Includes:

Pressure Regulating Devices in Standpipe Systems.

FIRE INVESTIGATION REPORT

One Meridian Plaza
Philadelphia, Pennsylvania
Three Fire Fighter Fatalities
February 23, 1991

Prepared by

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ABSTRACT

On Saturday, February 23, 1991, an early evening fire occurred at a 38-story high-rise building in downtown Philadelphia resulting in the death of 3 fire fighters, fire extension to 9 floors, and severe structural damage to the building. In addition, 24 fire fighters and 1 civilian were injured in this mostly unoccupied office building. The fire also resulted in economic chaos to numerous business enterprises located within the building, and also to properties adjacent to the fire building where owners could not return to their properties for long periods of time.

The fire department received the initial alarm from a person located outside the building just before 8:30 p.m. Upon arrival at One Meridian Plaza, the fire fighters observed heavy smoke at the mid-height of the building. Fire fighters soon observed flames extending from one window and exposing the floor above. A thick, dark column of smoke was seen extending up the building's facade from this point toward the roof, and smoke was also beginning to vent from several additional points along the north side of the floor of fire origin. The fire would eventually result in 12 alarms involving hundreds of fire suppression personnel. During the 18 1/2-hour effort to control the blaze, interior fire suppression activities were hampered by the loss of electrical power (including emergency power) and inadequate fire attack hose stream pressure. As a result, the fire spread from the floor of origin, the twenty-second floor, to the twenty-ninth floor by various spread mechanisms. Vertical fire spread was eventually stopped by the thirtieth floor automatic sprinkler system supplied by fire department pumpers through the siamese connection.
NFPA's analysis of the major factors contributing to the loss of life of the
fire fighters and severity of fire includes:

1) The lack of automatic fire sprinklers on the floor of fire origin;

2) The lack of an automatic early detection system;

3) Inadequate pressures for fire attack hose lines due to the improper
settings of the standpipe pressure regulating valves;

4) The unimpeded growth and spread of the fire on the
twenty-second floor;

5) The early loss of the main electrical service and the emergency
power to the building, including the loss of elevator service due
to a breach in the electric room enclosure on the floor of origin;

6) The improper storage and handling of linseed soaked rags
and other associated combustibles; and

Inhibiting the spread of fire is:

1) The effectiveness of automatic sprinklers on the thirtieth floor,
supplied by fire department pumphers, in stopping the vertical
fire spread.
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I. INTRODUCTION

The National Fire Protection Association (NFPA) investigated this incident with the cooperation and assistance of the Philadelphia Fire Department, the Building Officials and Code Administrators International (BOCA), and the Bureau of Alcohol, Tobacco and Firearms (ATF). The NFPA was assisted in data collection and analysis by BOCA under an agreement between NFPA and the three model building code organizations to investigate significant structural fires throughout the United States. In addition to BOCA, the other cooperating building groups are the International Conference of Building Officials (ICBO) and the Southern Building Code Congress International (SBCCI). The three model building code groups assist NFPA by providing technical staff support for on-site field work and building code analysis.

Thomas J. Klem, Director, Fire Investigations Department; Martin Henry, Assistant Vice President, Public Fire Protection Division; Robert Solomon, Senior Fire Protection Engineer; John Caloggero, Senior Electrical Specialist; and Roland Hall, Regional Engineer, Eastern Regional Office of BOCA, visited Philadelphia to document the facts related to this incident. Entry to the fire scene and data collection activities were made possible through the cooperation of the Philadelphia Fire Department. This report presents the findings of the data collection and analysis effort. Input to this report was provided by Robert Solomon, Martin Henry, and John Caloggero.

The cooperation and assistance of the Philadelphia Fire Department are acknowledged and appreciated. Particular thanks go to Fire Commissioner Roger Ulshafer, Deputy Chief Robert Wauhop, Lt. Clyde W. Millard, Lt. Matthew Medley, Battalion Chief Theodore C. Bateman, and to other members of the Philadelphia Fire Department who provided input to this report. Further, NFPA recognizes the assistance provided by ATF special agent Steven J. Avato and the other agents who assisted the Philadelphia Fire Department in the cause and origin of the fire.
II. BACKGROUND

Building

One Meridian Plaza is a 38-story, fire-resistive office building having 3 sub-basement levels. The building is located at 1414 South Penn Square in the heart of Philadelphia. The main entrance, on the north side, faces City Hall. The building is part of a one block complex that also includes One and Two Mellon Bank Center buildings and the Morris Building. (See Figure 1.) Several one-story occupancies are present along Ranstead Street, which borders the plaza building to its south. Building permits for One Meridian Plaza were originally issued in 1969, and an occupancy permit was granted in 1973 by the Philadelphia Department of Licenses and Inspections. (See Appendix II for a description of issued permits.)

The building is approximately 240 ft x 92 ft with 17,000 net sq ft per floor for occupant use (estimated 800,000 gross sq ft for the building) with the remaining area composed mostly of the building's core. The building is a structural steel frame with a 2 1/2-in. thick poured concrete floor on a steel deck. The steel is protected with a spray-on mineral material to provide a 4-hour fire-resistance rating for the columns and girders and a 3-hour fire-resistance rating for the floors. (See Figure 2.) Its exterior is comprised of a granite and glass facade in a manner that allows approximately 50 percent of its surface for natural illumination. The glass is 3/4-in. thick on floors 1 through 11, and 1/2-in. thick on floors 12 through 37, and is set in metal frames. The roof is equipped with two helicopter landing pads that were utilized during the fire. Although the building was in the process of
being completely sprinklered, the installation was not complete. It was considered an unsprinklered building at the time of the fire.

The core of the building is located on the south side of the building. It contains two masonry enclosed, interior stairways (west and central); passenger elevators; utility chase; and other vertical penetrations. The core enclosure and other vertical penetrations are intended to meet a 2-hour fire rating. A total of 4 elevator banks, each containing 6 elevators, extend through the core. An additional 2-hour enclosed stairway (east) and service elevator is positioned on the east side of the building. (See Figure 3.)

Access doors to the stairways were arranged to be locked from their interior side to prevent re-entry to floors for safety and security reasons. This arrangement was allowed in 1984 by a variance from the fire department.\(^1\) The variance specified that re-entry points were to be provided every three floors, and signs were to be placed at each interior stairway landing indicating the re-entry floor.

There were multiple tenants throughout the office building. Consulting firms, attorneys, communication companies, insurance companies, security firms and CPA firms were typical businesses. Material typically associated with these services resulted in a substantial fuel loading. (See Appendix III for a discussion of the implications of such a condition.) During normal business hours thousands of people worked within the structure. At the time of occurrence, however, there were only 3 people in the building.

\(^1\) Apparently prompting this action was an inspection that found the doors locked from the interior stairway side for security reasons.
Because of the multiple tenancy, the layout on each floor had a slightly different arrangement. In general, however, the floors were arranged with private offices along perimeter walls. Private offices were enclosed from floor to finished ceiling with 5/8-in. gypsum material attached to metal studs and provided with 1 3/4-in. solid wood access doors. Furnishings for the offices varied, as did their interior finish materials. For example, some private offices, including the room of fire origin, contained 3/4-in. wood paneling. A lay-in, noncombustible ceiling finish was provided throughout occupant areas. The distance from floor to finished ceiling was typically 8 ft, creating a 3 1/2-ft void space to the floor/ceiling assembly above. Floors of the building generally were carpeted.

Office arrangements included a large, open, unobstructed area where support staff stations were positioned outside of private offices. There were only a few floors that had floor-to-finish ceiling partitions within this area. More typical, five foot high dividers provided separation of work station areas. (See Appendix III for discussion of the fire spread mechanism resulting from large undivided floor areas.) Because a single tenant occupied floors 20, 21, and another occupied floors 24 and 25, an interior open convenience stairway was provided between each of these two floors.

**Fire Protection Equipment**

At the time of the fire the facility was equipped with several fire protection systems that had been installed during the original construction or that had been added or upgraded over the years. These systems included an
automatic fire alarm system containing manual pull stations and smoke
and heat detectors, standpipes for occupant and fire department use, and
an automatic sprinkler system that was being installed throughout the
building at the time of the fire. The sprinkler system was being installed in
accordance with a variance granted in 1988 concerning changes to the
building's standpipe system. (See later discussion) The variance specified,
among other details, that the building must be fully sprinklered within 5
years of the date of issuance of the variance.

The plan for a combination system (i.e., sprinkler standpipe) required
major revisions to the building's fire protection water system. With this in
mind, the dry standpipe (see later description and discussion) was
converted to a wet standpipe system connected to a 6-in. water supply. The
conversion also included the installation of two 750-gpm fire pumps — one
installed at the basement level and one on the twelfth floor (mechanical
floor). The plan further called for tenant floors to be sprinklered as they
became vacant or were renovated, with final installation of the automatic
sprinkler system completed by 1993.

At the time of the fire, sprinklers for light hazard occupancy were installed
on floors 30, 31, 34, and 35.2 (See sprinkler section for additional details.)

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2 A dining area on the thirty-seventh floor contained sprinklers, but they were
supplied from the domestic system.
Standpipes

The original construction of the building resulted in a set of independent standpipes. One standpipe system, a Class II system as defined by NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, was intended for occupant use and was supplied by the building's domestic water supply. This system incorporated preconnected 1 1/2-in. hose in 100-ft lengths, and two were positioned on each occupant floor area.\(^3\)

A standpipe system for fire department use was also provided at the time of original construction. This system was designed as a Class I system as defined by NFPA 14. Two 6-in. diameter risers were installed, one in the west stairway and the other in the central stairway. There was no standpipe riser in the east stairway. This Class I system was a dry standpipe having no permanent water supply. The water supply was solely from a fire department connection on each standpipe riser. Each fire department connection was equipped with one 3 1/2-in. connection and two 2 1/2-in. connections.

In the summer of 1988, a fire protection system upgrade converted the existing dry standpipe system to a wet type with a permanent water supply. The upgrade also included the installation of automatic sprinklers on select floors as well as the preparation of the standpipe system riser to accommodate sprinklers on all floors for installation at some point in the

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\(^3\) Upon discovering low pressure in fire attack lines, fire fighters attempted to utilize this system to suppress the fire. They reported inadequate pressure in this system as well. Domestic water pumps would have been inoperative once the building lost electrical power.
future. The upgrade set the stage for a combined system approach as described in Chapter 6 of NFPA 14.

After the conversion, the standpipe for fire department use and the sprinkler system were supplied by a 20-in. water main located on 15th Street that was attached to a 6-in. line into the building. This water supply was then augmented by 2 fire pumps, 1 on the basement level and 1 on the twelfth floor. An examination of these protection systems showed that a series of faults caused by the fire negated the automatic features normally associated with the system.

The upgrade program also included the installation of pressure regulating valves (PRVs) on the Class I outlets for each floor. The installation of such devices is required by NFPA 14, paragraph 4-7.1, when flowing pressures at a hose valve could exceed 100 psi. Pressure regulating valves control outlet pressures to reduce the available operating pressure available to the hose lines. There were 2 models of pressure regulating valves installed on the standpipe system. Both were field adjustable; one was only capable of controlling pressures on hose lines during flowing conditions, while the other model was capable of controlling static pressure within a hose line even when its nozzle was in the closed position (See NFPA Alert Bulletin No. 91-3 for further details provided as Appendix V.) The particular device installed had a nondimensional setting range of 60 to 175.

Due to the height of the building and the installation of the 2 stationary fire pumps, design parameters for correct operation of the standpipe system
would be expected to readily exceed 100 psi at the various hose connections in the building. Such pressures are also expected when the system is being supplemented by the fire department connection. An examination of these devices after the fire indicated that they had been set at the 80 nondimensional mark. Once set, no additional pressure would be available on the outlet side of the pressure regulating valve (PRV), no matter what pressure was being delivered on the inlet side of the valve.

The setting of the PRVs created a series of problems for the fire department as they attempted to control the fire. Radio transmissions from the upper floors indicated that the hose streams were marginal at best. The problem was attributed to a lack of pressure from the engine companies that were supplying the fire department connection, to a problem with the 2 stationary fire pumps, or possibly to a partially closed control valve somewhere within the system. None of these elements turned out to be the key impediment.

