Polytechnic Institute of Brooklyn
CENTER FOR URBAN ENVIRONMENTAL STUDIES

Report of

FIRE TESTS, ANALYSES AND EVALUATION OF STAIR PRESSURIZATION AND EXHAUST IN HIGH-RISE OFFICE BUILDINGS

Performed For

THE NEW YORK CITY FIRE DEPARTMENT
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PREFACE

The tests and other related studies reported herein were directed principally to consideration of the feasibility of pressurization of stairs in high-rise office buildings as a means of maintaining smoke-free conditions to permit safe evacuation of occupants and as an aid to fire fighters.

A limited number of measurements were also made with regard to the exhaust of smoke and other products of combustion from the fire area, using a stair to simulate a smoke shaft, and a number of observations were made in connection with the spread of smoke and heat through ducts and ceiling plenums.

It is essential that this report be prefaced with a statement concerning the need to consider the design and operational aspects of stair-pressurization and smoke exhaust in context of the overall complex system in which fire events occur. Recognition of the interrelationships between fire protection system elements becomes even more critical when conclusions and recommendations are to be formulated to provide direction and guidance for the writing of specific fire safety legislation.

Fire situations in high-rise buildings embody an extraordinary number of component elements which are set within three basic and highly interactive subsystems. These subsystems relate to the Building, the Fire and the Control and Extinguishment Resources which are available to combat the fire. These three subsystems are in themselves complex. For example, the Building has as significant subsets: (1) the structure including its geometry, dimensions, areas, volumes, openings and penetrations; (2) materials including construction materials, finishes, furnishings and stored materials; and (3) mechanical systems including electrical, plumbing, heating, ventilating and air conditioning, and vertical transportation and communications.

The Fire subsystem contains at least two obvious subdivisions: (1) the dynamics of the fire occurrence including such factors as ventilation, the fuel loading, duration, area involved and products of combustion; and (2) ambient conditions including temperature, pressure, humidity, and wind direction and velocity.

The Control and Extinguishment systems include (1) detection and alarm, having as elements of importance: in-house and fire department reporting and response times, and (2) evacuation procedures with components such as order of evacuation, routes for evacuation and areas of refuge.

The high degree of interaction between the subsystems described above and between elements within each subsystem demands that insertion into the total system of new safety components such as pressurized stairs and smoke exhaust shafts receive the most careful consideration. Such special care is warranted on the one hand, to ensure that such new systems will be fully effective when called into service, and on the other hand, to avoid the introduction of factors which may be unpredictable or present new hazards.

The general applicability of the concepts of stair pressurization and smoke exhaust systems appears to have been fairly well demonstrated in this country[2, 3, 12], in Canada[6, 7, 8, 9, 10, 11] in England[5, 26, 28] and in Australia[27]. (References are to the Bibliography). While there now appears to be wide agreement on the basic criteria for design, the specific configuration and details of such systems have not been standardized nor are they likely to be fully standardized. This is because the many variables previously described will force specific solutions which although following general performance guidelines, are likely to do so using designs which will differ in detail. For example, it must be expected that the number, locations and capacity of blowers, the routing of air supply and exhaust flows, and the location of devices used for detection and control will all be heavily dependent on such factors as: the age, size, configuration and use of the building.

As in the case of all building systems, the success of pressurization systems including cost aspects will depend to no small degree, on the competence of the design engineer. In the case of stair pressurization for existing buildings, design and installation constraints are somewhat greater than for buildings under design but the criteria and standards should not differ appreciably from those set for new buildings.

Finally, it should be emphasized that the measurements and observations made in an attempt to simulate a smoke exhaust system were extremely limited. The blower which was available at the roof level of the test building provided only a fraction of the proposed exhaust flow rate, and detailed computations and analyses of the rate of gas production and the volume and rates of removal required were not within the scope of this project.

ABSTRACT

The test program was conducted in a 22-story office building at 30 Church Street in Manhattan and was carried out in three principal stages.

In the first stage, the supply and exhaust blower units were installed, tested and calibrated, leakage rates within the test stair shaft were measured and the time for pressurization was noted. The effects of open doors (various numbers and locations) were also observed.

In the second stage, pressurization conditions and conclusions established in stage one were examined and verified with the use of cold smoke. The ability of the system to prevent smoke from entering the stairwell was observed and conditions, with regard to opening of doors, which would cause the system to fail, were studied. Limited observations were also made of the effects of other vertical shafts on smoke movement. The feasibility of supplying air downward from the roof level in the pressurization of the stairwell was subjected to a limited test. The exhaust blower located on the roof was reversed and operated at maximum flow rate and cold smoke was used to observe the travel of gases through the building with the first floor door open and with one other door at an upper floor open.

In stage three, both smoke and heat were generated by four fires set at three different locations on the seventh and tenth floors. In addition to smoke, temperature and pressure observations within the stairwell, measurements of smoke, temperature and oxygen and carbon monoxide concentrations were made at other locations in the vicinity of the fire rooms, at more remote locations on the fire floors and in lobby areas at several other floors.

During each of the actual fires, conditions in the test stairwell were also observed visually by officers of the New York City Fire Department and by members of the Polytechnic research team. Throughout the test program, other independent visual observations were made by representatives from the New York Board of Fire Underwriters, The Port Authority of New York and New Jersey and other interested agencies of the City, State and Federal Governments.

In general, the purpose of the first test was to verify the successful operation of the pressurization system under conditions of actual fire close to the stairwell, with substantial heat and smoke and possible elevated pressures.

Fires two and three were designed primarily to study the spread of smoke, heat and gases through ceiling areas. Fire test two was conducted with windows and doors closed and the air conditioning supply and exhaust systems inactive. Fire test three was conducted with the supply and exhaust system operating in an attempt to assess the rate and extent of spread of fire and products of combustion.

The fourth fire test was conducted in the same general location as test two and was planned to demonstrate the effectiveness of the roof exhaust unit, in conjunction with the fire compartments and stairwell, in the simulation of a smoke shaft system.

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SECTION I

INTRODUCTION

A. HISTORICAL BACKGROUND

1. New York City suffered two major and fatal fires in high-rise office buildings in 1970 which raised a number of questions with regard to the construction of the modern office building and high-rise buildings in general.

(a) One of these fires occurred in August 1970 at the 50-story office building known as One New York Plaza. Tenant finishing work was still under way at the time of the fire and two building employees died and 30 were injured, the two fatalities occurring in an elevator immobilized at the 33rd floor, the lowest of the three involved floors. Damage was estimated at approximately ten million dollars. The second fire took place in a carpeting showroom in a 47-story office building at 919 Third Avenue, known as the Carpet Center Building. Tenant finishing work was also in progress in this building and three workers were killed and 20 injured. Two of the fatalities occurred in the hall of the fire floor, the 5th, and one in an elevator immobilized at this floor. Damage was estimated at approximately two and one-half million dollars.

(b) In the same year, a serious fire struck a 52-story office building in San Francisco. This fire was contained on the 35th floor where it started and while considerable damage was done, there were no deaths.

(c) During this 1970-71 period, Chicago also experienced high-rise fires, but in this case, in a 38-story, 456 apartment building known as Hawthorne House. Five lives were lost in this building.

2. In studying the causes and related conditions leading to the New York City fires, and those in other cities as well, a number of specific elements of building design and construction were identified to be significant not only as to the immediate cause of the fire but in the rapidity and extent of its spread and, where deaths occurred, as to the determination of the cause of these deaths.

(a) In the two cases in New York City, a clear determination of whether building code provisions were violated was difficult since the One New York Plaza building was built under the previous building code. The 919 Third Avenue building was also built under that code but along with a few variances permitting the use of some of the present code provisions which became fully effective in December 1969.

(b) Examination of the fire areas revealed some conditions which may have contributed to the spread of fire but which are not now permitted for future construction such as unprotected openings in fire divisions for the passage of wire, cable and ducts, large concealed spaces not fire-stopped, unstopped space between exterior curtain walls and the skin face, and the like. In one case, it appears that the fire was caused by the unguarded use of a cutting torch in the area used as a carpet showroom. However, other conditions were also revealed which indicated that something needed to be done in the way of providing improved fire protection for these high-rise buildings. Although the fire record in these buildings has been relatively good and they are looked upon as safe, the feeling has been expressed that the potential for disaster exists and should be considered.

(c) The high-rise building is not similarly defined in the various large cities. The designation of height is closely related to the level beyond which the local fire department cannot effectively fight a fire from the street. In New York City this height is 100 ft. or approximately 10 stories. High-rise office buildings have two significant characteristics:

(1) They generally house very large number of occupants, often in the thousands, and since safeguarding life is the primary mission of fire protection, the evacuations of these occupants to safe areas within or outside the building, poses serious logistical problems.

(2) Finally, high-rise structures because of their very size and complexity (they often include deep inner spaces, numerous and relatively inaccessible levels below ground, high dependence on elevators, and limited opportunity for ventilating during fires) present special problems and hazards to the fire fighter as he attempts to protect lives and property.

3. What was learned from the New York City fires with respect to appropriate directions to take in providing greater protection in high-rise building was much the same in its major aspects as that recognized in other cities and by other interested public and private agencies studying the matter on a national and international basis and included the need for:

(a) A reassessment of the size of allowable areas which for the most part, have been permitted to be unlimited in office buildings of fire resistive construction. If, as pointed out above, a fire must be fought from the inside of high-rise buildings, it should be confined to an area compartmented to a size susceptible of better control by firefighters.

(b) Relatively safe access to the fire area by firefighters by means of elevators specifically designated and equipped for their control. This is in effect, an expansion of such firemen's service already required in most codes but usually to only a limited extent.

(c) Consideration of the role of stair, elevator and other shafts in transmitting smoke from a fire to other areas of a building.

(d) Study of the impact of duct work, plenums, and other elements of air conditioning and ventilating systems upon the fire fighting effort.

(e) Improvements in fire alarm and communication systems along with means for early detection. Also a means for better, centralized, control of these facilities. All this demonstrated as well, a need for better control of the movements of building occupants in fires or other emergencies, with emphasis upon their use of stairs in such movements.

4. Much more in the way of broad background of the current movement towards improved fire protection facilities in high-rise buildings both from the building code points of view and in maintenance and operation procedures could be discussed but the literature on the subject is extensive and readily available to those who wish to pursue it further.

B. DEVELOPMENTS IN NEW YORK CITY

1. New York City reacted promptly to the urgencies described in this brief background picture. On February 16, 1971, Mayor Lindsay appointed an "Advisory Committee to Improve Fire Safety in High-Rise Commercial Buildings" in response to the recommendations contained in a report issued by Deputy Mayor - City Administrator Timothy H. Costello in December 1970. His report "Fire Safety in High-Rise Buildings" was prepared after intensive investigation of the two high-rise fires cited by the Fire Department and the Building Department.

(a) The Mayor's Advisory Committee was chaired by Deputy Mayor - City Administrator Costello, with Charles E. Schaffner of Syska and Hennessy, as its Executive Director and with William H. Correale of the Polytechnic Institute of Brooklyn as its Technical Director. Other members were:

Robert W. Cutler	-	Partner, Skidmore, Owings & Merrill
Joseph Ferro	-	Commissioner, Department of Buildings
Philip Finkelstein	-	Deputy City Administrator
Robert O. Lowery	-	Fire Commissioner
James P. McGuire	-	VP, Cushman & Wakefield
Joseph H. Newman	-	VP, Tishman Research Corporation
John E. Plantinga	-	Partner, Meyer, Strong and Jones
W. Robert Powers	-	Superintendent, N.Y., Board of Fire Underwriters
Leonard Scholnick	-	Chairman, Buildings Committee of the City Council
Thomas Shortman	-	Pres. Service Employee Int'l. Union, Local 32B

(b) A technically oriented Fire Safety Committee was created by the New York Building Congress and a property owners committee was created by the Real Estate Board of New York, both to supplement the studies of the Mayor's Committee. Numerous other groups in specialized fields received an opportunity to participate, one of the most important of which represented the national elevator industry.

2. The recommendations of the report of the Deputy Mayor - City Administrator asked that the report's findings be reviewed and evaluated for possible amendment of the city's building code, and that such action be taken immediately with respect to the following seven areas:

(1) Early Notification

Smoke and heat detection devices should be required on every floor and should be connected to the building's and Fire Department's alarm systems.

(2) Evacuation Plan

Every high-rise building should have a fire emergency evacuation plan and training program.

(3) Elevators

Installation requirements for elevators should be re-evaluated to prevent malfunctioning in case of fire.

(4) Stairways

Stairways should be protected against entrance of smoke and heat.

(5) Venting of Fires

Means should be provided to open fixed or locked windows in order to vent a fire.

(6) Wiring

Telephone service and computer wiring should not be installed in concealed ceiling space but should be in the concrete floor raceways.

(7) Plenum Walls

Walls, partitions and other enclosures of plenum chambers or shafts subject to air pressure differentials should be strengthened.

The report concludes with further valuable suggestions that consideration be given to some control of the contents and furnishings of buildings, the confinement of fires to the smallest possible area on a floor to permit quickest possible extinguishment, and the need for constant review of changing needs and available technologies.

3. After approximately one year of continuous effort, the Mayor's Advisory Commiteee produced a series of building code and fire prevention code amendments for consideration by the Mayor who in turn had them introduced to the City Council for public hearing and adoption. The requirements of the amendments submitted would be applicable to both new and existing office buildings over 100 ft. in height with some variations in buildings where a mechanical ventilation or air conditioning system serves more than one floor and in fully sprinklered buildings.

(a) A summary of the amendments is given below as prepared by the Committee with full appreciation of the fact that public hearings and other considerations during the adoption process may alter them in some details:

Fire Safety

A new section C19-161.2 is added to the Fire Prevention Code to provide for fire safety in office buildings. It requires a Fire Safety Plan, Fire Safety Director, Fire Drill and Evacuation Plans. These requirements apply to all new and existing office buildings with an occupant load of more than a total of five hundred persons in the entire building.

- A Fire Department directive implementing this requirement is shown in Appendix C. A system of signs at elevator landings, stair and elevator identification signs, and stair reentry signs is also included within this requirement which is expanded upon by proposed building code provisions described below.
- A complementary document in the form of an advisory regarding the control of combustible office contents and furnishings is shown in Appendix D.

Compartmentation.

Section C26-504.1 of the Building Code is amended to mandate that open floor areas in office buildings be permitted to be of unlimited size only if protected throughout by sprinklers. In the absence of complete sprinkler protection, open floor areas in new and existing buildings that have an air conditioning and/or a mechanical ventilation system serving more than one floor, are required to be compartmented into areas of from 7500 square feet to 15,000 square feet. The size of the maximum uncompartmented area permitted would depend upon the enclosing partitions being 1 or 2 hour fire separations, and the number and type of heat and smoke detectors installed. All stories under 40 feet would be exempted from the compartmentation provisions. The compartmentation requirements may be varied by the Buildings Commissioner where practical difficulty is encountered in constructing compartments for existing buildings.

Smoke and Heat Venting.

A new section C26-504.15 is proposed which would mandate separate smoke exhaust shafts for new office buildings over 100 feet. This smoke shaft would be connected to openings on each floor and terminate at an exhaust fan at the roof level. In case of a fire the heat and smoke detecting devices are activated, which in turn will activate this exhaust fan and open the shaft dampers at the fire floor. This fan with at least 60 air changes per hour capacity would exhaust smoke from the fire floor.

Because of the impracticality of installing new shafts in existing buildings, an alternate method of air pressurization is proposed for keeping smoke out of stairwells. The system of pressurization entails the use of supply air under pressure to all stairwells other than access stairs and fire towers and is based on supplying sufficient pressure to keep smoke from entering while permitting stair doors to be used as needed. A test is recommended to be conducted on an existing building to determine the criteria and standards for such a system.

Sprinklered buildings are exempt from both of these requirements.

Sign Specifications.

Various sections of Article 6 Means of Egress, of the Building Code are amended to provide for signs in new and existing office buildings controlling the use of elevators and stairs during fires. These signs will direct the occupants of the building to use the stairs in case of fire unless otherwise instructed. Implied in this procedure is the theory of not letting the occupants use the elevators in evacuating the building; they should be given clear directions to use the stairs unless otherwise instructed. Further, in those cases when all elevators are recalled to the terminal floor, the only way for the occupants to evacuate the building would be to leave by the stairs. These sign specifications are also covered by the provisions of new section C19-161.2 in the Fire Prevention Code.

In addition, provisions are made permitting all stair doors to be locked from the stair side in buildings less than 100 feet. In buildings over 100 feet, stair doors only on every 4th floor need be openable from both sides. However, all of these doors may also be kept locked if they are equipped with a fail-safe automatic opening device.

Showroom Spaces.

Section C26-1703.1 and Table 17-2 of the building code are amended to require sprinkler systems in showrooms exceeding 7500 square feet in area in new and existing office buildings 100 feet or more in height having mechanical ventilation and/or having air conditioning systems that serve more than one story. Areas located less than 40 feet above curb level are exempt from this requirement.

Interior Fire Alarm Signal and Voice Communication Systems.

A new fire alarm signal system has been developed called a special class E fire alarm signal system which in effect is a fire alarm system combined with a voice communication system arranged so that the operation of any manual or automatic alarm device will identify its location at a fire command station and other locations. Details for the installation of this fire alarm signal and communication system in new and existing office buildings appear in a new and separate reference standard RS 17-3A, as well as in new subdivisions to section C26-1704.5. Additional reference standard RS 17-3B has also been added to permit the incorporation of combinations of the class E system with standpipe alarms, sprinkler flow alarms, and any existing alarm systems including those utilizing radio communication.

Fire Command Station.

Section C26-1704.8 provides details for the installation and operation of a fire command station called for as part of the new special Class E fire alarm signal and communication systems in new and existing office buildings. It requires that this important safety control facility be located in the lobby of the building on the entrance floor.

Elevators

Section C26-1800.8 and reference standard RS 18-1 provide new elevator controls and devices for new and existing office buildings, 100 feet or more in height. In the event that smoke and/or other detectors in elevator landings are activated, all elevator cars in motion serving affected floors will be instantly recalled to their terminal floor. The activation of the flow alarm by a sprinkler head either in the elevator landing or in any other part of a fully sprinklered building would perform this same function.

In addition, elevator cars are required to be in readiness for immediate use by the Fire Department, as follows:

(a) Where a floor is serviced by less than three cars, each car shall be equipped for firemen's service.

(b) Where a floor is serviced by three cars or more, at least three cars with a rated load capacity of not less than 6000 lbs. shall be equipped for fireman's service, two of which shall be service cars if existing.

(c) In hereafter erected buildings, all additional elevator cars shall be equipped for independent service.

(d) In new buildings, interlock wiring for all elevator hoistway doors will be required to be resistant to high temperatures. In existing buildings, such wiring will be required only in elevators to be held in readiness for immediate use by the Fire Department.

Fire Detection Devices

Reference Standard RS 13-1 of the Building Code requires in new and existing buildings 100 feet or more in height with central air conditioning, manual controls for operating the air handling fans in an air conditioning system. In addition, it requires products of combustion or smoke and heat detection devices to be located at the air return shafts at each floor so as to monitor the air inlets to the shaft. The requirement for additional fire detection devices at each elevator landing has already been described above. The new subdivision to section C26-504.1, relating to compartmentation, also requires such devices for protection of building areas exceeding 10,000 square feet.

(b) The proposed amendments in complete form as they were placed before the City Council appear in a bill bearing Introductory Number 752, dated December 29, 1971 and introduced by Councilman Leonard Scholnick.

4. As noted in the recommendations of the Mayor's Advisory Committee above, a test was recommended to be conducted upon an existing high-rise office building to verify the standards or modify them for an optimal system of air pressurization to keep smoke out of stairwells in existing buildings in lieu of the smoke shafts made mandatory for new buildings.

5. In developing the decision to run tests it was found from city records that at that time there were a total of 784 office buildings 100 feet and more in height in existence. The median height of these buildings

shafts as a safe, efficient method for the control of smoke and hot gases resulting from fire..."

and

"Undertake all analyses necessary to verify or modify the standards for stairwell pressurization in existing buildings tentatively described in local law Int. No. 752 of December 1971."

(b) The standards referred to as they appeared in the proposed legislation are reproduced in Appendix E.

4. Equipment and duct work installation were the first tasks. The capacity requirement for the supply blower included in the tentative building code requirements, called for about 20,000 cfm. However, in order to provide greater flexibility during the tests, a 40,000 cfm unit was selected.

(a) A vane axial type of blower was used, primarily to permit an unobstructed air channel, but other types such as propeller and centrifugal fan could serve this purpose, particularly where larger capacities are required.

(1) The tentative code provisions require that this fan be located at the lowest level of the stair with direct connection to the outdoors. The lowest level of the south stair selected for the pressurization test was located on the same level as the main lobby of the building. Locating the supply fan at this level in an active building would have been unsatisfactory for many reasons, most of them obvious, so that a location in an arcade behind and below the stairs' lowest

level was chosen. See photographs Nos. 11, 12 and 13 in Appendix B. A bulkhead with a door had to be erected between the corridor at the stairs' lowest level and the main lobby of the building. See photographs Nos. 10 and 14. Access to the outdoors however, was available at the level of the fan as was ample working area and the necessary electrical service.

(2) The fan chosen was an American Blower Series 203, Size 49, 764 RPM with a 10 HP motor. However, again to afford greater flexibility in calibrating and checking under a variety of conditions, the size of the motor was subsequently increased to 20 HP.

(b) A vane axial fan was also chosen for the smoke exhaust fan to be located at the roof level of the stair to satisfy the proposed code requirement.

(1) This work included also the necessary controls and ductwork but because of a sharp change in direction of air flow required by physical conditions on the roof, a transition chamber, with an access door, was included immediately adjacent to the roof door opening of the stairwell. See photos Nos. 15, 16 and 17. The necessary electrical supply was available from a nearby elevator machine room.

(2) Because the requirement also called for the size of exhaust blower to be one-quarter that of the air supply fan, a capacity of 10,000 cfm was selected.

It was also an American Blower Series 203, Size 25, 1516 RPM with a 3 HP motor.

(c) It should be pointed out that the controls for both fans were manual. The tentative code provisions require that they shall be capable of starting automatically upon activation of certain detectors in the building; with manual controls from local start-stop buttons at the fans and from either a fire command station or the mechanical control center in the building. However, there simply was not enough money available on the one hand and the availability of the building for fire testing purposes was too limited on the other to install automatic controls. It will be noted in later texts that the important consideration of time to achieve full pressurization versus time for a fire to grow was satisfied during the preliminary tests and the fire tests.

B. TEST BUILDING - GENERAL CHARACTERISTICS

1. As indicated above, the building made available for the test was a 22-story office building known both as 30 Church Street and the Hudson Terminal Building. It was formerly connected by two street bridges to a twin building to the north known as 50 Church Street, already demolished. The subject building was completed in 1908 and was intended to be something of a railroad industry center.

2. The main entrance of the building was on Church Street which formed its east boundary, between Dey Street on the north and Cortlandt Street on the south. Its west face included an annex extending the full front on its Greenwich Street side and rising the first five stories. An open court extended from north to south above the third story which

divided the structure above that level into an east and a west wing, with a connecting service core at approximately mid-point of the two wings.

(a) There was a below-street series of floors none of which related to the building occupancy except for a corner used for a utilities service entrance and a few work shops. The balance consisted of a high ceilinged arcade and concourse just below the street floor of the building which were used for railroad purposes. Included within them were a large number of shops and stores. Ticket booths, change booths, turnstiles and access stairs to train platforms predominated. Main entrance for the railroad users was from the side streets with very limited access to the arcade or concourse from the interior of the building.

(b) The gross floor area of the building above the third floor was approximately 29,000 sq. ft. or approximately 25,000 to 26,000 sq. ft. of net floor area. The annex is not included. The west wing contained about two thirds of this net area with about 2100 sq. ft. of core area.

(c) The ceiling heights for the street floor and the next floor above were approximately 17 ft. and 14 ft. respectively with stores occupying all of the first floor area not utilized as the street floor lobby. The second floor had been used for public purposes at one time but just prior to the tests, contained Port Authority Trade Center construction offices. Upper floors had a floor-to-floor height of 12 ft. to 12 ft. 6 inches with varying ceiling heights. These floors had all been used for commercial occupancy.

They were partially occupied when the study started by general offices of firms waiting to move into the just-about-ready World Trade Center. Space separations found in place on the several floors varied from temporary metal of less than ceiling height to fully fire resistant gypsum block, terra cotta block and concrete block walls. The separations found in the test areas are described in more detail under Part D - Full Scale Fire Tests.

3. The building was of steel frame construction with brick exterior walls. Columns extended down to foundation level passing through the concourse area on the way. All of the columns were fire protected with terra cotta tile and plaster and finished to match other room finishes. Exterior and interior columns were generally spaced at approximately 20 ft. and in most cases two windows were located between exterior columns. This was also the case in the walls forming the interior open court.

(a) Most office floors were wood finished although floor tile was found in some areas. Most of the lobby areas on the several floors were finished in terrazzo as were some of the corridors.

(b) Doors were generally of solid wood construction except that doors in the stairwells were fire rated, self-closing, Kalamein, well fitted. There was no door at the foot of the wide flight of stairs between the second floor and the street floor of the south stair. The stairwell exited into a short corridor which in turn exited into the street floor lobby with no intervening doors. See photos Nos. 9 and 10 in Appendix B.

(c) Ceilings in occupied areas consisted of a 9 inch concrete, reinforced, slab supported on steel beams spaced approximately 5 ft. 4 in. and having a depth of 12 inches. Hung ceilings existed in lobby areas on all floors and in office areas generally between the 9th and 22nd floor inclusive but not including the 16th floor.

(d) The underside of the permanent ceilings consisted of wire mesh and plaster hung just below the bottom flanges of the ceiling beams. In many areas, the finished surface added to the plaster was a combustible tile of celotex material. Where hung ceilings were installed, this construction was pierced for hangers but was otherwise left intact. Hung ceilings were generally about 2 to 2 1/2 ft. below the concrete slab.

(e) The floors with hung ceilings were air conditioned with controls in 8 separate fan rooms, only three of which controlled more than one floor as follows - (9 and 10), 11, 12, 13, (14 and 15), 17, (18 and 19), 20. The top two floors had not been in active use for some time. Personnel for operating these systems as needed for test purposes, were available in the building on a 24-hour basis. Each system was a continuous unit with central control for supply and return. Supply was basically by means of ducts and ceiling outlets and return by means of grills in the hung ceiling and flow through the ceiling plenums. Equipment for adding heat or fresh air was included.

4. The core area, or lobby area, on the upper floors was approximately 2100 sq. ft. in area. On the street floor this area and the entrance area were combined. Within the core were 16 elevators, not all of which served the full height of the building. Two of these were freight elevators, manually operated and in enclosed shafts with old, grill-type doors. The freight cars were the only elevators which went below the first floor to serve a loading platform at a lower level. All other cars in service were automatic and in modern, fire resistant types of shafts, cars, doors and other constructions. All elevators terminated in machine rooms on the roof.

(a) Two additional car shafts had been converted to other use, one as an electrical shaft and the other as a mechanical shaft. These were immediately adjacent to the active elevator shafts. There was still another large metal shaft, approximately 10 x 20 feet in area, located back-to-back with the two freight elevators and passed from the lower train platform and concourse levels without intermediate openings right up through the building and opened on the roof. It was used to provide air to the railroad terminal facilities below the building proper.

(b) Two stairwells served the building up to the roof level, one located within the core area and on its south side and the other immediately beyond the confines of the core area and located on the north side. See location plan Figure (7) Appendix A. The south stair extended the full height of the building from street floor to roof and was the stair selected for the stair pressurization test. It's characteristics are described in more detail in Part C below on FLOW TESTS. The second or north stair served the 3rd floor to roof part of the building only. Both stairs were about 8 ft. by 15 ft. in cross section except that the south stair widened from a 4 ft. width of zig-zag stair on the way down to a straight run of stair about 8 ft. in width between the second floor and the street floor. See photos Nos. 7 and 8 in Appendix B.

(c) Above the third floor there were four means of access from the lobby into office areas each of which were protected by a pair of smoke proof doors. The south stair was included within this protection. The north stair was outside of it. It should be noted that there also was a stair at the west end of the building that also opened into the lobby area and which served only several floors and an access stair between the 21st and 22nd floors in the center of the lobby area.

5. As can be seen in other photographs in the appendix, the test building was the last of a group of old buildings located within the World Trade Center complex in downtown Manhattan covering an area between Broadway and the Hudson River and from Fulton Street on the north to Liberty Street on the south. Among the buildings surrounding the test building, the two most prominent are the two towers of the World Trade Center each of them only a block away to the west. On the immediate north are some new buildings 8 to 10 stories in height which are within the Trade Center complex and beyond them the well known Federal building at 90 Church Street. To the northeast is the prominent Woolworth Building. To the immediate east is the 50-story U.S. Steel building and a little

further east, the 60-story Chase Manhattan Bank building. Looking south from the roof of the test building, one gets a view of the numerous tall buildings in the stretch from Wall Street to Whitehall Street, and a glimpse of the Statue of Liberty in upper New York Bay.

C. FLOW TESTS

1. Instrumentation and Flow Measurement

In order to design the test program so that the proposed code amendment on stairwell pressurization could be evaluated, a large fan was installed below the ground level of the stair shaft and a unit with roughly 25% of the supply fan capacity was installed on the roof. Although the proposed code required a supply fan with a capacity of about 20,000 cfm, it was felt that this could not provide sufficient flow rates to achieve the desired pressurization requirements. Therefore, the supply fan was upgraded to a capacity of 40,000 cfm which resulted in an exhaust fan capacity of approximately 10,000 cfm.

With these overrated capacities, a sufficient variation in both the supply and the exhaust fan flow rates could be achieved and an accurate estimate of the ultimate requirements could be assessed. The supply fan was installed in an arcade below ground floor level which permitted outside air to be drawn into the entrance and then ducted into the stairwell at the ground floor level.

Since a constant speed motor was provided due to the prohibitive cost of the variable speed drive system, other means had to be included to vary the flow rate of the fan. This was accomplished by a damper system for each fan, which included two shutter-type dampers. One was located in the main duct leading to the stairwell; the second damper was positioned upstream of the main damper and opened to the ambient surrounding atmosphere. With this arrangement, it was possible to vary the flow rate from the zero flow condition (with the main damper closed and the bypass damper open) to the full rated capacity of the fan (the main damper open and the bypass damper closed) while the fan turned over at a constant rpm.

Photographs of this illustration are shown in Appendix B and the layout of the fans and the ducting arrangements leading to the stairwell are shown diagramatically in Figure (1). (All Figures appear in Appendix A.) The exhaust fan was located on the roof and had a similar type of damper control connected to it. This fan was ducted directly into the entrance door from the roof to the test stairwell by means of a bulkhead and door arrangement as shown in the photographs.

In order to measure the actual flow rate produced by both the supply and exhaust fans, a grid was set up at the duct entrance to the stairwell for the supply fan and readings were made with a pitot static tube over the entire cross section. The entrance duct was approximately 20 square feet in area and the detailed distribution of flow velocities was obtained by taking 36 different readings at each blower setting. Integration of the velocity distribution over the cross sectional area thus provided the actual flow rate in cfm delivered by the fan.

Similar sets of readings were obtained in the duct leading to the exhaust fan on the roof. In this case, the cross sectional area was 9 square feet and a total of 9 readings were obtained for each damper position. The data thus obtained under a wide variety of damper positions was found to correlate reasonably well with the pressure drop measured across the fans. This provided an additional check against erroneous data acquisition or reduction procedures.

The pressures that were recorded by the pitot static tube were quite low for the lower velocity ranges, thereby necessitating an extremely accurate pressure differential measuring instrument. The MKS Baratron has such a capability. It is generally used in the Polytechnic Institute of Brooklyn Gas Dynamic research facilities as a reference transducer since it can measure to within an accuracy of 1 micron of mercury. It consists of a capacitance type mechanical transducer connected to a null circuit device which permits the pressure reading to be taken directly from the dials when the null reading is achieved. For accurate determination of the flow characteristics both within the stair shaft and throughout the building, it was also necessary to determine the temperature of the air at various locations. For example, the outside ambient temperature determines the variation of pressure with height on the outside surface of the building. Correspondingly, the temperature in the stairwell determines the pressure distribution inside the building stair shaft (this assumes, of course, that the velocity of the flow due either to external winds or to the pressurization is extremely small).

Other parameters which were necessary for the final data reduction and analysis of the test system are the barometric pressure, the absolute pressure at various levels within the building, and the wind velocity and direction. Although much of this data was obtained from the weather bureau, (i.e., conditions on the wind velocity and direction, barometric pressure, relative humidity, and ambient temperature) it was found from the instruments which were located at the test site that certain discrepancies occurred under particular conditions. For example, the wind anemometer that was located on the roof of the test building gave readings of wind velocity and direction which, under certain conditions, were completely different from the weather bureau measurements. This is due to the complex of building structures surrounding the test building which were many stories higher than the 22 story site at 30 Church Street. For data analyses in which the wind effects are important, therefore, it is necessary to have an accurate knowledge of the local conditions at the test site since they may be considerably different from those measured by a remotely located weather station. The local wind condition on the roof of the test building was measured by a WeatherMeasure Model W-123 wind monitoring system connected to a recorder which gave a continuous trace of wind speeds up to 100 mph and a recording of wind direction throughout a full 360° sector. The absolute pressure at any level in the building was determined with a Surveying Microbarograph readable to an accuracy of .002 inches of mercury; this is also a recording instrument thereby permitting a continuous trace of data to be obtained.

The temperatures were measured using standard iron constantan open-tip thermocouples connected to an Omega Icepoint Reference Chamber. This furnished all the temperatures of interest referenced to the freezing point of water (32°F) and also recorded them on a potentiometer strip chart recorder. With these instruments the conditions throughout the building at various floor levels were determined as were the ambient conditions outside of the building. These measurements sufficed for the major portion of the cold flow tests which were performed to determine the required flow rates for various pressurization levels in the stair shaft. As a by-product of these measurements, average leakage rates through the walls of the stairwell may be obtained and, in addition, flow rates through both open and closed doors are obtainable.

2. Stair Pressurization

To evaluate the specifications of the proposed code, two basic blower flow tests were conducted. One produced the maximum pressure difference of 0.3 inches of water across the stairwell door as specified, and the other was run at a supply flow rate of roughly 20,000 cfm. Although both of these conditions were in the proposed code, it was impossible to satisfy them simultaneously. This is evident from Figure (2a), where the results of both of these tests are presented. The pressure difference shown here is the pressure across the door between the stairwell and the surrounding corridor areas; the sign convention used here indicates a positive differential when the stairwell is at a higher pressure than the surrounding areas.

Figures (2a) and (2b) summarize the various tests that were run in the stairwell pressurization series and include the supply blower flow rate, the exhaust fan flow rate, and the condition of the door for each test. For the tests wherein all doors to the stairwell are closed, the pressure distributions are given in Figure (2a). Also shown in this figure is the ambient pressure difference between the stairwell and the surrounding lobby and hall areas, without the blower system operating. During this test, the outside temperature was 45°F while the inside temperature was 75°F. Here it is evident that due to the cold ambient condition and the heated building, the flow on the lower floors is into the stairwell while on the upper floors this flow is reversed.

In order to reduce the total number of test data points to be read, the stair pressurization data was taken at 7 different locations. These correspond to ground floor, 3rd, 7th, 10th, 14th, 18th, and roof levels. It is seen that a relatively smooth curve can be constructed through these discrete points. One may also note by comparing, for example, the data in Figure (2a) corresponding to the square symbols and the diamond symbols that the ground floor pressure level is directly related to the supply fan flow rate, while the distribution with height is also a strong function of the roof exhaust rate. If the exhaust rate is low, a more nearly constant distribution is obtained while for higher exhaust rates, a highly varying distribution in pressure differential results.

Figure (2b) shows a comparison between various tests obtained for combinations of doors on different floors being open. The pressure distribution in this case is shown as a dashed line for certain locations since, on the particular floors where the doors were left open, no differential pressure readings were obtained. It is known, however, from observation of trace elements of smoke flowing outward from the stair shaft that positive pressures resulted on these floors. The location of the open doors is shown by solid rectangles; these are not measured data points and only indicate the floor level of the open door, not the pressure differential. For all the runs shown on this figure, the damper controls were fixed resulting in a change in supply flow rate and exhaust flow rate as different doors were opened. No attempt was made to adjust the damper controls to give a constant flow rate for these tests. The differences in flow rates between tests in this group, however, do not affect qualitatively the overall pressure distributions obtained. It can be noted that the opening of doors has two significant effects; first, it decreases the pressure difference on all floors below those on which the open doors occur. Secondly, it affects the pressure distribution on the floors above the open door even more radically. This is evident from the data corresponding to the triangular and square symbols where it is seen that the floors above the uppermost open door correspond to a negative pressure in the stair shaft with respect to the surrounding floor areas. In this case, gases and air did flow into the shaft from these floors. The significance of this in designing a proper shaft pressurization system will be discussed in more detail later.

The main purpose of these detailed flow measurements was to obtain basic information on leakage rates and also to determine the applicability of the proposed code specifications. The question of opening doors in various locations is an important one even though this was not specifically noted in the proposed code. For the pressurization system to be a practical safety feature, one must assume that a certain number of doors will be open, and the conditions resulting must be considered in the design system. After completion of the flow tests presented in this section, it was possible to set the blowers at predetermined flow rates for the various fire tests without having to rerun the entire flow measuring survey at the supply and exhaust fans during the fires. In addition, the basic measurements obtained here provide information relating to the eventual design and extrapolation of the pressurization system to different buildings under different ambient conditions.

As an alternate to supplying air for stair pressurization from the ground floor level, the possibility of installing a supply fan on the roof has been suggested. This has certain advantages with respect to space allocation, convenience of installation, etc. For these reasons, tests were made with the fan on the roof reversed to serve as a supply and set at a flow rate of approximately 10,000 cfm. For these tests the basic assumption was that some smoke would enter the stair shaft and it was desired to determine the path this smoke would take once the blower system was turned on. For this test, the fan was turned on with the ground floor lobby door open and a smoke candle was ignited on the 10th floor level. The results of this test are shown in Figure (3) where the travel of smoke as noted by an observer walking down the test stairwell is plotted. The data shown are measured time intervals from ignition of the candle to when the smoke reached the particular floor. The smoke traveled down the stair shaft making visibility quite poor and eventually filled the lobby floor with a heavy density. As a result of this test it was concluded that this system was not desirable for a stairwell serving as an escape route and that exhaust at the lower level posed other disadvantages and therefore no further measurements were obtained for this configuration.

An additional observation resulting from the flow tests described above relates to the exhaust fan located at the top of the test stairwell. Figure (4) presents the flow rate exhausting from the top of the stair shaft to the outside atmosphere as a function of pressure differential between the stair and ambient conditions. The various settings of the fan motor and damper system are shown in the figure. It may be observed that the flow rate (with the unit operating) is on the order of 8000-9000 cfm, independent of the damper settings or the pressure drop across the fan. In this situation the fan is operating as a restriction (for the high pressure differentials) which maintains a constant flow rate. In fact, with the motor off, the flow rate varies more predictably with pressure differential as seen by the circle symbols. With the bypass damper full open, the curve indicates the theoretical behavior of the system; closer agreement with the test data would be obtained if the effective flow area of the windmilling fan were included. Since the higher exhaust rates require higher supply rates which in turn result in higher pressure differentials throughout the stairwell, the use of the exhaust fan is questionable. The final code recommendations discussed in Section III reflect this observation.

3. Smoke Tests

Following the test series described above, several smoke tests were run with cold smoke. The smoke is generated by smoke candles manufactured by E. Vernon Hill Corp. and is composed of zinc chloride, moisture, and traces of carbon and other combustion products. Various candle sizes were used to produce smoke in different quantities which in turn produced different obscuration effects. The smoke candles are available in sizes producing total quantities of smoke ranging between 8000 and 100,000 cubic feet. Various combinations of these candles can be used to produce any desired quantity.

