of Education and California Fire Chiefs' Association, 1971.

[2]The "red stairway" refers to the ventilating chimney, which is hazardous to life during ventilation operations.

Company Officers

Has preparation been made for a maximum effort at all times?

Is at least the basic required equipment available to be carried into building; namely, the following:

Engine companies: breathing apparatus, 100 feet of 1-½ inch hose, and a portable radio? (*Note:* The engineer should participate in fire fighting and not remain with his apparatus unless it is needed as a pumper.)

Truck companies: breathing apparatus, smoke ejectors, and a portable radio?

Salvage companies: breathing apparatus, covers. and sawdust?

Has it been determined what other equipment is needed; e.g., spare bottles and wrenches, lights, axes, ladders, chain saw, and so forth?

Have other requirements been made known to all as follows:

That breathing apparatus are to be worn by all company members, including the company commander?

That any unit able to give even an approximate location of the fire should contact the dispatch center for rebroadcast to all units?

That the fire commander or sector commander should be contacted before work is undertaken or as soon as possible thereafter?

That elevators should stop two floors below the fire floor?

That at least two (2) elevators should be placed on manual control for fire department use?

That radio messages should be repeated until they are acknowledged? (*Note:* Messages not getting through should be relayed by any unit in a position to do so.)

That portable radios should be turned off in the vicinity of the command post to eliminate feedback on the unit used by fire commander?

That lock-stop rubbers should be used as necessary?

APPENDIX B

Glossary

Combination wet standpipe system – A system of piping and fire pumps built into a structure to supply water under pressure for fire-fighting purposes. Fire department connections are provided so that fire department pumpers can supplement either the water supply or pressure. Combination wet standpipes are generally equipped with dry hose at valved outlets. Fire pumps operate on demand.

Critical-path construction – A system design used in construction projects to schedule various stages of construction operations for optimum speed of production. Such scheduling reduces interference between crafts and minimizes delays usually inherent at various stages of construction.

Dry standpipe system – A system of piping, with fire department connections, that is built into a structure. Water for fire fighting is supplied by fire department pumpers through the piping to fire department hose lines that may be connected to outlets on various floors.

Exterior or external exposure – The hazard of ignition to a building or its contents from a fire in an adjoining building or from some other exterior source.

HAD – An abbreviation for heat-activated device (thermostat).

Interior or internal exposure – The hazard of ignition to a room or its contents from a fire within the same building.

Limited-load area – A surface area that may appear to be solid but is actually designed to carry certain maximum-weight loads.

Nonrequired exit – a means of egress in addition to required exits.

Occupancy – The use or function of a building or a portion thereof; e.g., hotel, office, apartment, commercial building, and so forth.

Occupant load – The number of people normally occupying a building or a floor.

Pipe and duct shaft – A vertical or horizontal enclosed passageway housing service utilities, piping, and ducting.

Plenum – A container that encloses a volume of gas under greater pressure than the atmosphere surrounding the container.

Poke-through construction – A method used to bring service utilities into a building area of a given floor by drilling holes through the concrete floor. Ducts, service pipes, wiring, and the like are connected through these holes to the master utilities in the attic space in the floor below.

Programmed elevator – An elevator controlled by electronic devices. These devices automatically schedule stops at various floors to serve the demands of building occupants during periods of peak traffic.

Required exit – A legal means of egress for occupants of a building.

Scissor stairways – Two stairways in the same shaft that serve alternate exits or alternate floors. Scissor stairways may or may not include common landings.

Smoke tower – An enclosed stairway accessible from each floor only through balconies open to the outside air. Smoke and fire will not normally spread into the smoke tower even though the doors are left open.

Stack effect – The accelerated effect of the movement by convection of heated air that is enclosed, as in a smoke stack or chimney.

Structural-load design – The total weight that a structure or portion thereof is engineered to support.

Wet standpipe system – A system of piping that contains water for fire-fighting purposes and is built into a structure. The wet standpipe is generally equipped with dry fire hose at valved outlets.

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