During the fire, an employee of the sprinkler company that had been doing the upgrade work learned of the fire on the local news. The employee made his way to the fire scene and identified himself to the incident commander at the command post. The employee offered his services to the fire department in order to assist in their efforts at combatting the fire. Upon learning of the description of the poor quality hose streams being delivered, the employee took a special tool up to the staging area and fire floors and began a floor-by-floor sweep adjusting the PRVs to an approximate setting of 100 to 120 (nondimensional).
The employee was manually adjusting the pressure reduction feature of each hose connection. The engine company reported an almost immediate improvement in the discharge rate and quality of their hose streams. (See Table 1 for calculations of resulting pressures at 2 of the valves' nondimensional settings.)

At the same time, a member of the building engineering team thought that the inoperative fire pump on the twelfth floor may have been hindering the flow of water. The engineer made his way in complete darkness to the mechanical space on the twelfth floor and proceeded to remove the pump coupling guard. Once this guard was removed, he made an effort to take apart the two housings that are used to connect the pump to the driver. Once these housings were loose, the rubber gear drive mechanism was freed up, thus resulting in the uncoupling of the pump from the driver. This effort was futile since the pump would spin free with or without the driver connected.

The investigation of the fire led to the conclusion that the preset positions of the PRVs were at a level that made the standpipe hose connections ineffective. The standpipe packs carried by an engine company in the fire department consist of three 50-ft lengths of preconnected 1 3/4 in. hose with 1 1/2 in. couplings, a gated 2 1/2-in. by 1 1/2-in. by 1 1/2-in. wye, and an adjustable flow fog nozzle. The pressure being permitted by the PRVs was of little benefit given the fact that the fog nozzle alone requires a nominal pressure of 100 psi to be effective. Friction loss through the hose would result in another 20 to 40 lbs of pressure loss depending upon the flow. The fog nozzle has a rated range of flow 50 gpm to 350 gpm. The adjustment
made by the sprinkler contractor brought the system parameters to within acceptable values.

After the fire, the PRV manufacturer's representative made calculations of pressures at various floor levels that would be provided through 100 ft of 2 1/2-in. hose having a 1 1/2-in. straight tip nozzle and a flow rate of 250 gpm. The results are presented in Table 1. (Also see Appendix I for further discussion.)

<table>
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<tr>
<th>Floor</th>
<th>Residual Inlet</th>
<th>PRV Setting 100</th>
<th>PRV Setting 80</th>
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<td></td>
<td>At Outlet/At Nozzle</td>
<td>At Outlet/At Nozzle</td>
</tr>
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<td>178 psi</td>
<td>76 psi</td>
<td>57 psi</td>
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<td>173 psi</td>
<td>76 psi</td>
<td>57 psi</td>
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<td>56 psi</td>
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<tr>
<td>26</td>
<td>137.6 psi</td>
<td>73 psi</td>
<td>55 psi</td>
</tr>
</tbody>
</table>

**Fire Pumps**

During the fire protection system upgrade program that was started in 1988, 2 fire pumps were installed in the building. The pumps were intended to support the standpipe system, the sprinklers that were being installed on 6 floors, and the sprinklers that would be installed throughout the building in the future.

The basement of the building contained a 750 gpm pump rated at 125 psi. The pump was an electric drive type and was supplied by 2 power sources that served the building. The particular arrangement of the electrical
service did not comply with NFPA 20 in that the service came from the same electrical grid. In addition, the electrical service was not dedicated to the fire pump as required by NFPA 20. The building electrical service for the fire pump also served other building electrical loads. This situation is not permitted unless an independent back-up source is made available, such as a generator. No independent power source was provided for this pump.

A transfer switch was provided with the pump controller. This transfer switch would permit the transfer from the "A" power source to the "B" power source. An examination of the transfer switch just after the fire showed it to still be in its normal position. As a result, the device did not transfer for one of two reasons: the secondary source faulted before the primary source, or both the primary and secondary services faulted at the same time. The two sources of electricity into the building shared their vertical run through the building. Their enclosure on the 22nd floor was violated by the fire, probably within the first 30 minutes of the event, thus causing a catastrophic fault of the entire building electrical system. This single event thus rendered the primary energy source to both pumps ineffective.

The fire pump installed on the twelfth floor was similar to the basement pump. It was rated at 750 gpm at 165 psi. This pump also did not have a dedicated electrical service. It was, however, connected to a natural gas powered emergency engine generator. This sort of alternative arrangement is permitted by NFPA 20. An evaluation of the transfer switch associated with this pump controller also showed it to be in the normal position. (See
electrical description for further details.) Evidently, when the primary power for the building was terminated by the fault, the emergency generator started but failed to provide electrical energy output. The transfer switch is arranged to operate only when the emergency load side of the transfer switch "senses" a voltage after the normal side of the switch loses power.

The fire pumps were each equipped with a bypass line. The pumps were also set up in a fashion such that the water supply to the pump on the twelfth floor was supplied through the pump in the basement by a single zone standpipe riser. This configuration is somewhat of a deviation from the requirements contained in NFPA 14 with respect to the water supply configuration. An express riser normally is required to support standpipes at heights in excess of 275 ft. The arrangement of the pumps in series is permissible, but a dedicated supply line would be expected for the standpipe system that continued between floors 13 through 39. However, there is no indication that this configuration played any part in the outcome of this fire. This variance from the standard is thought to have been allowed as an incentive for owners to completely sprinkler the building.

**Sprinkler System**

Originally the building was provided with automatic sprinklers for a portion of the sub-basement levels.\(^4\)

\(^4\) The building is considered unsprinklered. The building was in the process of being sprinklered; however, at the time of the fire, only a few floors and sub-basement levels were provided with sprinklers. The thirtieth floor, which was provided with an automatic sprinkler system, was the first floor protected above the fire floor.
Automatic sprinklers were installed as part of tenant renovation work on floors 30, 31, 34 and 35. This program was undertaken in 1988 in conjunction with the standpipe conversion plan. This project also involved the installation of the 2 fire pumps.

Design parameters for the sprinkler system included satisfaction of criteria for a light hazard occupancy as defined by NFPA 13, *Standard for the Installation of Sprinkler Systems*. The system density was based upon 0.1 gpm/sf over the hydraulically most remote 1500 ft² area. The hydraulic nameplate data located on the thirtieth floor indicated that the sprinkler system required 354 gpm at 84 psi. It also noted that an additional 100 gpm was included for the fire hose stream demand. This criteria assumed a maximum area of coverage of 225 ft² per sprinkler. Several sprinklers covered less area than this due to the partitions that divided the floor.

By the time the fire had progressed to the thirtieth floor, the only water supply available to the sprinkler system was from the fire department connections. At this point, the fire department had withdrawn from the building because of the possibility of a massive structural collapse. (See later discussion.) As the heat from the fire began breaching the floor slab between the twenty-ninth and thirtieth floor, individual sprinklers responded to multiple ignition points and extinguished each fire.

A sprinkler system is not necessarily designed to completely halt an advancing fire when it is coming from an unsprinklered area to a sprinklered area. In addition, a sprinkler system of this nature is not designed to suppress a fire to the point of total extinguishment. This
system was able to do both for two reasons. The compartmentation feature between floors impeded the fire's progress between floors. This gave the sprinklers adequate time to operate in relatively small areas and to prohibit the fire from getting a head start on the thirtieth floor. The suppression feature of this sprinkler system was unusual in that in one case, the breach point of the fire involved a small wastebasket under a desk as the ignition source. Even in this severely obstructed scenario, the fire was extinguished by the sprinkler in that area. A total of only 10 sprinklers operated on the thirtieth floor. The fire on the twenty-ninth floor eventually consumed all available fuel.

The second reason that sprinklers were able to go beyond their normal control capability was due to the high pressure available to the system through the fire department connection. The pressure being generated by the fire department apparatus would likely have resulted in flows to the sprinkler system that generated water densities in the range of .4 to .5 gpm/sf.

**Fire Alarm System**

The building had a manual and automatic fire alarm system. Smoke and heat detectors were part of the system, but their locations were not consistent throughout the tenant floors. The elevator lobby areas were generally equipped with smoke detectors. Additional detectors were provided when lobbies were enclosed with glass partitions separating them from tenant areas. In this case, a smoke detector would be mounted on the finished ceiling on the tenant side of the doors. Additional smoke detectors were located in tenant areas near stairway access locations and in other
common tenant locations. Other components of the system included manual pull stations and automatic sprinkler flow alarms.

Activation of the fire alarm system was designed to provide an audible signal throughout the building, provide a signal at the security guard station and at the annunciator panel, automatically transmit an alarm signal to the central station location, and recall elevators.

**The Electrical System**

Two 13.2 kv, 3-phase supply systems were used to provide the primary electrical service to the building. In addition, these same 2 services provided electric power to the adjacent buildings within the complex. The feeders received their power from the Philadelphia Electric Company. Both services entered the electric vault at the basement level where they terminated in the service equipment disconnecting means and overcurrent protective devices.

The electrical system for One Meridian Plaza was dual fed with each set of service conductors supplying three 1200 ampere, 3-pole, 15 kv disconnects, which included one spare conductor in each service. The 2 feeders were designed to supply power to each other's loads by means of a 1200 ampere bus tie switch that would close automatically upon failure of power from either service.

Two 6-in. aluminum conduit runs containing three 13.2 kv system cables each were then routed vertically through the building and electric rooms located on each occupied floor. The rooms were positioned one above the
other. As the cables reached an electrical room they supplied substation transformers at each floor level. These 13.2 kv system vertical risers eventually terminated at a substation in the mechanical equipment room on the 38th floor. The investigation determined that intense heat from the fire entered the electrical room on the twenty-second floor from the direction of the room of fire origin by means of a breach in the wall above the dropped ceiling used to route electrical conduits in or out of the electric room. This opening was approximately 18-in. x 36-in. and was located above the distribution panels within the room. Intense heat entering the electrical room approximately 9 to 10 ft above the floor impinged directly on the electrical conduits on the opposite wall at approximately the same height as the breach.

The intense heat caused the 2 aluminum conduits containing the 13.2 kv feeders to transfer heat to the insulation of the enclosed conductor. This heat caused breakdown in the dielectric strength of the conductor insulation. Once the dielectric strength of the insulation decreased to the point where the 13.2 kv potential allowed current leakage to ground or between phases, arcing could occur, damaging the conductors and conduit. This resulted in tripping the overcurrent device in the 13.2 kv feeder circuit, which in turn caused the 1200 ampere bus tie switch to close and supply energy from the second set of service conductors. It is believed that both 13.2 kv vertical risers in the switch room sustained similar damage at very close time intervals. When the bus tie switch closed, it closed on a fault and caused the second service overcurrent device to actuate. Clocks in locations close to the twenty-second floor stopped at 8:37 p.m.
At the request of the fire incident commander, the Philadelphia Electric Company personnel attempted to re-energize the 13.2 kv feeders, but the breaker tripped immediately. Upon failure of the 2 services, a 340 kw natural gas-driven, 3-phase, 480/277 volt generator started and ran. This was verified by building maintenance and building engineering personnel as well as the running time clock on the generator control panel. The emergency generator was designed to supply an elevator in each bank of elevators, the fire alarm system, the fire pump, and emergency lighting. A visual inspection was made of the transfer switch at the generator location, twelfth floor elevator transfer switches, and twelfth floor fire pump controller transfer switch. All the preceding switches were still in the normal mode configuration.

The basement fire pump did not receive power when the bus tie transfer took place since it evidently closed on a fault and tripped, thereby causing the fire pump transfer switch to remain in its normal operating mode. The elevators, twelfth floor fire pump, and generator transfer switches did not activate due to lack of voltage output from the generator. Lack of voltage output from the generator was observed by building maintenance and engineering personnel who noticed that none of the indicating lamps on the transfer switch were illuminated. The indicator lamps were replaced, and then a voltmeter was used to test all line and load terminals for voltage. It was concluded that the generator was not producing any voltage.