Since the amount of smoke produced in a typical fire is related to the gases and combustion products, in lieu of specific concentration measurements, one can use smoke density as an indication of the diffusion of combustion products resulting from the fire. Another independent quantity of significance in fire safety is the effective transparency, or opacity, of the smoke produced since even in the absence of toxic gases this can affect evacuation rescue and fire extinguishment operations (these effects are discussed in detail in Item 24 in the Bibliography. As a result, smoke meters have been developed which measure the optical density per unit path length which is related to the visibility. In the subject tests, two different units were available. Those supplied by the National Bureau of Standards are constructed as portable units with a 1.5 ft. path length. A light source is focused through a lens into a parallel beam which traverses the test gas and is refocused onto a phototube. The output of the phototube is then recorded, and by a simple calibration procedure this can be related to the obscuration level. The scales used to present this data in this report vary between 0 obscuration (indicating a clear path) and an obscuration level of 1.0 (or 100%) indicating zero light transmission over a 1 foot length. The NBS instrument is described in detail in Item 25 in the Bibliography wherein the photometer design, data reduction, and calibration procedure is described.

In addition to the NBS instruments, the American District Telegraph Corporation supplied five fixed units which were installed in various lobby areas of interest. These instruments had path lengths ranging between 50 feet and 70 feet thereby permitting an extremely sensitive reading. This is evident since 95% obscuration level over a 50 foot path length corresponds to an extremely small obscuration normalized for a 1 foot length (roughly 6%).

Prior to running the full scale fire tests, it was desired to obtain some indication of the effectiveness of stair pressurization using cold smoke. The blower setting corresponding to the results presented in Figure (2b) for the condition with all doors closed was chosen for the first test. The NBS smoke meters were installed throughout the stairwell at different floor levels between the 7th floor and the roof and the ADT meters were installed in the lobby areas. The blowers were turned on and the smoke candles were ignited in room 737 which was across the corridor from the test stairwell; 180,000 cubic feet of smoke was generated. As seen in Figure (5a), the smoke density in the hall outside of the test stair, reached 100% within 5 minutes after ignition of the smoke candles. Relatively little smoke entered the 7th floor lobby area until the lobby doors were opened 11.5 minutes after ignition. At this point, the obscuration in the lobby also increased rapidly to 100%. Throughout this test, all doors to the stairwell remained closed and the smoke indicators in the stairwell and in the 8th, 10th, 11th and 18th floor lobbies recorded zero smoke concentration.

With the blowers set at the same flow rates, the test was repeated with the following sequence of events: the smoke candles were lit producing 200,000 cubic feet of smoke. Eight and a half minutes later the stairwell door on the 6th floor was opened. At 10.3 minutes after ignition, the 7th floor stair door was opened and at 12.6 minutes, the 8th floor stair door was opened. The 7th floor lobby doors remained closed throughout the test. Figure (5b) shows the smoke obscuration in the corridor outside of the test stair, and the readings noted in the lobby on the 7th floor. Again it is seen that the corridor reached total obscuration in a relatively short time. However, in this case only a small amount of smoke was transmitted to the lobby. The stairwell photometers, however, again recorded zero obscuration throughout the test, indicating that the pressurization system at the indicated flow rates was completely effective in keeping the stair shaft clear even with the three doors open.

In order to determine the timing sequence and required time response of detection devices, a smoke test was conducted in which the sequence of events was somewhat different from previous tests. In this case, the smoke candles were ignited in the hall adjacent to the stairwell on the 7th floor, producing 120,000 cubic feet of smoke over a three minute period (50,000 cu. ft. were produced in the first minute with the remaining 70,000 cu. ft. equally distributed over the next two minutes). During this period the pressurization system was inoperative and the stair door was closed, simulating the initial phase of an actual fire. Three-and-a-quarter minutes after ignition, the door to the stair was chocked open thus simulating occupants leaving the fire area by the accepted escape route.

Figure (6) presents the smoke obscuration data in the stairwell as a function of time measured from ignition of the smoke candles. Although there was a photometer located in the shaft on the 7th floor, these readings were erratic since the smoke immediately assumed an upward motion on entry to the stairwell. The photometer, which was located in the center of the stair at about five feet above floor level, was not in the direct path of the smoke and therefore did not register any significant smoke concentration. Within 30 seconds of the 7th floor door opening, however, the concentration on the 8th floor of the stair shaft increased rapidly. One may also note the delay in time between the first observation of the smoke at subsequently higher floors.

At 6.6 minutes from ignition, the "detector" initiated the operation of the pressurization system supply fan.* The rapid decrease of smoke

*This was actually done manually on signal from the observers in the shaft (wearing masks) when it was felt that a sufficient quantity of smoke was present to allow its path to be traced through the building.

on the 8th floor (and at later times at higher floor levels) indicates the effectiveness of the pressurization system in clearing the stairwell of any smoke that might enter in the early stages of the fire. With the pressurization system now operating, the smoke initially in the stair is driven mainly out of the roof exhaust and, to a lesser extent, through the door leakage areas to other floors. To determine the dispersion on floors above the 7th, the ADT photometers in the lobby areas were monitored and indicated essentially clear air (obscuration/ft was less than .004 on all levels other than the 7th floor).

D. FULL SCALE FIRE TESTS

Although both the flow tests and the cold smoke tests described above verified the efficacy of the stairwell pressurization technique in keeping the stairs clear of smoke under various flow conditions, the ultimate tests devised were the full scale fires. These would include the effects of increased fire pressure, thermal gradients, and buoyancy (which were absent in previous tests) on the overall flow of air through the building passageways. Fire Tests No. 1 and No. 2 were directed toward this goal and differed in the supply and exhaust flow rates produced and in other particulars discussed below.

Another design condition of significance in determining the spread of smoke and gases through a building is the action of air handling systems and their particular construction. Hung ceilings which form an integral part of air-conditioning and heating return and supply systems represent one such configuration. Fires No. 2 and No. 3 relate directly to this question and were conducted to evaluate the smoke and gas transmission characteristics of such configurations, and also the effects of having the air supply systems on or off during a fire situation. Fire

No. 2, therefore, was run with the air-conditioning off, while Fire No. 3 had this system in full operation.

Evaluation of smoke exhaust shaft requirements was conducted to a lesser extent by conducting Fire No. 4 in roughly the same location as Fire No. 2. Whereas in Fire No. 2 the stair pressurization system was in operation, only the exhaust fan on the roof was running during Fire No. 4, thereby utilizing the stairwell to simulate a smoke exhaust shaft. Comparison of the results of these tests provides some indication of smoke exhaust shaft requirements.

In the sections below, the details of construction, location, instrumentation, and observed results are presented for each of the four test fires. These results, in addition to a comparison of measurements and observations for the different tests as discussed previously, provide the bases for the new code specifications suggested in the section on Recommendations.

1. Fire Test No. 1

(a) Purpose - This test was the one most directly responsive to the contract requirement that proposed code provisions regulating stair pressurization in existing high-rise buildings be verified or recommendations developed for their modification. In addition, other scientific information on the behavior of a full scale, well ventilated fire was to be obtained.

(b) Location - The area selected for this fire was in the south end of the west wing of the building, on the 7th floor. The relationship of this area to the building floor layout, and to the test stairwell is shown in Figures 7 and 8. The area had two outside exposures, one to the south with four windows, and one to the east on an open court with six windows. In order to limit the amount of ventilation obtainable from the outside air, three of the windows facing the open court were left open (glass removed) all of the others were covered with galvanized sheet metal attached to the inside frames.

(c) Construction - One of the criteria used in the selection of the space was that it be capable of sustaining a fire for about one-half hour. The size of the test room selected was 54 ft. by 32 ft. (1728 sq. ft.). One door from this area to adjacent spaces was blocked off with a gypsum board, fire resistant bulkhead to match the rating of the two plastered gypsum interior block walls. A second door from the test area entered a corridor leading to other spaces, the 7th floor center lobby and the south stairwell. A fire resistant bulkhead and door were erected to close off this corridor from the center lobby. The corridor area enclosed between this bulkhead and the open door of the fire room was 364 sq. ft. making a total test area of approximately 2100 sq. ft. All other corridor doors were kept closed during the test except that the stairwell door was manipulated for test purposes.

The ceiling of the test room was the original ceiling attached to the steel floor beams and consisted of lath and plaster, with a finish of celotex tile. The floor was wood finished. There was no hung ceiling and the only mechanical ventilation system served this one room, and was not operated during the test.

Two 1-1/2 in. steel water spray lines were hung along the long dimension walls each equipped with wall-hung type spray heads spaced at about 10 ft. intervals. These lines terminated in the adjacent room at the short dimension of the test area at its east end, and were fitted with hose connections. The gypsum block wall at this end was also perforated near the floor with two 9 inch diameter openings for fog nozzle use. Fire extinguishment was to be accomplished initially from this room which could be safely entered by men with hose lines from another fire protected area on the east side of the center lobby.

(d) Fire Load - To prepare the fire considered best suited to the test purposes, the decision was made to reproduce a working office area using a total of 32 wood desks and chairs of roughly 200 lbs. weight for each desk-chair unit used. In addition, approximately 100 lbs. of paper was placed in and on each desk and each chair had a foam rubber cushion placed on it. A total of fifteen pounds of polyurethane (scraps) were also scattered throughout the area and there was some over-stuffed furniture located in one corner of the room corresponding to an additional weight of 150 lbs. Finally, there were 150 lbs. of wood studs in an exposed partition frame in one corner of the room. This represented a total fire loading of approximately 6.3 pounds per square foot over the entire test area. (c.f. photograph 36 in Appendix B).

(e) Instrumentation and Observations - The instrumentation for this test consisted of thermocouples located at various positions throughout the test room including the ceiling, walls and the floor. In addition, thermocouples were located in the corridor leading from the test room to the fire stair. The remaining instrumentation, that is, the smoke density indicators in the lobbies and in the test stairway, were the same as described previously. The detailed layout of the instrumentation is shown in Figure (9). In addition to the temperature measurements in the test room, a pressure measurement was taken in the center of the room at a location approximately two feet below the ceiling. This was connected to a Baratron which was located in the control room located across the open court. Since the Baratron is a differential pressure measuring device, the other end was left open to ambient pressure in the control room. In order to monitor the air pressure in the control room, an absolute pressure recording microbarograph was used as a reference. In addition, to determine the effects of outside pressure fluctuations which might be caused by gusts of wind, an additional Baratron was used to record the outside ambient pressure with respect to the control room pressure. The ambient pressure was also recorded throughout the test sequence.

The pressure in the fire room is plotted in Figure (10) as a function of time. This is the actual pressure buildup due to the increase in gas temperature in the fire area over its normal pressure level in the absence of a fire. The initial buildup is seen to be quite rapid with a maximum level of roughly 0.15 inches of water achieved for a short time, at four minutes from ignition.

The temperatures are plotted as a function of time in Figure (11) at various locations in the area. It is seen that peak temperatures were reached within four minutes after ignition, following which the temperatures oscillated about a mean value of approximately 1400°F. Although the fire initially was planned to have a controlled amount of ventilation, the sheet metal covers on the window were heated to a glowing red condition and the subsequent buckling of these sheets caused the tearing out of the attachment devices. After this, the metal sheets fell from the frame allowing the heat to break the windows and full venting occurred. It can also be noted that the temperatures were relatively uniform throughout the entire test period of roughly 30 minutes and only started to decline significantly when extinguishment was initiated.

It was observed that the time to achieve maximum pressure corresponded closely with the time required to achieve maximum temperature. The pressure level then remained relatively constant until the door to the pressurized stair on the fire floor was opened. At this point, a fairly rapid increase in the pressure was noted and this can also be correlated with the peak in temperature in the fire room that is observed shortly thereafter. This also coincides with the decrease in temperature noted as in the corridor as seen in Figures (11d) and (11e), when the 7th floor stair door was opened. The decrease from 500°F to below 100°F is extremely important from the fire fighting point of view since the firemen would normally utilize this route in approaching the fire in the extinguishment process. Opening of subsequent stair doors (see test sequence below) tended to increase the corridor temperature to its original level, while shutting all the stair doors (including the 7th floor door) at 17 minutes from ignition created a more rapid increase in corridor temperature.

Smoke observation measurements in the test stair shaft are shown in Figure (12a). Although the fire reached its maximum intensity in both pressure and temperature roughly four minutes from ignition, the stair is seen to remain clear of smoke for the first 15 minutes. This coincides with the opening of the fourth door (on the 3rd floor) into the stairwell. At this time, some traces of smoke were seen to enter the stairwell and travel up to the 8th floor and subsequently higher levels. Relatively high concentrations of smoke are observed during this period; however, as the doors are shut the smoke density decreases rapidly as the pressurization system clears the stairwell. The final readings do not return to zero since the lenses on the photometers were later found to be coated with a sooty residue, preventing a "clear" reading. Observers in the stair, however, noted rapid smoke clearing and the absence of smoke following the closing of the doors.

Additional smoke density data were obtained in the lobby areas and are shown in Figure (12b). The 7th floor corridor and lobby are seen to become rapidly laden with smoke, a similar observation followed for the 8th floor lobby. After this, the 18th floor appears to reach a higher level of smoke concentration before either the 10th or 11th floors receive the effect of the fire. Although the specific reasons for this are not yet completely understood, it is assumed that this increase on the upper floors is due to travel through vertical shafts such as the elevators, pipe chases, electrical shafts, mail chutes, etc.

Some additional observations which may be made are that although the pressure in the immediate fire area reached a level of roughly 0.15 inches of water above its level prior to the fire, the stair pressurization appeared to work quite well with as many as three doors remaining open. It was also observed that the elevators responded to the call buttons which were activated by the smoke and gases in the center lobby on the 7th floor. Even through the initial phase of the fire, when no significant heat was present in the lobby area, the elevators still stopped at the floor and went through the normal door opening and closing cycle without being manually signalled.

(f) <u>Test Sequence of Events</u> - All the doors of the rooms adjacent to the corridor between the fire room and the exit stair were closed with the exception of the door to the fire room, which remained open throughout the test. The door in the center lobby bulkhead also was closed. Both the supply blower and the exhaust fan were in operation prior to the ignition of the fire and were set to provide 23,900 cfm of supply air and approximately 9,900 cfm of exhaust respectively. Since no attempt was made to control the fan flow rates during the test, these values correspond only to the initial values with all doors to the stair shaft closed. As various doors were opened, both the supply and exhaust flow rates varied due to the reduction in the back-pressure in the stair shaft. The exact values of supply and exhaust flows for any combination of open doors can be obtained from the previous section in which the fan and stairwell pressurization characteristics were described. The stair pressure differentials corresponding to this test are also shown in Figure (2b).

The zero time scale was set at the time the fire was ignited. As the fire developed, the door between the corridor and the fire room remained open; however, the bulkhead door between the corridor and the lobby was closed. Firemen who had been stationed in the stairwell then opened the stair door to the 7th floor after the fire had been burning for 10 minutes. Since the stairway pressurization system seemed to continue to work well, the 6th floor door to the stair was opened at 13 minutes, followed by the 4th floor at 14.5 minutes, and the 3rd floor door at 15.3 minutes. Following the opening of the fourth door (on the 3rd floor) a small amount of smoke started to enter the stair shaft from the fire floor. At this point the various doors were all closed in reverse sequence, starting with the 3rd floor at 16.5 minutes and ending with the 7th floor at 17 minutes from ignition.

(g) Extinguishment - Initial extinguishment was by use of fog nozzles brought into Room 734 as shown in Figure (8) from the safe area in the adjacent space near the east wing. Water supply was obtained from standpipes in the building. Secondary extinguishment was obtained by activation of the water spray lines and final extinguishment by hand hose lines brought in by way of the center lobby and the test area corridor. It was determined after examination of the fire room that approximately 70 to 80% destruction of its contents had occurred.

2. Fire Test No. 2

(a) Purpose - The purpose of this test was to verify the effectiveness of stair pressurization under reduced supply flow rates in comparison to Fire Test No. 1. Since the area chosen for this test was air-conditioned and had a hung ceiling which acted as the plenum for the return, the effect of this construction on the travel of smoke and fire was also to be examined and a comparison was to be made between this test (with air supply and return off) and a subsequent test (No. 3 with a supply and return operating).

(b) Location - The area selected for the fire was on the 10th floor and was located in the southwest wing, as shown in Figures (7) and (13). The fire location was confined to a portion of the room as shown in Figure (13).

(c) Construction - The fire area was generally surrounded by other partitioned spaces most of which had separations of unrated, non-combustible metal. The room in the southwest corner of the wing, on the other hand, was subdivided by plastered gypsum block divisions and it was in this southwest corner that some test measurements were made to study gas and smoke movement.

The area covered by the test fire was approximately 25 ft. x 14 ft. in a room 48 ft. -6 in. by 14 ft. -3 in. in overall size. The hung ceiling was suspended from the floor construction above by metal hangers, holding a metal grid which in turn carried fire-resistive, acoustic, movable tile. The floor to ceiling height was about 8 ft. The floor had a combustible finish. The space between the hung ceiling and the floor slab above was about two and one-half feet. The entire south end of the west wing contained windows on three sides, all of which were closed for the test. The north end of the area was separated from the elevators and other building area by fire rated masonry construction except for a corridor. The corridor led to the south stair and the center lobby at the entrance to which a fire resistant bulkhead and door were erected. Two steel, water spray lines 1-1/2 in. in diameter were hung in the fire area to assist in the fire extinguishment. These were fitted with spray heads or sprinkler heads with fusible links removed. Both lines terminated in the center lobby beyond the temporary door and bulkhead and were fitted with hose connections.

(d) Fire Load - An office type fire loading was prepared for this area also and it involved the use of six desks and chairs loaded with paper and other combustibles. In the area of the fire, which consisted of approximately half of the room, the fire loading was built up to a density of about 5.1 pounds per sq. ft.

(e) Instrumentation and Observations - The instrumentation layout is shown schematically in Figure (14). Locations 1 and 2 are in the immediate fire area while locations 3 to 6 are in remotely located rooms in the same wing of the building. Location 7 is in the corridor immediately outside of the test stair. At these locations the instrumentation consisted of thermocouples suspended 6 inches below the ceiling (denoted by C in the figures) and corresponding thermocouples, located above the hung ceiling (these are denoted by DC in the figures).

For this test and also for test No. 3, some additional measurements were obtained of the concentration of oxygen and carbon monoxide at various locations. The instrumentation was supplied, installed, and operated by Mr. S. Steele of NBS and consisted of sampling tubes connected to a vacuum pump which created a flow of gas from the test locations to the sampling device. At specified times, the gas sample was introduced into either the oxygen detector which is a paramagnetic resonance cell manufactured by the Beckman Instrument Co., or the carbon monoxide cell which operates on the principle of non-dispersal infrared absorption and is manufactured by Mine Safety Appliances Corp. Following the recording of the sample data, the cells are purged in preparation of the receipt of a gas sample from the next location.

The pressure history during the fire was obtained by a copper tube hung from the ceiling between locations 1 and 2. The distribution of pressure with time is shown in Figure (15). It is seen that during the first five minutes following ignition, the pressure level in the fire area increases to its maximum value. Subsequent to the test, when the tubing was examined, it was found that the heat and débris had sealed off the tube when the tubing dropped from its supports. Thus the readings taken after six or seven minutes from ignition during this test are believed to have no significance. Figure (16) shows the temperature histories at various locations, both in the fire room and at the more remote areas. Here again it is seen that the fire achieved its maximum intensity within five minutes from ignition. Although there is some difference observed between the temperatures obtained below the ceiling and in the plenum at the various locations, this difference is somewhat erratic, indicating that the travel of heat through the ceiling area was probably no more excessive than through the room areas. The temperatures in the hall at location 7 remained relatively low until the corridor doors were opened, approximately nine minutes after ignition. The temperatures then started to climb and reached a level of approximately 500°. Following this, extinguishment was initiated and the temperatures in this area dropped back to normal.

Figure (17) shows the smoke concentration achieved at various locations surrounding the fire area. The smoke meters were not located in the fire room since previous experience indicated that they would record 100% obscuration in a relatively short time. As a result, they were located in the more remote areas. Two of these indicators did not function during the test, however, the data obtained from the remaining stations is shown in Figure (17a). Initially, a small amount of smoke is seen in the corridor area. This probably entered as the observers and firemen who ignited the fire were leaving the fire room. Following the closing of the corridor doors the temperatures and smoke level here seems to decrease with time and increase again only after the corridor doors were reopened. Location 6, which was in one of the more remote areas from the fire, reached a relatively high concentration of smoke quite rapidly, whereas location 5 in the opposite corner of the wing was relatively clear throughout the test. The smoke density in the lobbies on various floors is shown in Figure (17b). As expected, the 10th floor lobby increased most rapidly initially and upper floors reached higher concentrations at later times. It was somewhat surprising to note that the concentration of smoke in the 18th floor lobby again increased more rapidly than that on the 11th floor which was immediately above the fire floor. This particular figure will be referred to again later when a comparison is drawn between the results of Fire No. 4 and Fire No. 2.

The oxygen concentration is shown as a function of time in Figure (18). Although some decrease is noted, the oxygen depletion observed in the areas measured is not too severe. The carbon monoxide concentration, on the other hand, which is shown in Figure (19), is seen to increase rapidly. The maximum level of carbon monoxide obtainable with the system used corresponds to 0.2%. However, the rate of increase observed indicates that significantly higher concentrations were obtained during the test. Here again, it is noted that locations which were somewhat remote from the fire achieved a relatively high concentration of carbon monoxide and moreover, these did not necessarily correspond to regions wherein either the temperature or the smoke concentration was extremely high. This would imply that even though the fire did not necessarily spread primarily through the plenum, the combustion products could travel quite rapidly through these areas. It should be emphasized here that the ventilating systems were off during this test and therefore the travel through the plenum area was initiated by the normal air currents and the thermal effects of the fire.

Although the measured concentration of carbon monoxide was quite low, even this concentration may have serious consequences on building occupants or firemen entering these areas. For example, a concentration of 0.30% will cause headache and dizziness after an exposure of only 5-10 minutes, while continued exposures up to 30 minutes can cause unconsciousness, collapse or death. Since this is the same order as the concentrations measured in the subject tests, this information is significant to the understanding of fire dynamics and in the development of fire safety practices.

(f) Sequence of Events - During this test the supply and exhaust blowers were set to give a maximum pressure difference of 0.3 inches of water across the stairwell door at the ground floor level. The corresponding pressure differential distribution throughout the building can be seen in Figure (2a). The lower flow rate, corresponding to these pressures, was used in this test since this is one of the criteria that were specified in the proposed building code provisions.

Following ignition of the fire, the observers retreated behind the corridor doors which were located as shown in Figure (13) and are between locations 2 and 7 in Figure (14). After the fire was in progress for seven minutes, the door to the stairwell on the 10th floor was opened. One may note that the temperature at location 7 then dropped back to normal ambient temperature as the clean pressurization air entered the corridor. After nine minutes from ignition, the corridor doors were opened, exposing the corridor outside the stairwell to the full effect of the fire. At this point it was noted that the temperature in the corridor started to increase more rapidly. At 12.5 minutes from ignition the 9th floor stair door was opened and no smoke was observed in the stairwell. The thermocouples which were located at various levels throughout the stairwell also indicated no increase in temperature above ambient throughout the test. The doors to the stairwell were left open for a few minutes and were then closed and extinguishment of the fire initiated.

(g) Extinguishment - Initial extinguishment was by use of the fog nozzle through the corridor and the smoke-proof doors into the fire area and the activation of the spray lines. Final extinguishment was by hand hose lines and direct approach from the floor lobby.

3. Fire Test No. 3

(a) Purpose - The primary purpose of this test was to determine the influence of the operating air handling system in spreading the fire, smoke, and combustion products throughout the building. In the previous test, which was also conducted on the 10th floor, the air conditioning system was off. In the test described here, however, these systems were in operation with the damper set at 100% return. By comparing the results of fire tests No. 2 and No. 3, one can obtain some indication of the effect of operating the building ventilation and air conditioning systems.

(b) Location - The area selected for this test was in the east wing of the building. It was in a room at the junction of the two main corridors serving this half of the building. A door opened from the corridor into an outer office which was connected to two inner offices which faced on the exterior wall of the building. The detailed layout is shown in Figure (20).

(c) Construction - This fire area was relatively small, measuring 10 ft. x 20 ft. and enclosed within metal and glass partitions. The ceiling construction and the construction of the hung ceiling were similar to that described for Fire Test No. 2. A photograph taken above the hung ceiling in this fire area appears in Appendix B as photograph No. 72. It shows the original ceiling of the building including the celotex tile finish. The floor finish was also combustible tile.

(d) Fire Load - An office type fire made up of six desks of heavily loaded waste paper and other combustibles giving approximate 9 lbs. per sq. ft. of fire load. Two 1-1/2 in. steel, water spray lines were hung in the area, both connected to a single hose connection located in a safe area behind a gypsum block partition across the longitudinal corridor.

(e) Instrumentation and Observations - Figure (21) shows the instrumentation layout for Fire No. 3. In this case it is seen that the instrumentation is located in areas that are significantly more remote from the fire than in previous tests. This was done to insure observation of data obtained as the smoke and gases traveled through the ventilating system and thereby redistributed throughout the building. It may be noted that the central air handling system in this particular area was operated by a fan and blower system on the 9th floor and only served the 9th and 10th floors. Most of the other floors had individual floor type ventilation.

At the various locations shown in Figure (21), the instrumentation used to obtain data corresponded to thermocouples, smoke photometers, carbon monoxide detectors, and oxygen concentration samplers. The fire pressure was measured (as in all fires) by a tube suspended 1 ft. below the ceiling and located midway between locations 1 and 2 in the fire room. The pressure history resulting from this test is shown in Figure (22). The peak intensity in this test was reached within four minutes of ignition. The pressure level achieved is also seen to be significantly higher than in the previous test which was of a similar nature; the pressure here is comparable to Fire No. 1 although this was not as extensive or as well ventilated (by natural means) as Fire No. 1. Temperature histories at various locations are shown in Figure (23). Here also one may note that the temperatures achieved in the fire area are significantly higher than in previous tests. In fact, at several times throughout the fire, the thermocouples recorded temperatures beyond the limit of the recorder, indicating that temperatures higher than 2200°F were achieved. Another significant result is that the thermocouples located above the hung ceiling(denoted by DC) in the plenum area recorded temperatures consistently higher than those in the room areas below the ceiling. This is particularly evident in locations 3, 4 and 5 wherein the temperature differences measured across the hung ceiling were several hundred degrees. One may also note that even after extinguishment decreased the temperatures in the immediate vicinity of the fire, the temperatures at location 7, which was quite remote, were still in excess of 500°F. Examination of the 10th floor subsequent to the test, indicated that the fire traveled primarily through the plenum area thereby increasing its rate and extent of spread significantly.

Figures (24a) and (24b) present the smoke obscuration on the fire floor, and in the lobbies of adjacent floors, respectively. One may note that the smoke obscuration reached 100% at location 6 which was quite far from the fire. Surprisingly, the temperatures in other remote areas were somewhat higher than in location 6. Figure (25) shows the corresponding carbon monoxide concentration. Relatively rapid increases of CO are observed both in the vicinity of the fire and in remote areas. In fact, in location 8 which is in the far wing of the building, the carbon monoxide concentration is almost as high as in the area immediately adjacent to the fire. At this location, neither a large temperature change nor a large smoke concentration was achieved, although in the previous figure, it is seen that the oxygen depletion in this location is comparable to all other test measurement areas on the floor. The major conclusion that one can draw from this test sequence is that the spread of combustion products and smoke is significantly more rapid with the ventilation systems on than with these systems inoperative.

(f) Test Sequence of Events - Since this particular test site was quite remote from the stairwell, and the main purpose was to obtain information on the building air handling systems rather than the pressurization system, the doors to the stairwell remained closed during this test except when it was utilized by firemen and observers and no information other than visual observations was obtained with respect to the conditions in the test stair. The fire was ignited and after a period of intensive burning, extinguishment was initiated, without regard to stair door opening and closing sequence.

(g) Extinguishment - Initial extinguishment was by means of fog nozzles and spray lines followed by hand hose lines brought in through the smoke-proof doors from the central lobby. Although extinguishment in the fire room was fairly rapid, other areas on the floor continued burning, and therefore, the entire extinguishment procedure took considerably more than for the other fires.

4. Fire Test No. 4

(a) Purpose - In addition to stair pressurization, the proposed building code changes include a smoke shaft, as a means of increasing fire safety,and it was felt that much of value could be learned by using the south stairwell to simulate a smoke shaft. To accomplish this, the supply fan for the stairwell was turned off with both dampers closed, and the exhaust fan was operated at its full capacity of 10,000 cfm.

(b) Location - This test was also conducted on the 10th floor in the south end of the west wing in the same area in which Test No. 2 was performed, cf. Figure (13). The fire area was quite close to the smoke-proof doors and the corridor which was desirable since the purpose of this test was to observe the capabilities of the stairwell as a smoke shaft.

(c) Construction - Part of the large room available after Fire Test No. 2 was in sufficiently good condition for use in this test. Although some hung ceilings had fallen and some of the metal partitions were warped, the windows were in good condition as were all of the permanent building elements. The water spray line was rebuilt. The smokeproof doors to the corridor were to be kept open to permit travel of the smoke and gases to the stairwell whose door was also kept open to simulate a smoke shaft louver. The bulkhead and door into the 10th floor central lobby was closed during the early part of the test but later manipulated for observation purposes.

(d) Fire Load - A total of six desks and large quantities of waste paper and other combustibles were used for the fire load; the loading was approximately the same as in Fire Test No. 2 (5. 1 pounds per square foot). The humid atmosphere following extinguishment of Fire No. 2 slowed this burning but otherwise was not detrimental.

(e) Instrumentation and Observations - There was relatively little instrumentation installed for this test since the main object was to determine by more general visual observation how effective the roof exhaust fan was in removing smoke and heat from the fire floor. Thermocouples were located in the stairwell on the 10th, 11th and 14th floors to indicate whether a significant portion of the combustion gases were being drawn up through the shaft. In addition, the smoke obscuration devices located in the center lobbies of the 8th, 10th, 11th and 18th floors were also used.

Figure 27 shows the temperature history in the stairwell following ignition of the fire. It is seen that the temperatures reach a maximum of 230^{o} before extinguishment. A slight decrease in temperature is seen as the hot gases travel upward from the fire floor towards the roof.

Figure 28 shows smoke obscuration in the lobbies of the various floors. An interesting point to be noted here is that the 8th floor and the 11th floor exhibit the same low level of obscuration, whereas the fire floor (10th) and the 18th floor indicate a very rapid increase in smoke density. Moreover, if one compares these results with the corresponding results of Fire No. 2, wherein only stair pressurization was in effect, it is seen that there is little recognizable difference between the smoke density in the lobbies of both the 10th and 18th floors in these tests. This somewhat negative result may be offset by the visual observations that were made while the fire was in progress. In particular, the smoke obscuration meters in the lobby areas were located a foot below the ceiling level. At eye level, however, it appeared to many observers that the smoke intensity in the 10th floor lobby was lower in Test 4 in comparison to Test 2. This is a somewhat subjective observation, however, and it is, therefore, quite difficult to reach strong conclusions on the basis of this limited test.

(f) Test Sequence of Events - Following ignition, the observers retreated into the lobby area leaving the door to the lobby and the door to the stair shaft open. The stair shaft in this case was operating as a smoke exhaust shaft, therefore, the pressure in the shaft was lower than the surrounding areas causing smoke and gases to be drawn into the shaft. The fire was allowed to burn for about fifty minutes. However, at thirty-two minutes after ignition, the supply blower was turned on causing the system to operate in the stair pressurization mode. The effects of this on the gas temperature in the stairwell are evident in Figure 27 wherein it is seen that the temperature drops down to ambient almost instantaneously.

(g) Extinguishment - The steel spray line with its hose connection in the center lobby, for nozzles and hand hose lines brought in through both sets of doors were used for extinguishment.

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Stair Pressurization

(a) The feasibility of using stair pressurization as a means for ensuring smoke-free conditions in high-rise office buildings was demonstrated.

(b) During the first three fire tests, measurements of smoke levels and direct visual observations made in the stair by members of the Polytechnic Institute of Brooklyn research team, officers of the New York City Fire Department and representatives of other agencies including the New York Board of Fire Underwriters indicated that with as many as three doors wide open, the entire stairwell remained free of smoke.

(c) While the corridor and adjacent lobby areas on the fire floor were observed to have heavy smoke levels, the test stair provided a clear and safe passage for evacuation of occupants and an effective route by which firefighters could approach the fire location.

(d) By selecting and locating blower equipment with appropriate characteristics and suitable damper controls, systems can be designed to meet requirements with regard to: time for pressurization and acceptable limits for door opening force (using door opening aids as required).

(e) Measurements made with respect to the performance of the exhaust fan (as originally specified) indicate that elimination of this unit with appropriate sizing of the exhaust opening will improve the overall operation of the stair pressurization system.

(1) The flow rate in the passive system (no exhaust fan) approaches zero as the pressure drop approaches zero which is more desirable than the condition which exists with the exhaust unit in operation in which a constant (limiting) flow rate is maintained independent of the pressure drop.

(f) The criteria for which specific standards should be formulated include:

(1) A minimum positive pressure with respect to the adjacent floor area should be maintained throughout the stair. A numerical, measurable value should be specified for this pressure.

(2) A higher positive pressure should be specified at the fire floor level so that with doors open at this level and at least two other floors, the pressure within the stair will be great enough to prevent the entry of smoke and gases into the stair.

(3) The maximum force required at the door knob to open any door should be specified using mechanical means for assistance as may be required.

(4) The direction of air flow in the stair should be upward at all levels. This will prevent any initial smoke and gases, which may have entered the stair, from travelling downward. The roof terminus for the exhausted smoke and gases is also considered to be

preferable to the street (lobby) level(with downward flow) where fire fighters will be entering and occupants leaving.

(5) With the door on the fire floor open, and all other doors closed, a maximum permitted flow velocity through this door should be specified.

(g) One or more blowers of sufficient capacity and necessary controls should be utilized or installed to create a pressurization system in compliance with the above criteria. The capacity of the blower should be sufficient to maintain required pressure while supplying flow rates required through the three open doors and any other leakage estimated through the stair walls.

2. Smoke Exhaust Systems

(a) Simulation of Smoke Shaft Action

Visual observations and thermocouple measurements of temperature made within the stairwell (used as a smoke shaft) during Test No. 4 attest to the removal of quantities of smoke and heat from the fire area. In spite of this, no conclusive evidence of reductions of smoke reaching and accumulating in lobby areas was indicated by the lobby smoke meters although visual observations seemed to show somewhat less smoke on the 10th (fire) floor than was observed during Test No. 2. It must be remembered that the capacity of the roof exhaust unit used in Test No. 4 provided somewhat less than the 60 changes per hour rate proposed in the code (depending upon the compartment size assumed, this might have been as little as 6 changes) and that both entry and physical conditions in the stair were at best only rough approximations of what might be expected in a proper smoke exhaust system design.

(b) No attempt was made to investigate the effects of approach or shaft entry velocities of the magnitudes anticipated in an actual working exhaust system and further study of these issues as well as other related details, should be undertaken as part of the development of design methodology in this area.

3. Additional Observations

While stair pressurization was the principle area of interest in this investigation, a number of additional observations were made from which conclusions relevant to the overall question of fire safety in high-rise office buildings may be drawn.

(a) Fire Growth Rate

The extremely rapid rate of fire growth which is possible in the presence of ample fuel and ventilation was vividly demonstrated in Test No. 1 in which maximum buildup of temperature and pressure were reached within four minutes after ignition. The critical importance of early detection and reporting of fires, of quick and efficient evacuation of occupants from the fire floor and adjacent areas, and of timely response and rapid access of firefighters to the fire site must be measured against this order of time.

(b) Importance of Ventilation

The special hazards which accompany under-ventilated fires, capable of producing large quantities of smoke, was observed in connection with Test No. 2. This fire was set in an interior area with no natural or mechanical air supply, and no appreciable avenue for escape of heat or gases. Following a short period of build-up to a vigorous burning condition, consumption of available air in the generally confined space brought a dramatic and almost instantaneous disappearance of open flame. Large quantities of combustible gases at elevated temperatures were still present and the situation was conducive to "smoke explosion." The need for fire-fighter-controlled means for ventilating an involved area was clearly demonstrated in this case.

(c) Effects of Mechanical Ventilation and Return Systems

Observations and comparisons relating to the rate and extent of fire growth, temperatures and pressures reached, spread of smoke, gases and heat, and to the extent of damage resulting from Tests 2 and 3, indicated that maintenance of the mechanical system of air supply and return to the fire area stimulated every one of these elements. Each of the two system phases, supply and return, continued in operation in Test No. 3, contributed to the increased severity of the fire event. The fact that both supply and return air flows were produced by a single fan unit somewhat obscures the issue as to the exact extent to which continued supply of air stimulated the fire, with all of the resultant consequences noted above, and the extent to which the action of the return flow carried the heat and gases to other areas by way of the ceiling space. Clearly, the two actions are interdependent to a large degree but still, the conclusion may be drawn that regulations should be adopted which require that air supply and return systems be turned off in the fire area.

The practice of exhausting air from the fire area to the outside (through the normal air handling system) is another matter, and while this action would appear to be desirable, the manner in which it is accomplished, and the routing of duct lines should be carefully examined since, as pointed out above, under certain conditions, such duct work and/or ceiling plenum returns are easily able to contribute to the spread of heat and gases.

(d) Spread of Harmful Gases

Even with mechanical air supply and return systems inoperative as was the case in Fire Test No. 2, it was observed that rapid spreading of toxic concentrations of gases (carbon monoxide in this case) could take place through ducts and ceiling plenums. This condition can occur without appreciable quantities of accompanying heat or smoke, which suggests an even more sinister danger and, therefore, requires consideration in connection with both evacuation and fire fighting procedures as well as with regard to design of the building systems in question.

(e) Presence of Combustible Materials in Ceiling Areas.

Temperature histories observed and recorded during Fire No. 3 indicated extremely high temperatures (in excess of 2200 degrees F) in the ceiling spaces. The existence of combustible ceiling tiles and cement materials used to hold these tiles to the underside of the upper slab is considered to be the cause of these high temperatures.

During Fire Test No. 3 high and persistent (even after initial extinguishment) levels of heat were observed in ceiling areas in which relatively large amounts of polyvinyl plastic covered wire and cable were present.

The comparative ease with which heat and gases can enter and travel through ceiling spaces as noted previously, together with the presence of combustibles in this most vulnerable area, demands that special attention be given to the need for fire stopping and exclusion of combustibles in these locations.

(f) Elevator Action During Tests

During the running of Fire Test No. 1 it was observed that elevators responded (elevators came to the 7th floor which was the fire floor) to signals emanating from call buttons actuated by smoke and/or other products of combustion. Heat levels measured in the elevator lobby on this floor had not reached appreciable levels. This occurrence was of interest to a number of observers who made their own independent notations of the incident and it was brought to the attention of representatives of the elevator manufacturers who were at the test site at the time.

It was believed that this problem has been recognized for some time, is under study by others, and that certain remedial actions are underway.

B. RECOMMENDATIONS

1. Stair Pressurization

(a) Stair pressurization reference standards should contain the following specific requirements:

(1) The air shall be mechanically supplied at one or more levels.

(2) The flow of air shall be upward at all levels.

(3) Each blower shall supply 100 percent outdoor air except that where this requirement is impractical and the Commissioner deems that the lowest lobby area can be safely used to conduct air from the outside to the point of supply to the shaft, this requirement may be waived.

(4) The maximum velocity of the air supplied shall not exceed 3000 fpm.

(5) An automatically controlled louver and weather closure open to the exterior at the highest floor served by the stair shall be installed. The size shall not be less than 5 sq. in. per 100 cu. ft. of total shaft volume.

(6) The following pressures and velocities should be specified:

minimum differential pressure between the stair shaft and any floor level	0.02 inches of water
minimum differential pressure between the stair shaft and the design fire floor	0.05 inches of water

The determination of these pressure differentials shall be predicated upon the assumption that three stair doors are open, one of which shall be on the design fire floor and the other two chosen so as to give the most critical condition.