HVAC System
Conditioned air was distributed to most common areas of the building through HVAC (heating, ventilation and air conditioning) systems located
on the building's mechanical floors. Distribution ducts were positioned at each corner of the building to supply the various floors. Private offices located in exterior areas of the occupied floors contained individual induction units. The units were supplied by a flexible duct in the void ceiling space from the floor below. The duct then penetrated the 2 1/2-in. concrete floor slab at its outer edge and connected to the unit. During the severe fire these penetrations on the fire floor did allow a means of smoke and heat transfer to the floors above. However, because metal lath and plaster materials were used to enclose these penetration areas, this fire spread mechanism was not as extensive as documented in other major high-rise office building fires.\footnote{See NFPA Fire Investigation Report, \textit{First Interstate Bank Building Fire}, \textit{Los Angeles, California, May 4, 1988}.}
III. FIRE INCIDENT

The Fire
Since the fire occurred in the early evening hours on Saturday, only a few people were in the building at the time of the alarm. A security guard and a maintenance worker were located at the first floor guard's desk at the time of the initial alarm. Investigators from the Philadelphia Fire Department determined that an automatic fire alarm was first received at the building's guard desk at approximately 8:23 p.m. Upon receiving the alarm, the building maintenance person determined from the fire alarm annunciator panel located near the elevator bank that the fire was on the twenty-second floor. He went by elevator to investigate the source of the alarm. Upon reaching the floor, the elevator doors opened, and he was confronted with dense smoke and heat. He fell to the floor and notified the security guard by portable radio that there was indeed a fire and that he could not close the elevator doors. However, since the elevator was being operated on its emergency mode, he was able to tell the guard how to override the elevator controls and return it to the first floor. The guard was eventually able to control the elevator, and the maintenance man was safely returned to the ground level.

During the initial minutes of the investigation of the source of the alarm, the guard apparently received a telephone call from the fire alarm company (central station). The alarm company was told that its source was being investigated. During this time, however, the fire department was not
notified of the alarm within the building, and they later determined that a 4 to 5 minute delay occurred before they were notified.

The first notification to the Philadelphia Fire Department came by telephone from a person outside the building just before 8:30 p.m. This person, not sure of his exact location nor that of the building, reported smoke coming from a building on the 14th or 15th floor. Soon after the call, numerous additional calls were received including one from the central station company. The dispatch of four engine and two ladder companies and two battalion chiefs occurred at 8:27 pm, and the first fire department unit arrived on the scene at 8:31 pm. This first unit reported heavy smoke from a broken glass panel at the midpoint of the building, and within minutes a second alarm was sounded. The fire would rapidly progress to a fifth alarm in just over a half-hour and further progress to a 12 alarm fire as additional manpower and equipment were needed and as fire fighters began to tire from hours of fire suppression efforts.

A battalion chief and several units that arrived first were told by the security guard that the fire was on the twenty-second floor. Cautious so as not to endanger his crew, and aware of the conflicting information regarding the location of the fire, the battalion chief decided to take an elevator to the eleventh floor and then use a stairway until they were able to locate the exact location of the fire. Soon after his arrival on the eleventh floor, he reported a complete electrical power failure to the building. Electrical power was never restored for the remainder of the fire fighting operation.

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6 Fire dispatchers had to communicate with the caller for several minutes before they were able to identify the building that the caller was referring to.
The electrical failure had an immediate and severe impact on fire fighting operations. Despite attempts to restore power, the darkened condition would exist throughout the remainder of the fire. Fire fighters not only were in complete darkness, but the massive amount of equipment needed to suppress a fire of this magnitude would now have to be hand-carried 20 floors by the fire fighters to the staging area and then to fire attack locations. Throughout the night the incident commander would commit numerous personnel to the effort of supplying fire attack crews with necessary equipment. As a result, many fire fighters spent as much as 8 hours within darkened stairways shuttling the equipment through the entire building.

During their ascent through the building, the initial attack crew decided to examine several floor levels to determine floor layout and location of key fire protection features. As they approached the twenty-second floor, they began to be confronted with smoke conditions within the stairway. As they positioned themselves for fire attack, they reported that the fire had progressed to the stairway door on the twenty-second floor. At this time they also reported difficulty in forcing open a stairway door that was locked from the interior side. After forcing the door open and advancing toward the fire, they reported poor water pressure in their attack lines. The fire officers reported that their hose streams were of poor quality and of limited reach. As a result, the initial attack lines could not be advanced and fire fighters took a defensive, protected position at the stairway door until adequate water supply for fire fighting could be established.
Other fire fighters made an assessment of the twenty-third and twenty-fourth floors and found no fire extension as yet, but reported extreme heat and heavy smoke conditions. An initial assessment reported that fire conditions on these floors were severe, but as yet the fire had not spread beyond the floor of fire origin. Lines were stretched to the floor in anticipation of extension, but available water pressure severely limited their capability. Fire fighters soon discovered that the open personnel stairway described earlier had allowed smoke and fire to drop to the twenty-first floor. The small fires that resulted were quickly extinguished, and then the personnel stairway was utilized by fire fighters attempting to advance to the twenty-second floor. Fire suppression attempts at this time were described as ineffective.

A staging area was established on the twentieth floor, 2 floors below the floor of fire origin. Among the main activities that would take place on this floor were those related to staffing needs and air supply for the SCBA.

During the next several hours fire fighters would attempt numerous methods to improve water supply to the fire attack hose lines. Hose lines were laid from an adjacent building, operating pressures on pumpers were increased, and fire pumps within the building were examined to determine why they were not operating and for potential blockage. None of these actions, accomplished by fire fighters in complete darkness, restored adequate water pressure to fire fighting hose lines. As a result, the incident commander ordered that an initial 5-in. supply line from fire department pumpers be hand-carried through a stairway to supply fire attack lines. This labor intensive effort was accomplished approximately 5
1/2 hours into the incident. By this time, however, the fire had spread to the twenty-third and twenty-fourth floors and was threatening the twenty-fifth floor.

Early operations were also hampered by the difficulty encountered in forcing open some of the doors in the fire stairs. Most likely this resulted from intense heat distorting the doors and that many doors were locked. In at least one case, the light panel in the door was broken out in order to operate a stream on the floor, pending successful forcible entry.

Smoke and heat conditions in 3 fire stairways were tenable in the early stages of the fire, but these conditions kept deteriorating due to the large scale fire suppression operation and the intensity of the fire.

Logistical problems were substantial from the earliest moments of the operation, and some of them increased with time. The following obstacles had to be addressed by the incident commander:

- Bring an adequate number of fire fighters to the upper floors via the 3 stairways;
- Supply air for the hundreds of depleted SCBA cylinders;
- Increase water pressure for all operating hose lines;
- Provide adequate lighting

As additional fire alarms were sounded by the incident commander, arriving fire department members were advised to bring a spare SCBA cylinder along to the upper floors. Air supply lines were stretched via the
outside of the building to an upper floor, and the department's air units pumped air for the refilling of cylinders. This operation was interrupted on one occasion when falling glass severed an air supply line.

A 3-in. line was taken from the ninth floor standpipe of the adjacent building and connected to the eleventh floor of the fire building to augment supply. Another 3-in. line was stretched from the eleventh floor to the thirteenth floor of the fire building in an effort to bypass the pump on the twelfth floor of the fire building. At the time it was thought that the pump and piping arrangement on the twelfth floor was causing a restriction in water flow. (See earlier discussion.)

Some engine companies were instructed to begin stretching 5-in. supply lines to the upper floors via the east stairway. Other companies carried 3-in. lines and lightweight monitor nozzles to the fire floors. When these supply lines were put into service, water pressure was adequate and the monitor nozzles were placed into action on floors above the original fire floor.

Several hours into the operation, after adjustments were made to the pressure reducing devices, water pressure at the standpipe outlets proved adequate. However, by that time fire had made headway to several floors above the floor of origin.

Large diameter (5-in.) lines were used to supply the standpipe systems in an adjacent and a nearby building, and exterior hose lines were then directed to the upper floors of the fire building.
A 3-in. line from the thirtieth to the thirty-fifth floor of the adjacent building was used to supply 2 deluge sets to operate onto the exterior of the fire building.

After approximately 11 hours of fire fighting, the fire had been controlled on floors 21 through 24. Major fire fighting efforts were still underway on the twenty-fifth and twenty-sixth floors, but the fire continued to extend despite all efforts to control it. It was evident that the fire was spreading at a rate faster than it could be controlled, despite all of the available efforts that were brought to bear. In addition, the structural damage to the building was severe, leading to a concern that the building might be in danger of partial collapse.

At about the first hour after arrival of the first units, or shortly thereafter, a team of an officer and 2 fire fighters was sent from the twenty-second floor via the center stairway to attempt to open the roof door. The purpose was to allow the accumulating smoke and heat to vent at roof level, thereby improving tenability of that stair. The team consisted of fire fighters 43 years old and 29 years old led by their captain from Engine 11, 52 years old. Engine 11 was the fourth engine on the first alarm assignment.

After an undetermined period of time subsequent to the start of their mission, the team reported by portable radio that they were experiencing difficulty and that they were going to leave the stairway at the thirtieth floor. A subsequent transmission requested permission to break a window. It was followed by a message indicating that the captain was down and that
they were in trouble. Efforts to direct them to an alternate stairway proved unsuccessful.

A massive effort was undertaken to locate the trapped fire fighters. Rescue teams proceeded up the 3 interior stairways to begin searches on floors 30 and above. A helicopter transported rescuers to the roof to open roof doors. The various attempts to locate the men continued unabated for a few hours. The helicopter circled the structure to see if it could locate any sign of the fire fighters. A broken window was finally spotted through the thick smoke billowing from the lower floors. It was on the twenty-eighth floor.

A rescue team proceeded up the east stairway, moved in on the twenty-eighth floor, and located the bodies of their 3 comrades at approximately 2:00 a.m. Their bodies were removed to street level. At this time, the fire was still out of control on floors 23 and 24, and extension to floor 25 was taking place.

Prior to finding the 3 fire fighters, roof helicopter operations had to be halted because of the dangers associated with the fire. A total of 14 fire fighters were removed from the roof to the street. Some of the 14 were men who had reached the roof in a search and rescue effort via an interior stair approach.

Available water pressure for fire suppression efforts began to improve somewhat approximately 4 hours into the operation when a sprinkler contractor, who had worked in the building, came to the fire scene to assist
the fire department.\(^7\) The contractor, who had knowledge of the standpipe system and the tools necessary to make adjustments, was able to adjust the settings on the standpipe's PRVs.

Immediately after the adjustment to the PRVs, fire fighters reported improved fire streams.\(^8\) Approximately 5 1/2 hours into the suppression effort, the 5-in. supply line was completed and was being utilized by fire fighters to extinguish the fire. The fire had spread to multiple floor locations by this time, however, and was threatening other floors. The fire fighters would struggle over the next several hours to gain headway on the fire and resupply and replenish manpower.

However, even with these improvements and efforts, the incident commander was still faced with the fact that suppression had been ongoing for 11 hours at this point, and he had received information from a structural engineer's evaluation warning of potential floor collapse. There was a particular concern that a partial floor collapse could occur, resulting in a progressive collapse of the floors below. At this point, the fire had been controlled on floors 21 through 24 (fuels mostly consumed), and suppression efforts were underway on 25 and 26, but the fire was still spreading despite all of the fire fighting efforts. Faced with these circumstances, the incident commander removed all fire fighters from the

\(^{7}\) This was occurring while the 5-in. supply line was being positioned for supply.

\(^{8}\) Some postfire testing of the standpipe system conducted by the Philadelphia Fire Department indicated that there were no obstructions and that adequate supply to fire hoses was achieved by increasing the setting on the PRVs.
building. He decided that he would not endanger fire fighters but instead would supply the sprinkler system located on the thirtieth floor through fire department pumpers.

The water being supplied to the fire department connections was maintained, and the lines being operated from nearby structures continued to operate. Exterior lines on the street were covered with plywood to protect them from falling glass.