Consideration shall be given to the inclusion of:

1. A door on a floor at which the air supply is furnished.

2. The doors above and below the design fire floor.

(7) Maximum velocity permitted through a single open door with all other doors closed	2000 fpm
(8) Maximum door opening force at the door knob utilizing mechanical assistance as required.	25 pounds

2. Smoke Exhaust

(a) Until further studies can be made it is recommended that the rate of exhaust of 60 changes per hour from the largest compartment served by the shaft as specified in the proposed reference standard be maintained.

(b) Since no specific studies or tests were conducted which relate to the limiting velocities now specified in the proposed smoke shaft reference standard, no comment is made.

3. Future Studies

(a) While the feasibility and the principles and criteria upon which stair pressurization systems may be designed have been established by studies and tests made during the past several years, the organization and assembly of available information useful to the design engineer has not progressed as well. This means that although equipment controls, and general design methodology are available, and sufficient,suitable tables, curves, charts and other design aids routinely used by engineers have not yet been developed for this application.

The gathering of coefficients necessary to establish leakage rates through walls, around closed doors and through open doors and to calculate pressure losses of flowing air through stair shafts will be of value to the design process.

Where further tests and studies are still to be made, approximations and estimates will have to be made by the engineer and capacities of air handling equipment sized to permit final setting of controls to bring the system within the specified operating limits of reference standards. Such estimating and approximating are typically part of most engineering design methodologies. In the case of stair pressurization systems it is expected that there will be a continuous refinement of both the design process and the engineering information used within the design process and that it will take place at a faster pace if further efforts are made by the profession and other interested agencies in sponsoring and participating in such endeavors.

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APPENDIX A

FIGURES

List of Figures

Figure

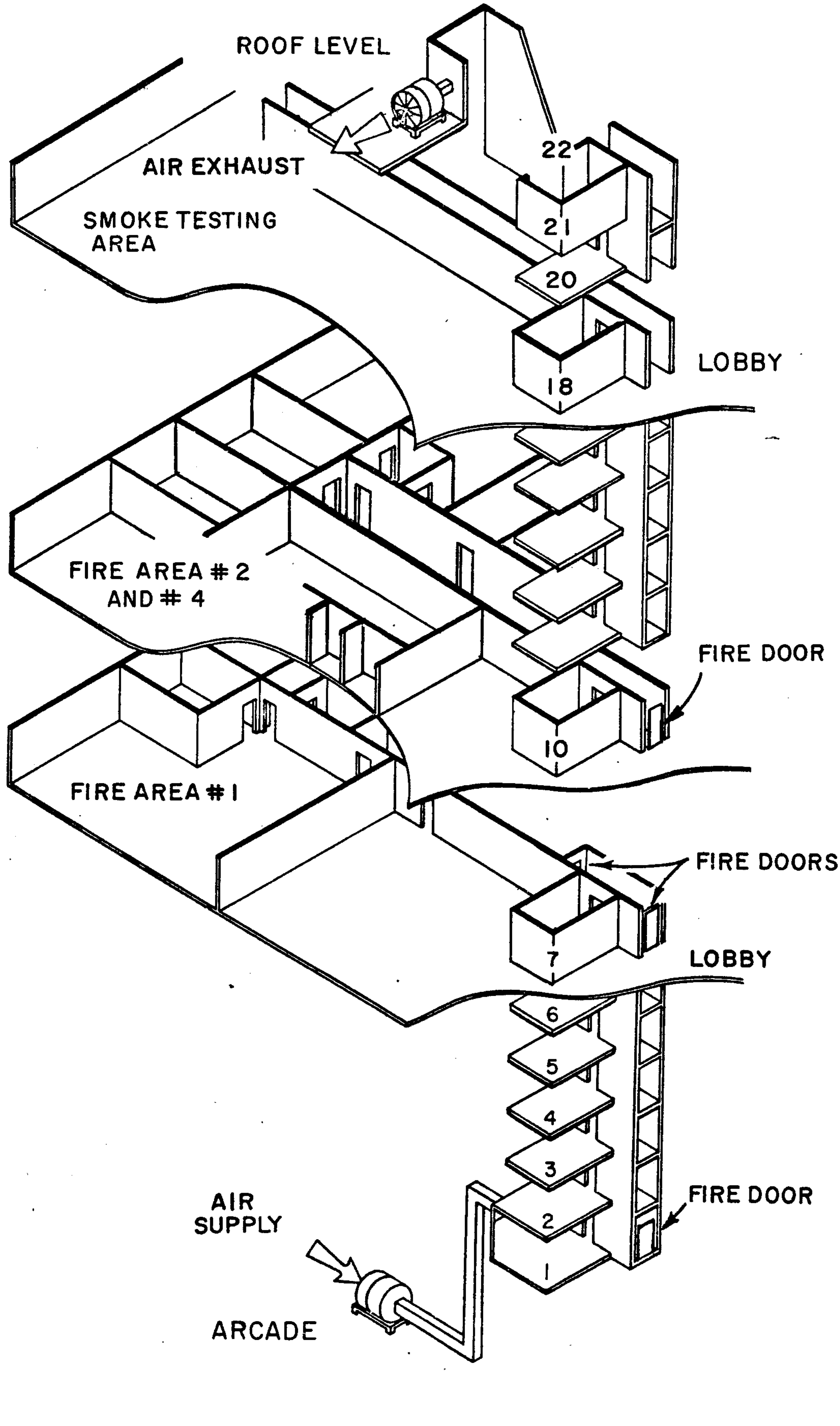


FIG. (I) DIAGRAMMATIC VIEW OF PRESSURIZED STAIR AND FANS - 30 CHURCH ST.