The fire would burn freely through the remaining floors to the thirtieth floor where sprinklers would be relied upon to stop the vertical spread. The importance of the fire department pumpers maintaining adequate pressure into the standpipe system to supply the sprinkler on the thirtieth floor should be emphasized as should the hazard to fire fighters in maintaining its supply.9 Operating sprinkler densities could have been as high as .4 gpm/ft² to .5 gpm/ft² because of the source of this supply. Design standards for this light hazard occupancy would have been .1 gpm/ft² over the most hydraulically remote 1500 ft² The activation of 10 sprinklers at various locations throughout the thirtieth floor was successful in completely stopping the vertical progression of the fire.

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9 Many of the fire department’s supply hoses were severed by falling debris during this operation. Fire fighters attempted to protect the hoses, but failures still occurred. During their replacement, fire fighters were exposed to the hazard of falling glass, etc., resulting in some injuries.
Most of the 24 fire fighter injuries were related to exhaustion, strains, and being struck by falling glass. Three of the injured fire fighters required hospitalization.

Fire Damage

The fire resulted in severe structural damage and total destruction of the contents of floors 22 through 29. Further, water and/or smoke damage occurred throughout the remainder of the building. In general, the steel framing on the fire floors was highly damaged and distorted. The main support beams exhibited excessive deflections, in some cases as much as 18-in. At the east end of the tower on the twenty-second floor the entire area had deflected as much as 4 to 5 ft. On the twenty-third floor a typical floor girder had sheared off from its supporting girder and was hanging approximately 6-in. below the floor slab. Further, the east stairway masonry walls had considerable cracking indicating that the structure had gone through substantial movement. There were indications that a number of exterior cladding panels had fallen from the connecting link on the building's north and east faces.

In addition to the hundreds of millions of dollars of direct property loss, extensive repairs to the building will be necessary before it can be re-occupied. To this date, the building has not been re-occupied. This has resulted in the loss of rental income for over a year, and might well result in many of the tenants never returning. Further, this fire resulted in other
business losses not directly affected by the fire. Many small businesses along Chestnut and 15th Streets could not reopen for many months after the fire because of the unstable condition of this plaza's facade. Some of the businesses never reopened.
IV. ANALYSIS AND FINDINGS

Investigators from the Philadelphia Fire Department have concluded that the fire originated on the twenty-second floor in a private office located on the north side of the building. The cause was determined to be spontaneous ignition of linseed-soaked rags used for restoring and cleaning wood paneling within the floor area. Once reaching the open-flaming stage of combustion, the fire was able to involve other stored volatile materials within the room of origin and soon involved the room's combustible interior furnishings and finish materials. These materials presented a substantial fuel load that is not normally encountered in such office environments and illustrates the importance of isolating (or protecting) flammable materials that are temporarily brought into such environments. The burning of these materials would have led to rapid growth and spread of the fire and to flashover conditions within the room in less than 5 minutes.

The extent of the fire beyond the room of origin at the time of detection is not known, nor is it known if room flashover occurred before the detection. Once the fire department arrived on the scene, however, room flashover had occurred as evidenced by the fire venting from the building. At this point, and to some extent before this point, the fire had likely spread to the space above the suspended ceiling and to adjacent areas within the interior of the floor of fire origin and was beginning to spread products of combustion by way of vertical voids throughout the fire floor and to other floors. In time the magnitude of the fire would increase dramatically since there were no fire barriers to inhibit its spread. Corroborating the severity
of the fire soon after automatic detection is the account of the maintenance person who went to the fire floor via an elevator and was confronted with severe fire conditions that threatened his life.

Investigators have further concluded that there was a 4 to 5 minute delay in notifying the fire department while the severity of the fire was surveyed by building maintenance personnel. This delay, coupled with the flammable nature of initial materials, resulted in a severe fire when the fire department arrived. Such severe and difficult to control fires are likely when office buildings are unoccupied and when early detection or suppression equipment is not present. Further, when the magnitude of the fire reaches the level encountered by these first arriving fire fighters, little can be done to quickly intervene and suppress the fire. This further emphasizes the importance of in-place automatic suppression systems. Further, this fire occurred in a large metropolitan area served by a fire department having hundreds of personnel that have extensive experience in fighting severe high-rise fires. Similarly protected high-rise buildings in more suburban areas may well prove to be more catastrophic.

At the time of fire department notification this severe fire continued to grow unchecked while fire fighters were positioning for attack. The first reports by fire fighters indicated that the fire had spread to the stairway door (center stairway), and likely had also spread throughout the open floor area as well. Also, at this time the fire spread mechanisms to the floors above were becoming more and more significant. On the exterior of the building a long, wide thermal column was extending up the facade of the building and interior voids resulted in the preheating of combustibles on the upper
floors. Eventually these spread mechanisms would cause ignition of combustibles and then rapid fire spread throughout yet another open floor plan. This rapid vertical spread of fire progressed faster than fire suppression forces could be prepared, positioned, and deployed to the advancing front. Further, the fire fighters were hampered in their efforts by the inadequate water supply.

The initial attack crew reported the electric power failure on their way to the fire floor, meaning that intense heat had penetrated into the electrical room (approximately 60 ft from room of fire origin) and affected both of the main electrical feeders to the building. The masonry enclosure of the twenty-second floor electrical room had been breached. The openings allowed heat from the fire to impinge upon the service conductors, causing them to be destroyed.

Although the building was provided with an emergency electrical generator (natural-gas fueled) designed to operate in such a situation, investigators determined that the generator started but did not produce output voltage. As a result, emergency power for the elevators, lights, and the building’s fire pumps was not supplied.

Even though there were some delays in notifying the fire department of the fire and though it took time to position fire fighters for initial attack, and though the fire’s initial growth and spread were rapid, the fire might have been controlled through fire department intervention at the time of their arrival. However, such manual intervention at this point is near totally dependent on fire hose streams delivering water of sufficient quantity and
having maximum stream penetration for suppression to be successful. This did not occur until at least 5 hours into the suppression effort, underscoring the difficult task of the fire department. Fire fighter attempts at establishing adequate hose streams had to be accomplished in a darkened, smoke-filled environment. Investigators determined that the PRVs on the standpipe system were not properly adjusted. As a result, initial fire crews did not have adequate water to suppress the fire, and the fire reached such severe magnitude that it spread unimpeded from floor to floor until extinguished by the automatic sprinkler system on the thirtieth floor.

Three fire fighters were conducting assignments thought to be normal for high-rise building fire fighting when apparently their self-contained breathing apparatus (SCBA) ran out of air, and they took refuge on the twenty-eighth floor. They thought that they were on the thirtieth floor, and this was reported to the incident command. Despite valiant efforts, other fire fighters were not able to locate them in time to save their lives. This is not the first incident of fire fighter fatalities in high-rise buildings. (See Appendix IV.) This tragic occurrence underscores the importance of not only providing adequate fire protection to the occupants of high-rise buildings, but also providing it to the fire fighters who are summoned to suppress fires in such occupancies.

Once the continuity of the suppression operation was re-established and adequate water supply maintained, the fire was beyond manual control capability until the fuels were consumed. Further, the incident
commander faced the possibility that the severe structural damage that was identified within the building might result in partial collapse.

As a result, all fire fighters were removed for their safety at approximately 7:00 a.m. on Sunday, and the fire was allowed to burn unchecked on floors 27, 28, and 29 until it reached the thirtieth floor. Several sprinklers supplied by fire department pumpers began to activate at various locations on the thirtieth floor. It appears that the sprinklers activated as the result of heat transferred from a number of sources, including that which entered the thirtieth floor by way of broken windows, that which was transmitted though a void space between the floor slab and the exterior granite facade, and that which was transmitted by heat through the concrete floor slab (conduction from structural beams and through cracks caused by the floor buckling). Each of these heat transfer mechanisms resulted in the ignition of incidental combustibles, causing multiple ignitions throughout the floor. All were extinguished by sprinklers. A total of 10 sprinklers were determined to have operated and stopped the spread of the fire on the thirtieth floor. The 10 sprinklers were distributed throughout the floor, and although many that activated were positioned along the north face of the building where the main fire assault occurred, others operated in areas where ignitions had occurred from more subtle means of heat transfer. In general, their activation appears to be in response to multiple ignitions that occurred at several different intervals rather than a major simultaneous ignition over a large floor area. This phenomenon is likely a factor in the effectiveness of the sprinklers.
Based on NFPA's findings, the following items have been determined to be significant factors affecting the outcome of this fire:

1) The lack of automatic fire sprinklers on the floor of fire origin;

2) The lack of an automatic early detection system;

3) Inadequate pressures for fire attack hose lines due to the improper settings of the standpipe pressure regulating valves;

4) The unimpeded growth and spread of the fire on the twenty-second floor;

5) The early loss of the main electrical service and the emergency power to the building, including the loss of elevator service due to a breach in the electric room enclosure on the floor of origin;

6) The improper storage and handling of linseed soaked rags and other associated combustibles; and

7) Inhibiting the spread of fire is: the effectiveness of automatic sprinklers on the thirtieth floor, supplied by fire department pumers, in stopping the vertical fire spread.
V. APPENDICES
Figure 2
APPENDIX I

Summary Results on the Fire Department Survey on Standpipes

Conducted for the Technical Committee on Standpipes

Background

In early June a survey was sent to a sample of fire departments requesting information on standpipes and associated equipment. A copy of the survey can be found in Attachment A. (Not provided in the investigative report.) The questions mainly concerned the types of standpipes found in each community, the presence and setting of pressure-reducing valves used in the communities, descriptions of the capacity of first-response pumpers and of standpipe packs used, and length of pre-connected attack lines, if any. Space on the survey form was also left for comments to the Technical Committee on Standpipes on experiences with standpipes in each community.

The intent of the survey project was to obtain a base of understanding on the current practices and capabilities of fire departments with respect to standpipe systems. The results will be used by the technical committee in considering changes for the next edition of NFPA 14, Standard for the Installation of Standpipe and Hose Systems, and by NFPA representatives to the Board for the Coordination of Model Codes seeking to harmonize standpipe and hose provisions of the Life Safety Code® and the three model building codes.

This summary report will present some of the overall results of the survey. A more detailed analysis will be completed over the next few months.

Survey Population

A copy of the survey form was sent to all U.S. fire departments protecting populations of at least 500,000; to 47 of the 54 departments protecting between 250,000 and 499,999; half of the departments protecting 100,000 to 249,999; and to 28% of the departments protecting between 50,000 and 99,999. The response rate varied from 63% for the two lowest population intervals to 80% for the departments that protect over 1,000,000. A total of 204 departments returned completed survey forms. These included the departments mentioned above, as well as 4 departments in British Columbia and 2 U.S. departments that currently report populations of less than 50,000.
Presence of Standpipes in the Community

The first question asked if there were any buildings in the community with standpipes. Of the 204 respondents, 199 responded that they did have standpipes. No further information was requested from the 5 departments that did not have standpipes.

The remainder of this report then includes the responses of the 199 departments.

Type of Standpipes

Multiple responses to this question were allowed. Of the 199 respondents, 160 have standpipes designed for fire department and occupant use, 46 have standpipes designed for occupant use only, and 123 have standpipes designed for fire department use only. Of the 46 departments with standpipes designed for occupant use only, none had those as the only type of standpipe in the community.

Location of Standpipes Used by Fire Department

Multiple responses to this question were allowed. Of the 199 respondents, 189 had standpipe connections located in stairwells, 95 had them located in stair lobbies, and 123 had them located in the middle of floors. In addition, 45 reported standpipe connections located in other areas. These other areas included: at the end of corridors near stairwells; on the roof; on the exterior of the building; in corridors; in mall exit areas; throughout open areas of the buildings; in parking garages, jails, or public assembly areas; and in tunnels and on bridges. Some of these “other” areas may be equivalent to some of the listed areas.

Water Supply for Standpipes Used by Fire Department

Multiple responses to this question were allowed. Of the 199 respondents, 189 use fire department connections and 167 use automatically operated fire pumps. In addition, 52 reported other water supply sources. Of these 52 fire departments, 34 use city or municipal water mains. One did not specify the other source. The other 17 use the domestic water supply, gravity tanks and towers, the water supply for the sprinkler system, or dedicated pressure lines.