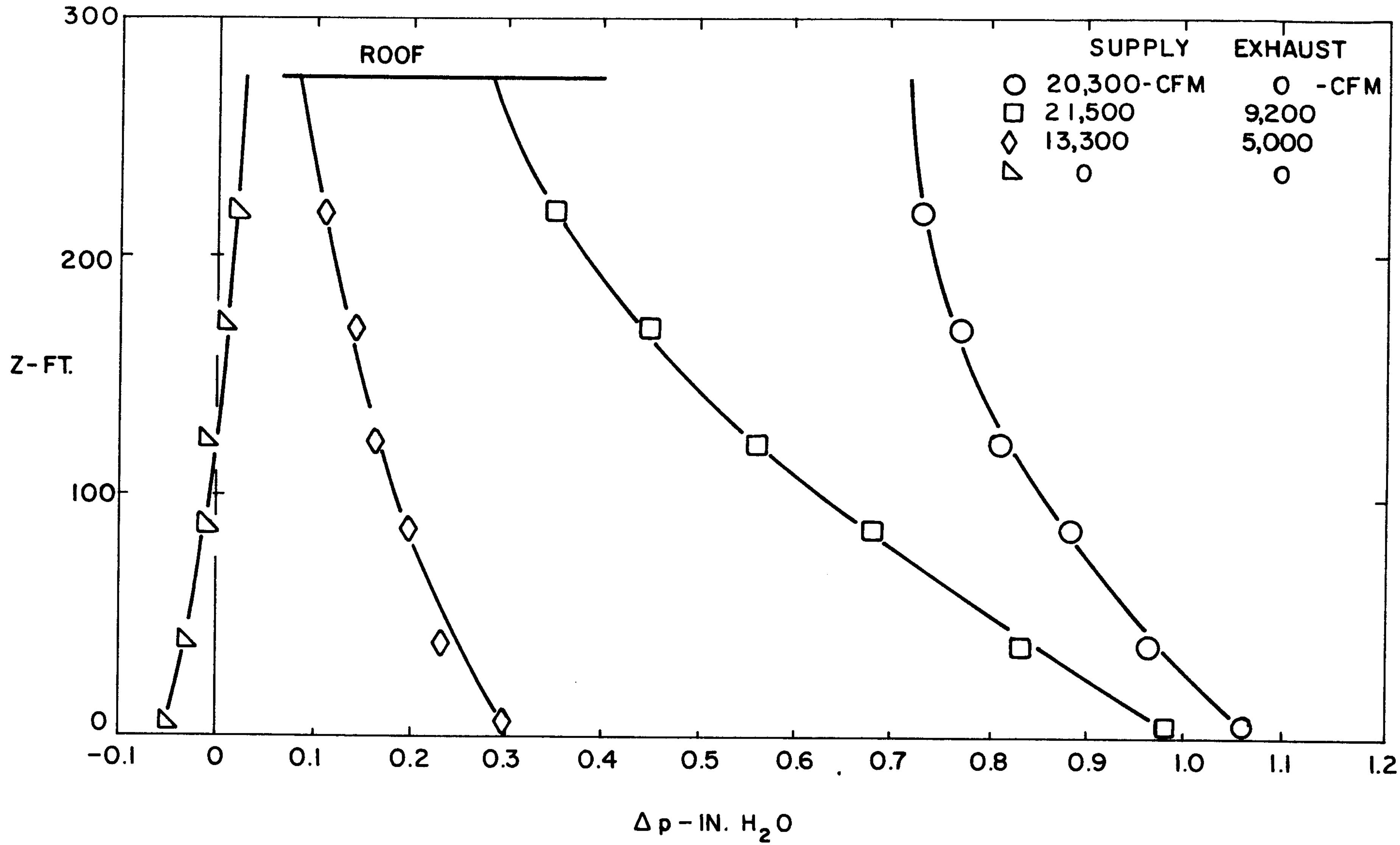


FIG. (2) PRESSURE DISTRIBUTION IN STAIR WELL
(a) ALL DOORS CLOSED

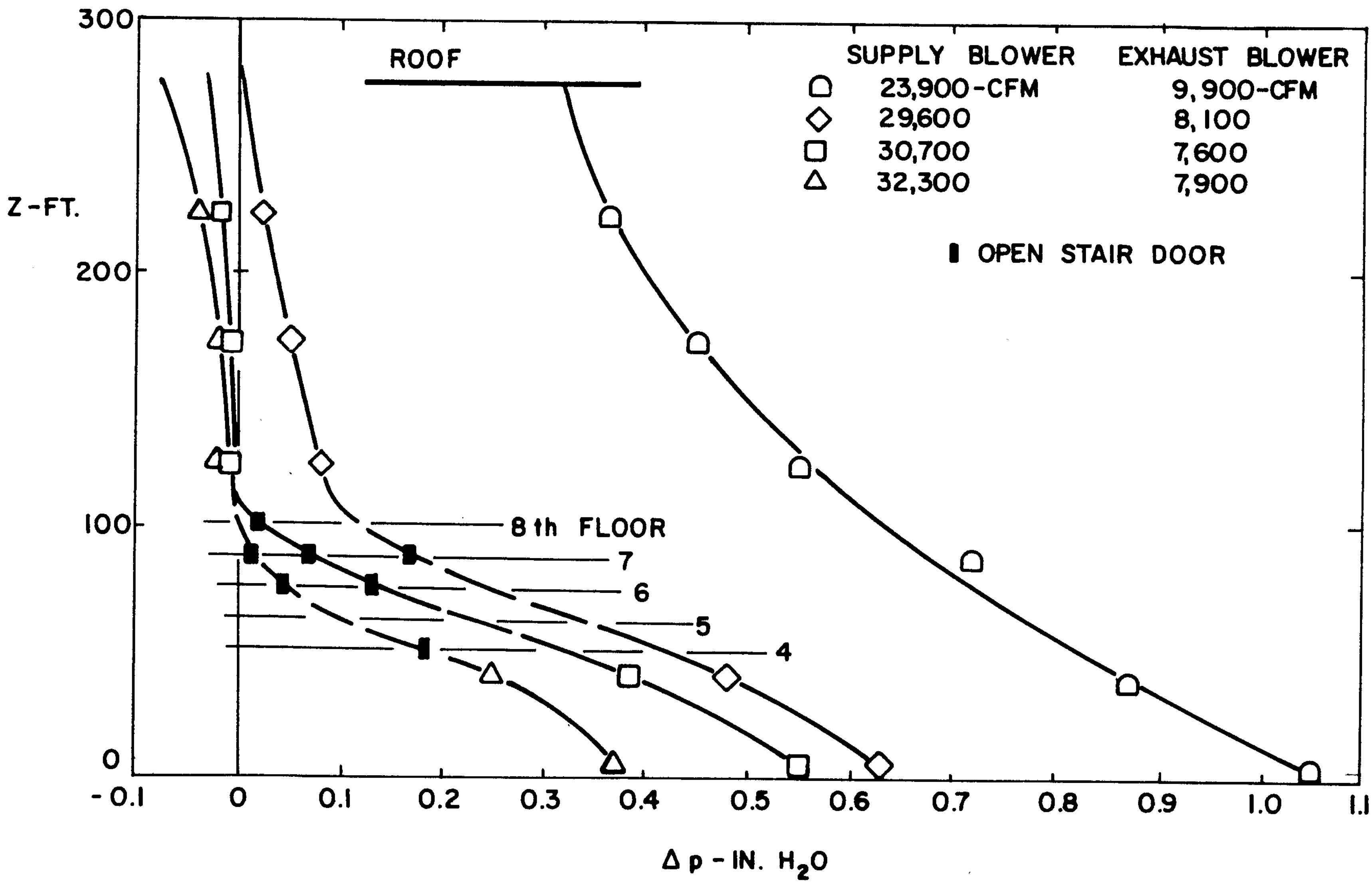


FIG. (2) PRESSURE DISTRIBUTION IN STAIR WELL
(b) STAIR DOORS OPEN

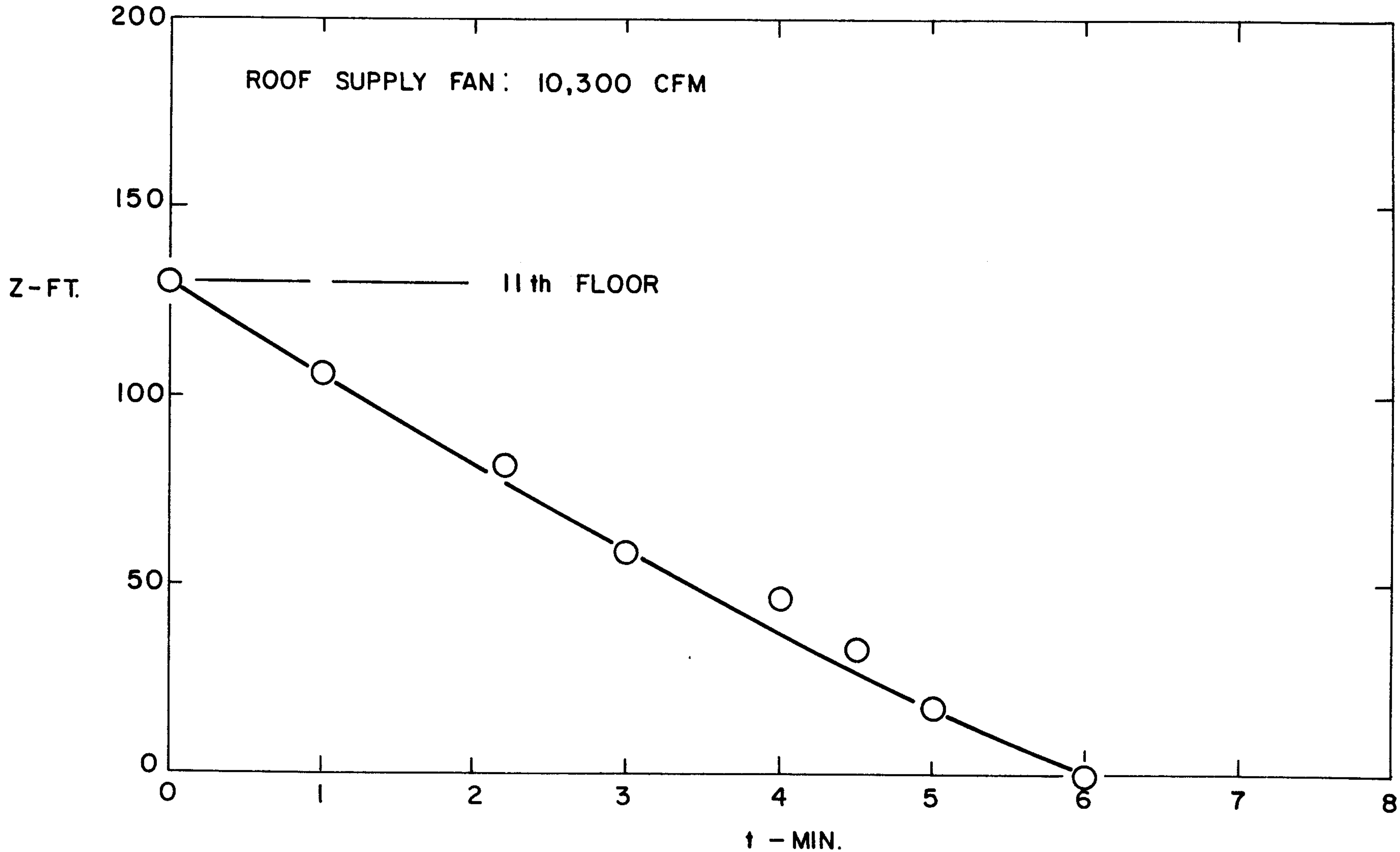


FIG. (3) SMOKE TRAVEL IN STAIR SHAFT WITH PRESSURIZATION FROM ROOF LEVEL

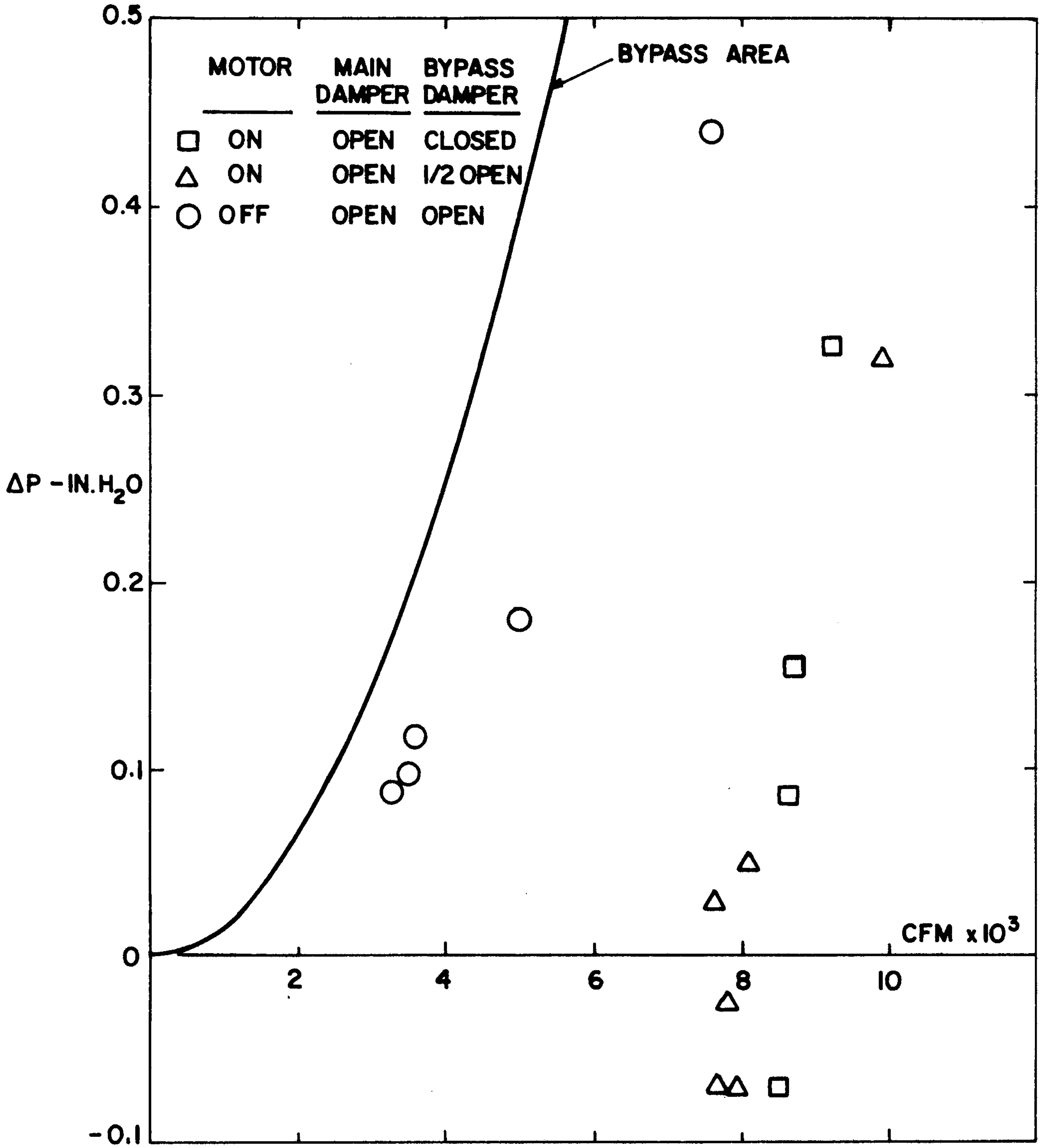


FIG. (4) EXHAUST FAN PERFORMANCE CHARACTERISTICS

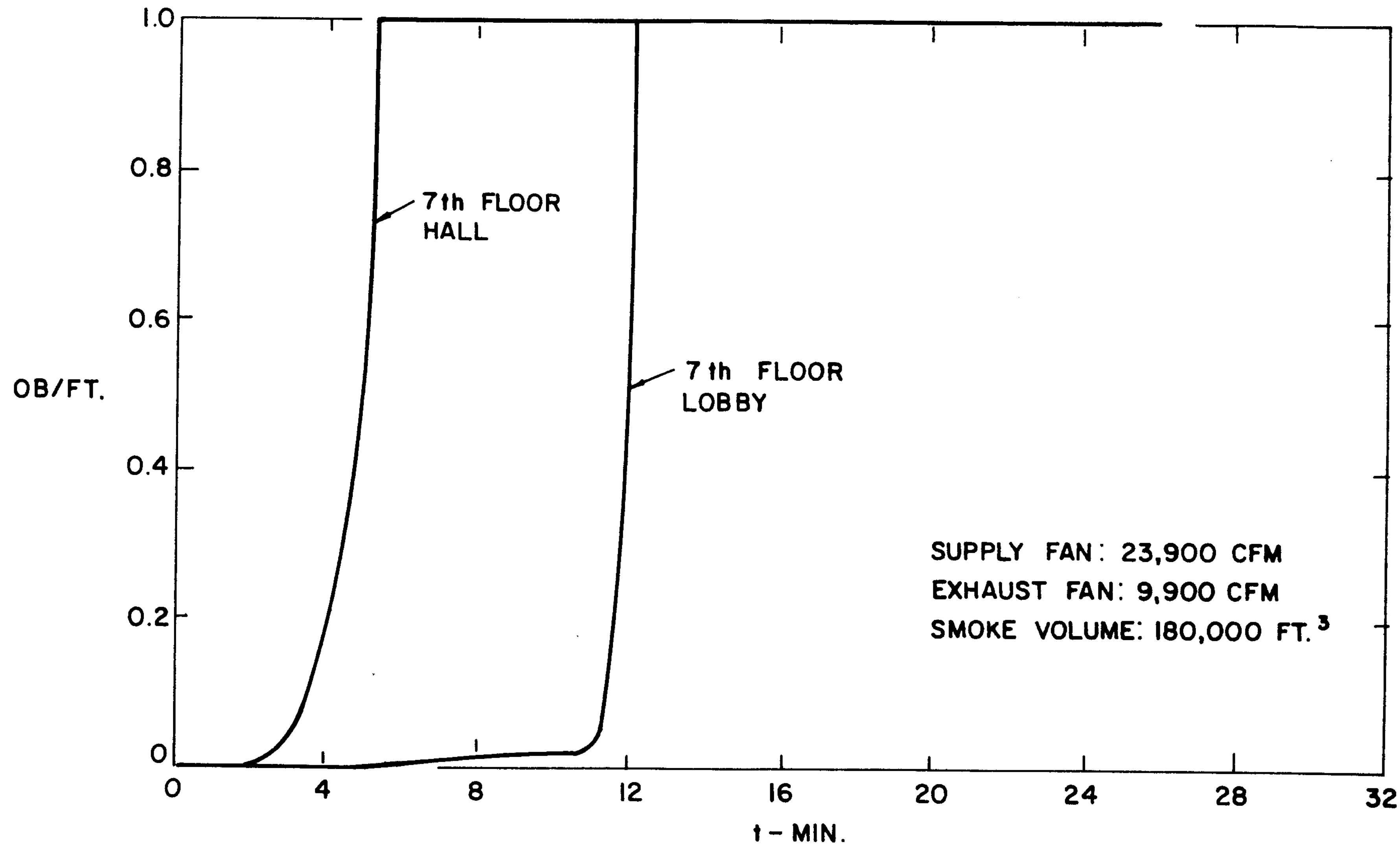


FIG. (5) COLD SMOKE OBSCURATION TESTS
(a) STAIR DOORS CLOSED

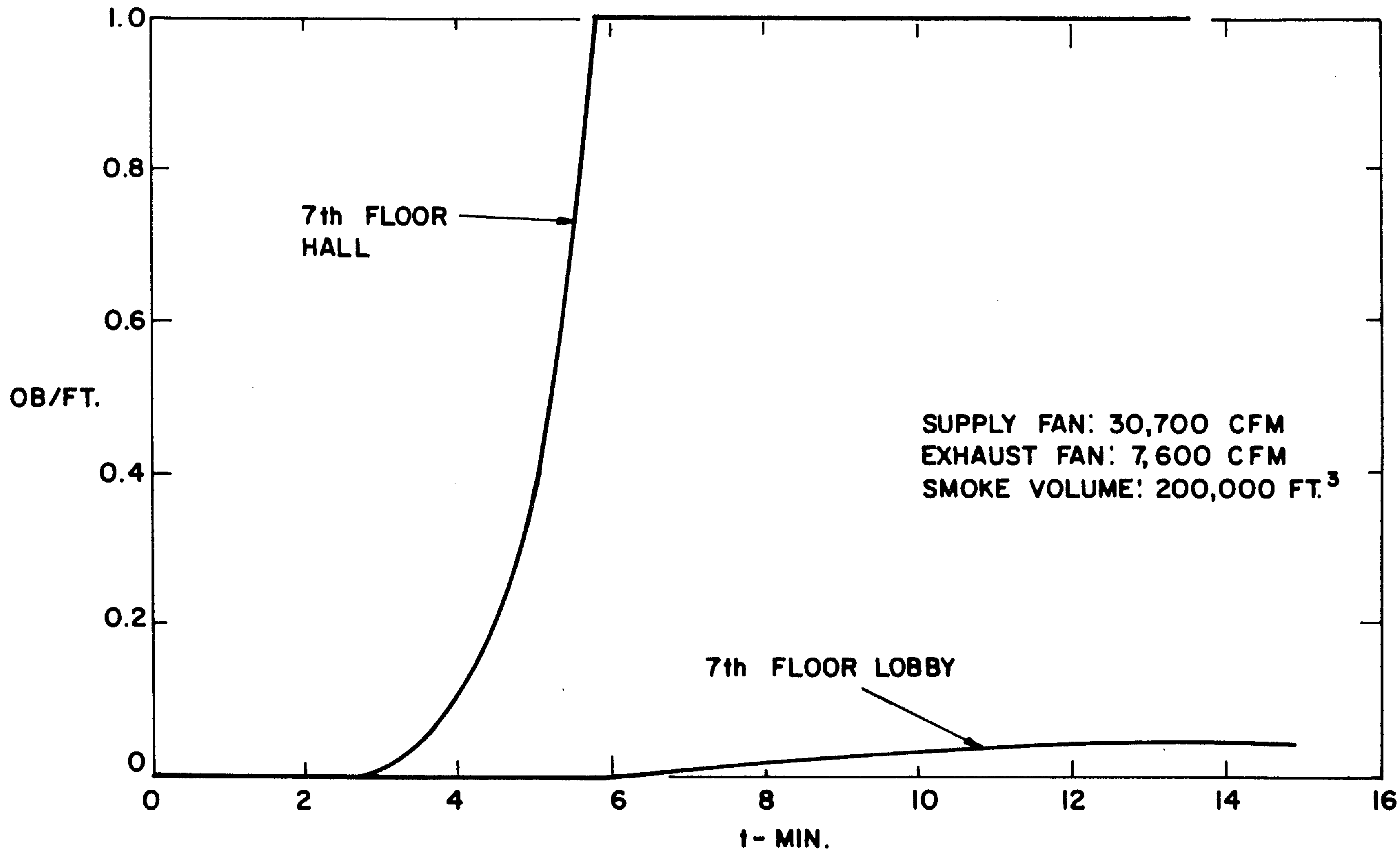


FIG. (5) COLD SMOKE OBSCURATION TESTS
(b) 6th, 7th, 8th FLOOR DOORS OPEN

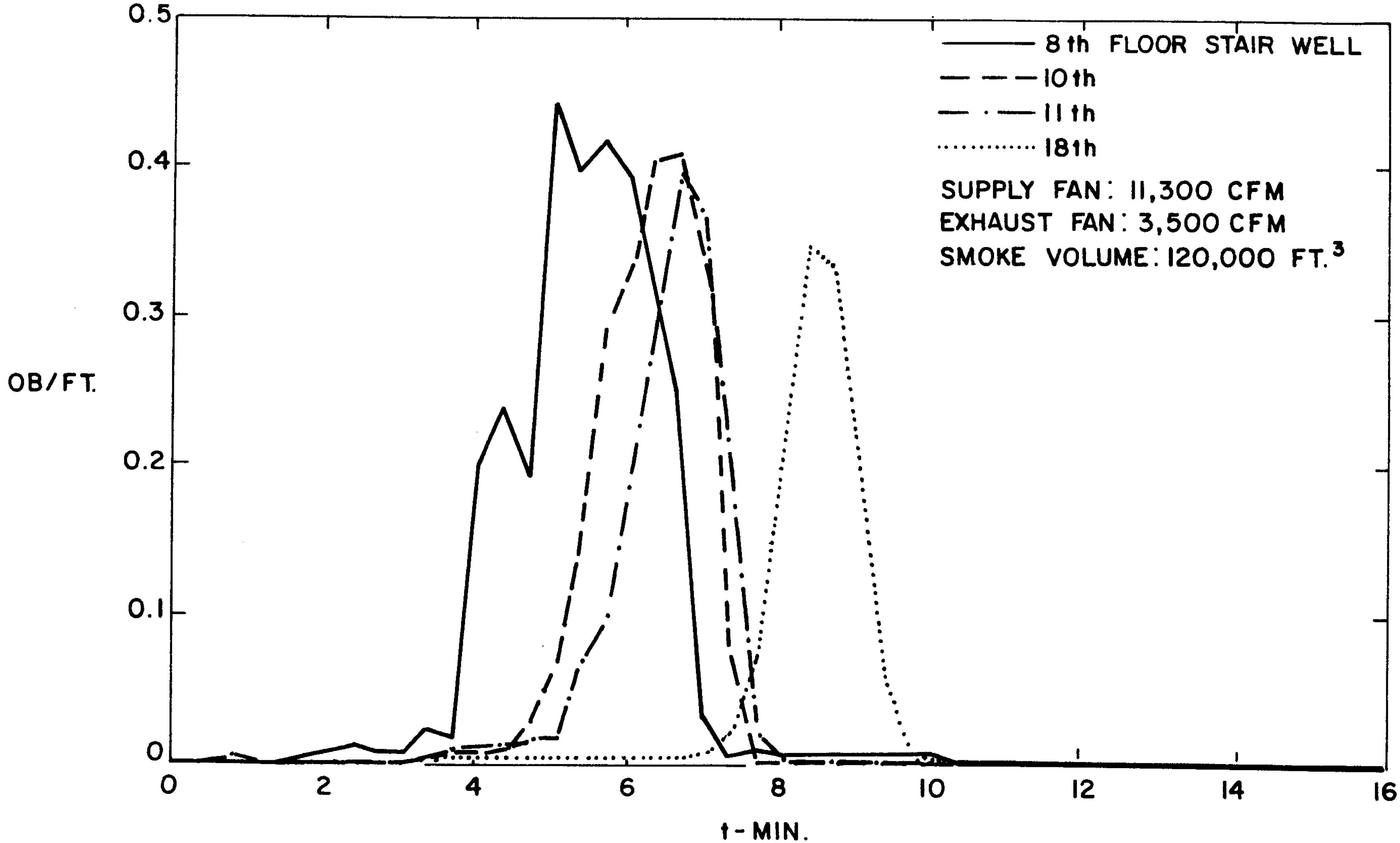


FIG. (6) SMOKE CLEARING EFFECTIVENESS OF STAIR WELL PRESSURIZATION

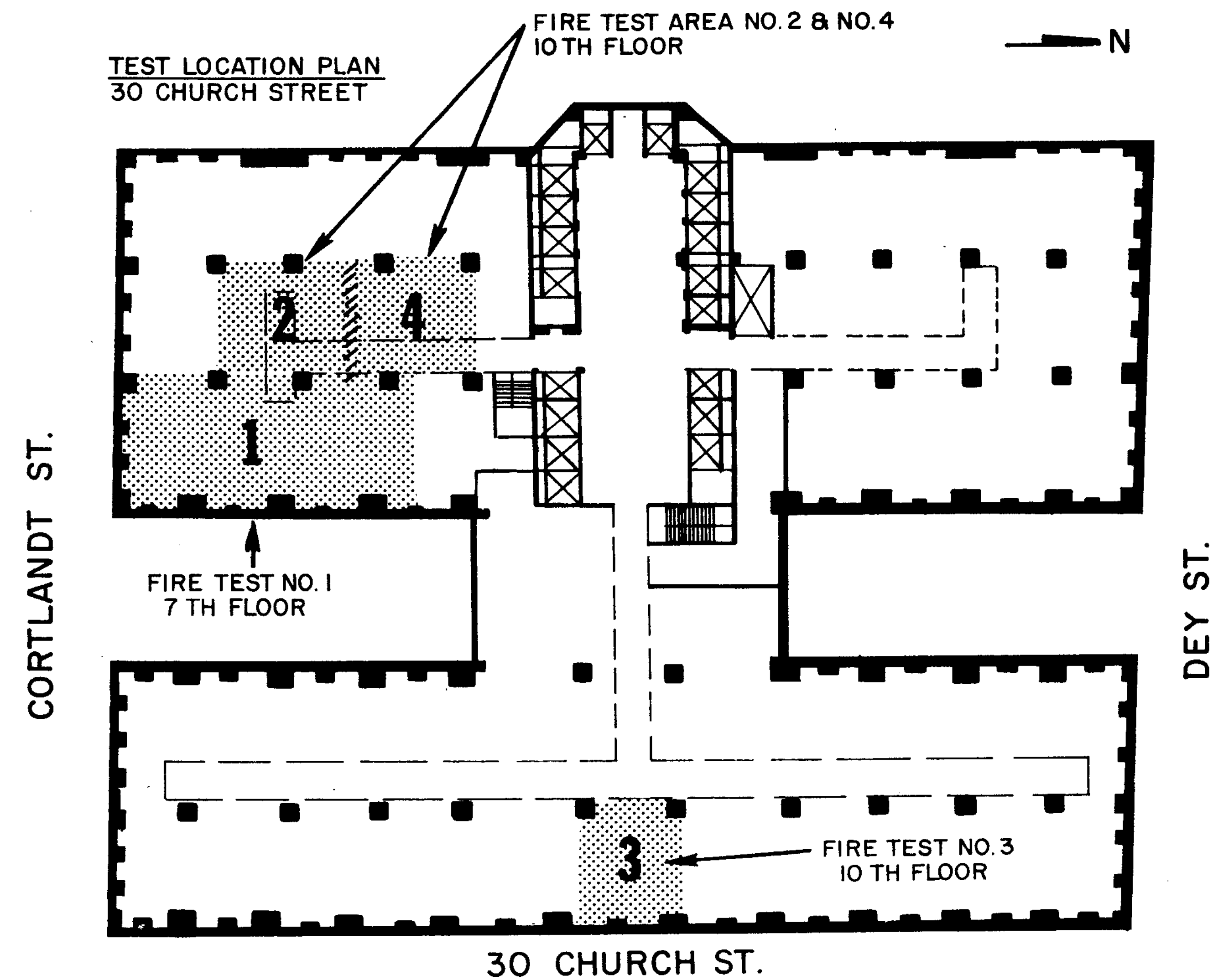


FIG. (7) FIRE TEST LOCATION PLAN

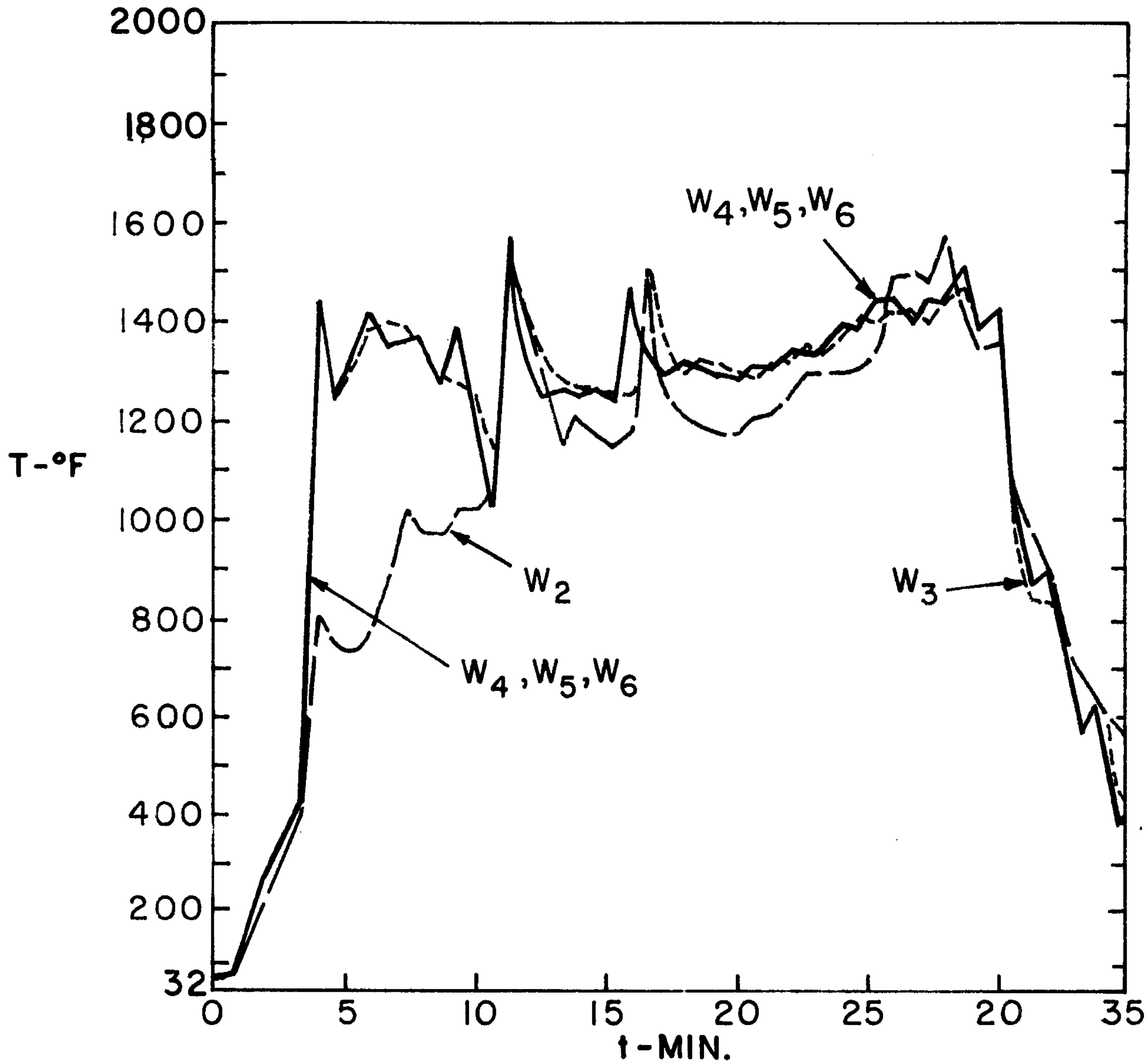


FIG. (11) TEMPERATURE HISTORY - FIRE #1
(b) WALLS IN FIRE ROOM

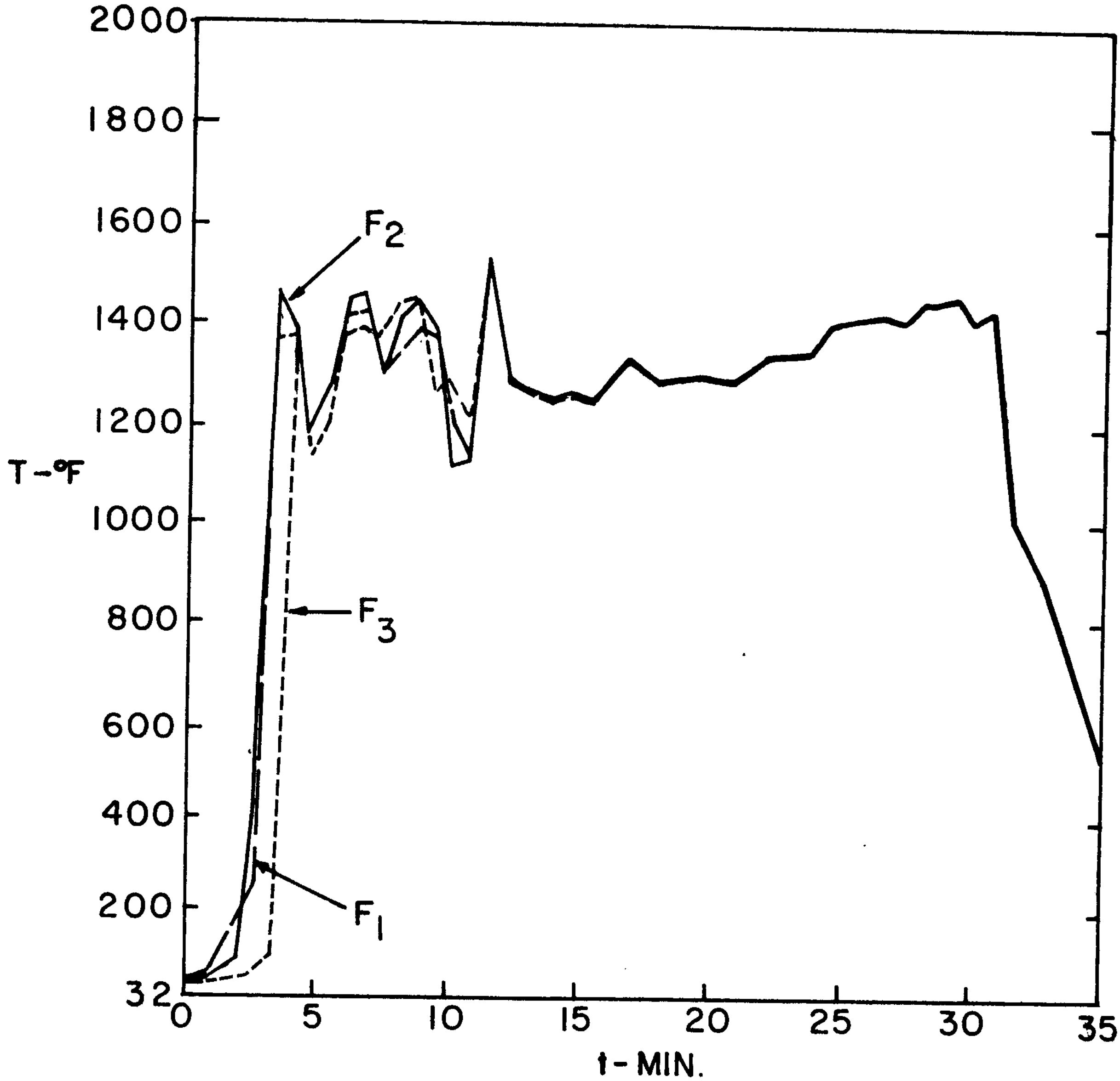
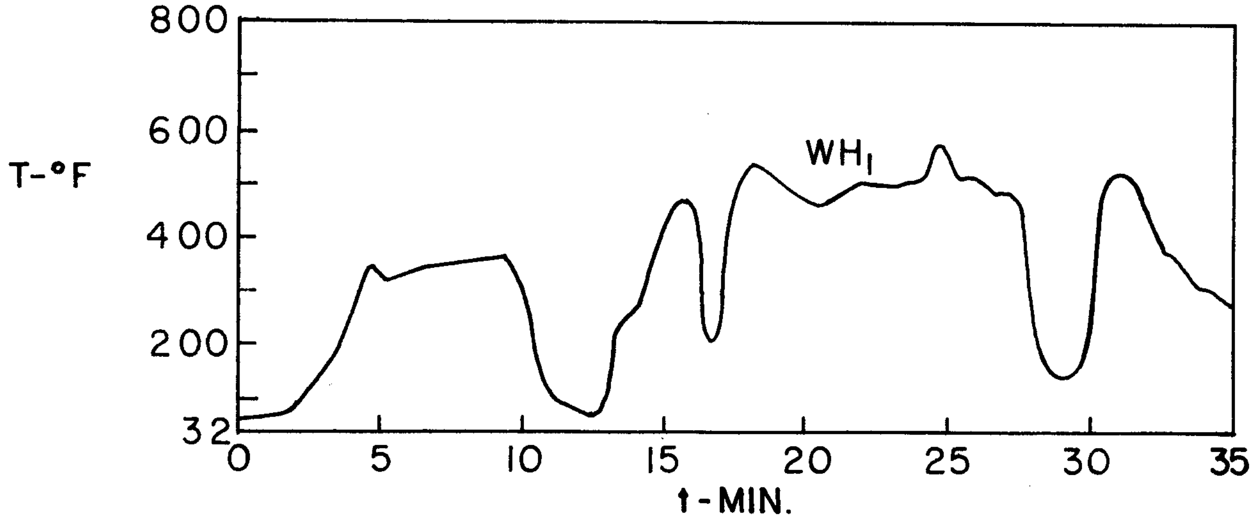
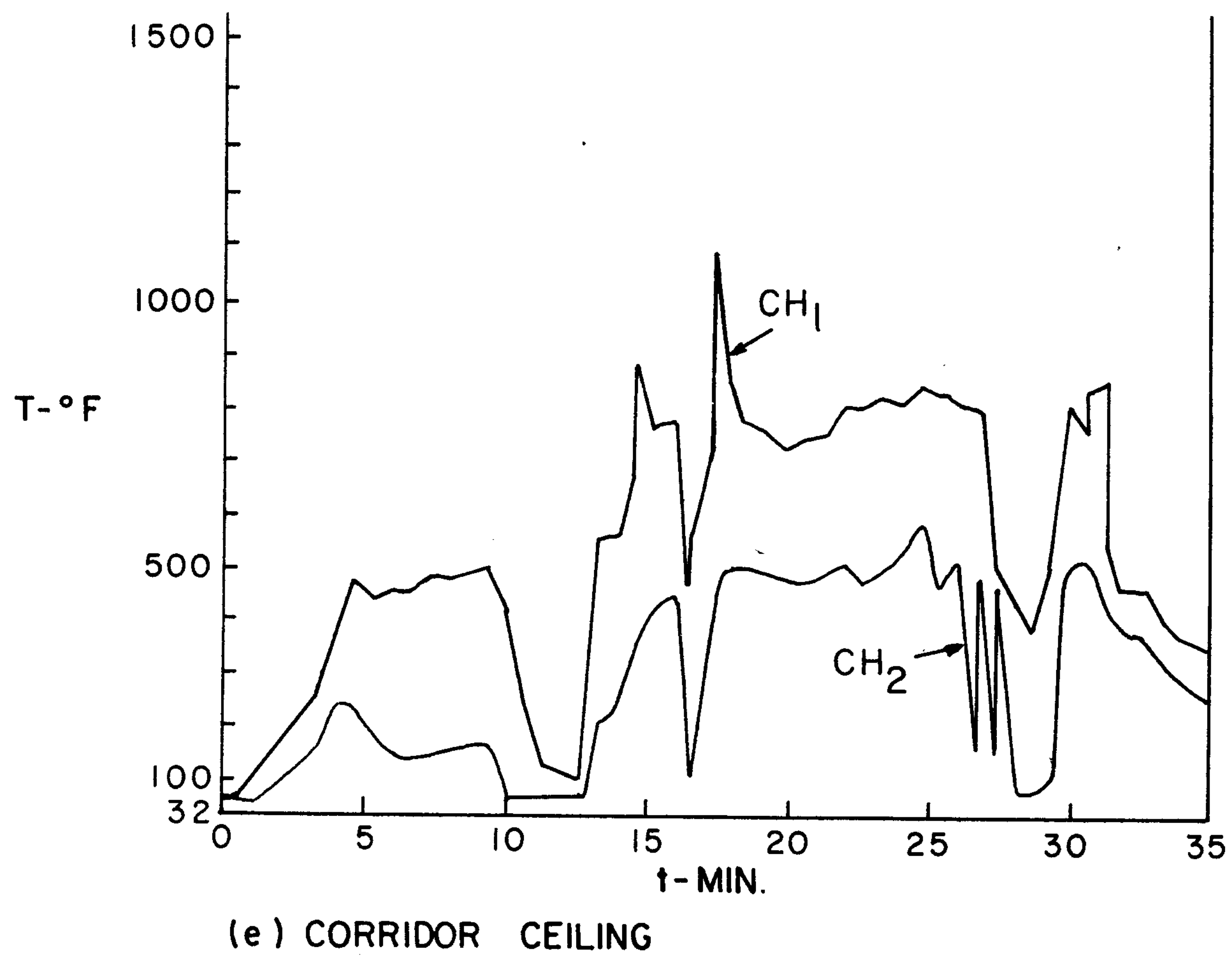


FIG. (11) TEMPERATURE HISTORY - FIRE #1
(c) FLOOR IN FIRE ROOM



(d) CORRIDOR WALL



(e) CORRIDOR CEILING

FIG. (II) TEMPERATURE HISTORY-FIRE # I

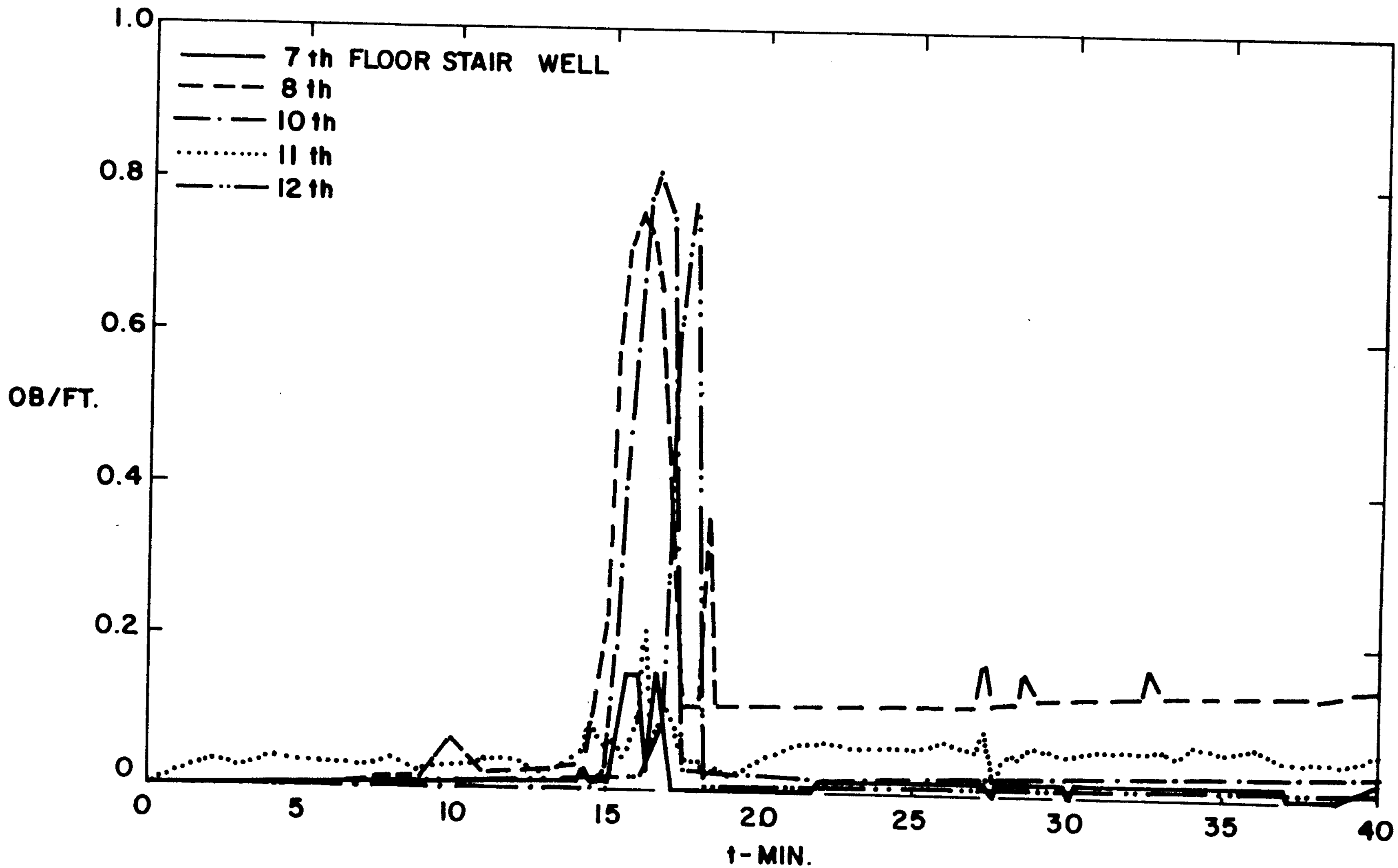


FIG. (12) SMOKE OBSCURATION PER FOOT - FIRE # 1
(a) STAIR WELL MEASUREMENTS

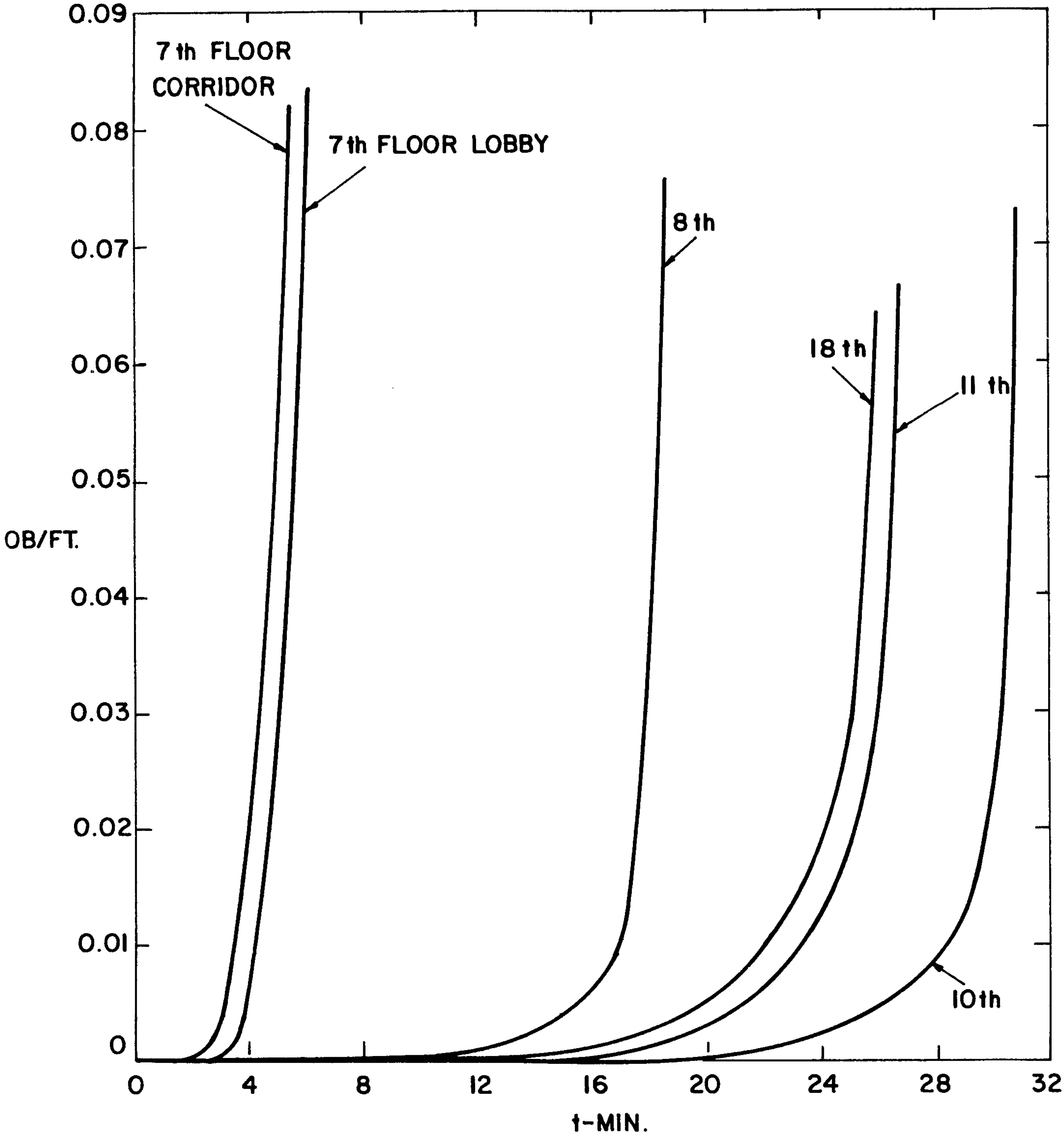


FIG. (12) SMOKE OBSCURATION PER FOOT-FIRE # 1
(b) LOBBY AREAS

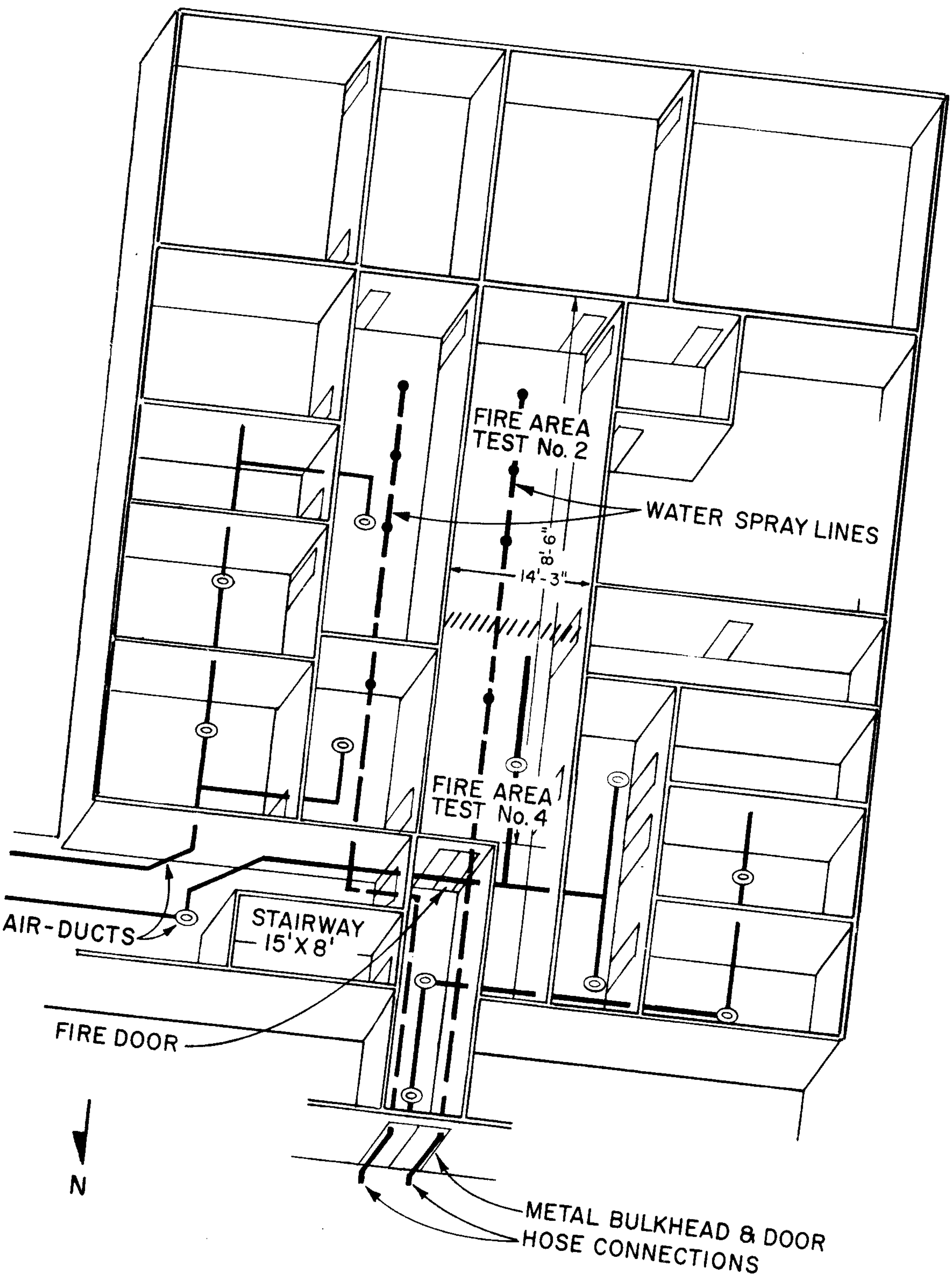


FIG. (13) LAYOUT OF 10th FLOOR, FIRE TEST # 2, 4

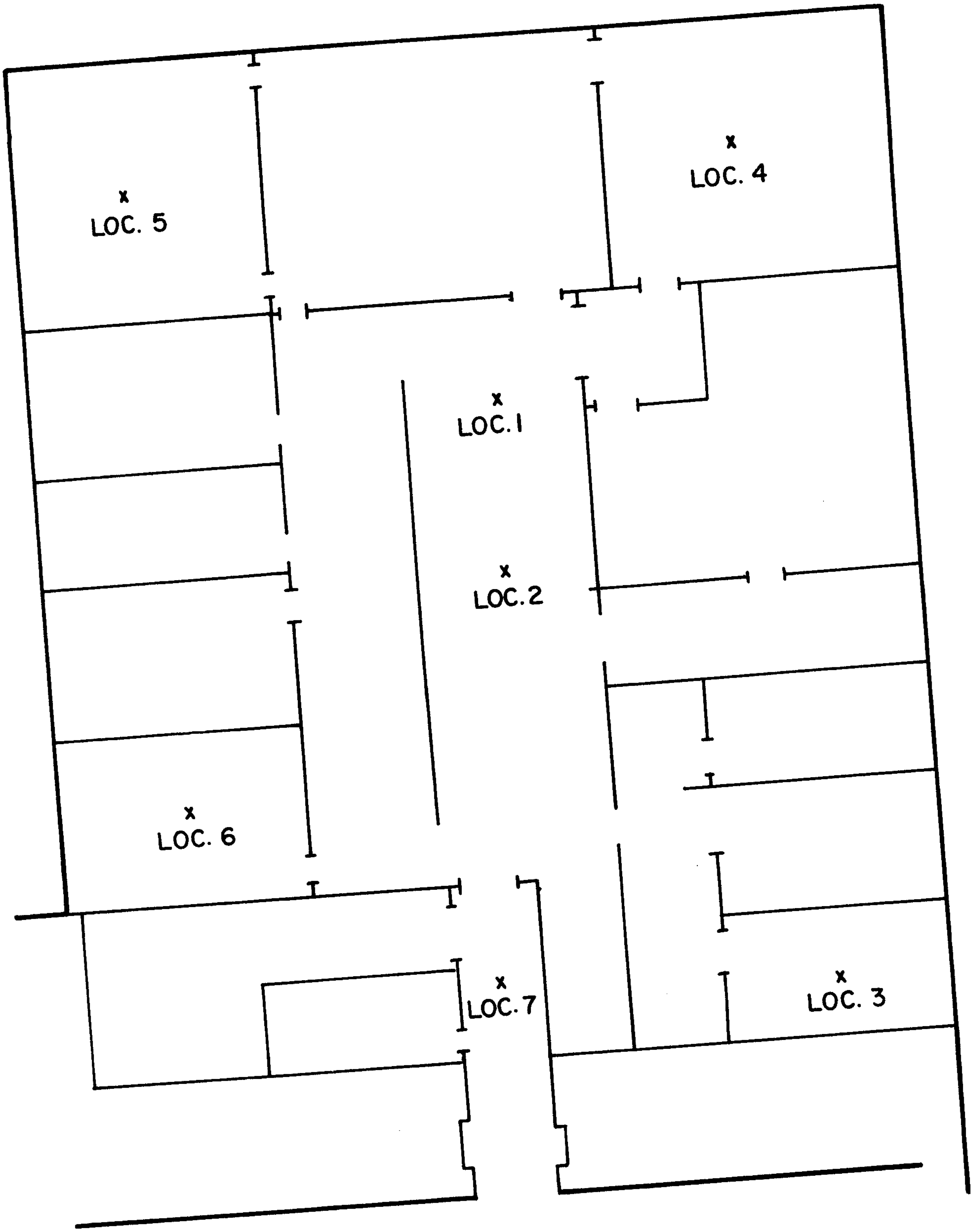


FIG. (14) INSTRUMENTATION LAYOUT ON 10th FLOOR — FIRE # 2

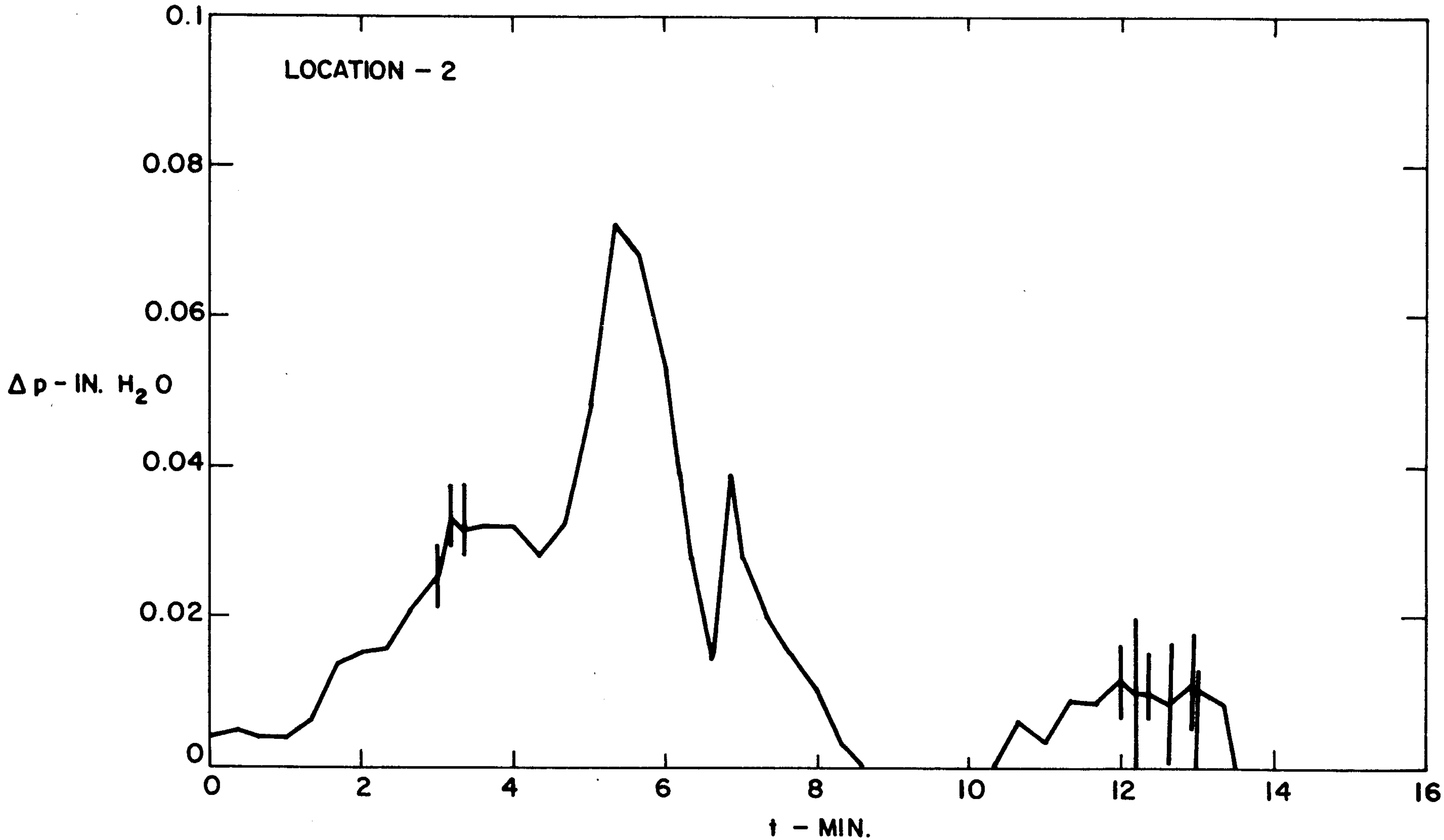


FIG. (15) PRESSURE HISTORY - FIRE # 2

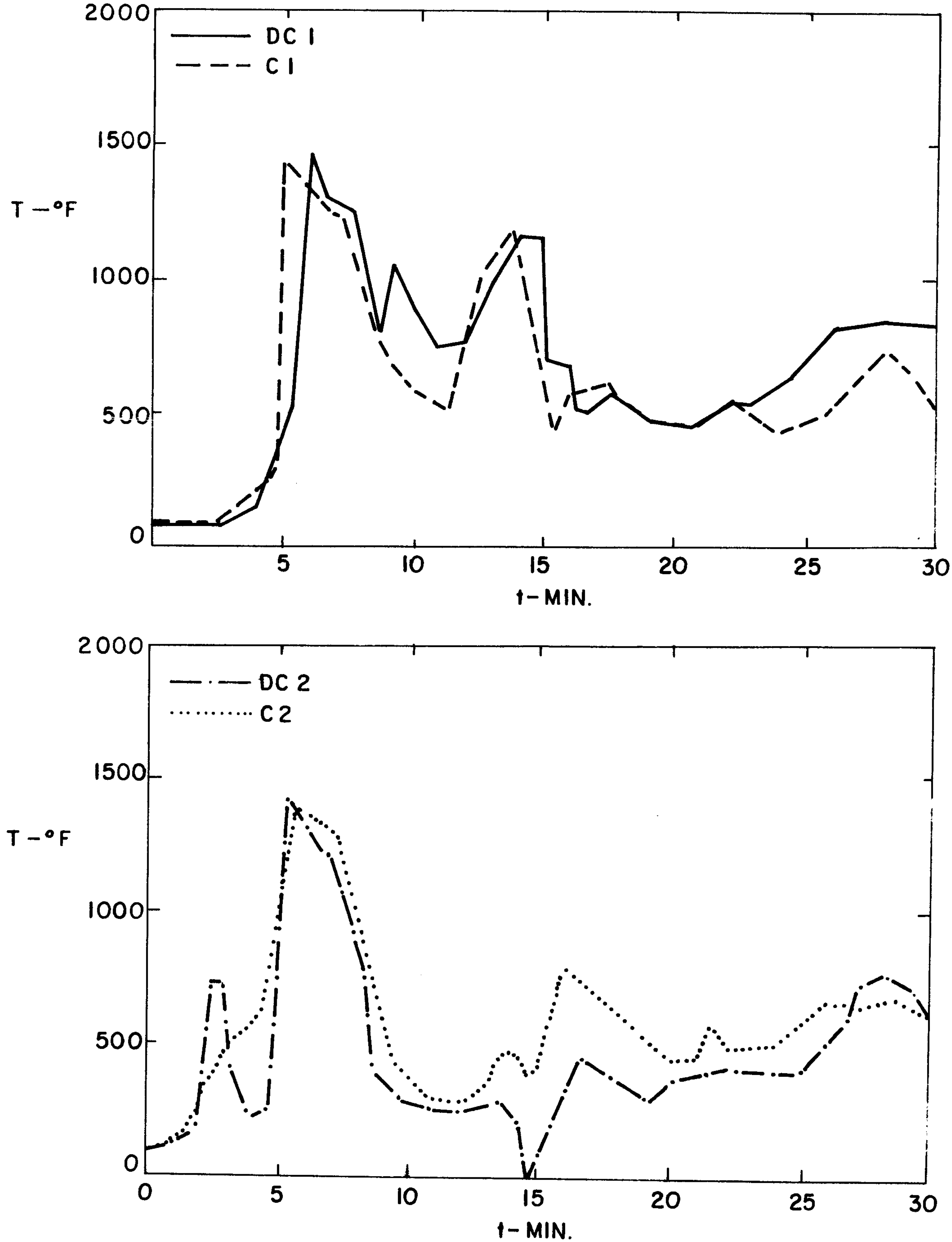


FIG. (16) TEMPERATURE HISTORY – FIRE # 2
(a) FIRE ROOM

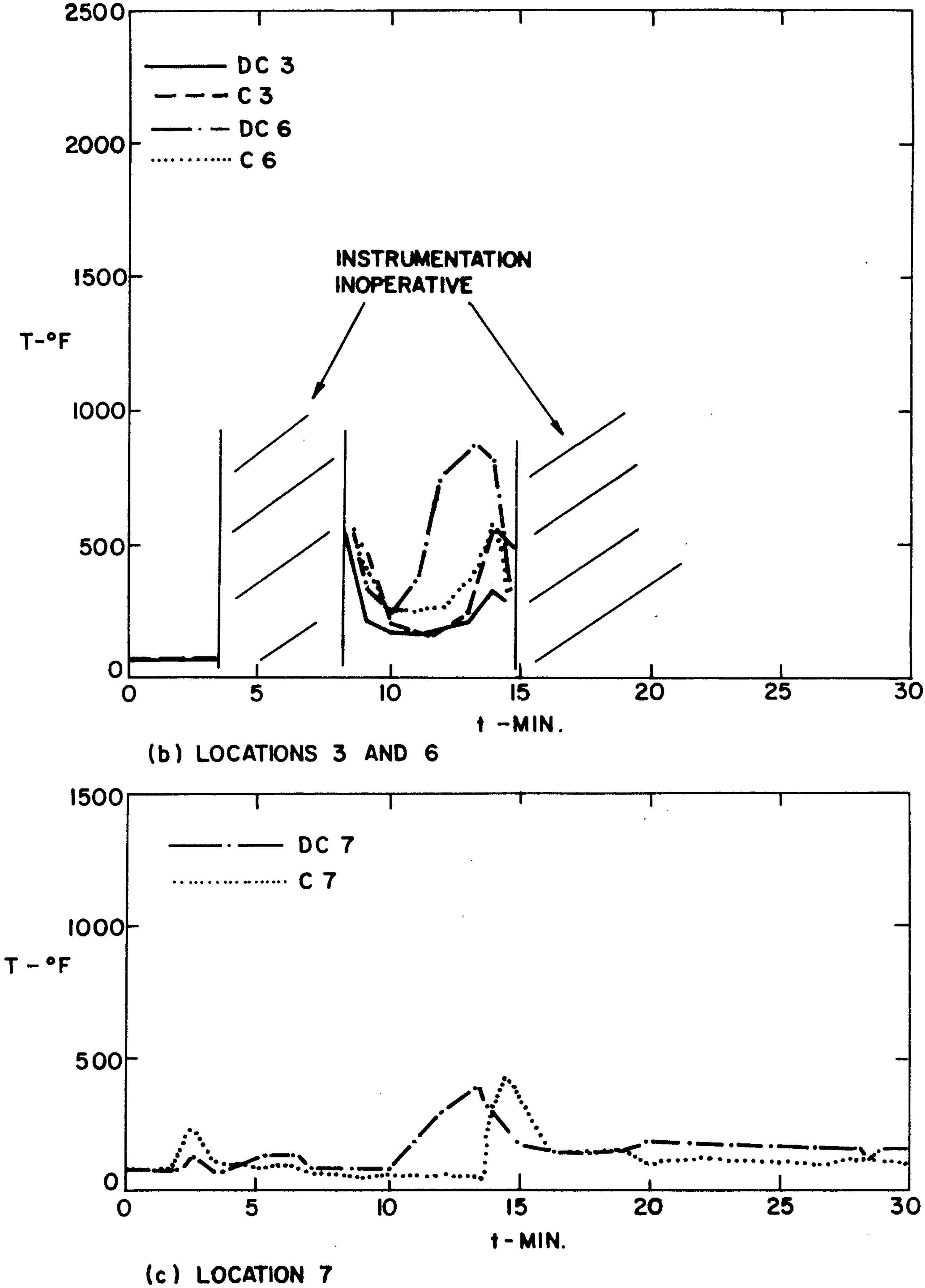


FIG. (16) TEMPERATURE HISTORY - FIRE # 2

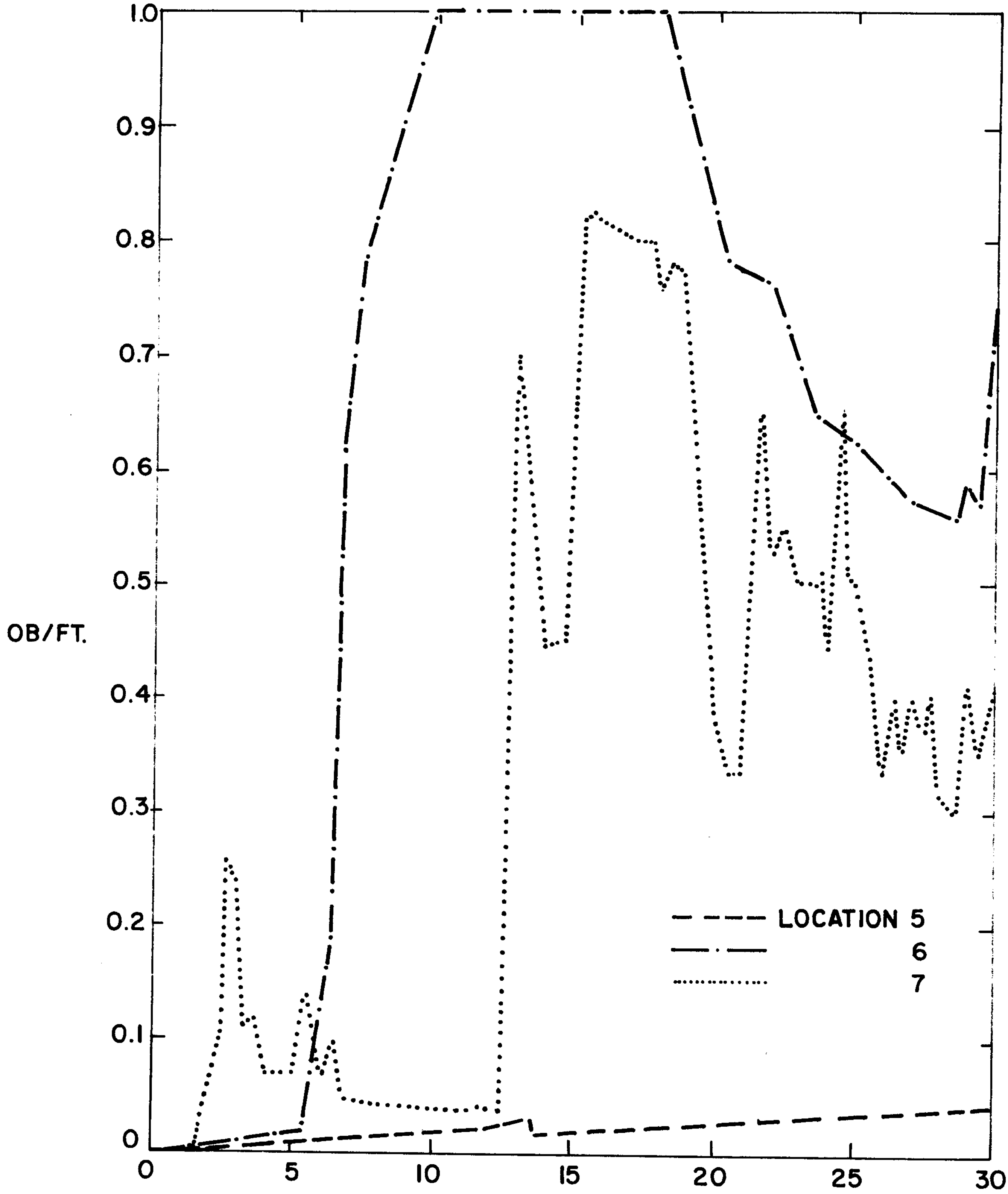


FIG. (17) SMOKE OBSCURATION PER FOOT-FIRE # 2
(a) FIRE AREA

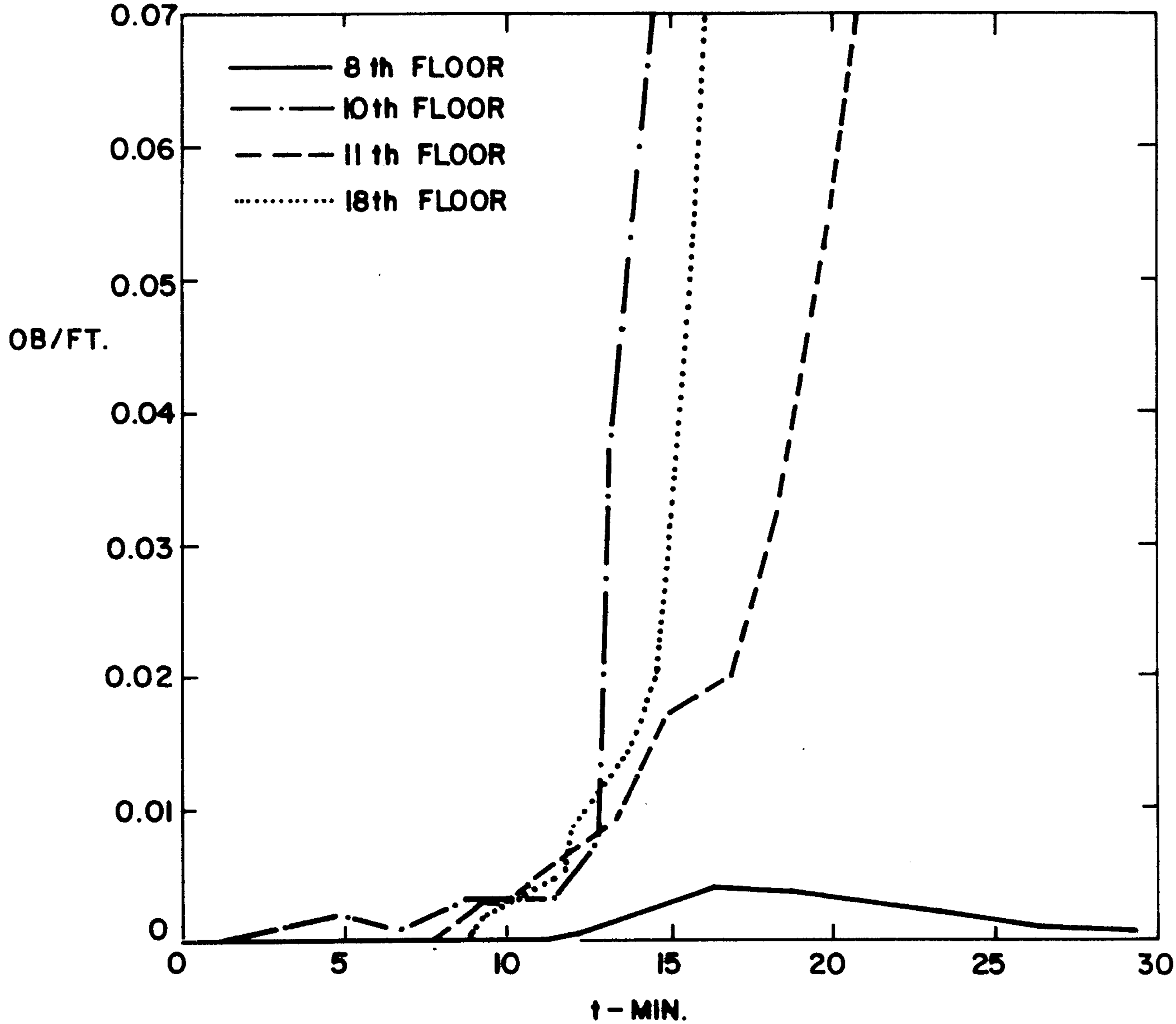


FIG. (17) SMOKE OBSCURATION PER FOOT — FIRE #2
(b) LOBBY AREAS

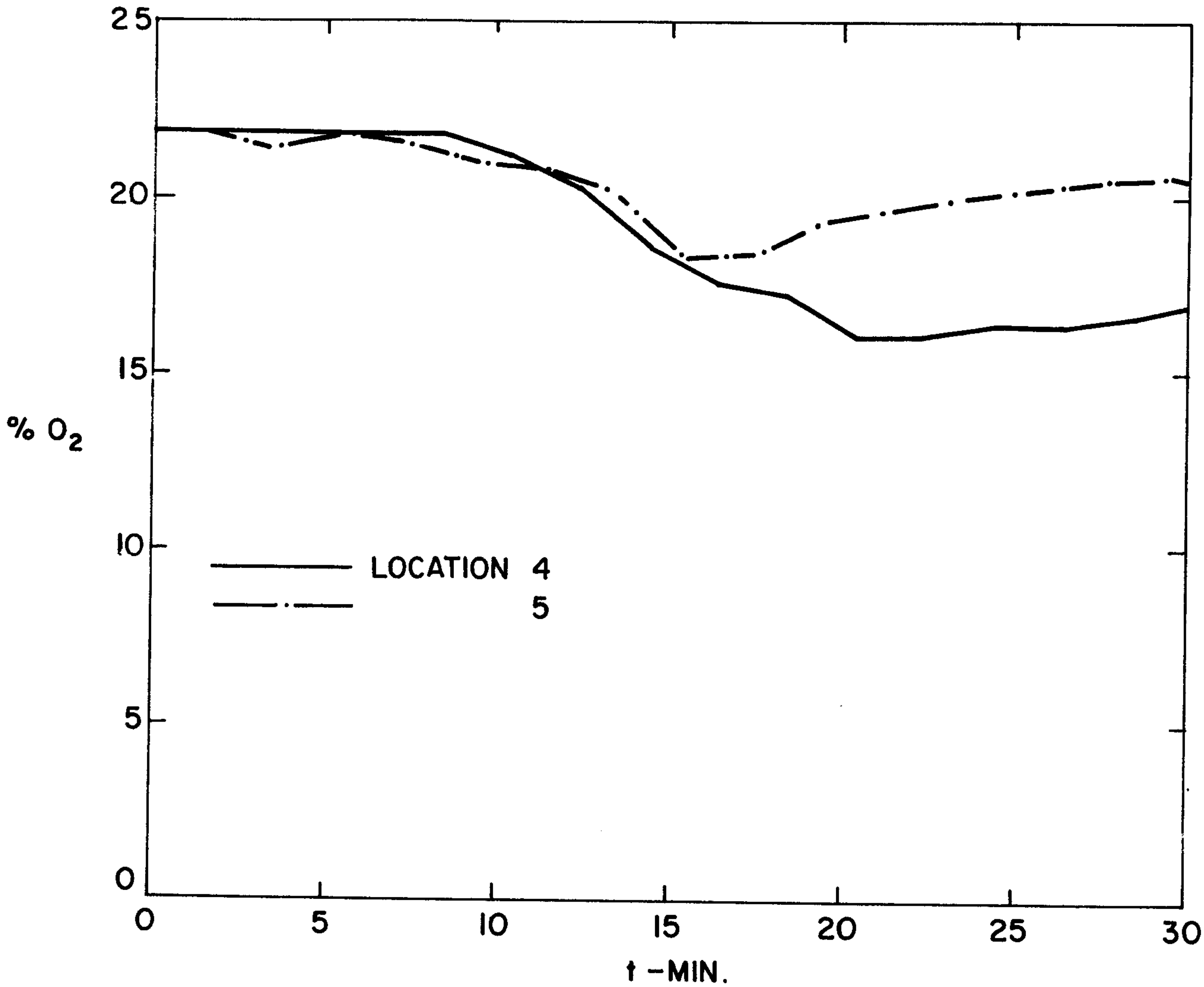


FIG. (18) OXYGEN CONCENTRATION - FIRE #2

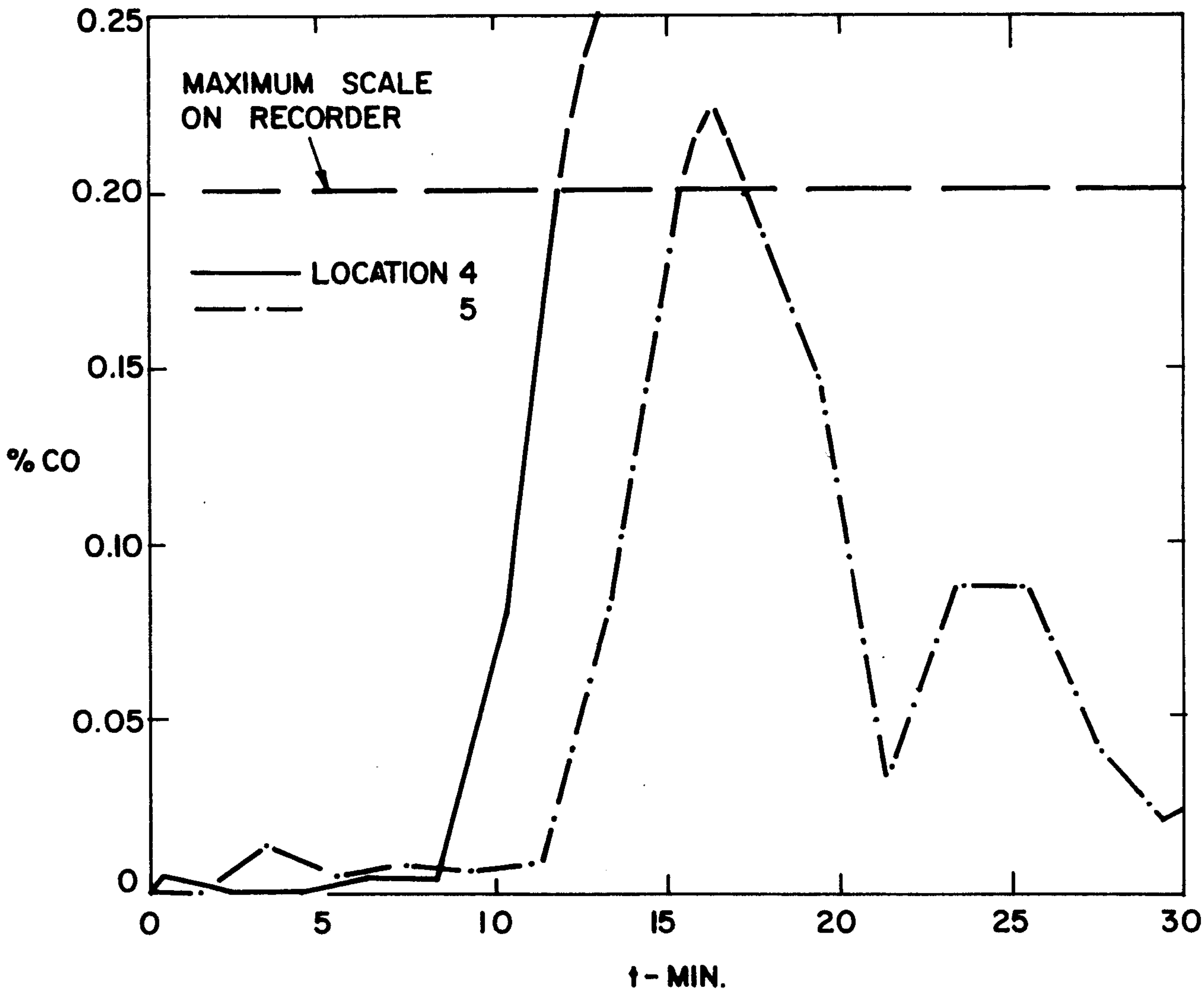


FIG. (19) CARBON MONOXIDE CONCENTRATION - FIRE #2

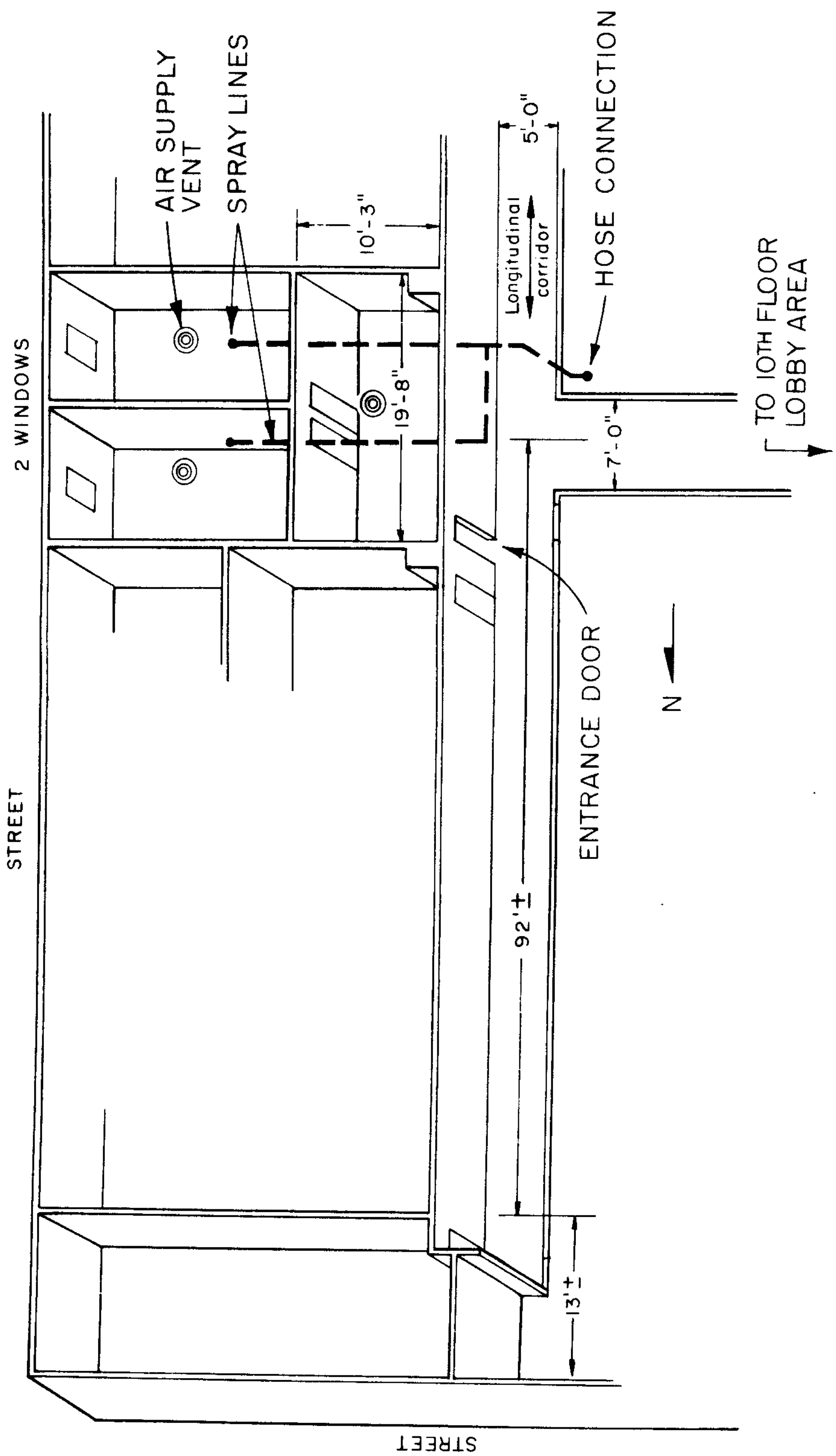


FIG.(20) LAYOUT OF 10th FLOOR, FIRE TEST # 3

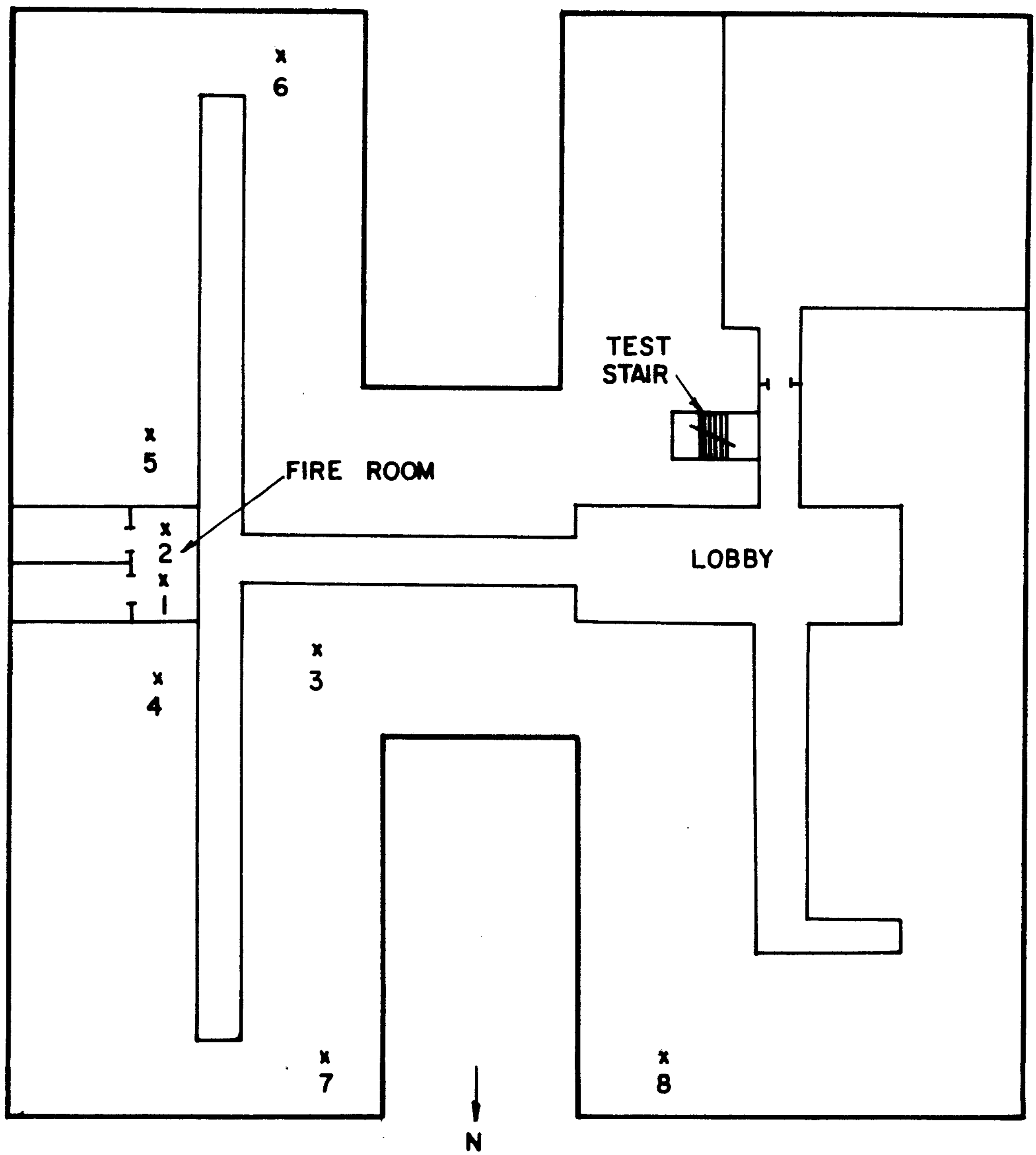


FIG. (21) INSTRUMENTATION LAYOUT ON 10th FLOOR - FIRE # 3

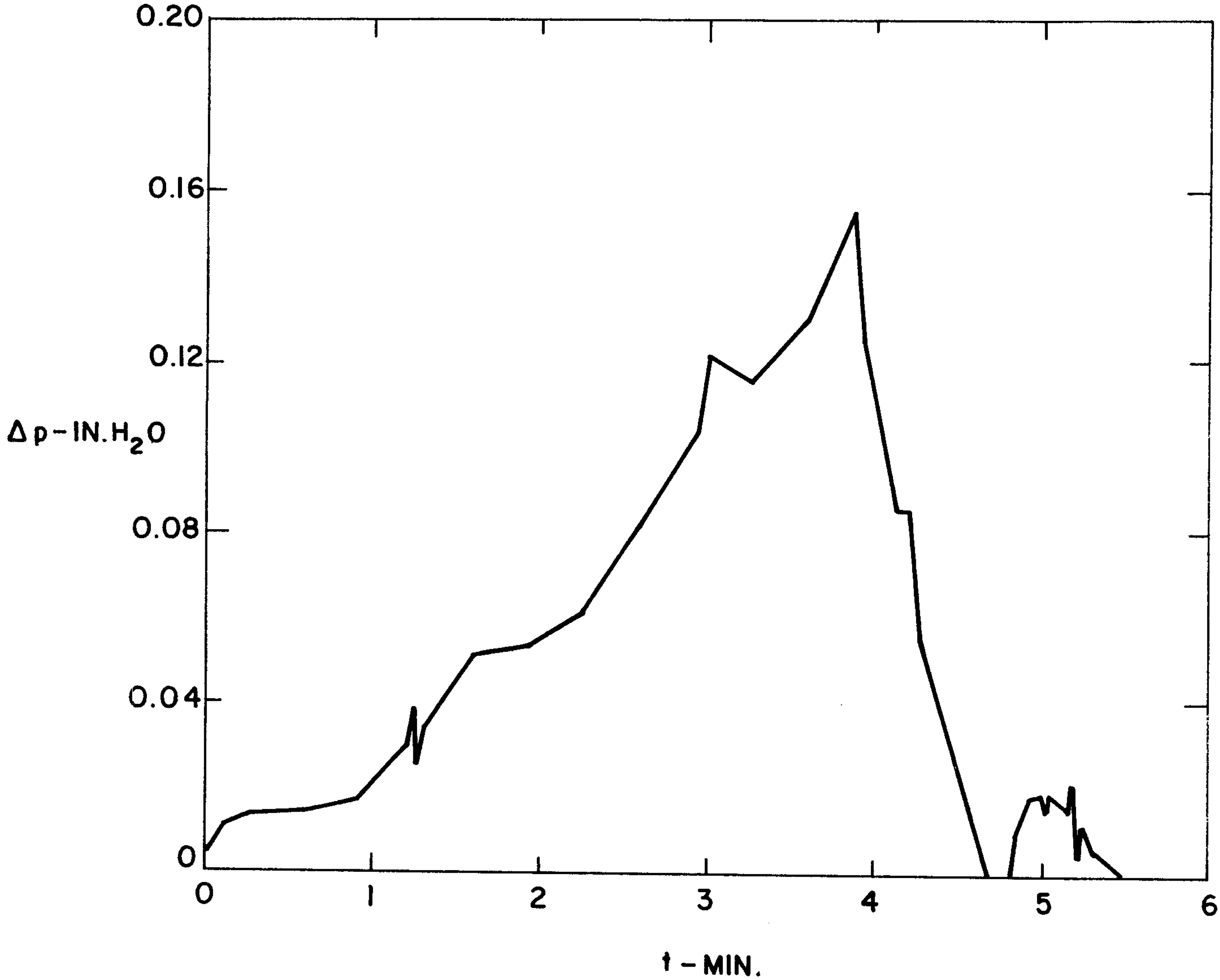
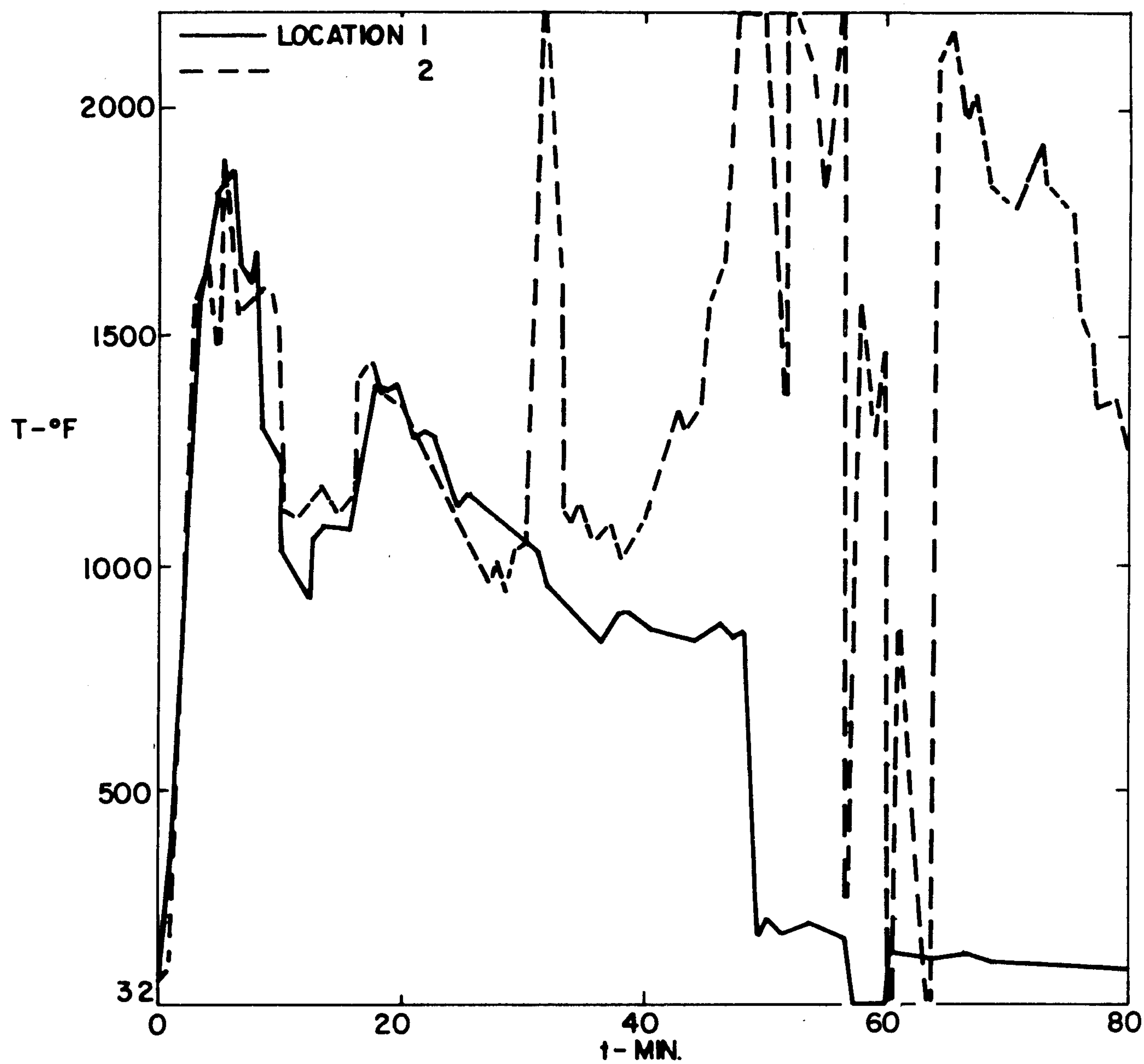
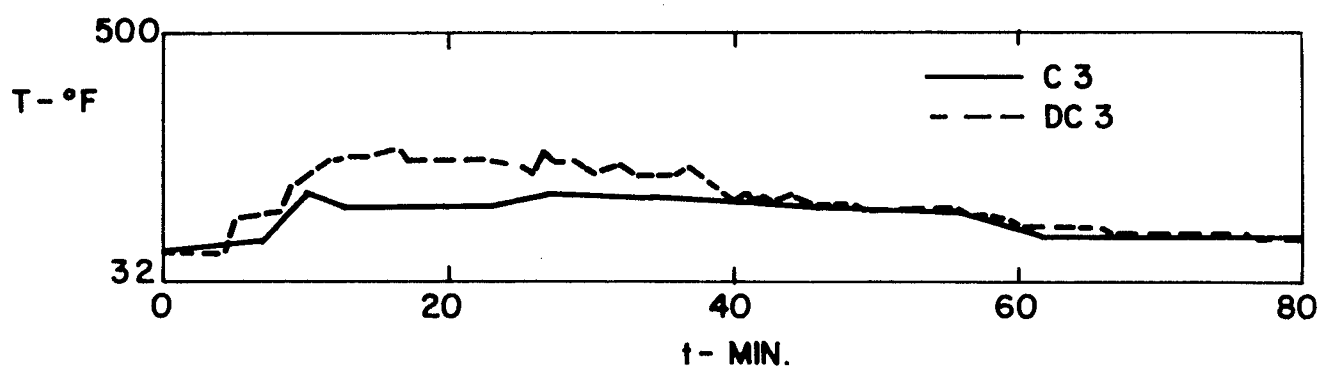


FIG. (22) PRESSURE HISTORY - FIRE # 3



(a) FIRE ROOM



(b) LOCATION 3

FIG. (23) TEMPERATURE HISTORY - FIRE # 3

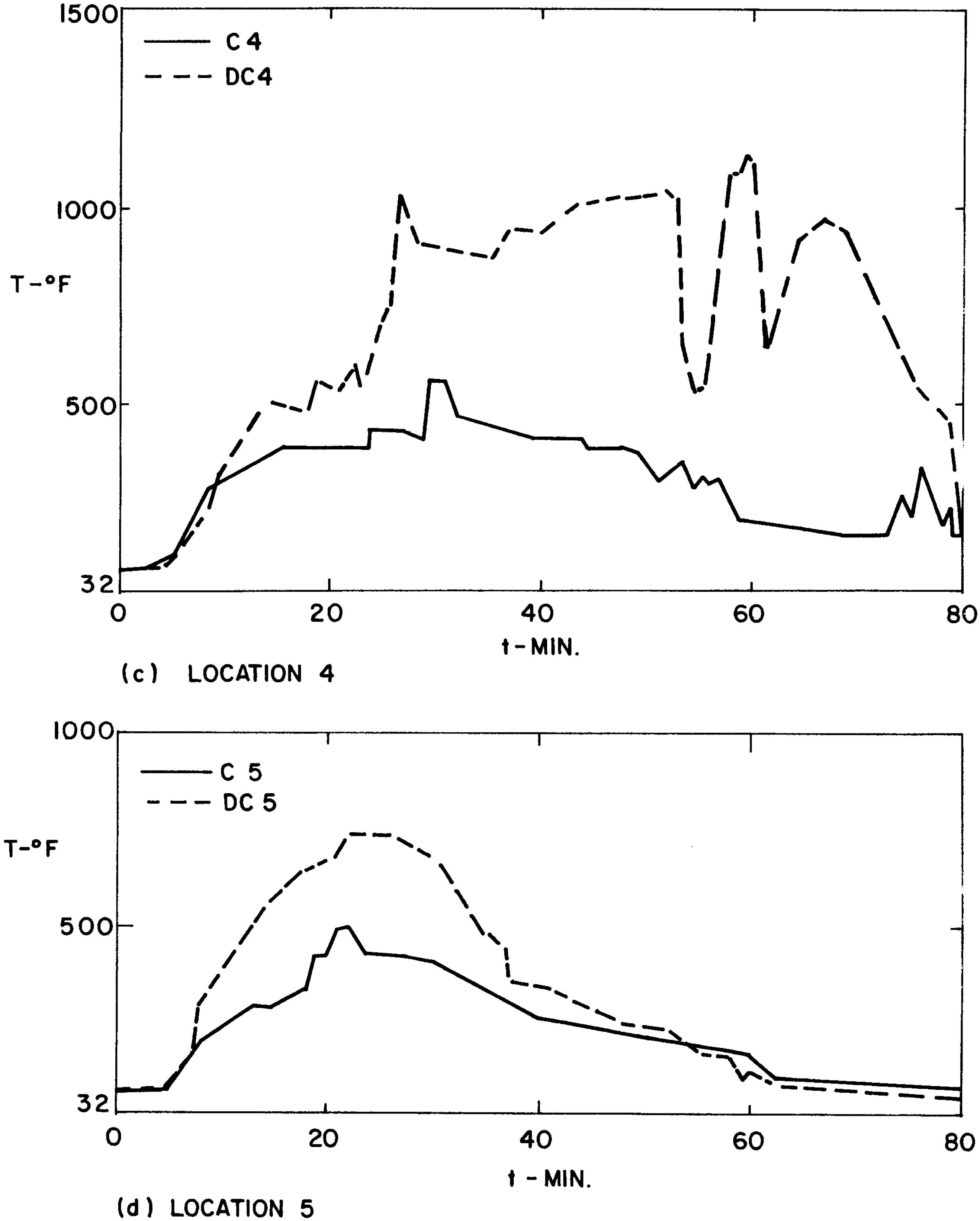
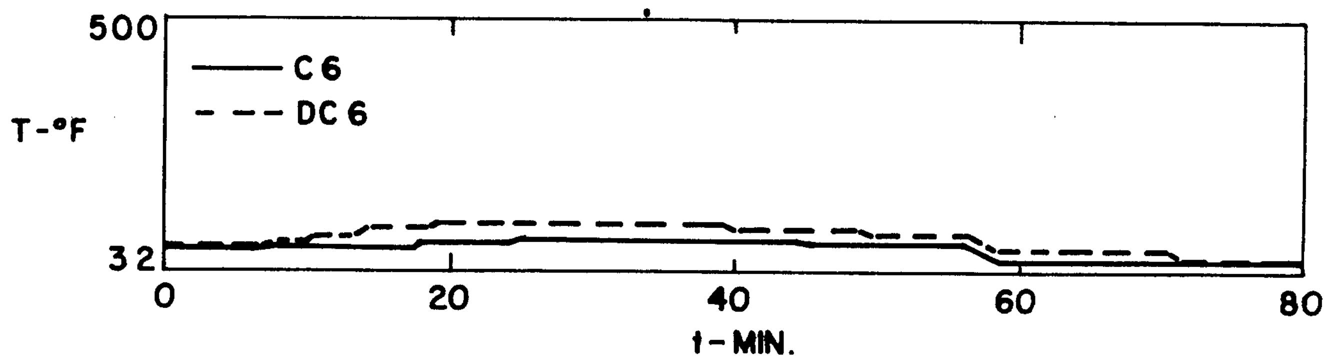
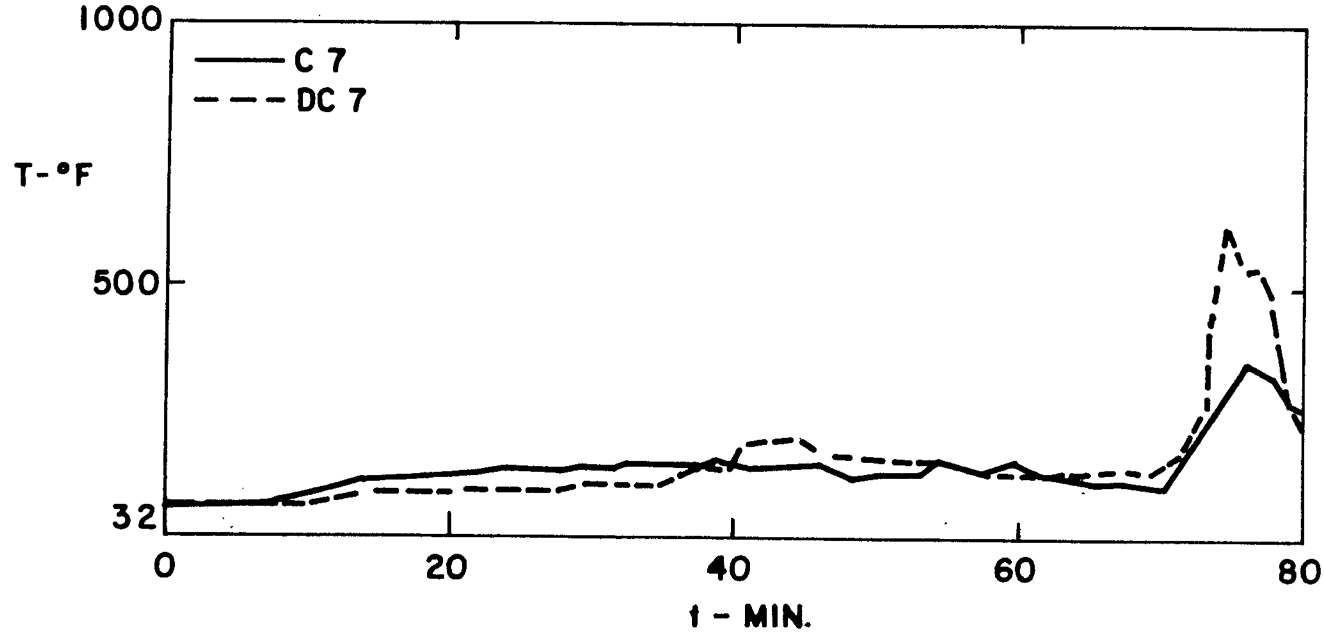


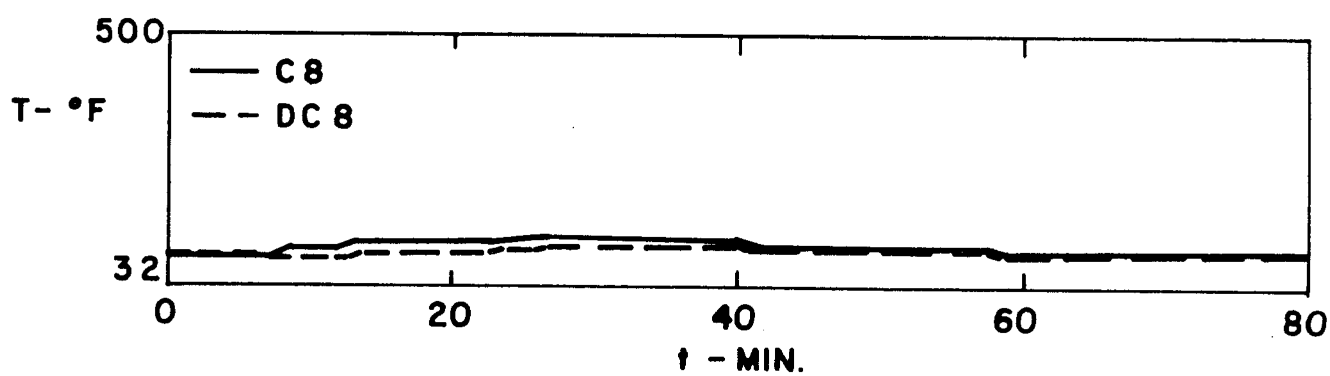
FIG. (23) TEMPERATURE HISTORY - FIRE # 3