Height of Buildings

This question asked for the height of the tallest building supplied only by fire department connections. The responses ranged from a low of 1 story to a high of 50 stories. The median reported height was 7 stories. The most frequently reported height was 4 stories.
Pressure Reducing Valves

Of the 199 fire departments, 92 reported that pressure-reducing valves are used on standpipes in their communities, 88 reported that they are not used, and 18 respondents did not know. Of the 92 fire departments reporting use of such valves, 67 reported at which pressure reducing point the valves were set. These points ranged from 60 to 300 psi. The median (and most frequently reported) point was 100 psi.

Capacity of First-Response Pumpers

Multiple responses to this question were allowed. The respondents were asked to check off the capacity of any first-response pumper they have and to indicate which size pumper was most typical for their department. The breakdown of responses is shown in the following table:

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Have At Least One</th>
<th>Most Common Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 500 gpm</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>501 - 750 gpm</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>751 - 1000 gpm</td>
<td>53</td>
<td>22</td>
</tr>
<tr>
<td>1001 - 1250 gpm</td>
<td>121</td>
<td>71</td>
</tr>
<tr>
<td>1251 - 1500 gpm</td>
<td>135</td>
<td>92</td>
</tr>
<tr>
<td>Over 1500 gpm</td>
<td>24</td>
<td>5</td>
</tr>
</tbody>
</table>

Five departments checked off more than one type of pumper as most common for their department. Their responses are not included in that column.

Diameter of Hose Lines

Multiple responses to this question were allowed. The respondents were asked to check off the diameter of hose lines in their standpipe packs and to indicate which diameter was most typical for their department. The breakdown of responses is shown in the following table:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Have At Least One</th>
<th>Most Typical Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2&quot;</td>
<td>106</td>
<td>71</td>
</tr>
<tr>
<td>1-3/4&quot;</td>
<td>115</td>
<td>91</td>
</tr>
<tr>
<td>2-1/2&quot;</td>
<td>58</td>
<td>7</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>

The 5 fire departments that checked off "Other" as the most typical diameter gave actual diameters of 1 in. (1 department), 2 in. (3 departments) and 3 in. (1 department). Another 18 departments checked off more than one diameter as most typical for their department. Their responses are not included in that column.
Hose Lengths

Multiple responses to this question were allowed. The respondents were asked to check off the hose lengths in their standpipe packs and to indicate which length was most typical for their department. The breakdown of responses is shown in the following table:

<table>
<thead>
<tr>
<th>Length</th>
<th>Have At Least One</th>
<th>Most Typical Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>100'</td>
<td>124</td>
<td>113</td>
</tr>
<tr>
<td>150'</td>
<td>65</td>
<td>53</td>
</tr>
<tr>
<td>200'</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

The 6 fire departments that checked off "Other" as the most typical length gave actual hose lengths of 50 ft (4 departments), 75 ft (1 department) and 225 ft (1 department). Another department checked off more than one length as most typical for their department. That response is not included in that column.

Nozzle Type

Multiple responses to this question were allowed. The respondents were asked to check off the type of nozzles in their standpipe packs and to indicate which type was most typical for their department. Departments with any straight-tip nozzles in their standpipe packs were asked to give their typical diameter. The breakdown of responses is shown below:

<table>
<thead>
<tr>
<th>Type</th>
<th>Have At Least One</th>
<th>Most Typical Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight Tip</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>Adjustable Type</td>
<td>154</td>
<td>134</td>
</tr>
<tr>
<td>Automatic Type</td>
<td>68</td>
<td>44</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

The respondents were also asked to check off, for each nozzle type they have, whether the minimum effective nozzle pressure was less than or at least 100 psi. Those breakdowns will be described in a future, more complete analysis.

Of the 19 departments that reported having straight-tip nozzles, 11 gave their typical diameter, 2 gave more than one diameter as typical, and 6 did not answer the question. Of the 11 who gave a single answer, the diameters ranged from 0.25 in. to 1.75 in. The median response was 0.75 in: and the most frequently reported diameter was 0.5 in.
Length of PreConnected Attack Lines

Fire departments were asked if they have any preconnected attack lines on their pumpers or engines. Of the 199 respondents, 174 reported having them on all their pumpers and engines, 11 have them on most, 10 have them on some, 2 have none and 2 left this question blank.

Fire departments that have any preconnected attack lines were then asked to check off the lengths of these lines and to indicate the most typical length they carry. The breakdown of responses is shown in the following table:

<table>
<thead>
<tr>
<th>Length</th>
<th>Have At Least One</th>
<th>Most Typical Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>100'</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>150'</td>
<td>120</td>
<td>61</td>
</tr>
<tr>
<td>200'</td>
<td>146</td>
<td>77</td>
</tr>
<tr>
<td>Other</td>
<td>37</td>
<td>8</td>
</tr>
</tbody>
</table>

The 8 fire departments that checked off "Other" as the most typical length gave actual hose lengths of 300 ft (1 department) and 250 ft (7 department). Another 27 departments checked off more than one length as most typical for their department. Those responses are not included in that column.

The respondents were also asked for the typical diameter of each length of preconnected line they carry. The breakdown of responses is shown in the following table:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>100'</th>
<th>150'</th>
<th>200'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0&quot;</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1.5&quot;</td>
<td>8</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>1.75&quot;</td>
<td>12</td>
<td>58</td>
<td>75</td>
</tr>
<tr>
<td>2.0&quot;</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2.5&quot;</td>
<td>6</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>4.0&quot;</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>blank</td>
<td>6</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>multiple</td>
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**Future Analyses**

This summary analysis presented an overview of the responses received from 199 fire departments. The complete analysis will look at some of the questions in more detail and will include analyses by size of population protected where appropriate.
APPENDIX II

Fact Sheet from the
Philadelphia Department of Licenses and Inspectors

04/25/87  Alteration permit issued to:
Nason & Cullen, 150 South Warner Road, Wayne, PA, for
tenant alterations to Floors 20, 21, and 22 including a stair
between 21 and 22.

11/21/88  The Board of Building Standards granted a variance to
eliminate a separate fire department connection for the high
zone of the standpipe provided the entire building be
sprinklered by 11/21/93.

12/01/88  John William Peterson, Jr.
4319 Leiper Street, Philadelphia, PA, 19124, received electrical
permit related to the fire pump installation. Municipal
Inspections Corporation inspected and approved the
installation on 1/25/89.

12/05/88  Delmont Fire Protection Service
242 Pembroke Avenue, Lansdowne, PA, received a permit to
convert the existing dry standpipe to a wet standpipe system
including the installation of 2 fire pumps.

02/14/89  Permit issued to Oliver Sprinkler Company, Inc.
501 West Feheley Drive, King of Prussia, PA, to install
sprinklers in floors 30, 31, 34, and 35. Final compliance
inspection 10/20/89.

03/20/89  Building in full compliance with the fire code requirements
for existing high-rise buildings.

12/09/89  Permit issued to Oliver Sprinkler Company, Inc. for
alterations to the sprinkler system in the basement and
thirty-seventh floor.
02/26/90  Fire department approved revised evacuation plans for the building.

04/02/90  Permit to add to sprinkler system in the basement issued to Oliver Sprinkler Company, Inc.

04/17/90  The building's sprinkler and standpipe systems were tested and certified by Penn Sprinkler Company. (Note: Penn was not the installing contractor for sprinkler installations.)

06/05/90  Various fire code violations were issued to tenants on 06/05/90 for such items as providing or recharging fire extinguishers, providing or repairing exit signs, posting lawful occupancy signs, and widening aisle ways. Of 16 violations, 13 were compiled as of 08/15/90 and the remaining 3 were prosecuted in Municipal Court on 02/11/91 with a fine of $76.50 and conditional fine of $250 if not complied by 03/11/91.

08/25/90  Permit to relocate sprinklers in the concourse level issued to Oliver Sprinkler Company, Inc.

10/09/90  Relocate sprinklers in the first floor issued to Safe-T-Fire Protection Company, Inc. of Riverton, NJ.

11/05/90  Install water curtain in the fifteenth floor issued to Oliver Sprinkler Company, Inc.
APPENDIX III

PRESS RELEASE

NEED FOR AUTOMATIC SPRINKLER PROTECTION POINTED OUT IN HIGH-RISE FIRES REPORT
NFPA says recent Los Angeles County Health building among those high-rises lacking.

Lack of automatic sprinkler protection is among several common factors of recent major high-rise office building fires reviewed in a report just released by the nonprofit National Fire Protection Association (NFPA). Other important factors which contributed to extensive fire damage and, in some cases loss of life, include large, open-area office configurations without floor-to-ceiling compartmentation and delay in reporting the fires to the fire departments.

The NFPA is reviewing these major fires again as a result of the Los Angeles County Health Department building fire which occurred early last month. Collecting data on the latest fire in cooperation with the Los Angeles City Fire Department, Tom Klem, NFPA's director of Fire Investigations, points out several key factors common to the buildings which suffered severe damage.

- More -
"The most significant finding from all of these fires is that automatic sprinkler protection would have mitigated damage dramatically," Mr. Klem says. "Fires which reach the magnitude of those singled out in the report, often as a result of the open work areas typical of modern office environments, cannot be extinguished as quickly by manual fire suppression alone. Automatic extinguishment is vital."

Fortunately, fire protection provisions exist. According to NFPA's report, national consensus fire codes and standards are available and should be adopted and enforced at the local level to prevent tragedies like the fires outlined in the report. NFPA 101, Life Safety Code®, contains provisions that would have dramatically reduced the fire loss resulting from the high-rise office building fires. According to the report, "the code requires that both new and existing high-rise office buildings have an integrated fire detection system to provide early detection of a fire in the controllable stage and an automatic sprinkler system to deliver water for suppression while the fire department is en route."

Established in 1896, the NFPA is an international, nonprofit, voluntary membership association with more than 60,000 members worldwide. Publisher of the National Fire Codes® and the Learn Not to Burn® public firesafety education program, the NFPA also prepares many statistical reports on fire prevention and protection. NFPA headquarters is in Quincy, Massachusetts.
High-Rise Office Building Fires

Over the past several years, the fire protection community has witnessed several severe high-rise office building fires including the highly publicized One Meridian Plaza fire in Philadelphia and the First Interstate Bank Building fire in Los Angeles, resulting in life loss, hundreds of millions of dollars of direct property damage, and business loss. The Philadelphia and Los Angeles fires are of major technical importance since each occurred in modern structures located in areas protected by major metropolitan fire departments. In spite of this, these fires spread far beyond the intended fire protection design area, spreading the uncontrolled fire through the interior and over the exterior of the building vertically toward the roof. These fires were of such severe magnitude that the manual fire suppression forces (fire fighters) could not immediately control their spread, and the fire incident commanders feared there would be a major structural collapse of the buildings. The One Meridian Plaza fire resulted in the tragic death of three fire fighters, further underscoring the need for improved fire protection design features, not only to provide life safety protection for the occupants and to ensure continuity of business activities in high-rise structures, but also to protect the fire fighters who respond to high-rise fires.

More recently, another spectacular high-rise office building fire occurred on February 15, 1992, at the Los Angeles County Health Building in downtown Los Angeles. Once again, similar devastation occurred. Fortunately, however, the well-trained and experienced Los Angeles City
fire fighters were able to bring this spectacular blaze under control, but not before the fire had consumed much of the contents on the seventh floor, threatened occupants' lives, and spread products of combustion throughout adjoining floors.

The purpose of this paper is to present summaries of each of these 3 fires, present common or significant factors resulting in the losses, and examine firesafety code and enforcement issues. This analysis can assist high-rise building owners and managers, corporate officers whose businesses occupy office space in high-rise buildings, public officials responsible for determining adequate levels of fire protection in high-rise buildings, and other concerned parties in evaluating the firesafety hazards associated with high-rise office buildings. If this indicates that adequate levels of fire protection are not provided, steps should be taken to assure that more acceptable levels of fire protection are afforded for these structures and other high-rise occupancies having similar fire protection concerns. (See Discussion section of this report.)