(e) LOCATION 6



(f) LOCATION 7



(g) LOCATION 8

FIG. (23) TEMPERATURE HISTORY - FIRE #3

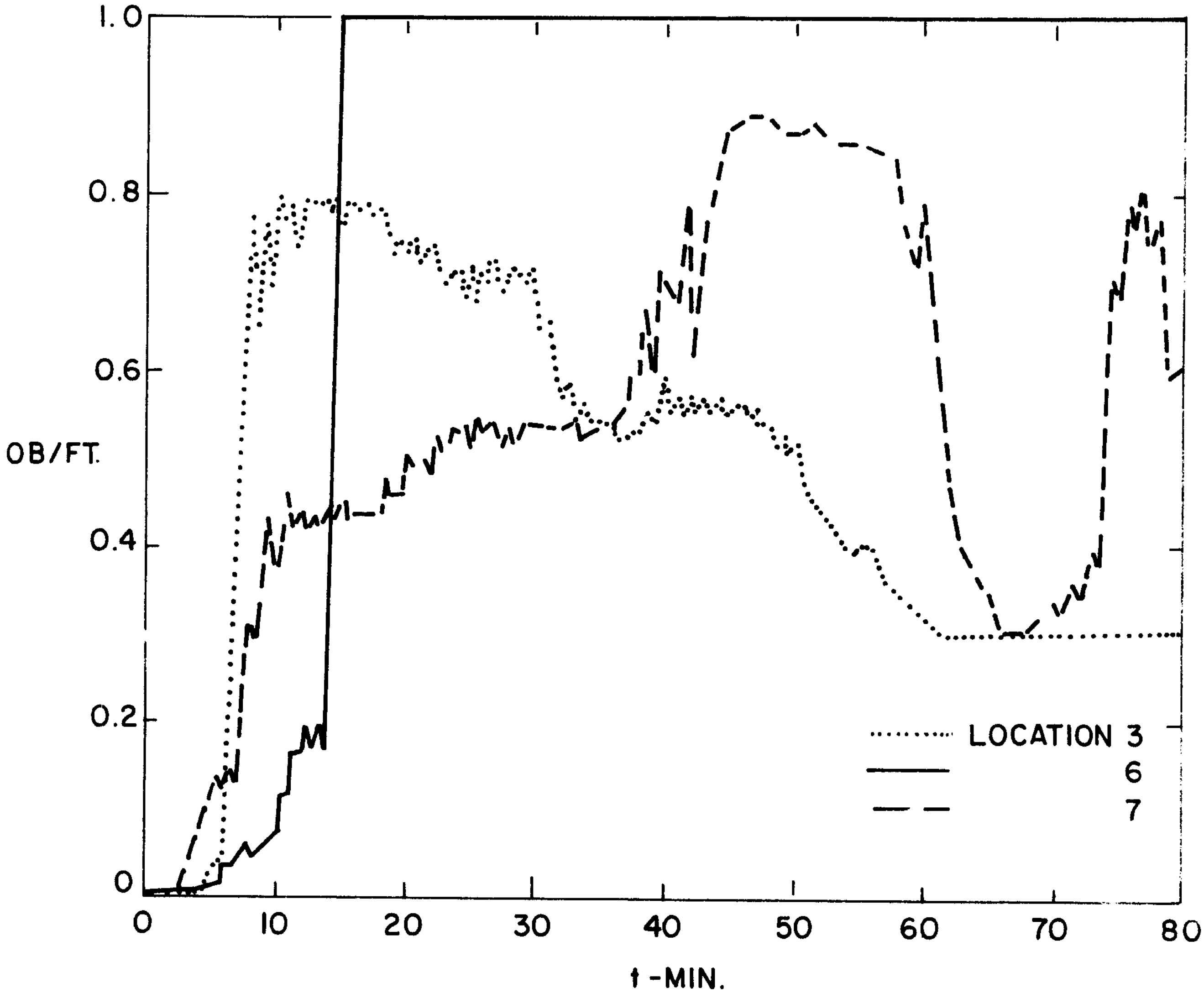


FIG. (24) SMOKE OBSCURATION PER FOOT-FIRE # 3
(a) FIRE AREA

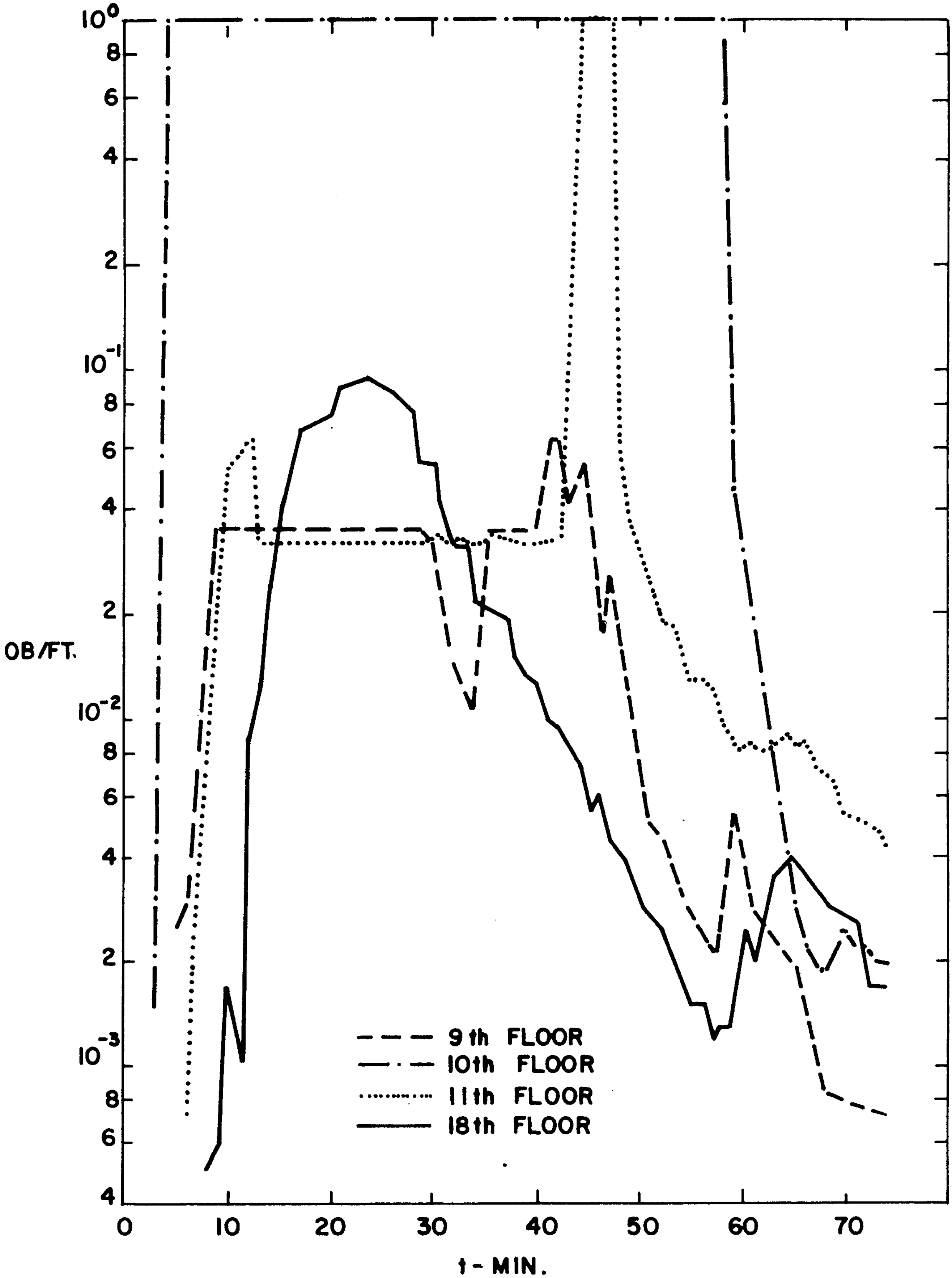


FIG. (24) SMOKE OBSCURATION PER FOOT-FIRE # 3
(b) LOBBY AREAS

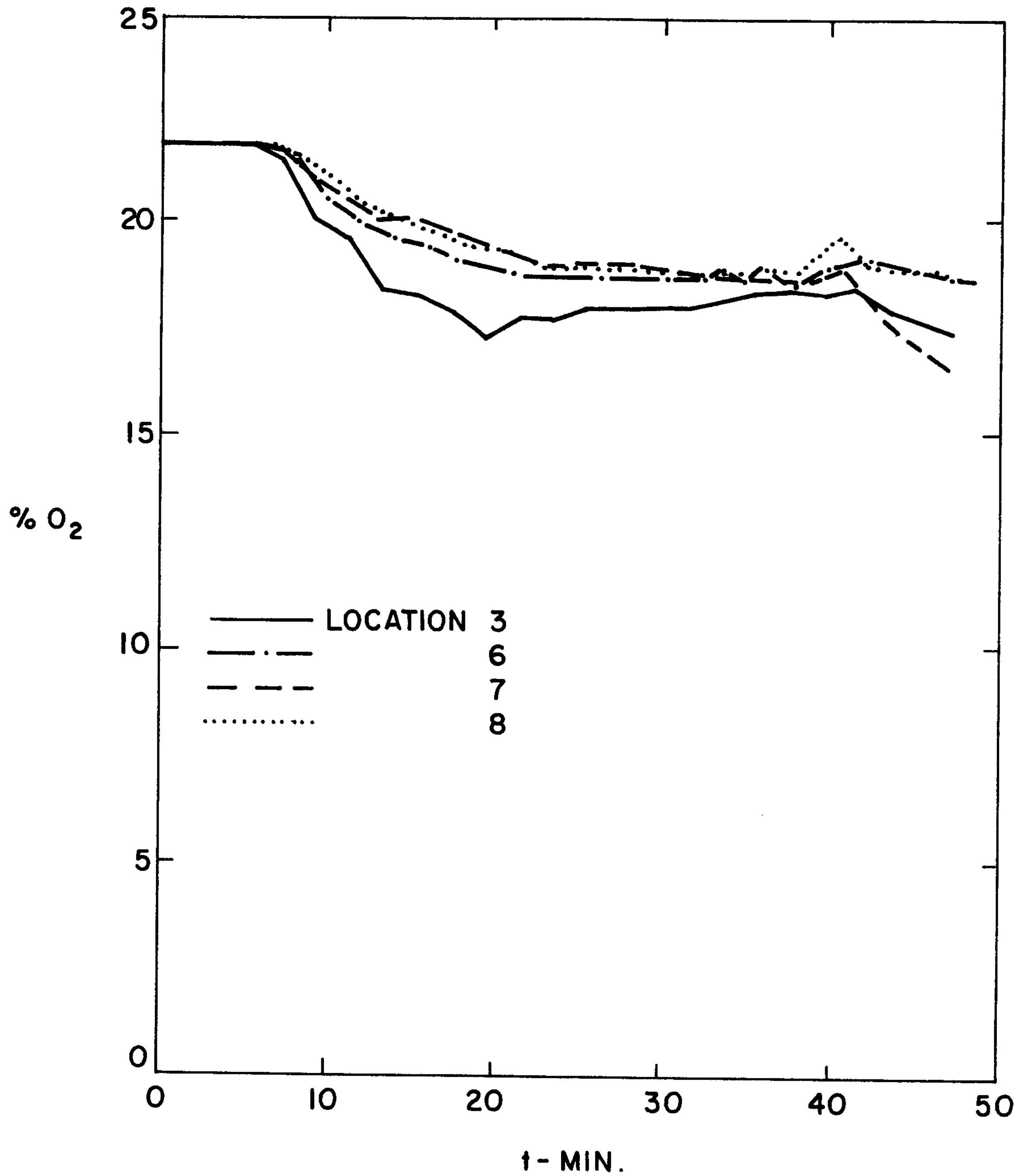


FIG. (25) OXYGEN CONCENTRATION - FIRE # 3

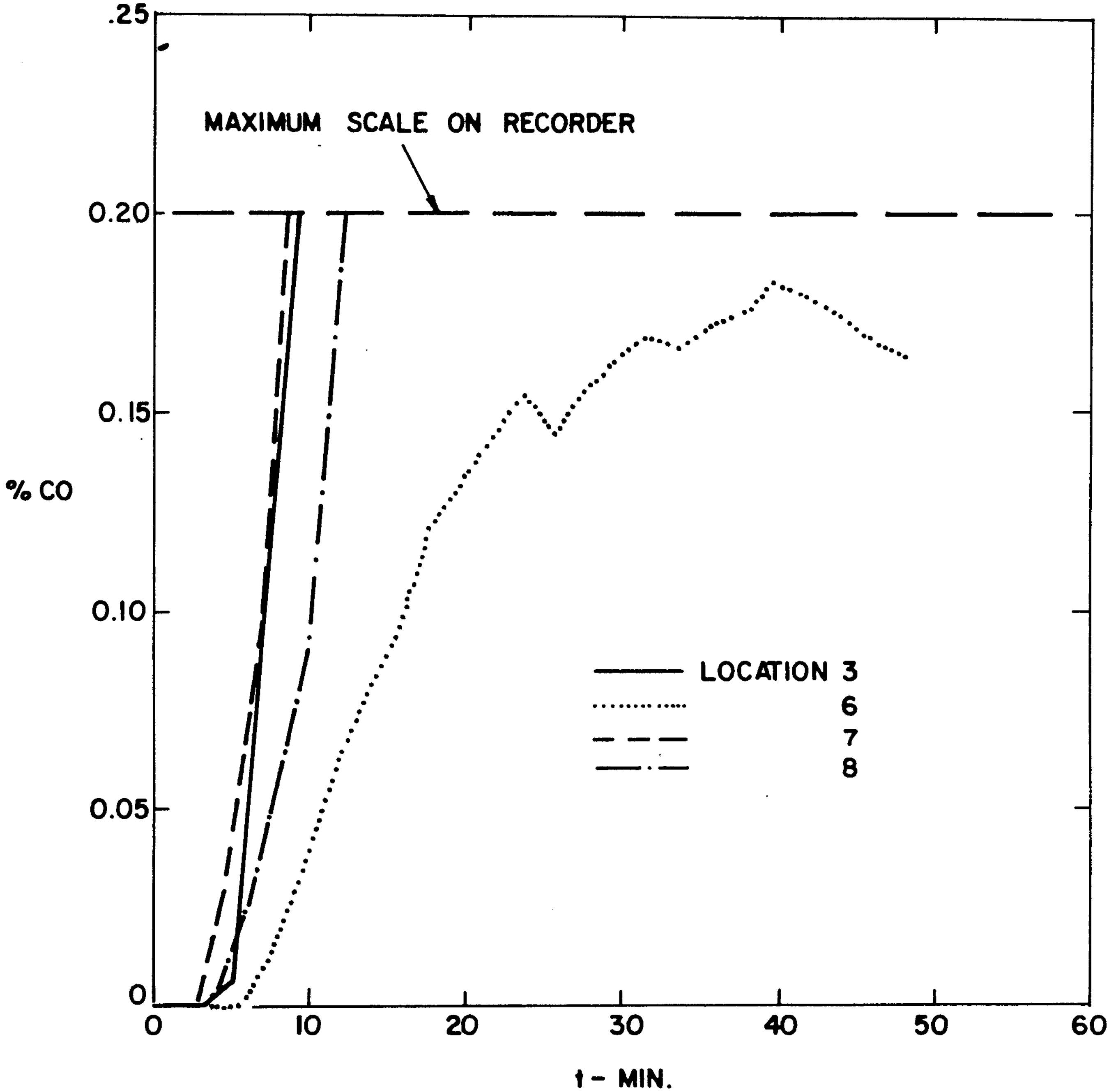


FIG. (26) CARBON MONOXIDE CONCENTRATION - FIRE #3

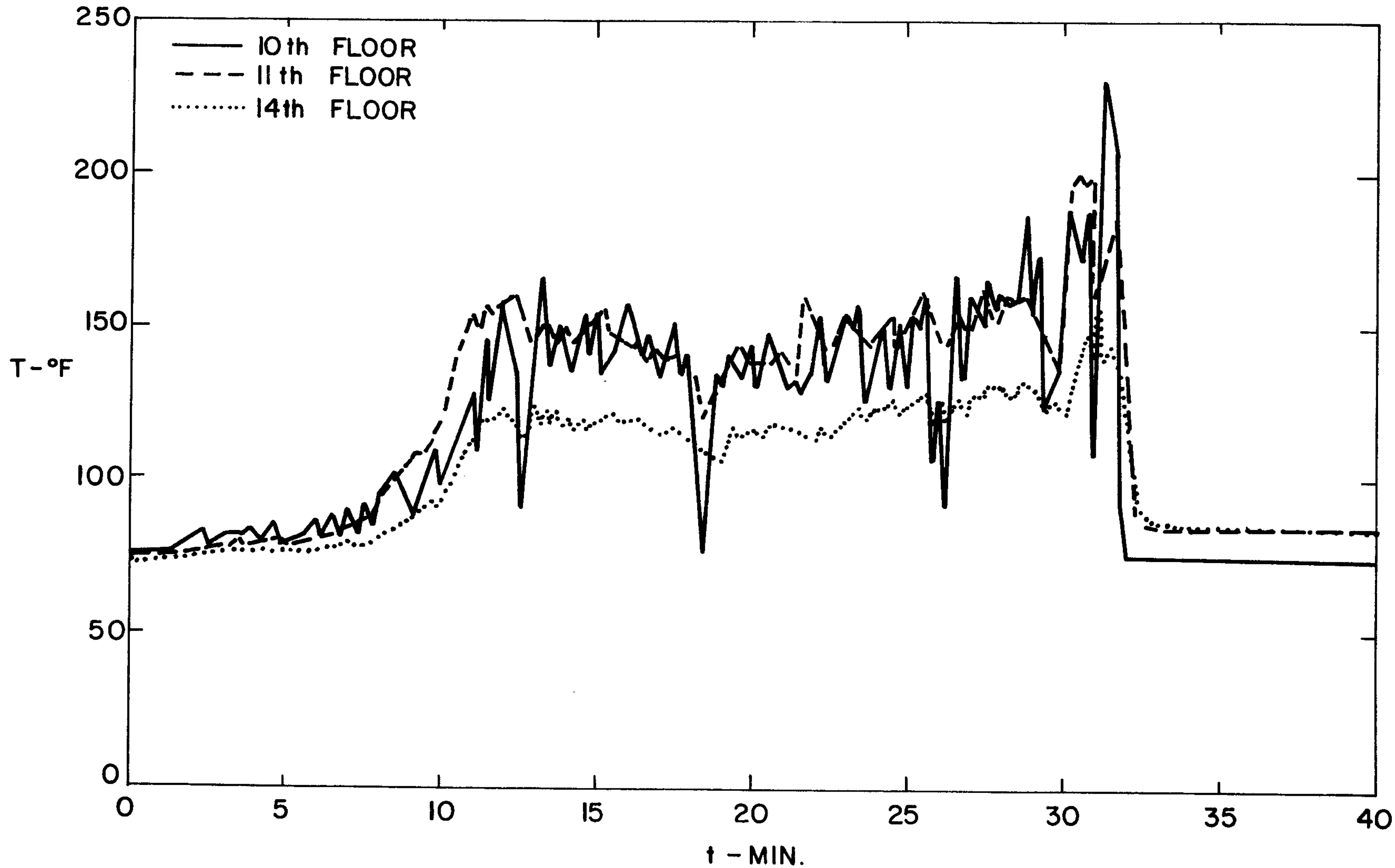


FIG. (27) TEMPERATURE HISTORY IN STAIRWELL — FIRE # 4

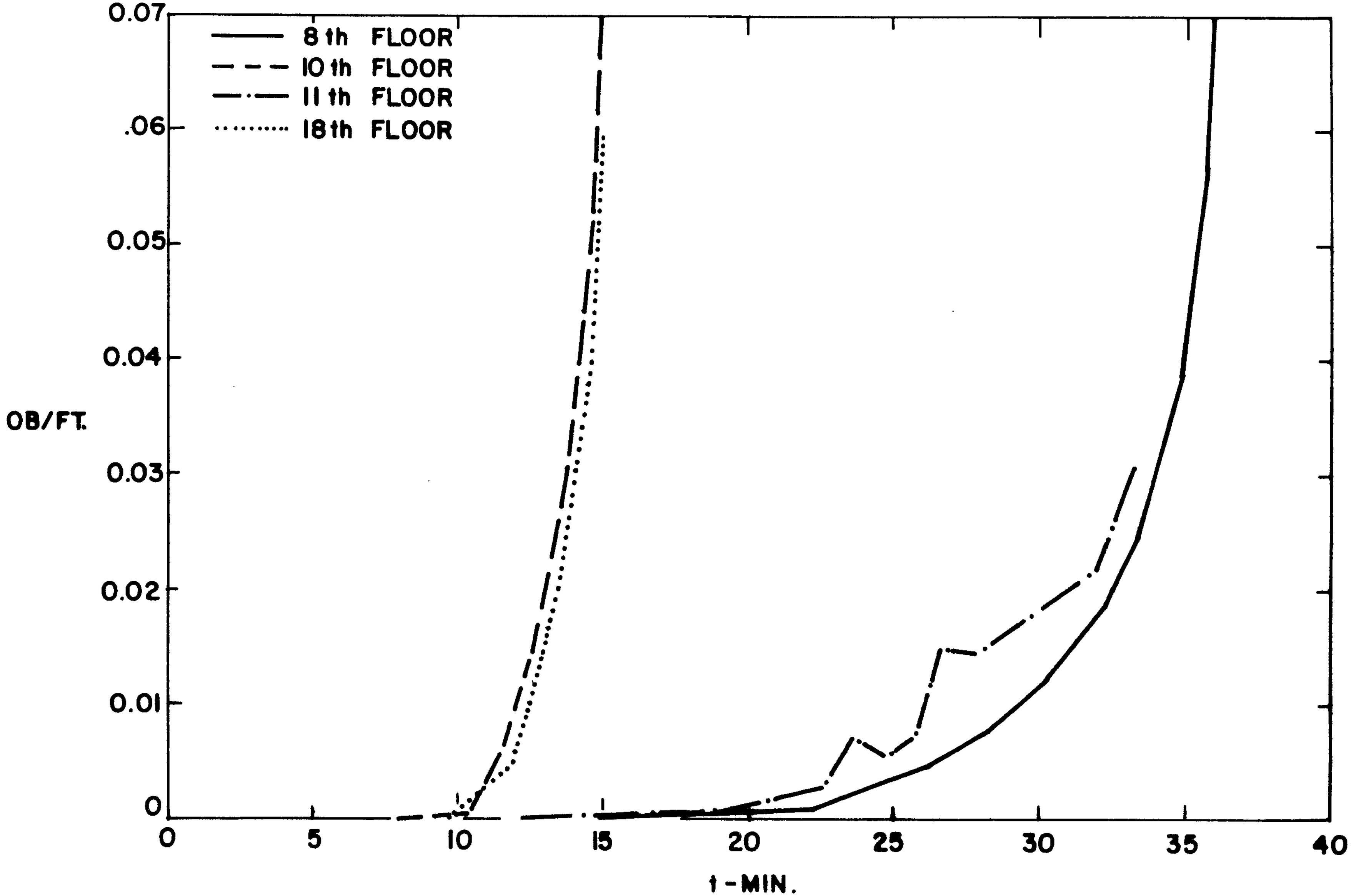


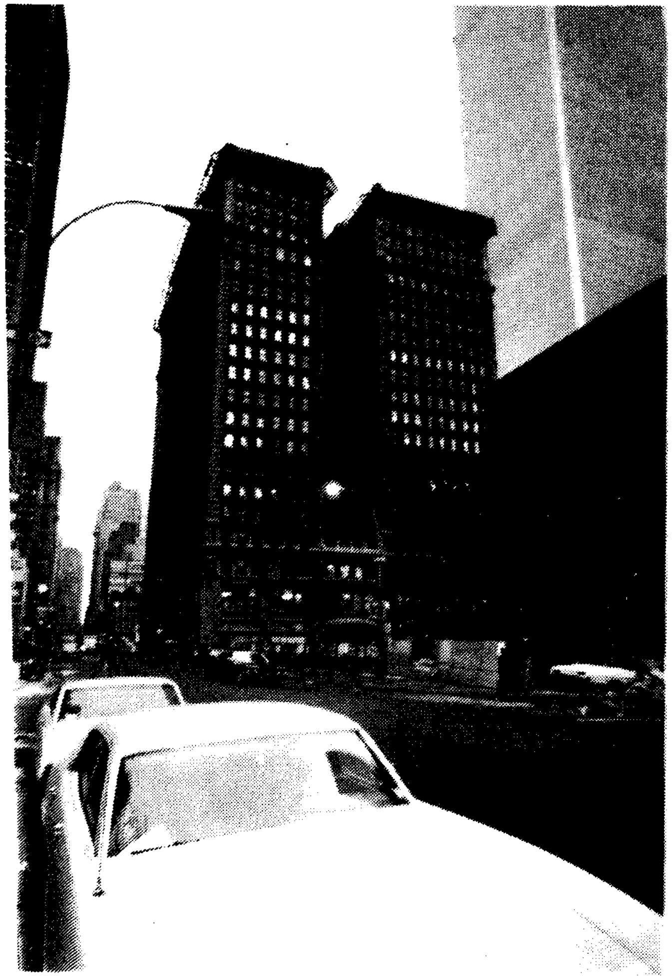
FIG. (28) SMOKE OBSCURATION PER FOOT IN LOBBY — FIRE # 4

APPENDIX B

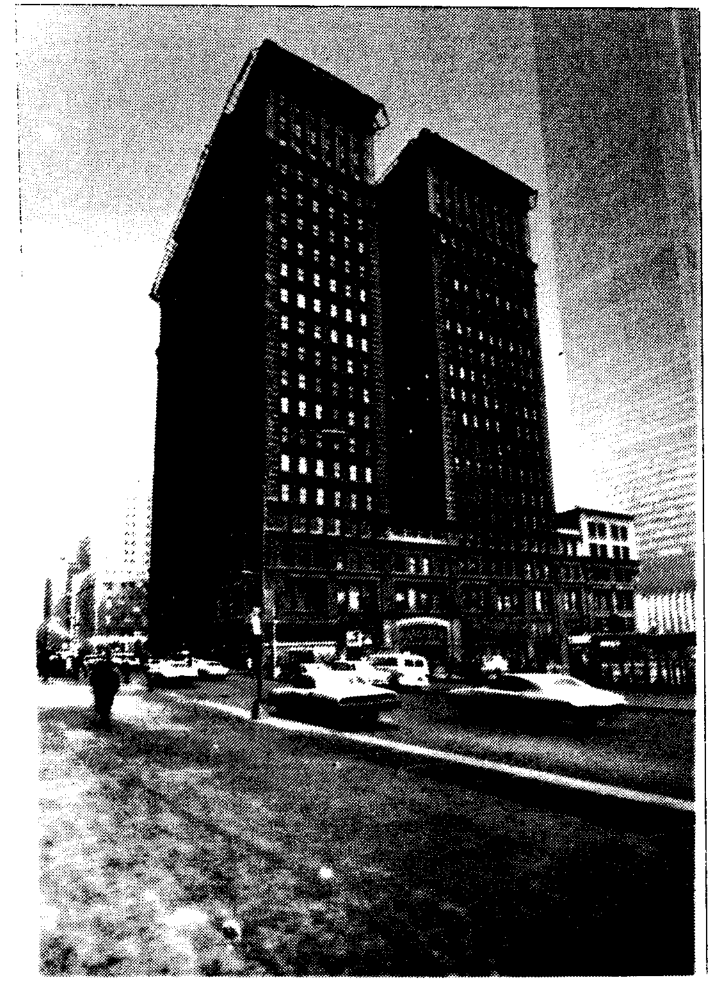
THE PURPOSE OF THIS APPENDIX IS TO PRESENT A PHOTOGRAPHIC RECORD OF SOME TEST BUILDING DETAILS, EQUIPMENT UTILIZED, CONTROL INSTRUMENTATION, AND MAJOR STEPS TAKEN DURING THE CONDUCT OF STAIRWELL PRESSURIZATION AND OTHER RELATED FIRE AND COLD SMOKE TESTS.

Additional photographs in both still, time lapse and movie form are in the files of the New York City Fire Department and the Port Authority of New York and New Jersey.

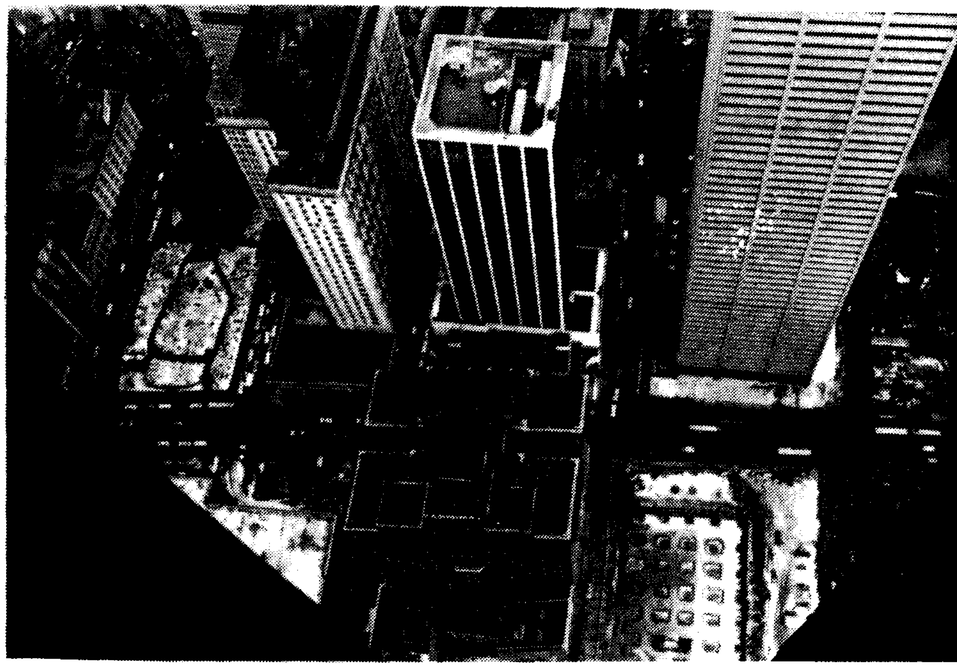
LIST OF PHOTOGRAPHS



No. 1 - Twenty-two story test building at 30 Church Street in downtown Manhattan located within the World Trade Center Complex. View looking south along Church St.



No. 2 - Test building at 30 Church Street looking north along Church Street.



No. 3 - Test building at 30 Church Street. View looking down from west showing H-plan. Surrounding buildings suggest impact upon local aerodynamics.

No. 4 - Different types of structures surrounding 30 Church Street Building shown in center of photo.

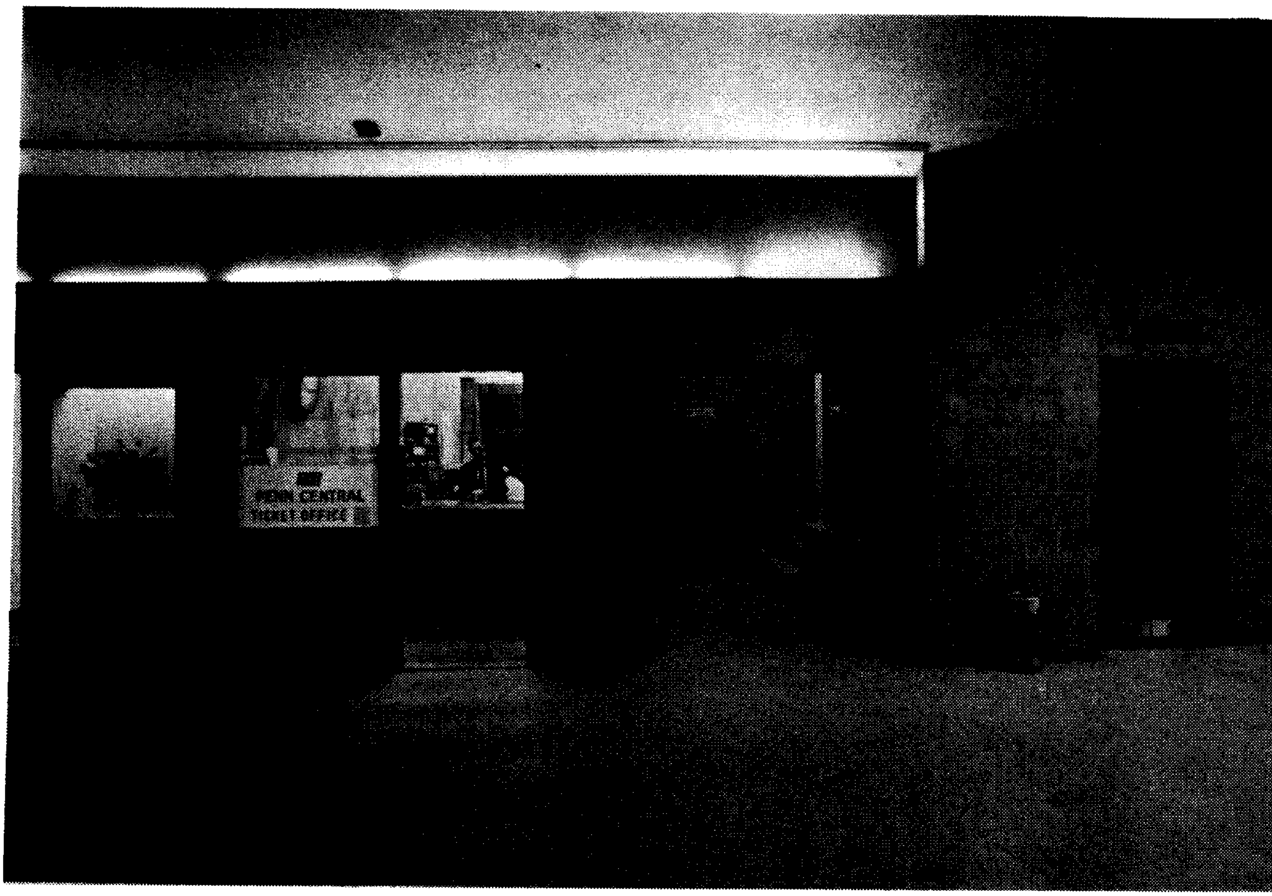
No. 5 - Roof level south (stair pressurization test) stairwell that serviced the full height of the build ing from street level. Door in rear wall leads to elevator machine room.

No. 6 - Section of stair in south stair-well and details of shaft. Construction and configuration influence leakage and frictional losses.

No. 7 - Section of stair in south stairwell showing transition in shaft construction at 2nd floor and from 2nd floor to street floor. Floor to floor heights between 1st and 2nd and 2nd and 3rd floors exceed typical of photo no. 6

No. 8 - Section of stair in south stairwell between street and second floors.

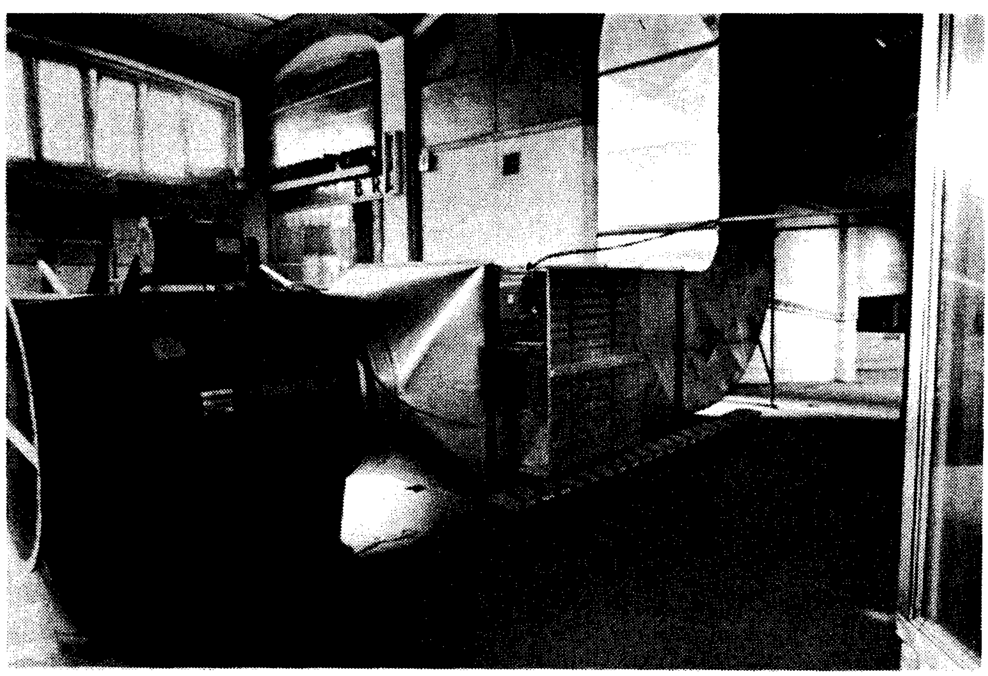
No. 9 - Street floor terminus of south stairwell at public corridor. Air supply to stair will enter above telephone booths. View from lobby.



No. 10 - Main lobby of 30 Church Street showing corridor to south stairwell of the building. Main entrance into building is towards the left.

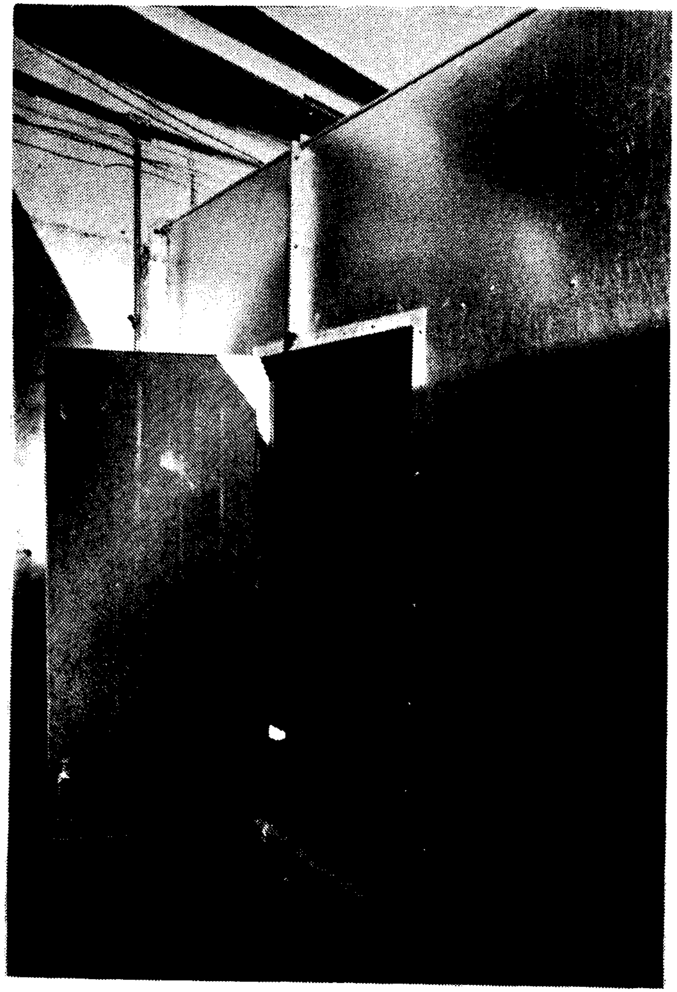
No. 11 - Arcade from Cortlandt St. on left leading to former passenger concourse of Hudson-Manhattan trains Street floor level at top of stores. Site of air supply blower. See photo no. 12.

No. 12 - 40,000 cfm blower installed in Cortlandt St. arcade. Fresh air supply through arcade entrance doors to left. Fan is vane axial type.



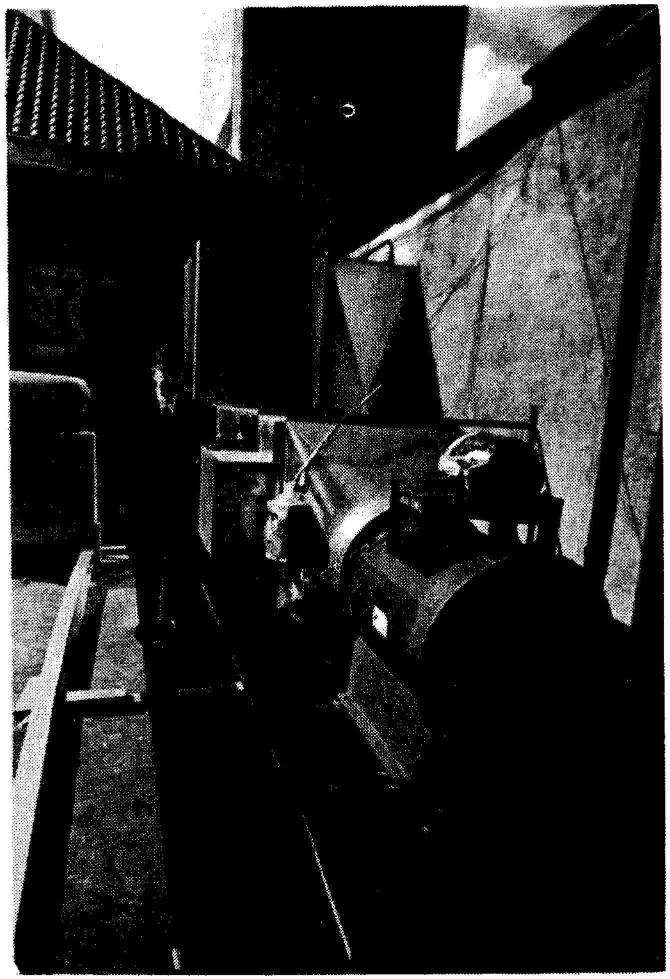
No. 13 - Another view of supply blower and duct work showing air spill section. Control damper for air flow regulation provided in rectangular section ahead of 90° bend.

No. 14 - Air supply delivery (55 in x 60 in) with baffle and grill into corridor of south stairwell. Corridor isolated from street floor lobby by bulkhead and door not shown.

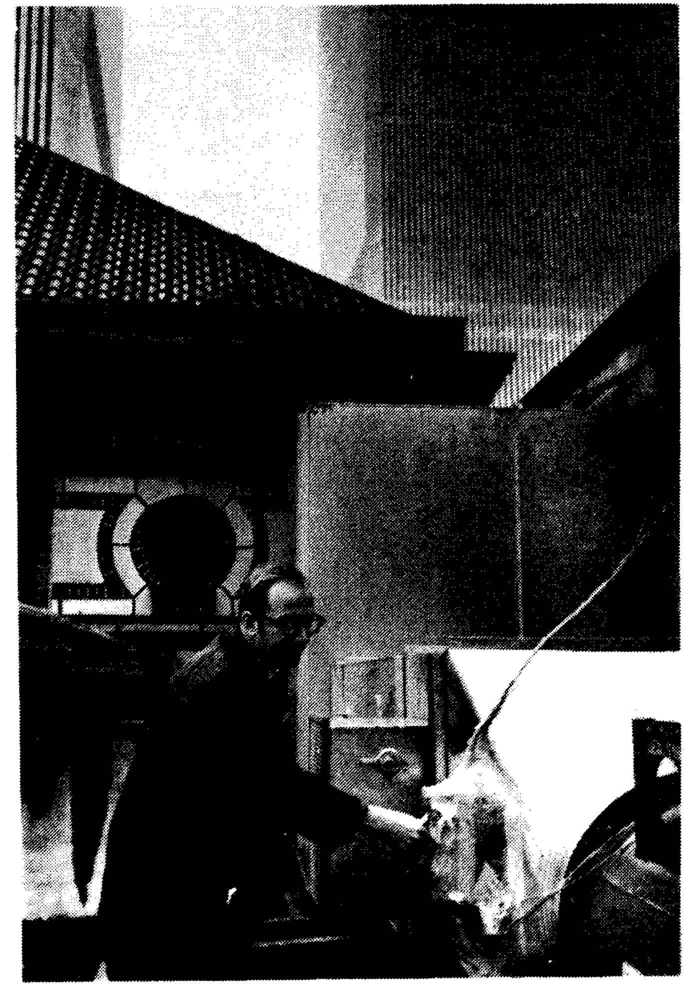


No. 16 - Access bulkhead and opening in exhaust duct work transition chamber from roof area side.

No. 15 - At roof level of south stairwell showing entrance to exhaust air duct work. Note control damper at lead-in to exhaust fan.

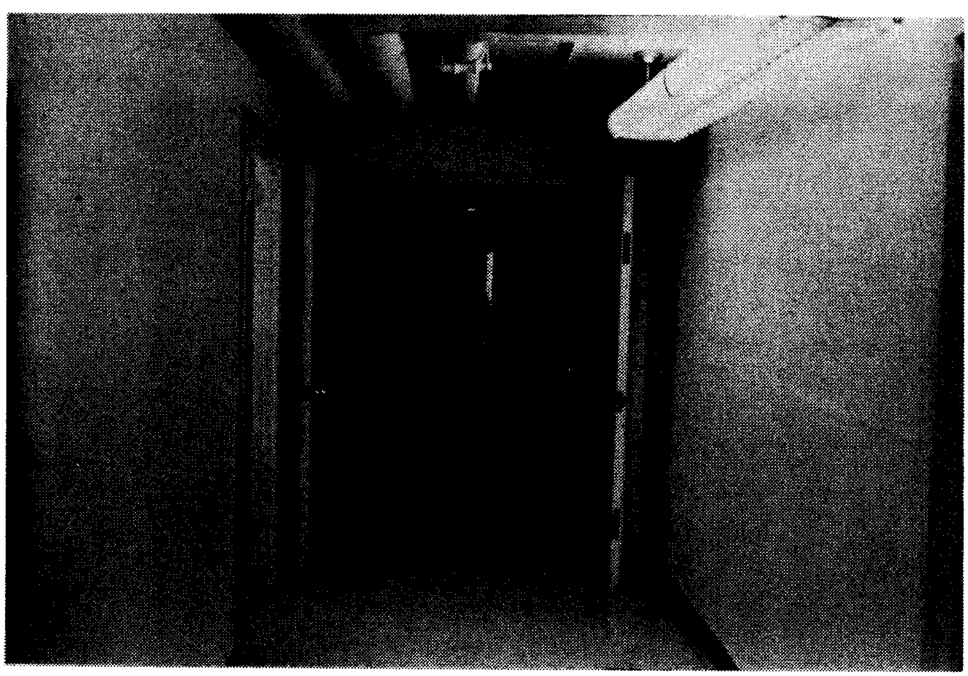


No. 17 - 10,000 cfm roof exhaust fan and duct work connected to south stairwell shaft. Note transition chamber at rear.



No. 18 - Roof exhaust fan and duct work showing bypass damper and other controls

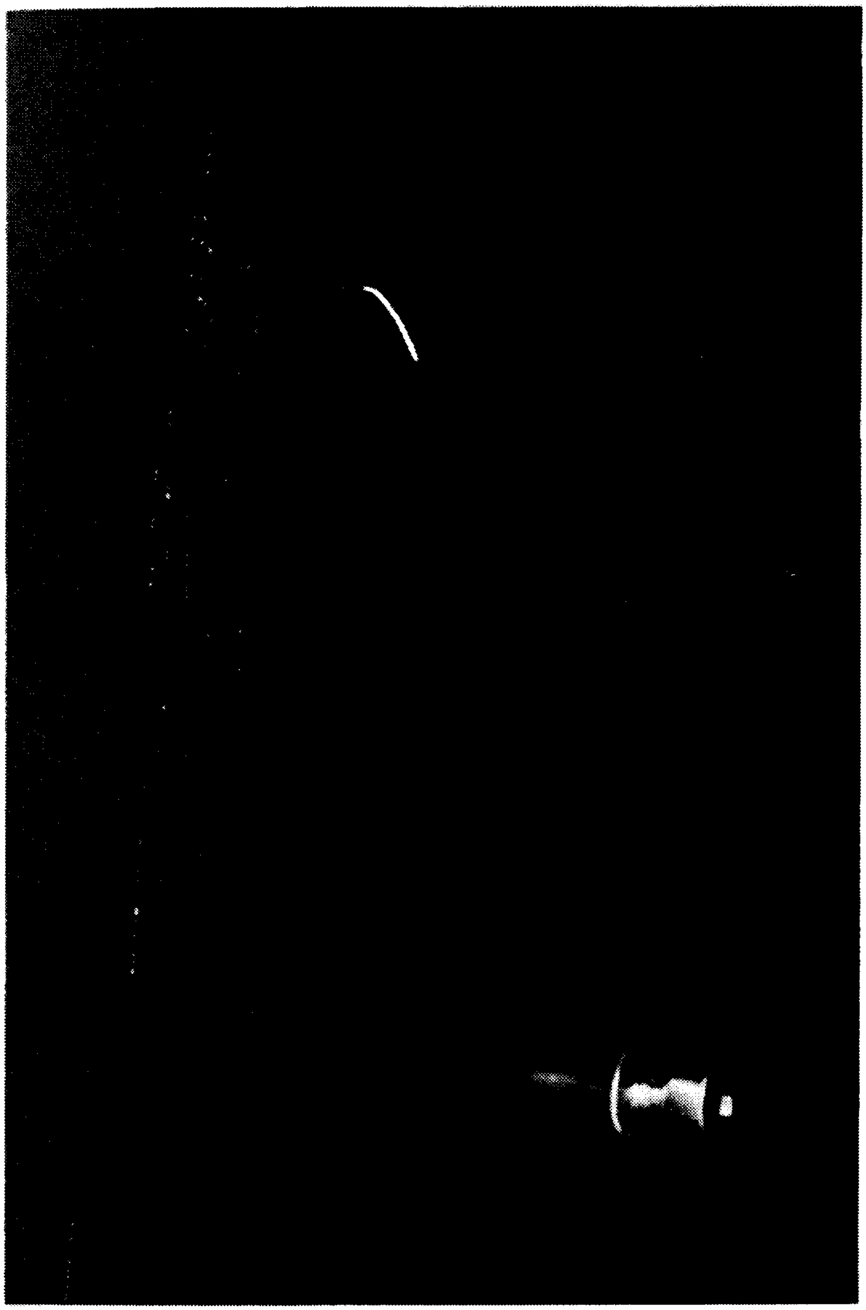
No. 19 - Typical upper floor center lobby area showing two of four banks of elevators. Note hung ceiling, terrazzo floor and access to office areas.



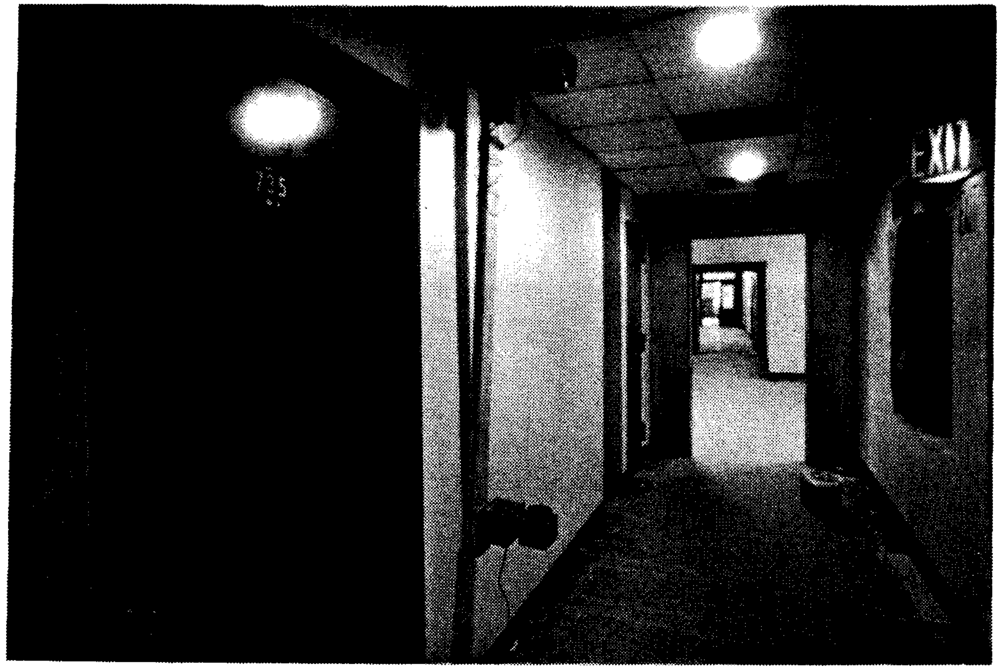
No. 20 - Typical upper floor corridor from office area to exit stair and center lobby area.

SOME DETAILS OF TEST

INSTRUMENTATION

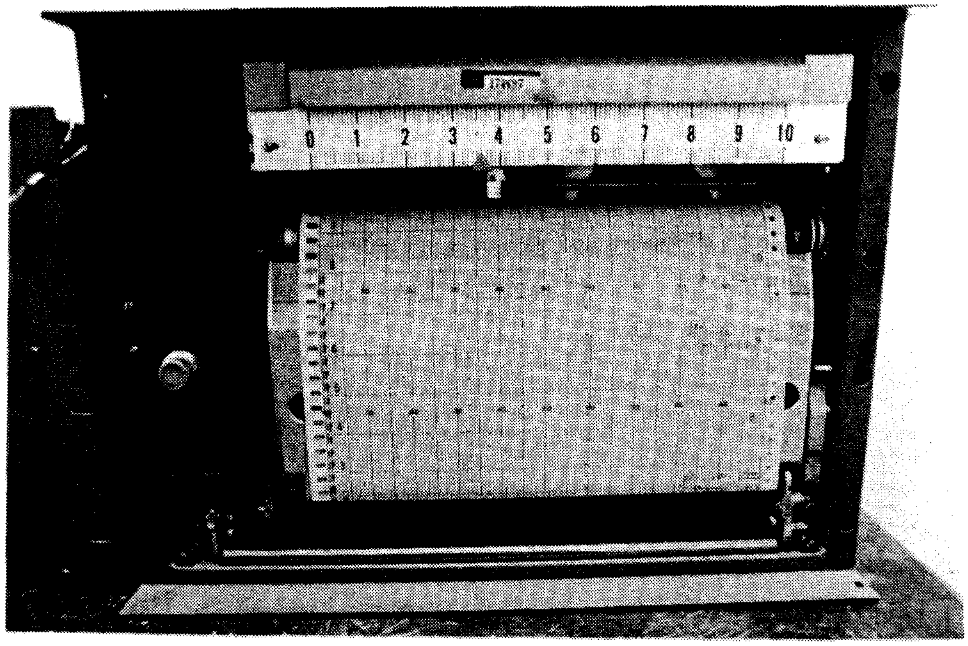


No. 21 - Typical air pressure differential probe passing through a stairwell door into corridor.



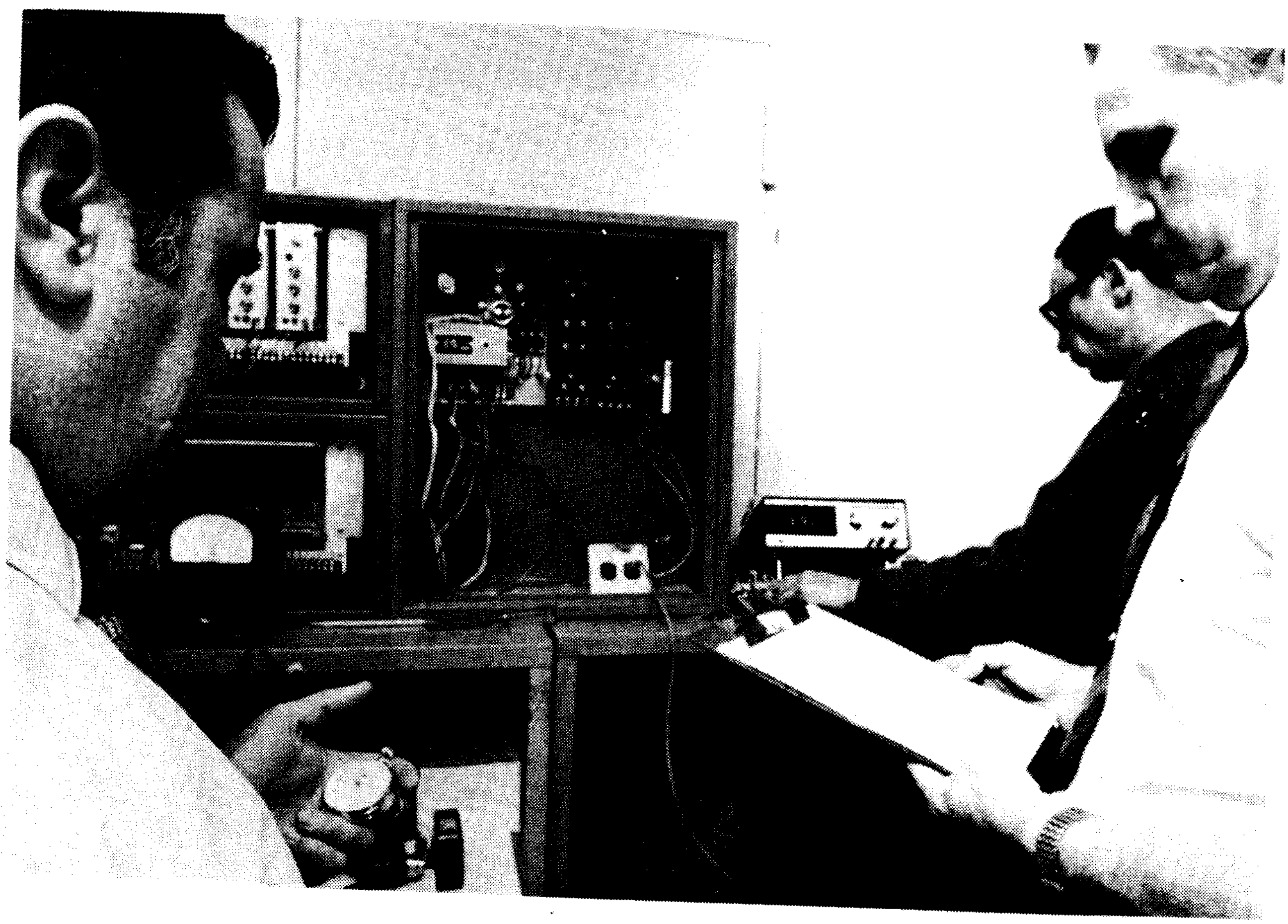
No. 26 - Close-up of smoke density indicator in place in corridor as used in Fire Test No. 1.

No. 27 - Close-up view of instrumentation wiring and tubing passing through stairwell to recording instruments at the control station.



No. 28 - One type of chart recorder used in the fire tests to record temperature levels from thermocouples set in fire area.

No. 29 - Some typical recording instruments at one of several control stations established for the tests.

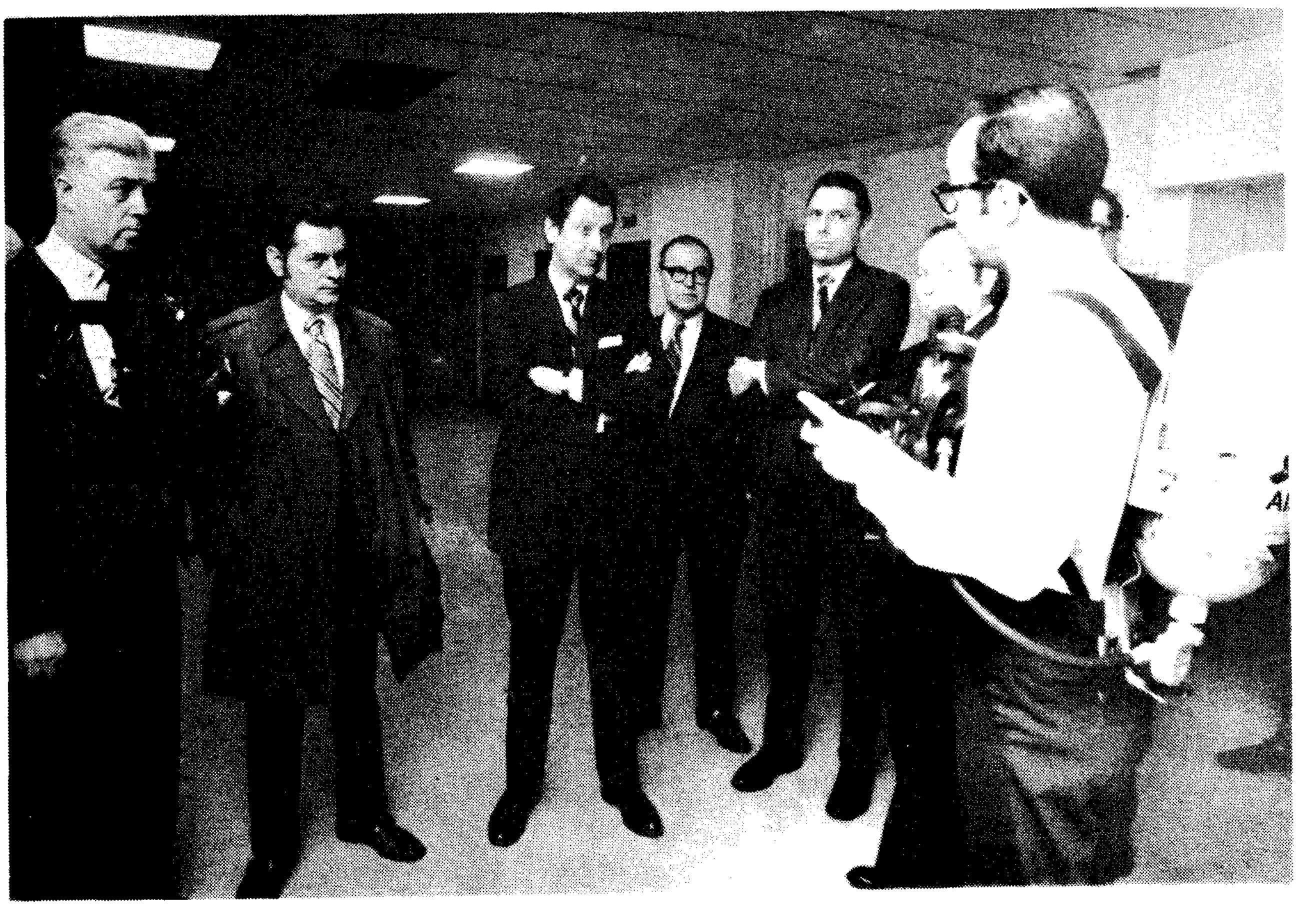


No. 30 - Recording device for smoke obscuration indicators set in 6th floor lobby area by A.D.T.

PRELIMINARY TESTING OF

STAIR PRESSURIZATION

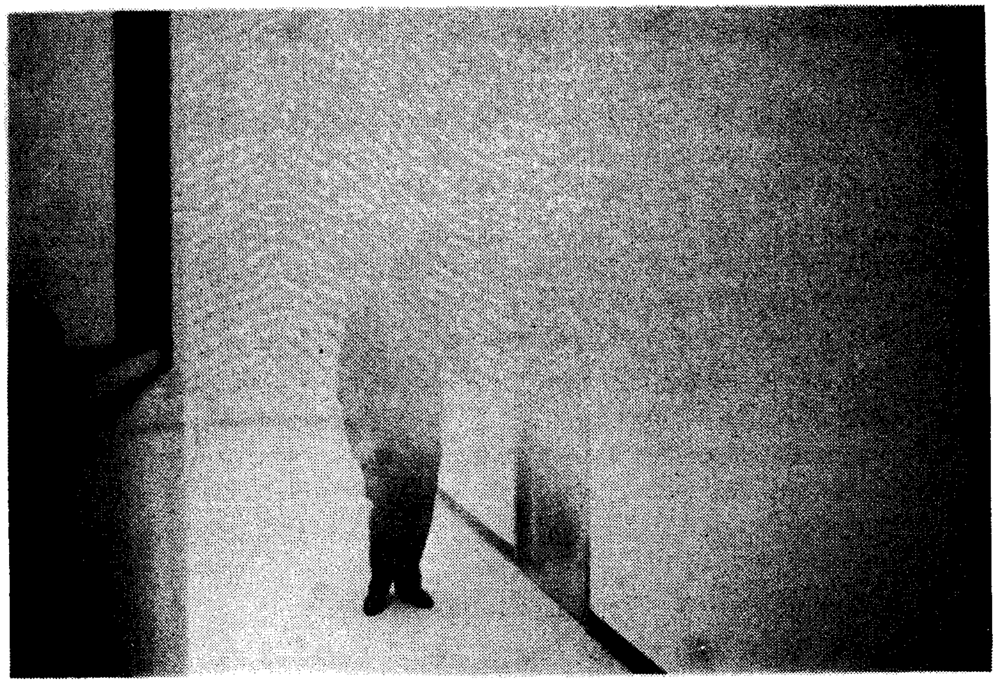
WITH SMOKE AND NO HEAT



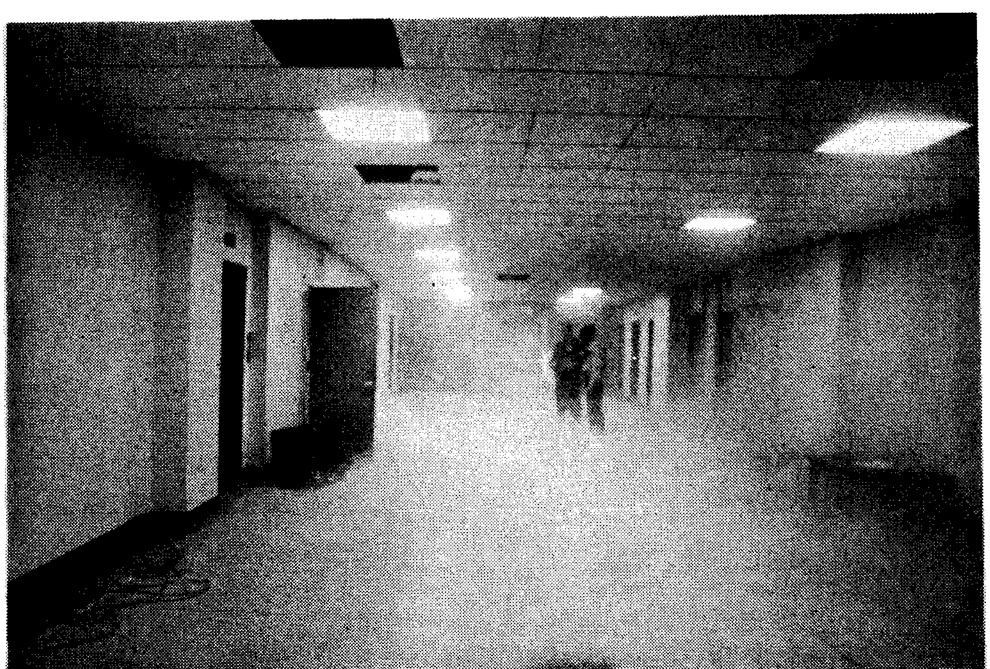
No. 31 - Orientation session prior to preliminary cold smoke tests. Atending are representatives of governmental agencies, fire protection groups and the Polytechnic Institute of Brooklyn.

No. 32 - Ignition of smoke candles preparatory to cold smoke tests.

No. 33 - Establishing stair pressurization level in test stairwell during cold smoke tests. Note differential pressure gauages in use.



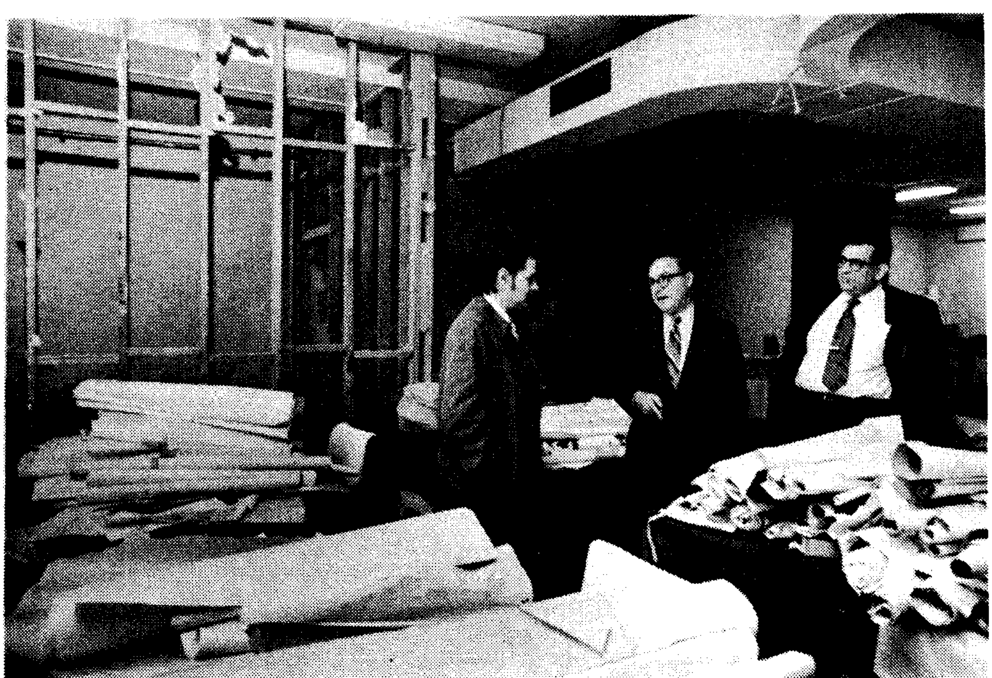
No. 34 - Corridor of 7th floor south end, west wing, following ignition of smoke candles.



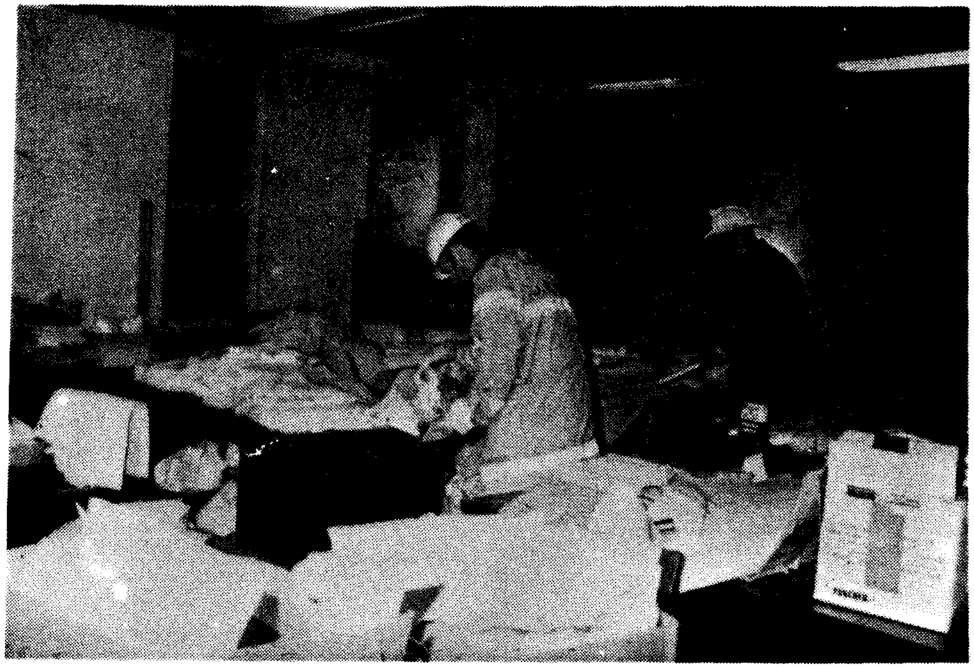
No. 35 - Increasing smoke density in center lobby area. Note open bulkhead door leading from the source of generated smoke.

FIRE TEST NO. 1

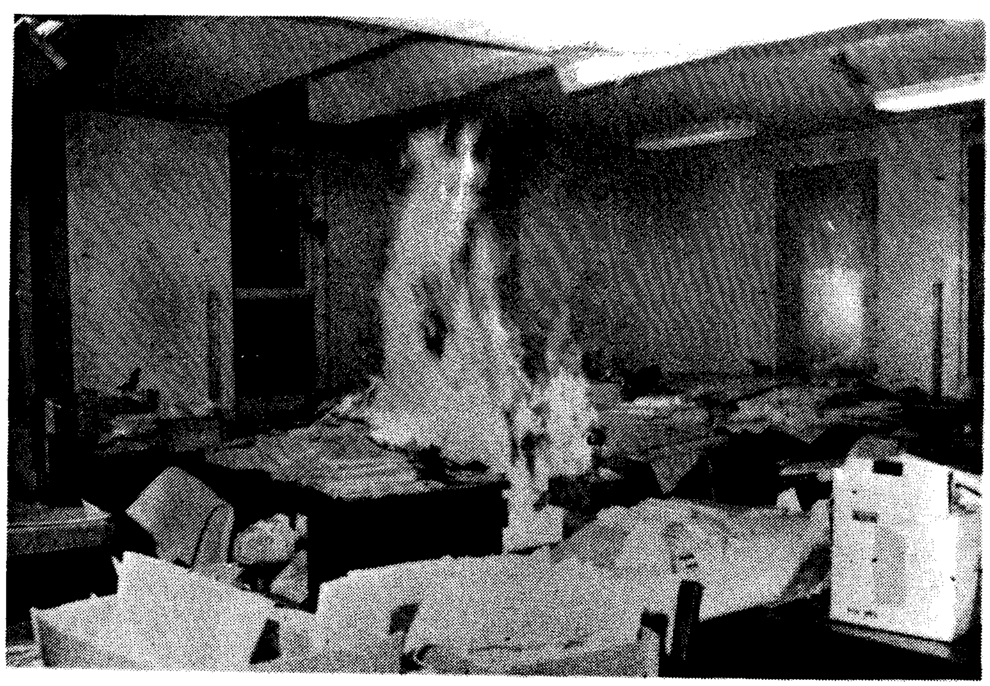
No. 36 - Completion of build-up of fire load in the 7th floor, west wing area for test No. 1. Approximately 6.3 lbs. per sq. ft. of floor area.



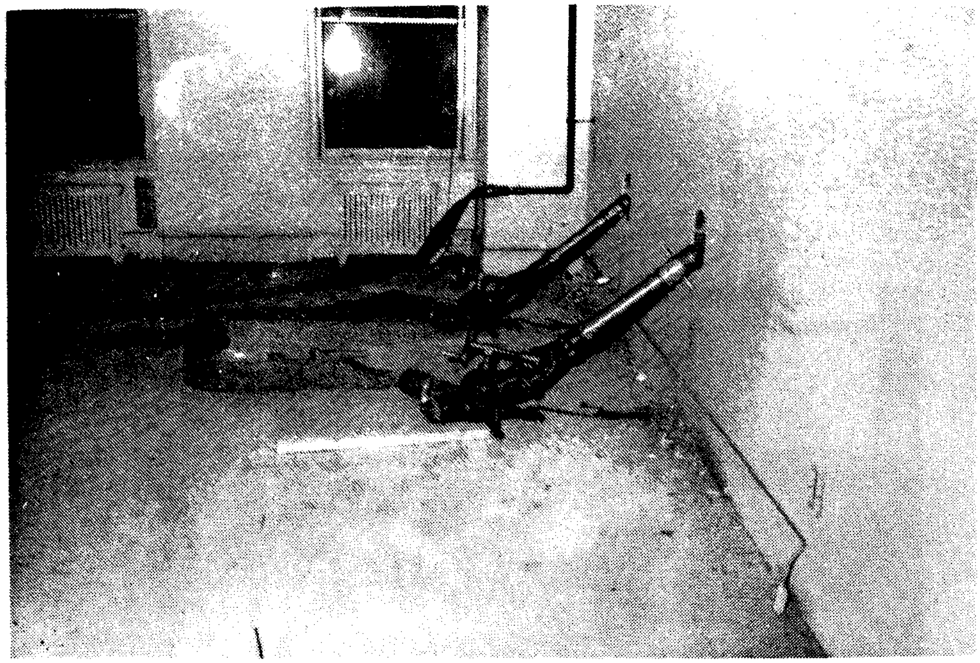
No. 37 - View of Room with fire load for Test No. 1. Note wood partition studs left in place to augment fire load.



No. 41 - Test No. 1 ignition. Note control of window ventilation.



No. 42 - Test No. 1 fire successfully under way. Note falling light fixture in upper left hand corner.



No. 43 - Test No. 1 fog nozzles and water spray connections in adjacent safe area readied for extinguishment.

No. 44 - Test area No. 1 after extinguishment of fire. View looking south. Ceiling tiles dropped and burned. Duct work has fallen. Estimated 80 per cent contents consumed.

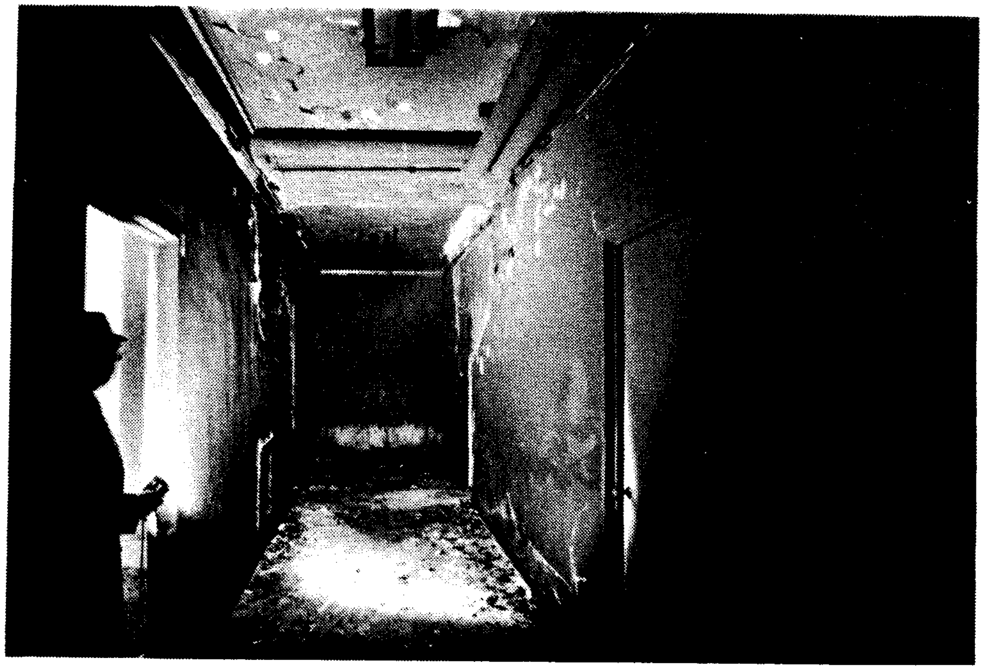
No. 45 - Close-up of south
corner of 7th floor test area
after fire extinguishment.
Most of unburned material was in
this area.

No. 46 - View of 7th floor test area after extinguishment looking north. Most of unburned material was metal. Note exposed adjacent partition at left background.

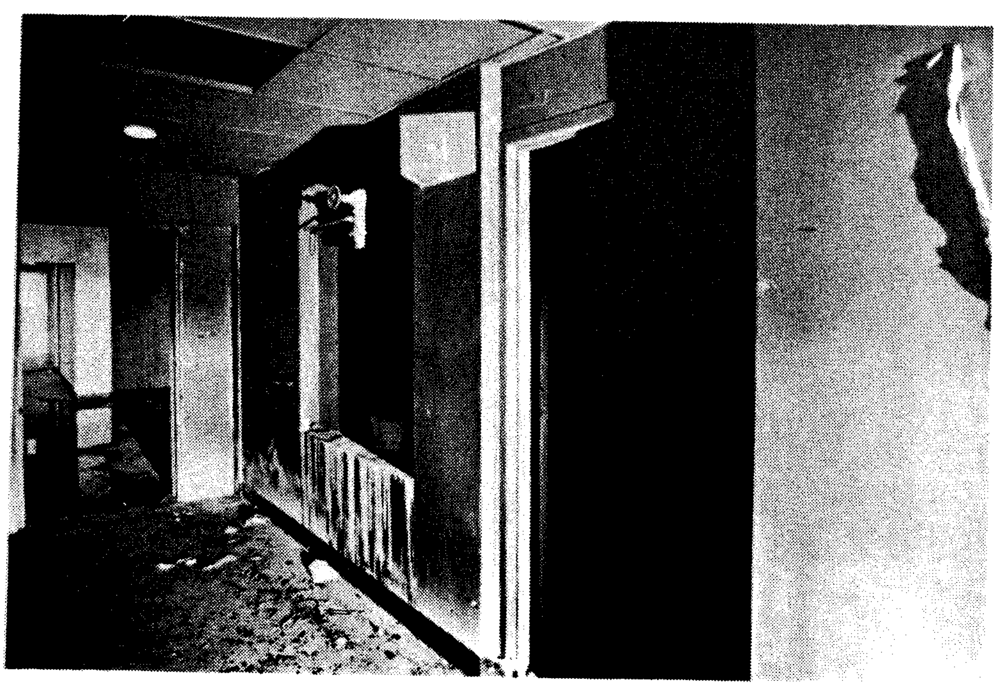
No. 47 - Another view of 7th floor fire area after extinguishment looking north and showing exterior wall. Windows seen across the open court are those of the test observation area.