**Los Angeles County Health Building Fire**

At 10:06 a.m. on Saturday, February 15, 1992, the Los Angeles City Fire Department received a telephone report of a fire at the Los Angeles County Health Building. The fire occurred in a 14-story high-rise building measuring 154 ft by 88 ft that was constructed in 1970. Upon their arrival they found fire venting from the seventh floor and 20-ft flames extending from windows and threatening the floors above.
The building's construction consisted of a metal frame structural support with concrete floor slabs on metal decking, and a concrete and glass exterior facade. All of its structural members and the metal components of the floor assemblies were encased with materials that provided the building with a fire-resistance rating. Fire protection equipment for the building included a 1 1/2-in. wet standpipe system and hoselines for occupant use, a 2 1/2-in. wet standpipe system and hoselines in stairways for fire department use, a 750-gpm fire pump, and an emergency electric generator. The building was also equipped with a fire alarm system consisting of manual pull stations and smoke detectors in the elevator lobby areas.

Los Angeles City fire fighters were able to control the blaze within 80 minutes, but not before the fire consumed most combustible materials in about one-half of the seventh story, the floor of fire origin, and caused extensive heat and smoke damage to the remainder of the floor. In addition, smoke and heat damage occurred on floors above the floor of origin, and there was water damage on lower floors. Fire fighters found that the seventh floor had an open office arrangement with work stations divided by movable partitions, and these work areas were furnished with an assortment of office furniture, computers, copying equipment, filing cabinets, and accompanying combustible papers in the area.

The fire occurred on a Saturday, and thus did not pose a threat to a large number of building occupants. However, 10 persons were reportedly in various locations throughout the building at the time of the fire.
At approximately 9:00 a.m., an office worker entered the seventh floor and smelled "something electrical," but continued to her work area nonetheless. While leaving the building about 1 hour later, she observed flames above a movable partition in the corner of the building. She reported the fire to a security person who, in turn, immediately called the fire department.

The first arriving fire companies found heavy smoke visible outside of the building, and flames were venting from several windows on the seventh story. Fire command officers knew these severe fire conditions would threaten any building occupants and fire fighters who would be required to enter the building during suppression operations. Ultimately, 46 fire apparatus and 220 fire fighters and EMS personnel would respond to the fire, and through a well-managed effort, would "knock down" the fire 1 hour and 20 minutes after the initial alarm.

The cause of the fire is still under investigation; however, fire investigators believe that the rapidly growing fire was fueled primarily by a concentration of computer hardware and ordinary office furnishings and contents. The fire's ability to readily spread horizontally throughout the floor of origin was attributed to the open office plan. Even though intense flames vented from seventh story windows and broke several eighth floor windows, virtually no fire spread vertically in this way.

However, extensive amounts of products of combustion were distributed to the eighth and ninth floors by the building's heating, ventilation, and air conditioning (HVAC) system before being shut down by fire fighters. Apparently, the HVAC system did not have automatic shutdown provisions
upon detection of smoke in the system. As a result, smoke was distributed to adjacent floors served by the operating HVAC equipment. In addition to this, smoke was also distributed when the smoke on the exterior of the building entered outside air make-up intakes and was circulated by the HVAC system.

Fire department investigators reported that all of the building's fire protection equipment, including fire pump, generator, standpipes, and the passive fire protection provisions, performed according to design in this incident.

Significant factors affecting property loss in this incident included:

1) Lack of automatic sprinklers to bring the incipient fire under control and prevent its spread;

2) Lack of automatic fire detection equipment in the area of fire origin for early awareness of an incipient fire;

3) Lack of compartmentation to contain the fire to an area more easily controlled by manual fire suppression forces;

4) Lack of automatic shutdown features for the HVAC system.

**One Meridian Plaza Building Fire**

On Saturday, February 23, 1991, an early evening fire occurred at a 38-story high-rise building in downtown Philadelphia, resulting in the death of three fire fighters, fire extension to 9 floors, and severe structural damage to the building. During the 18 1/2-hour effort to control the blaze, fire fighting activities were hampered by the loss of electrical power (including emergency power) and inadequate fire attack hose stream pressure to
suppress the fire. As a result, the fire was able to spread from the floor of origin, the twenty-second floor, to the twenty-ninth floor. The vertical fire spread was completely stopped at the thirtieth floor by an automatic sprinkler system supplied with water by fire department pumpers through the siamese connection.¹

The structure at One Meridian Plaza is a fire-resistive office building with 3 sub-basement levels. The building is located in the heart of the city, and its north side, its point of main entrance, faces City Hall. Its exterior is composed of a granite and glass facade constructed in a manner that allows approximately 50 percent of the exterior surface to be openings for natural illumination to the interior. Structural steel framing, protected with spray-on material and poured concrete flooring on a metal deck, provides the structural integrity of the building.

The building is approximately 240 ft x 92 ft with 17,000 ft² per floor for occupant use with the remaining area composed mostly of the building’s core. The core contains 2 of the building’s 3 interior stairways, elevators, utility chase, and other vertical penetrations. Stairways and vertical shafts were intended to meet a 2-hour fire rating.

Since the fire occurred in the early evening hours on a Saturday, only a few people were in the building at the time of the alarm. A security guard and a maintenance worker were located at the first floor guard’s desk at the

¹ The building is considered unsprinklered. The building was in the process of being sprinklered; however, at the time of the fire, only a few floors and sub-basement levels were provided with sprinklers. The 30th floor, which was provided with an automatic sprinkler system, was the first protected floor above the fire floor.
time of the initial alarm. Investigators from the Philadelphia Fire Department determined that an automatic fire alarm was first received at the building's guard desk at approximately 8:23 p.m. Upon receiving the alarm, the building maintenance person determined from the fire alarm annunciator panel located near the elevator bank that the fire was on the twenty-second floor and, using an elevator, he went to investigate the source of the alarm. Upon reaching the floor, the elevator doors opened, and he was confronted with dense smoke and heat. He fell to the floor and notified the security guard by portable radio that there was indeed a fire and that he could not close the elevator doors. However, he was able to tell the guard how to could override the elevator controls and return it to the first floor. The guard was eventually able to control the elevator, and the maintenance man was safely returned to the ground level.

During the initial minutes of the investigation of the source of the alarm, the guard apparently received a telephone call from the fire alarm company. The alarm company was told that its source was being investigated. During this time, however, the fire department was not notified of the alarm within the building.

Investigators from the Philadelphia Fire Department have concluded that the fire originated on the twenty-second floor in a private office located on the north side of the building. The cause was determined to be spontaneous ignition of improperly stored linseed-soaked rags used for restoring and cleaning wood paneling within the floor area. Once the fire was ignited, it was able to involve other volatile materials also contained within the room
of origin and soon involved the combustible interior furnishings and finish materials.

At the time of fire department notification this severe fire continued to grow unchecked while fire fighters were positioning for attack. The first reports by fire fighters indicated that the fire had spread to the stairway door, and it is likely that it had also spread throughout the open floor area as well.

The initial attack crew reported the electric power failure on their way to the fire floor, indicating that intense heat had penetrated into the electrical room (approximately 60 ft from room of fire origin) and affected both of the main electrical services to the building. The masonry enclosure of the twenty-second floor electrical room did not extend to the underside of the floor above. The openings allowed heat from the fire to impinge upon the feeder conduits in a vertical shaft, causing them to be destroyed. Sadly, during the massive suppression effort, 3 Philadelphia fire fighters perished while extinguishing the blaze.

At approximately 7:00 a.m. on Sunday all fire fighters were removed for their safety, and the fire was allowed to burn unchecked on floors 27, 28, and 29 until it reached the thirtieth floor. The sprinkler system on the thirtieth floor supplied with water by fire department pumpers began to activate at various locations on the thirtieth floor. A total of 10 sprinklers were determined to have operated and stopped the spread of the fire to and on the thirtieth floor.
The following items have been determined to be significant factors affecting the outcome of this fire:

1) The lack of automatic fire sprinklers on the floor of fire origin;
2) The lack of early detection by automatic means of the fire in its incipient stage;
3) Inadequate pressures for fire attack hose lines due to the settings of the PRVs, which were too low for the specific application in this building;
4) The rapid growth, development, and spread of the fire on the floor of origin;
5) The early loss of the main electrical service and the emergency power to the building;
6) The effectiveness of automatic sprinklers on the thirtieth floor, supplied by fire department pumper, in stopping the vertical fire spread.

**First Interstate Bank Building Fire**

A major high-rise office building fire occurred after business hours on Wednesday, May 4, 1988, in the City of Los Angeles, California, resulting in 1 fatality and ultimately destroying 4 floors of the First Interstate Bank Building. The 62-story fire-resistive building is located in the heart of the city's business district. The Los Angeles City Fire Department described the suppression effort as the most challenging and difficult high-rise fire in the city's history. It took a total of 64 fire companies and 383 fire fighters more than 3 1/2 hours to control the fire. The fire is of great technical significance because of the interior and exterior fire spread, the significant internal smoke migration, and the role of modern office environment materials and their arrangement in relation to the fire growth and development.
At the time of the fire there were only about 40 occupants in the building. They included bank employees who were working late, building security and maintenance personnel, a cleaning crew, and workers installing an automatic sprinkler system in the building. Although the building was in the process of being retrofitted with automatic sprinklers, the system was not complete and was not operational at the time of the fire.

At 10:37 p.m., the fire department received the first of several telephone calls reporting a fire at the First Interstate Bank Building. Soon after the initial fire department response and the arrival of the first due fire companies at 10:39 p.m., the first responding chief fire officer reported that a significant portion of the twelfth floor was involved in flame. Utilizing the high-rise incident command system, fire fighters prepared for an interior attack. During this time, the fire was progressing rapidly and flames were seen venting to the exterior of the building and extending to the thirteenth floor. Further, heavy smoke could be seen rising up the exterior glass and aluminum facade of the building to the roof.

At approximately 11:00 p.m., fire suppression crews reached the twelfth floor via a stairway, charged hose lines supplied from the standpipe system, and began to advance onto the floor. However, the crews had to retreat into the stairway due to an insufficient water supply. After a brief delay, an adequate water supply was established and fire fighters made another attack on the fire. By this time (approximately 11:15 p.m.) the fire was thought to have involved the majority of the 17,500 square feet of
occupied floor space on the twelfth floor and to have extended to the thirteenth floor on the south and east sides.

Despite the response of numerous additional fire crews divided between suppression and suppression support functions, 2 additional floors became involved before sufficient personnel and equipment could be effectively deployed to hold the rapidly advancing fire. Fearing that the fire would involve even more floors, the fire department incident commander decided to make a major defensive stand on the not yet involved floor. In addition to the suppression crews already committed on floors 12 through 15, several fire fighting crews were positioned on the floor.

In the process of controlling the fire, fire suppression crews rescued 2 persons from the thirty-seventh floor and 1 individual from the fiftieth floor. During the search of the building, the body of a maintenance worker was found in a service elevator that he had taken to the fire floor to investigate the source of an automatic fire alarm. The rest of the building occupants were taken from the roof by police and fire helicopters or were able to escape on their own.

NFPA's analysis of the data pointing to the major factors contributing to the loss of life and the severity of fire includes:

1) The lack of automatic fire sprinklers on the floor of fire origin;
2) Delay in notifying the fire department upon receipt of an internal automatic fire alarm;
3) Rapid initial growth, development, and spread of the fire due to the combustible nature and geometric arrangement of the office furnishings in a large open office floor plan;

4) Significant floor-to-floor fire extension by internal and external means;

5) Significant floor-to-floor smoke spread by way of stairways, elevators, utility shafts and penetrations, and HVAC ducts.

Discussion

Each of these fires in high-rise office buildings occurred after business hours, and each building lacked state-of-the-art fire protection systems to limit the severe fire growth. The fires grew undetected for significant periods of time until they reached such severe magnitude that they could not be easily controlled. Delay in fire department notification further enabled the fires to grow and spread throughout the structures. Fire suppression of such severe fires in a high-rise setting is a difficult and dangerous challenge.

Severe fires in occupied office buildings during business hours are very rare, due in large part to the added awareness people have to unusual conditions within the building. Occupants of high-rise office buildings are mobile, awake, and alert, and are effective early detectors if adequately trained to summon help. When such alerting occurs, fires are usually in their initial phase of growth when they can be more easily controlled. This illustrates the importance of occupants' training that includes emergency

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11 A recent exception to this rule was an office building fire in Atlanta, GA. This fire was caused by improper repairs to an electrical distribution system resulting in an extreme, sudden, and intense fire. See NFPA Fire Investigation Report, "Fatal Office Building Fire, Atlanta, Georgia, June 30, 1989."
fire notification procedures. Classically, during nonbusiness hours the protection of these buildings depends on combinations of fixed fire protection equipment coupled with security guard service for fire detection. Reliability of such protection depends on the completeness of the fixed detection and suppression equipment and emergency fire procedure training of security staff. If many of these areas are deficient, severe fires are more likely to occur. For these reasons it is believed that during nonbusiness hours where reliable fixed fire protection systems are not present, high-rise buildings simply are more vulnerable to the potential for large losses.

Further, as illustrated by each of these cases, the magnitude of the fire at the time of discovery typically is severe. Reliance on quick, effective fire service intervention at this point in fire growth may not be easily achieved. Fire fighters can be further hampered by smoke spread throughout the building and by having their internal vertical access limited to stairways. Among the more effective fire protection intervention strategies to prevent such severe fire growth and spread are early fire warning provided by a properly installed fire detection system, and fire control or extinguishment provided by a properly installed complete automatic sprinkler system. Early awareness of fire coupled with prompt fire department notification results in less severe fires and in giving the fire department more time to control its growth and spread. In addition, automatic sprinklers also provide immediate action to control or extinguish the fire in its early stage. None of the illustrated buildings contained the full protection of such systems, and 2 of the fires demonstrated the severe results when fire department notification is delayed. After burning out of control despite
extensive suppression operations for over 12 hours, the vertical fire spread at One Meridian Plaza was stopped by 10 sprinklers on the thirtieth floor, dramatically demonstrating the effectiveness of automatic sprinkler protection.

The office environment has changed drastically in the past 15 years. Modern technology has added to the fuel load of office occupancies. Further, large open plan areas (those having few wall partitions), found in typical modern office environments, not protected with automatic sprinklers allow for rapid fire spread throughout the floor of origin and to adjacent floor areas. Once ignition occurs, these office fuel packages release energy (heat) over the large floor area rapidly, making fire suppression impossible by manual means until combustibles are largely consumed. In each fire scenario examined, a significant amount of combustible fuels was available in a large open floor plan.

These intense fires not only destroy the contents of the floor, but are also likely to cause structural failure as the fires burn for hours and spread horizontally and vertically throughout the building. Interior vertical voids and single vertical plane exterior glass curtain walls can enable the fire to spread to adjacent floors, thus further intensifying the fire's magnitude and compounding the danger to fire fighters. Voids between floors and the exterior walls have been demonstrated to be a means of additional vertical fire spread, and buildings can suffer severe structural damage. Manual fire suppression units could not control the raging fire at One Meridian Plaza due to equipment problems. As a result, fire fighters were withdrawn for fear of structural collapse.
Improved levels of fire protection can be obtained for high-rise office buildings by application of state-of-the-art fire protection designs reflected in modern building and fire codes. NFPA's Life Safety Code,® for example, requires that both new and existing high-rise office buildings have an integrated fire detection system to provide early detection of a fire in the controllable stage and an automatic sprinkler system to deliver water for fire control while the fire department is en route.

With such effective fire protection design alternatives available, why do severe high-rise building fires still persist? The answer is complicated, but is no doubt related to the fact that the public is not aware of the potential fire hazard of such buildings. The reality is that the public relies on fire officials and other public officials, building owners and designers, and business owners to provide adequate levels of fire protection for them in the workplace. While occupants of high-rise buildings must place their safety in the hands of those who build, manage, and maintain the buildings, NFPA believes these people can also take responsibility for their own safety to some degree. This includes appealing for adequate fire protection equipment installation and code and standard compliance along with firesafety provisions such as regular fire drills and evacuation training. Public attention to the need for improved firesafety will go a long way toward reducing severe losses in fires in such high-rise buildings.

Also, public officials should examine all aspects of their building and fire code enforcement process to ensure that it contains provisions to maintain adequate levels of fire protection for high-rise office buildings. As a
minimum, national consensus fire codes and standards should be in place, reflecting state-of-the-art levels of fire protection. Based on this examination, authorities should then determine if adoption of new codes or updating of existing codes is needed. NFPA's *Life Safety Code* provides for acceptable levels of fire protection in both new and existing high-rise office buildings (an important consideration in enforcement and broad compliance with fundamental firesafety principles) and eliminates the likelihood of such severe fires from occurring where protection features are maintained. In their assessment, public officials should also determine if a building plan review and an inspection process is in place to establish that appropriate codes are followed. Finally, provisions must also be provided for periodic follow-up inspection of existing high-rise buildings to ensure that the levels of fire protection are maintained throughout the life of the building.

This paper cannot address all the complicated aspects of high-rise office building fire protection, nor does it address the similar fire protection concerns of other high-rise buildings such as residential and institutional buildings. However, it does address many of the concerns of the fire protection community based on these recent high-rise fires. It recommends to building owners, designers, code officials, and other concerned parties that high-rise office buildings must be examined for fire risks. It also suggests a basis for such hazard assessment and suggests actions to be taken to reduce the likelihood of loss of life and property, and business interruption. Additional information on the fire protection issues associated with high-rise office buildings can be obtained by contacting local fire officials or the NFPA.
APPENDIX IV

Fire Fighter Fatalities in High-Rises
Prepared by
NFPA Fire Analysis and Research Division

Attached is a list that shows all known fire fighter deaths during, or as a result of, high-rise fires in the United States. This list is derived from our list of known fatal high-rise fires since 1911.

The following is a brief description of the 7 fire fighter fatalities from that list that were not the result of stress-related heart attacks and that occurred in nonfarm high-rise buildings since 1977.

May 10, 1977  37-story office building  Baltimore, MD
This fire fighter was found dead in an elevator stopped on the fire floor. He had died of asphyxiation. He was not wearing protective clothing or carrying or using self-contained breathing apparatus (SCBA), leading the fire department to believe that it was as a result of an elevator malfunction that he arrived at the fire floor.

May 19, 1977  8-story vacant hotel  Omaha, NE
This fire fighter had been assisting at this fire in the lobby of the hotel when he complained of not feeling well. He was assisted to the outside of the building, where he collapsed. He suffered a fatal heart attack whose contributing cause was reported to be exposure to smoke. He had not been wearing SCBA while working at the fire.

June 14, 1979  20-story department store  New York, NY
This fire fighter became separated from the 2 others he was working with when fire conditions rapidly deteriorated as they were searching for the fire. An immediate search attempt was defeated because of severe heat and fire conditions. When rescuers eventually discovered the victim, his air cylinder was empty and his facepiece was slightly askew. He died of asphyxiation from the inhalation of smoke and carbon monoxide.
(This fire was investigated by Dick Best. The Fire Journal and Fire Command articles are attached.)

September 22, 1981  38-story office building  Chicago, IL
These 2 fire fighters were trapped by heat and smoke on the fire floor. One stepped into an open elevator shaft and fell from the twenty-fifth floor to the ninth floor onto the elevator car, which was also burning. The other fire fighter, attempting to locate and rescue the first fire fighter, also stepped into the open shaft.
August 12, 1984    14-story office building    Newark, NJ
While operating on the seventh floor, this fire fighter became disoriented because of the thick smoke, ran out of air and died of asphyxiation.

December 1, 1984    13-story school building    New York, NY
This fire fighter was searching and ventilating the floor above the fire when he was overcome. His death was due to asphyxiation caused by inhalation of smoke and carbon monoxide.
# Fire Fighter Deaths in U.S. Fires in High-Rise Buildings

*All Fires Known to NFPA, 1911 to Present*

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APPENDIX V.

NFPA: ALERT BULLETIN™

Engineering Division
National Fire Protection Association
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Quincy, Massachusetts 02269-9101

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PRESSURE REGULATING DEVICES IN STANDPIPE SYSTEMS

The NFPA is issuing this Alert Bulletin in response to inquiries regarding the high-rise fire that occurred in Philadelphia, PA on February 23, 1991. Specifically, the Bulletin addresses the use of various devices that can regulate the amount of pressure through a standpipe connection. This information is being provided for the fire service, building owners, and those individuals who are responsible for the design, installation, and maintenance of pressure regulating devices so that steps can be taken to ensure that such devices are properly adjusted to function as intended. The Bulletin also includes a brief history and background of these devices and a review of the requirements contained in NFPA 14, Standard for the Installation of Standpipe and Hose Systems.

Regardless of the presence of pressure regulating devices, NFPA 14A, Recommended Practice for the Inspection, Testing, and Maintenance of Standpipe and Hose Systems, recommends that all standpipe systems be periodically flow tested. The frequency and test procedure used should be discussed in advance with the fire department. The test should be conducted in such a manner as to determine if the system design parameters (pressure and flow) are being satisfied at the most remote hose stations. Standpipe systems are typically designed to provide 65 psi at the highest outlet with 500 gpm flowing (250 gpm from each of two standpipe outlets).

PRESSURE REGULATING DEVICES

There are several acceptable methods of regulating the pressure in a standpipe system. The simplest method involves restricting devices. These include a variety of devices that act to obstruct or restrict the orifice (flow area) on the standpipe hose outlet. Other options include the use of complex appliances that dynamically respond to variations in pressure changes. These appliances are generally categorized as pressure reducing valves (PRV).

Although pressure regulating devices for fire department standpipes were not recognized by NFPA 14 until 1974, all standpipe systems should be checked for the presence of such devices. These devices often appear to be conventional shutoff valves as they may perform dual functions. Building owners should utilize qualified engineers to work with the fire department to make sure that any such devices are correctly installed and set. Fire fighters should be available to witness these tests and should be familiar with the basic operation of a pressure regulating device. It is extremely important to follow the manufacturer's instructions when determining the correct settings for all pressure regulating devices.

It is very important to note that pressure regulating devices use a relative, dimensionless setting configuration on their bonnet. It is essential that these numbers not be interpreted as pressure settings. They are calibration set points and not pressure or flow settings. The outlet pressure of the device will vary significantly depending on the inlet pressure and flow conditions.

When determining the set feature of a pressure regulating device, a thorough analysis of the fire department's fire suppression operation (SOP) is necessary to ascertain the correct combinations of inlet and outlet pressures and flows.

Restricting Devices. Restricting devices can only regulate the flowing pressure available in a standpipe system. Three general types of restricting devices may be found on a standpipe system. These are thought to be the simplest and most reliable pressure regulating devices.
Restricting-type devices may be used as long as the static pressure on the standpipe system is less than 175 psi.

**Restricting Orifice.**
The basic concept of this device is a drilled disc with a hollow center that can be inserted into the outlet pipe. The movement of water through the restricting orifice causes a pressure drop due to the turbulence of the stream passing through the orifice. These discs need to be sized based on the information known about desired pressure drop and the flow needed to satisfy the conditions of the system design. Restricting orifices need to be sized for any combination of pipe diameters, hose, and nozzle type intended for fire department use in standpipe packs. These devices are not adjustable and must be replaced to change outlet pressure conditions or requirements.

**Direct Acting.**
This device uses a semispherical disc configuration that is field adjustable to a predetermined position. This disc travels as the valve is operated from the closed to open position. The relative position of the disc will permit the waterway to be partially obstructed when the valve is fully open. The disc can be adjusted to accommodate a range of pressures and flows.

**Vane Type.**
This device uses a series of overlapping vanes that can be rotated to permit an increase or decrease in the cross-sectional area of the waterway. This results in an impedance to the water flow, thus allowing a reduction of flow pressure from the outlet. The device can also be adjusted to accommodate a range of pressures and flows.

Since the devices described above would always permit water pressure to be present at the outlet when the valve is open, they do not have the capability to control static (no flow condition) water pressures. For example, when the valve connection on the standpipe system is open and a hose line is attached with a closed nozzle, the pressure available in the hose line will be equal to the pressure in the standpipe system riser at the point of connection.

**Pressure Reducing Valves.** "PRV" devices have been recognized since 1974 by NFPA 14 as being an acceptable means of reducing the pressure going through a hose valve in a standpipe system. One type is the direct acting, pressure reducing valve. Most of these valves are designed with multiple features, such as shutoff and a check valve feature.

The pressure reducing feature of this valve is accomplished by a dynamic valve disc that normally impedes the waterway. The relative position of the disc is determined by the amount of compression applied to an integral (modulating) spring mechanism that is concealed within the valve housing of the device. The amount of pressure acting on the inlet side of the valve disc allows the disc to open to a predetermined position to permit a given flow at a given pressure to pass through the valve. The disc position can be either field adjustable or preset at the factory.

The mechanics associated with this type of device require that the utmost diligence be used to ensure selection of the correct device for the intended application. For a device that is not field adjustable, a specific bonnet configuration must be ordered directly from the manufacturer. Fixed setting pressure reducing valves of this nature are usually tagged at shipment time regarding floor location and setting for a particular job.

Field adjustable valves require that the detailed manufacturer's instructions be followed upon installation and setting. Normally, a series of calibration curves (i.e., charts) is supplied with the device to show relative set points. In order to establish the setting, the following three variables must be known: (1) valve inlet pressure, (2) required outlet pressure, and (3) required flow.

This type of valve is capable of responding to a range of inlet pressures. The device will still reduce the outlet pressure, but if a higher than expected inlet pressure occurs, it will modulate to allow a somewhat higher than desired outlet pressure.

**TESTING PRESSURE REDUCING VALVES**

Two methods of testing are considered to be acceptable. The devices can be tested in place or removed to be bench tested. Bench testing PRV's is the preferred method of evaluating the settings of the valve. "In-place" testing of these devices is not easy.

Testing the device in place can be accomplished where the building is equipped with a roof manifold or at least two standpipe risers. Testing at the roof manifold can be achieved, since the water can be discharged onto the roof. In order to determine if the PRV is at the correct setting, a pressure gauge is installed on both the inlet side of the device and the outlet side of the device. (NOTE: The gauge for the inlet side can be installed on a hose connection at the floor below.) Flow can be determined by either taking a Pitot tube reading or using a flow meter. A preset valve can be compared against one of the manufacturer's curves for the needed flow. If the setting appears to be incorrect for the desired flow (for example 250 gpm as required in NFPA 14), then the appropriate adjustment can be made on the device. As a minimum, testing a representative number of valves in this manner will provide a degree of confidence that the settings are correct. Once the representative group has been tested for calibration, all other similar devices should be visually checked to determine that the settings are correct.

If a roof manifold is not present but at least two standpipes are, then one of the standpipes can be taken out of service and set up to serve as a drain. This is accomplished by closing the water supply control valve and attaching hose lines to standpipe outlets located near the ground floors. These lines would then be run out to the street where the water from the riser to be tested will be discharged.
Extreme caution should be exercised when testing a system in this manner. Very high pressures can be developed at the base of the riser being used as a drain.

The standpipe riser is set up as previously described, but a flow meter is necessary for this method. Another hose line must be run across the floor between the riser to be tested and the riser that has been converted to a makeshift drain.

The drain riser must be free of any pressure reducing devices where these hose lines are to be connected.

A full flow test can now be conducted on the PRV, and any necessary adjustments can be made to the device.

Once the tests are completed, the standpipe system must be put back into service immediately. Any components removed during the test should be replaced. All control valves must be open, and any ancillary equipment such as fire pumps must be placed in their normal condition.

BACKGROUND

The first edition of NFPA 14 was published in 1912 when a rudimentary report on standpipes was prepared by the Technical Committee on Standpipe and Hose Systems. This report was refined and became an official NFPA standard in 1915. Numerous revisions were incorporated into the standard with some 23 updates being provided between 1915 and 1989. The current 1990 edition was adopted by the NFPA membership at the Fall 1989 Meeting in Seattle, WA and issued by the NFPA Standards Council in January, 1990.

Of all the changes and amendments made to the document over the years, the most significant modification incorporated information available from metropolitan fire departments that were facing the construction of numerous high-rise structures in the 1950’s and 1960’s. At issue were the type of nozzles used, the type of hose used, and the diameter of hose that was used by these fire departments. The thrust of these changes to the standard addressed the need to supply heavy hose streams for use by fire department personnel.

As a result, the standard provided for a minimum operating pressure of 50 psi at the end of the nozzle. The nozzle of choice at this point in history, some 20 years ago, was an 1\(\frac{1}{8}\)-in. straight tip nozzle. Using a nozzle coefficient of 37 in the formula \(Q=kp^{1/2}\), the resulting flow would be approximately 260 gpm.\(^3\) A nominal flow of 250 gpm was determined to be the base figure for establishing the demand point from a single 2\(\frac{1}{2}\)-in. hose connection.

In order to achieve a 50-psi nozzle pressure, a pressure of 65 psi was necessary at the outlet side of the hose connection. This was based on a friction loss of 15 psi through the 100 ft of 2\(\frac{1}{2}\)-in. hose, which was also determined to be the standard complement of hose that fire departments carried in their standpipe packs. The 1969 edition of the NFPA Fire Protection Handbook notes that a pressure drop of 13.2 psi could be expected in 100 ft of 2\(\frac{1}{2}\)-in. rubber lined fire hose when it was flowing 250 gpm.

The design point for standpipe systems was further modified by the committee in 1970 to require a 500 gpm flow from the first standpipe and 250 gpm from each of the other standpipes. Total maximum flows of 2500 gpm were also established. The 500 gpm demand requirement from the first standpipe is based upon a 250 gpm flow coming from the fire floor and the other 250 gpm coming from the floor immediately below the fire floor.

Another issue addressed in NFPA 14 concerned the total allowable height for a single standpipe riser. A base height of 275 ft was agreed to be a reasonable maximum height. At this elevation, the pressure necessary to overcome the change in elevation is 119 psi (433 psi/ft x 275 ft). This pressure added to the established pressure of 65 psi at the hose connection outlet plus any friction loss in the standpipe itself requires a total pressure of at least 184 psi at the base of the standpipe riser to satisfy the flow/pressure relationship. This arrangement permitted pressures well in excess of 100 psi at the lower hose connections of the standpipe system. The resulting reaction force for a 2\(\frac{1}{2}\)-in. line that has a 100-psi nozzle pressure can range up to 500 lb of force, a potential safety hazard for fire fighting personnel.

In 1973 the committee added an exception to the 275-ft height restriction for a standpipe riser or zone to permit a 400-ft vertical zone as long as the materials used in the system were capable of handling the greater pressures. Following the example used for the 275-ft zone, the pressure necessary to overcome the change in elevation for a 400-ft zone is 173 psi (433 psi/ft x 400 ft). A pressure of 65 psi must then be added to deliver the required standpipe outlet pressure to properly operate the standpipe hose connection. Pressures of at least 238 psi must be available at the lower levels in order to satisfy this criteria in a 400-ft vertical zone.

Nozzle pressures in excess of 150 psi would now be expected near the lower levels of a 400-ft zone. The reaction force on a 2\(\frac{1}{2}\)-in. line exposed to this much pressure would range up to 700 lb of force. Pressures that must be considered in the design of such a system require the piping and associated materials to be of extra heavy strength. The issue of fire fighter safety is even more relevant.

Materials to fabricate standpipes are readily available for use on fire protection systems that can accommodate 400 psi. Limitations of the ability of fire fighters to control these excess pressures on the end of an attack line are the issue. Special devices on the standpipe riser outlet are now required to be installed to reduce the available pressure being delivered to the end of the hose line. In addition, lined fire hose used by the fire department is tested between 250 and 300 psi. Safety and hose limitation requirements regarding standpipe systems intended for use by the building occupants, i.e., those with connections for 1\(\frac{1}{2}\)-in.
"occupant hose" stations, have been included in NFPA 14 since the 1940's. There was concern that a flowing pressure in excess of 100 psi would immediately result in dangerous conditions for the occupant. Pressure regulating devices were required by the standard for any system that was intended for use by the building occupants.

Later, the same concern was recognized by NFPA 14 for systems that were intended for use by fire departments. No matter how well-trained the fire fighter, there is a limit on the amount of end line pressure that can be handled safely. This issue becomes especially acute when the base standpipe zone height of 275 ft is exceeded. Based upon the information known about reaction forces caused by the combination of hoses and nozzles, the requirement for pressure reducing devices was expanded to include hose connections in systems in which the flowing pressure would exceed 100 psi under normal design circumstances.

In later editions of NFPA 14, paragraph 4-7.1 required an "approved device" to be installed on the standpipe hose connection to limit the outlet pressure to 100 psi. This same paragraph also permits the device to be modified to accommodate higher outlet pressures if the fire department so specifies. The 100-psi design parameter is predicated on the fire department using 100 ft of 2 1/2-in. hose and the 1 1/8-in. straight tip nozzle as previously described above. If, however, the fire department uses an automatic fog nozzle or an adjustable nozzle in the standpipe pack, there will be a need for a higher minimum operating nozzle pressure than the 50 psi for a straight tip. Assuming that 2 1/2-in. hose is still used in a 100-ft length with 250 gpm flowing (through a fog nozzle requiring 100 psi nozzle pressure), the needed pressure at the outlet connection jumps from 65 psi to 115 psi, nearly double the base parameter for pressure.

In a 275-ft high system, a minimum of 234 psi must be provided at the base of the riser to accommodate the 115-psi requirement at the highest hose connection in this example. If the exception for the 400-ft high zone is permitted, then a minimum pressure of 288 psi is necessary at the base of the riser to satisfy this type of nozzle. At the lower levels of these 275-ft and 400-ft zones, the need for some form of pressure reducing device is obvious.

If 3 1/4-in. or 2-in. hose is used or if hose lengths of 150 or 200 ft are permitted, additional friction loss must also be considered. Each factor different from the base parameters assumed by the NFPA 14 standard requires adjustment in the friction loss calculations to permit a particular type of nozzle to operate as intended. A standpipe system can be designed to accommodate almost any set of circumstances and combinations, provided the normal suppression operations of a fire department are readily understood by the system designers. The majority of systems are typically designed to provide only 65 psi at the highest outlet with 500 gpm flowing (250 gpm from each of two standpipe outlets).

CONCLUSION

A fire department's ability to successfully combat fires within buildings equipped with standpipe systems depends on the proper design, installation, and function of the system. This underscores the importance of the fire department's involvement in the standpipe design and approval process because issues such as the type of fire department standpipe pack that will be used must be integrated into the design considerations. This information is often not known by the standpipe system designer, but it illustrates the importance of the fire department's involvement in standpipe design and approval.

Fire departments should begin to check every standpipe-equipped building within their jurisdiction for the presence of pressure regulating devices. Further, they should become thoroughly familiar with the function of the various pressure regulating devices. If they find such devices, they should immediately contact the building owner and verify that the devices have been properly selected, installed, and adjusted to deliver the pressures and flows needed for fire fighting purposes. Information on the inspection, testing, and maintenance of standpipe systems is contained in NFPA 14A.

NFPA is cooperating with the Philadelphia Fire Department in documenting this significant high-rise fire and is also issuing at this time a Preliminary Technical Report of the incident. A final NFPA fire investigation report will be available upon completion of the analysis of the data.

This NFPA report may be reproduced freely with customary source credit.

Footnotes

1. Early in the fire fighting operation on this fire, chief officers on the firefloors reported hose stream penetrations of only 15 to 20 ft. Several efforts by the fire department to improve the hose stream quality failed. Later during fire fighting operations, a mechanic adjusted the pressure reducing valves at the standpipe connections using an adjustment tool, and nozzle pressure improved immediately.

2. One other method involves the use of a pilot operated device. This type of device would not normally be used at the hose connection but could be used in the water supply piping.

3. Flow formula used to determine quantity (Q) of water flowing through a smooth bore nozzle The flow is a function of the nozzle coefficient (k) and the nozzle pressure (p). Q is in gpm, k is a nozzle coefficient, and p is in psi.