No. 48 - Close-up view north end wall Test No. 1 fire area after extinguishment showing fog nozzle openings. The two windows shown had been covered with sheet metal.

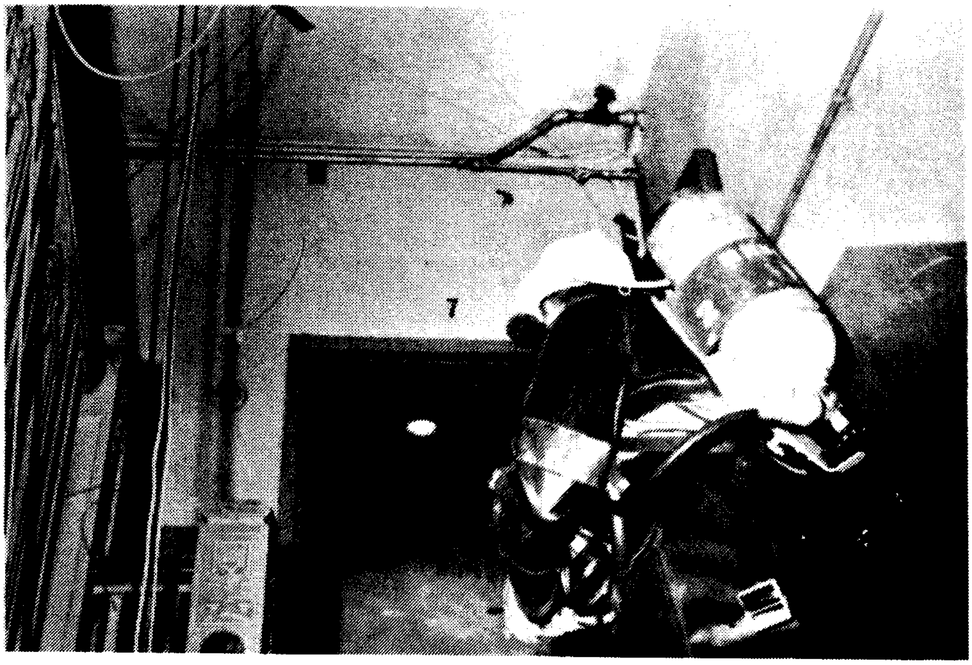
No. 49 - View of Test No. 1 fire area after extinguishment from room across corridor. The door from the fire area into corridor was left open.



No. 50 - Corridor leading from fire area of Test No. 1 to the pressurized test stairwell after extinguishment. The stairwell is at the near end to the left and off the photo.



No. 51 - View looking north towards 7th floor lobby from fire area No. 1 after test. Note bulkhead and door to contain smoke and heat during test. Test stairwell is at right.

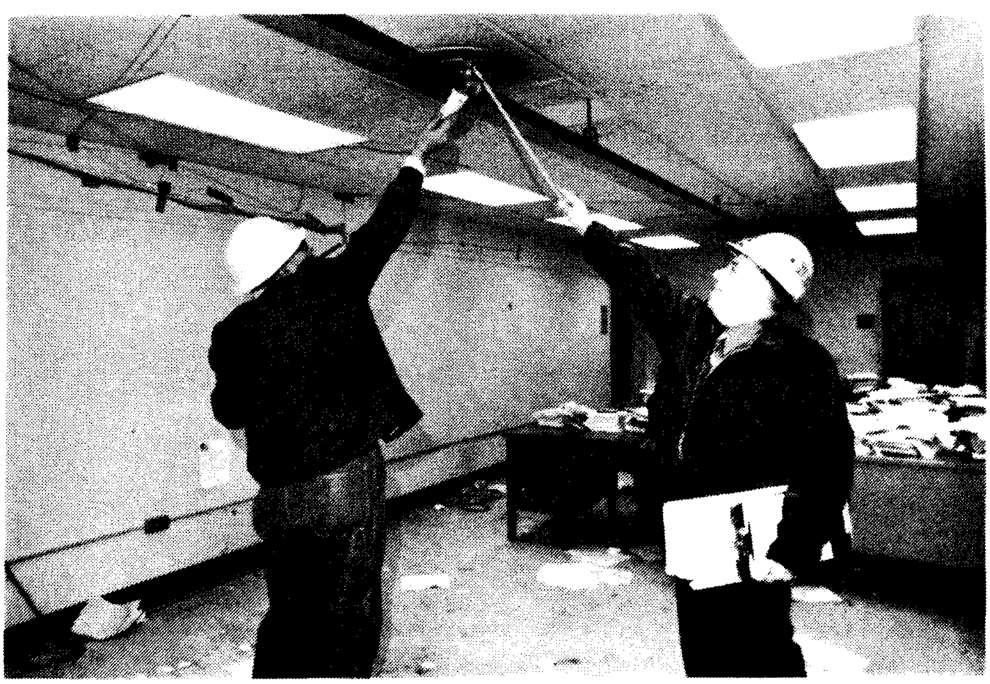


No. 52 - View of Test Stairwell taken during the progress of fire Test No. 1 after door to 7th floor had been opened. Note instrumentation wiring and tubing and stair free of smoke.

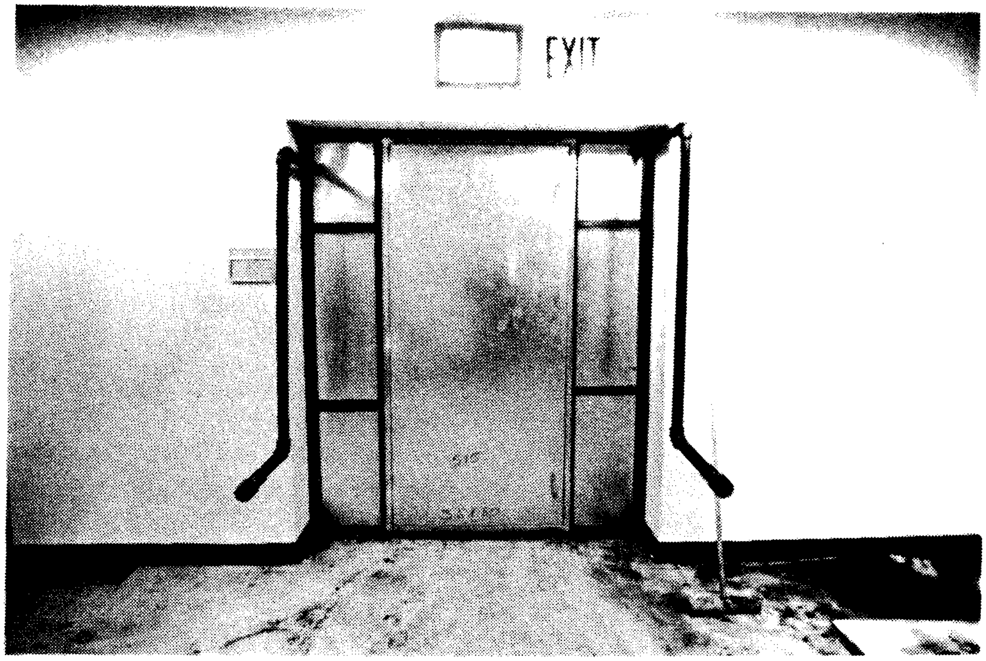
No. 53 - Staff Critique **held** after completion of Fire Test No. 1 preparatory to initiation of succeeding tests.

FIRE TEST NO. 2

No. 54 - Area selected for site of fire test No. 2 on 10th floor south end of west wing of building. It was planned to use area to be seen through the near door on left as site of fire test No. 3.

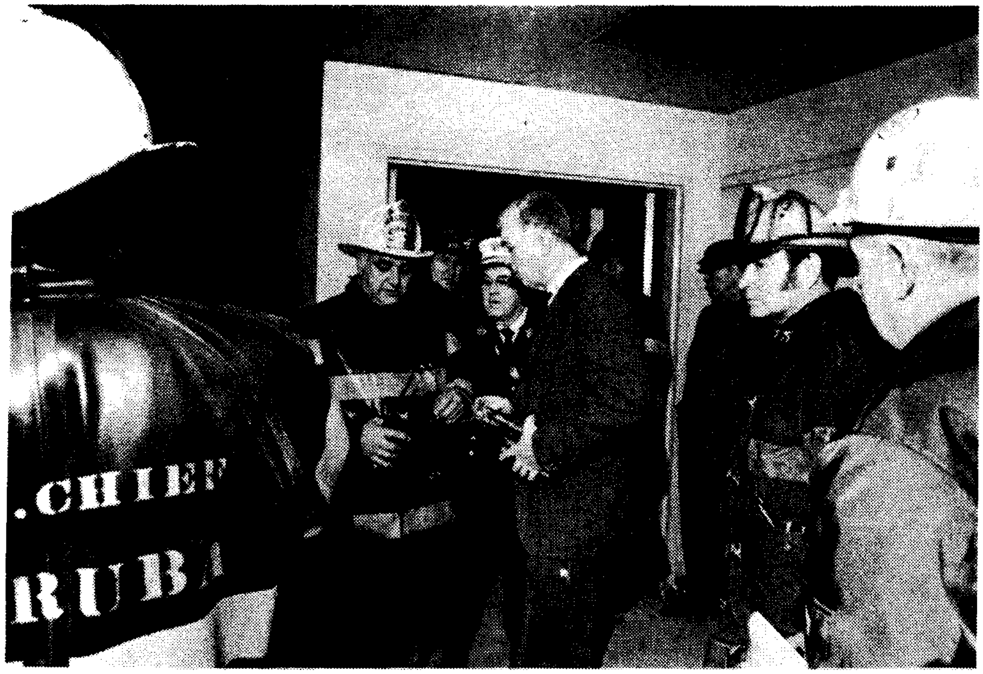


No. 55 - Fire load for Test No. 2 in background. Fusible link in water spray head being removed. Note instrumentation wiring and tubing along upper wall.

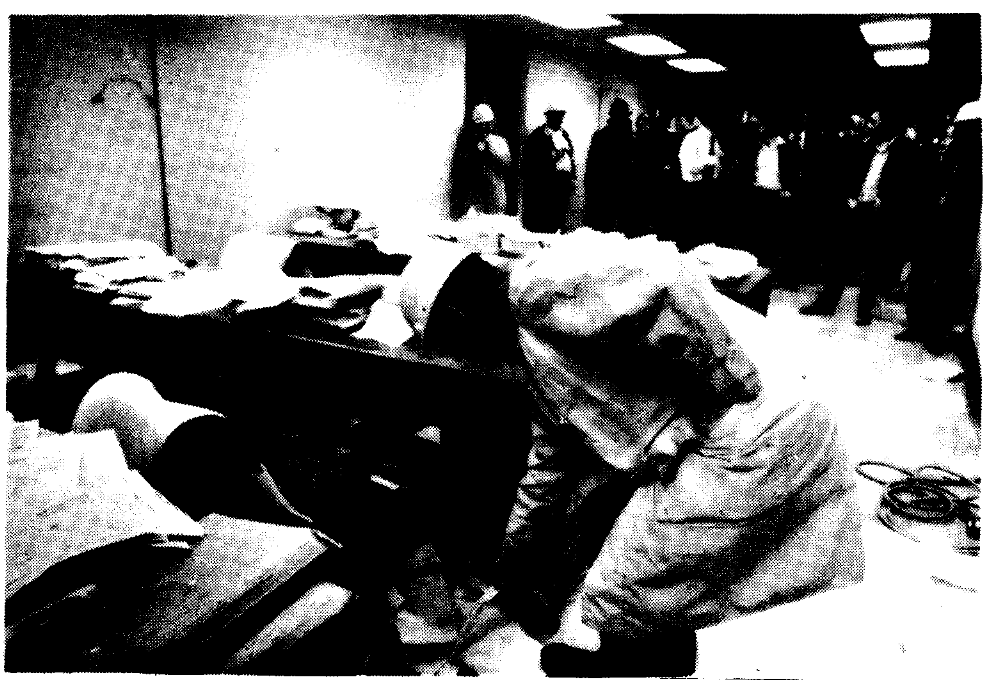


No. 56 - Bulkhead and door erected between center lobby and fire area for test No. 2 on 10th floor. Also showing hose connections for water spray pipe lines.

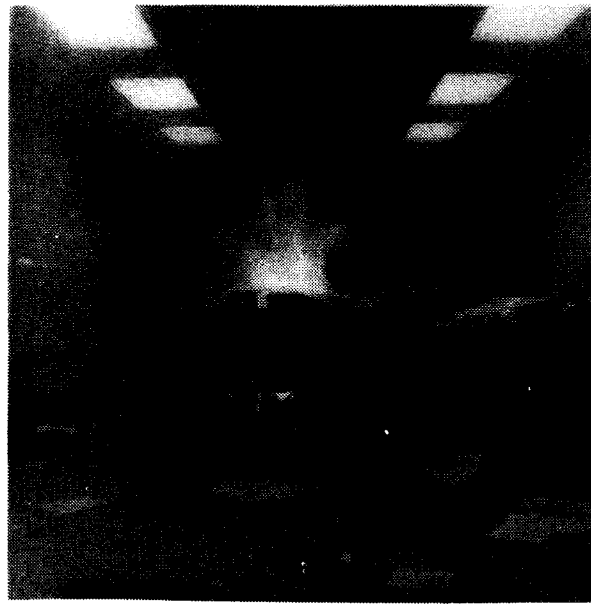
No. 57 - Completed build-up of fire load for Test No. 2 being readied for ignition. Air conditioning system in "off" position. View looking south.



No. 58 - Test No. 2 firefighters check communications before ignition.

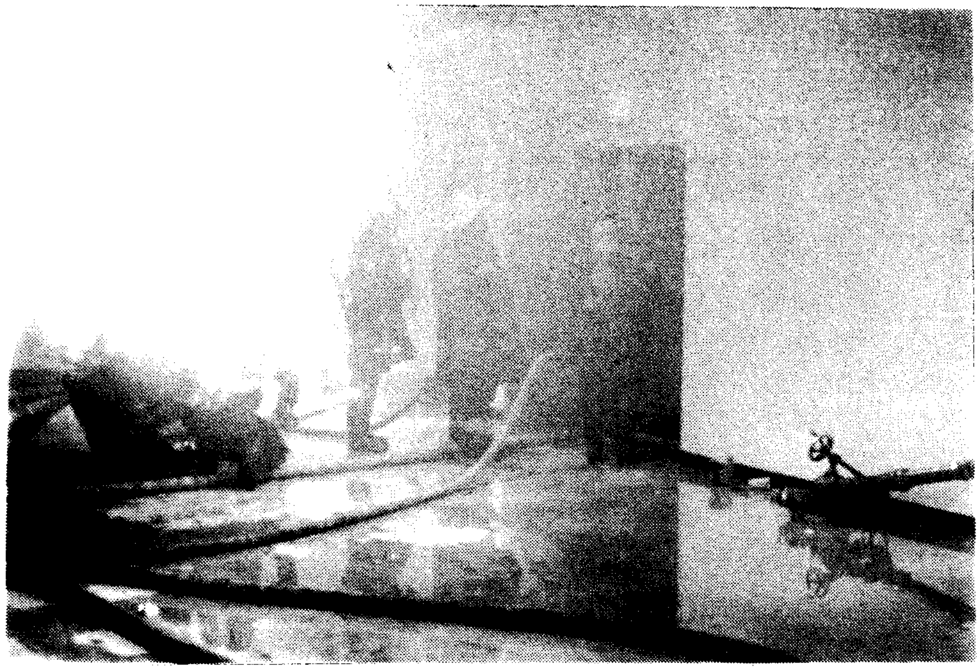


No. 59 - Test No. 2 fire ignited by the fire chief. View looking north.



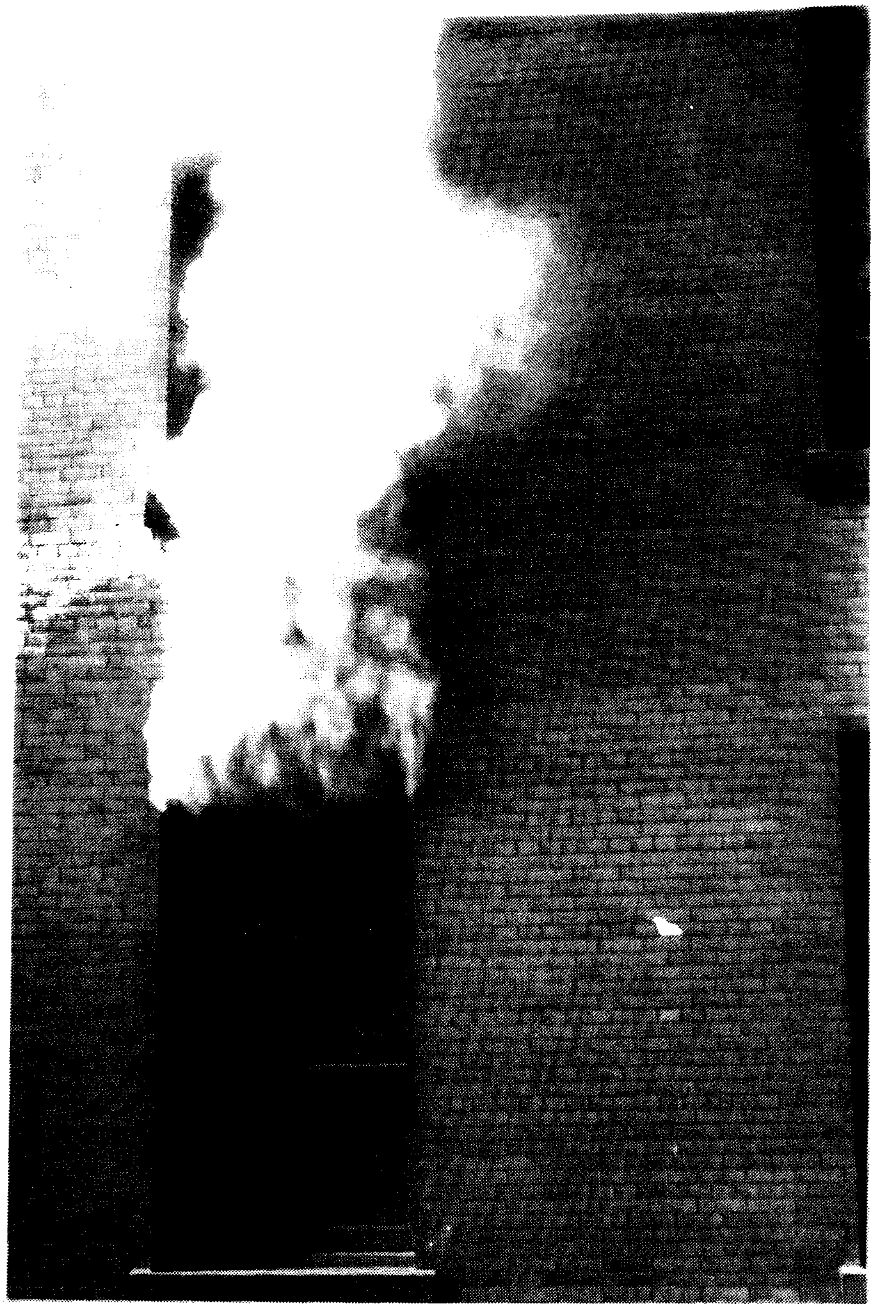
No. 60 - Test No. 2 fire under way.

No. 61 - Fire Test No. 2 - Observing early progress of the fire with firefighters standing by. Test stair is next to fire chief on the left. Double doors were opened later in test.



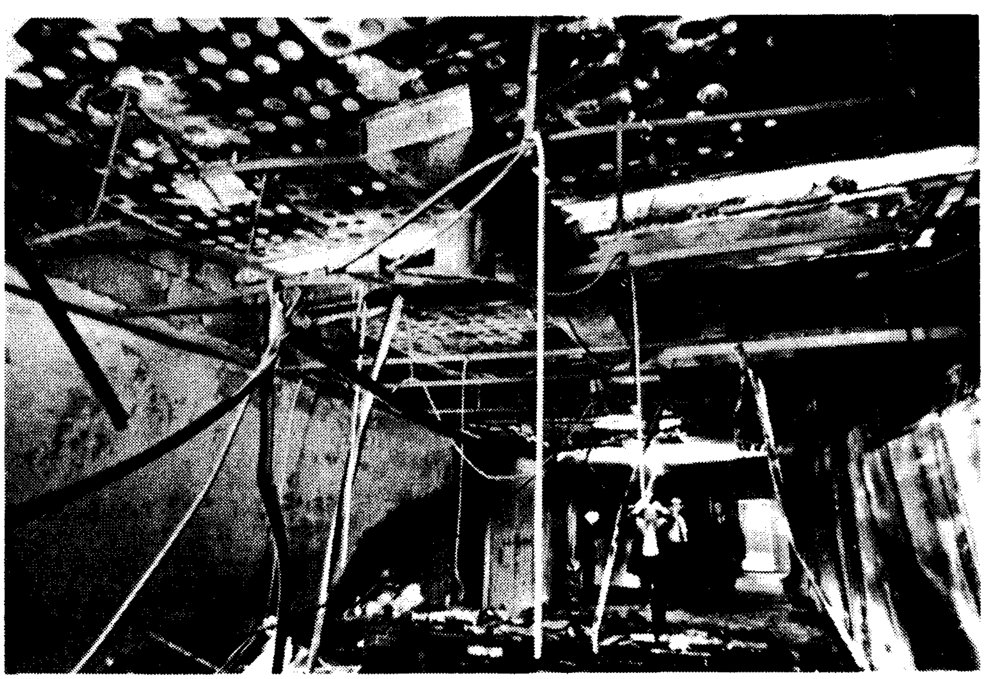
No. 63 - Fire Test No. 2 showing volume of smoke finding its way into center lobby. Note firefighters equipment ready for extinguishment.

No. 64 - Final extinguishment of fire for Test No. 2. View looking towards south end of room.



No. 62 - Fire Test No. 2 fire under way showing smoke escaping from a partly open window by way of the hung ceiling plenum.

No. 65 - After extinguishment of fire for Test No. 2 looking south. Note damage to wall adjacent to planned site for Fire Test No. 3.



No. 66 - After extinguishment of fire for Test No. 2 looking north. Note damage to wall on the right adjacent to planned site for Test No. 3.

No. 67 - Fire Test No. 2 showing close-up of damage to hung ceiling and to adjacent room partition on the left. View looking south.

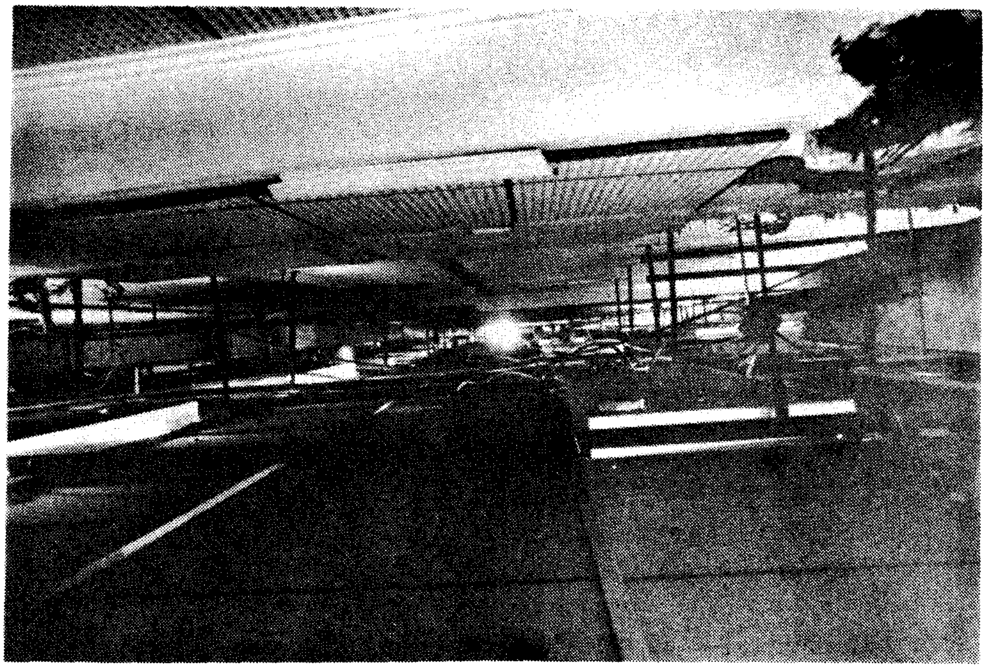
FIRE TEST NO. 3

No. 68 - Original site for Fire Test No. 3 can be seen in part through partition opening on the near left. View looking south in 10th floor south end of west wing.

No. 69 - Original site for fire for Test No. 3 as seen through near door on the right. View looking north. The area of fire Test No. 2 is seen on the left.

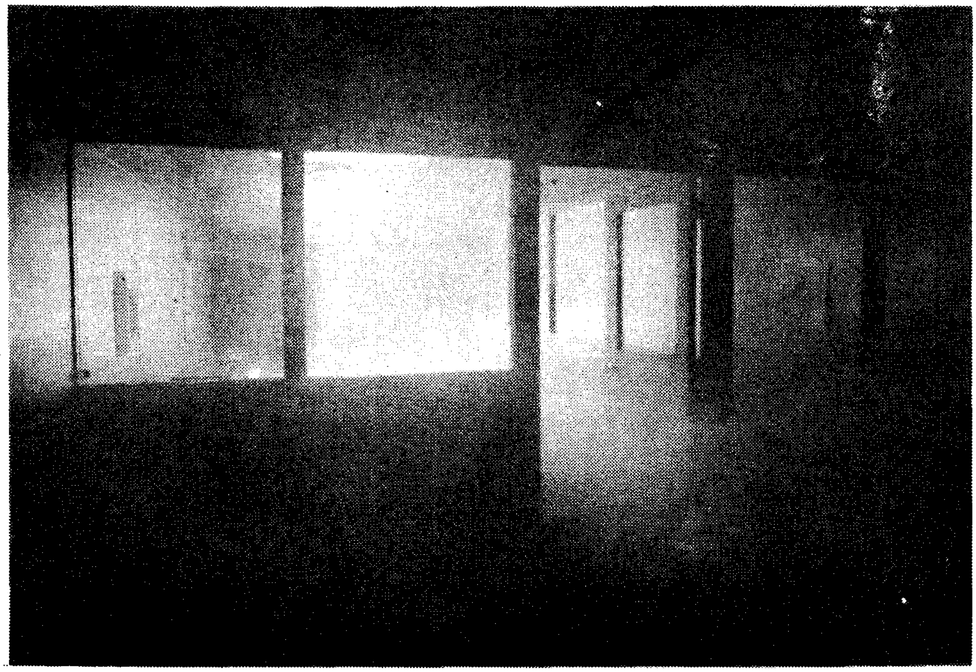
No. 70 - New site of fire test No. 3 at end of corridor from center lobby to east wing of 10th floor. Doors on right lead to location of hose connection to water spray lines.

No. 71 - Close-up view of the new site for Fire Test No. 3. Area is behind rear wall of photo in east wing of 10th floor. All ceiling tile replaced before test.



No. 72 - Plenum area showing construction over fire area for Test No. 3. View looking north along longitudinal axis of east wing 10th floor.

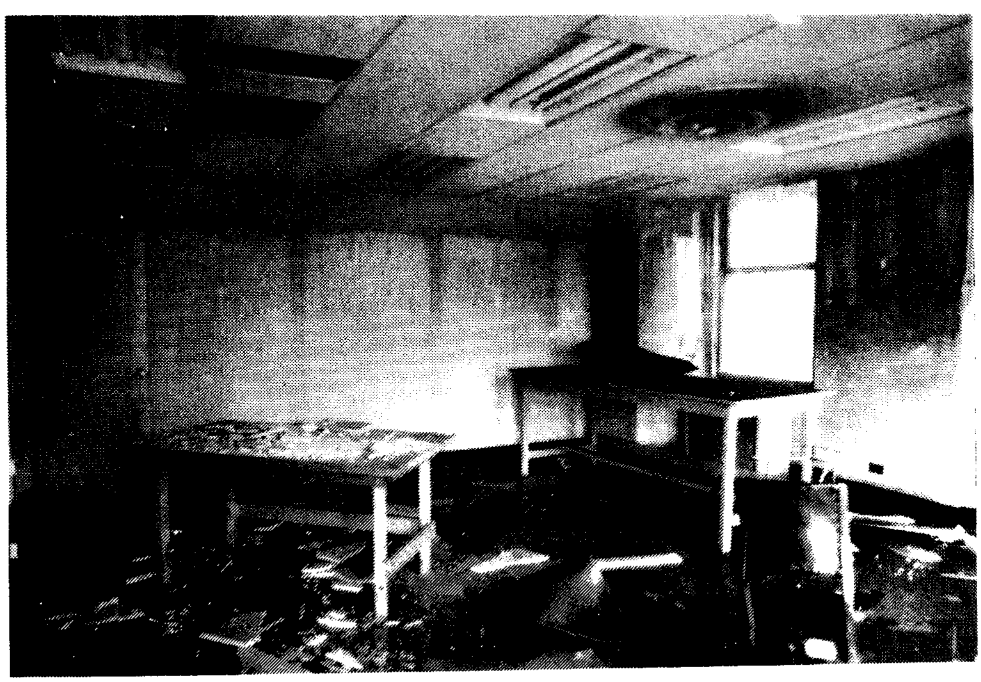
No. 73 - Test No. 3 fire area with fire load in place. Note one of two water spray lines in place below ceiling.



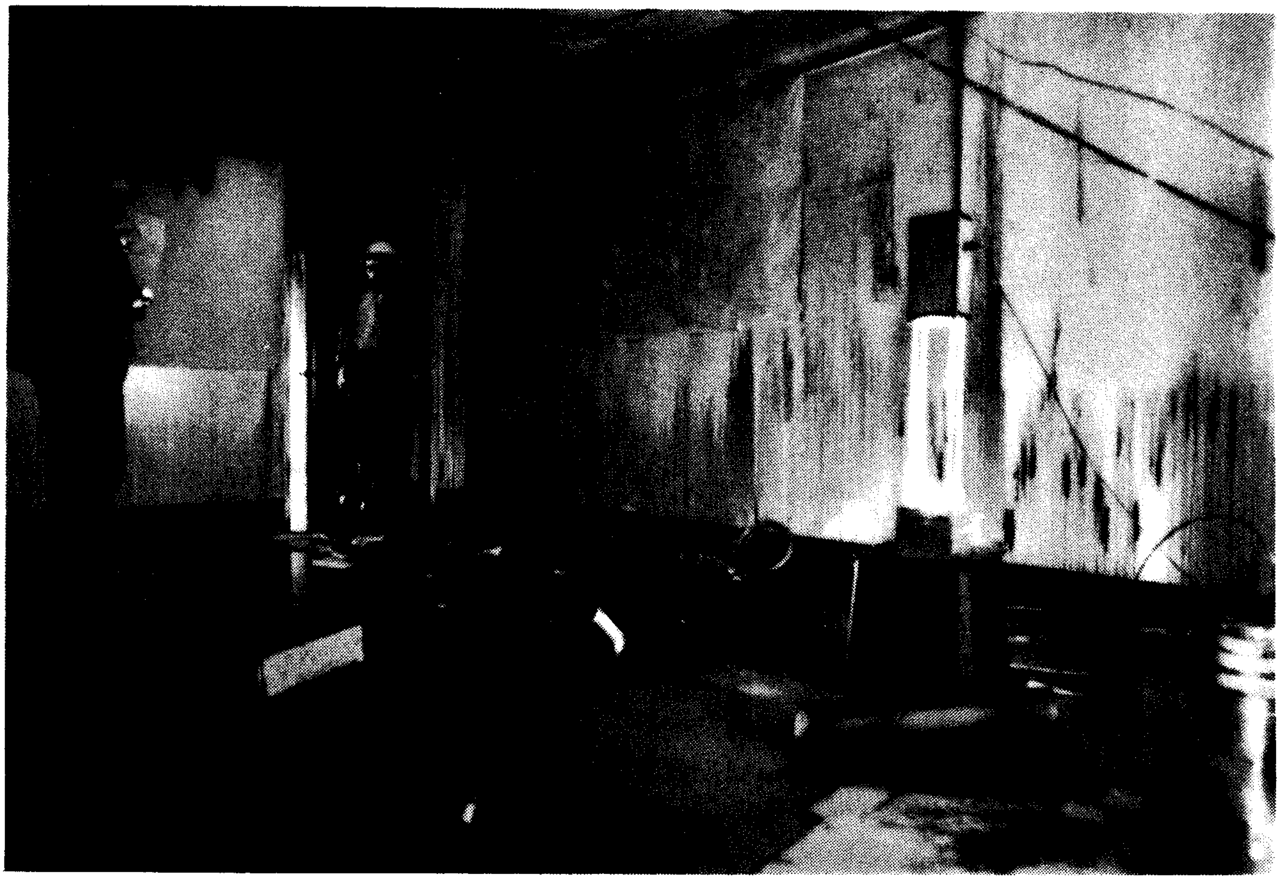
No. 74 - With the air conditioning system "on" showing rapid build-up of fire and smoke in Test Fire No. 3.

No. 75 - Fire Test No. 3 - Another photo showing the build up of smoke in area adjacent to the fire.

No. 76 - Fire Test No. 3 - showing impact of the fire in areas remote from the test fire site at north end of 10th floor east wing.

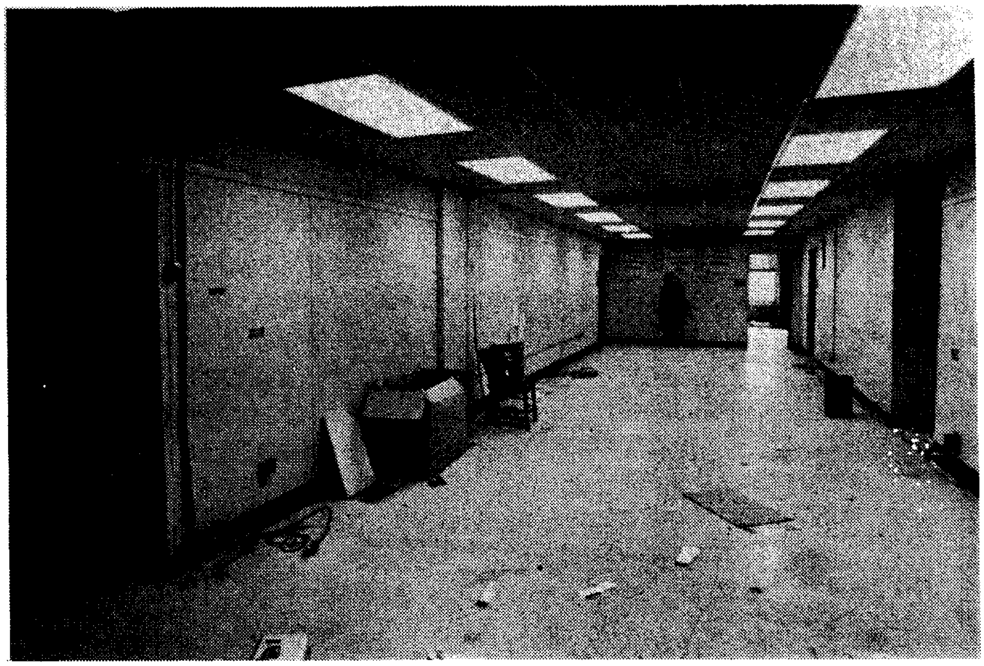


No. 77 - Fire Test No. 3 - additional evidence of the impact of the fire in another remote area at north end of 10th floor east wing.



No. 78 - Fire Test No. 3 - corner room at the north end of the east wing longitudinal corridor after extinguishment. Note smoke density indicator still in place.

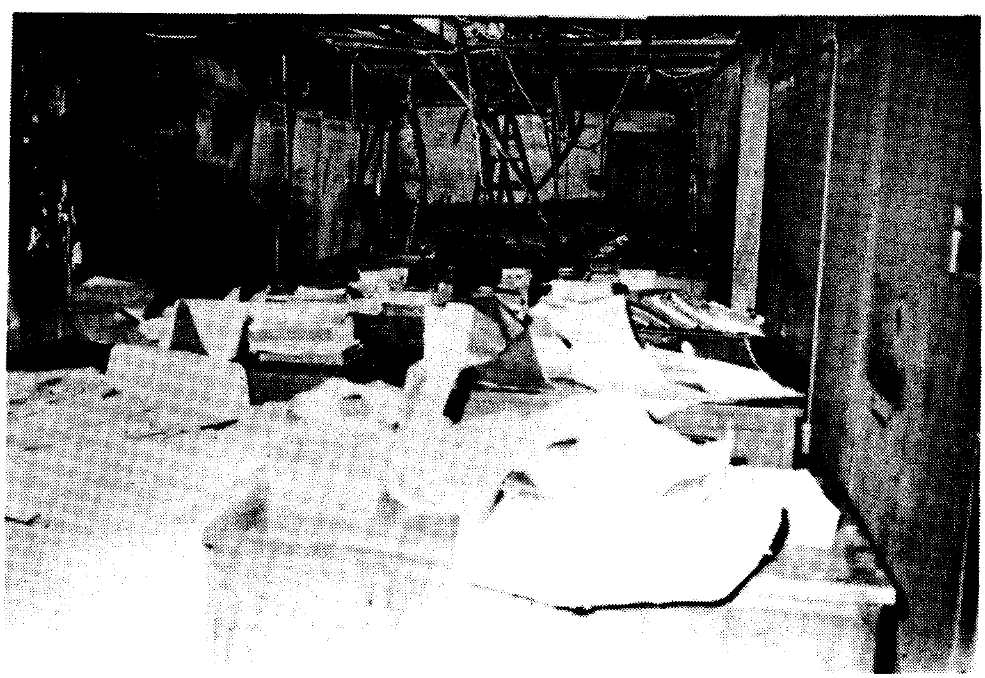
FIRE TEST NO. 4



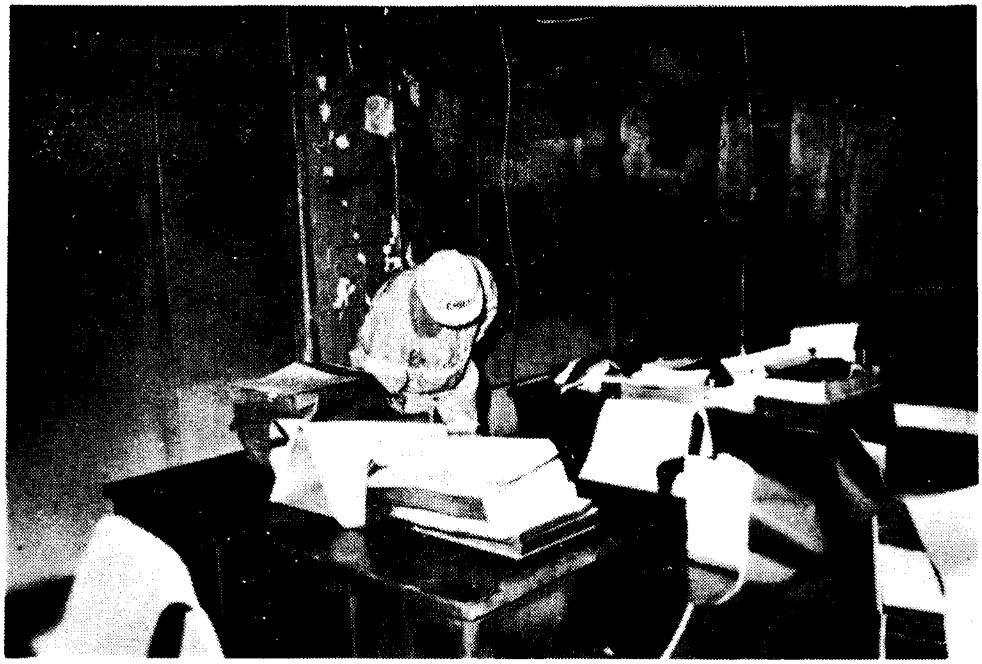
No. 79 - Fire for Test No. 4 was built in the space nearest the camera in the same 10th floor room in south end of west wing used for Fire Test No. 2.

No. 80 - Area nearest the camera utilized for Fire Test No. 4 shown after extinguishment of fire for test No. 2.

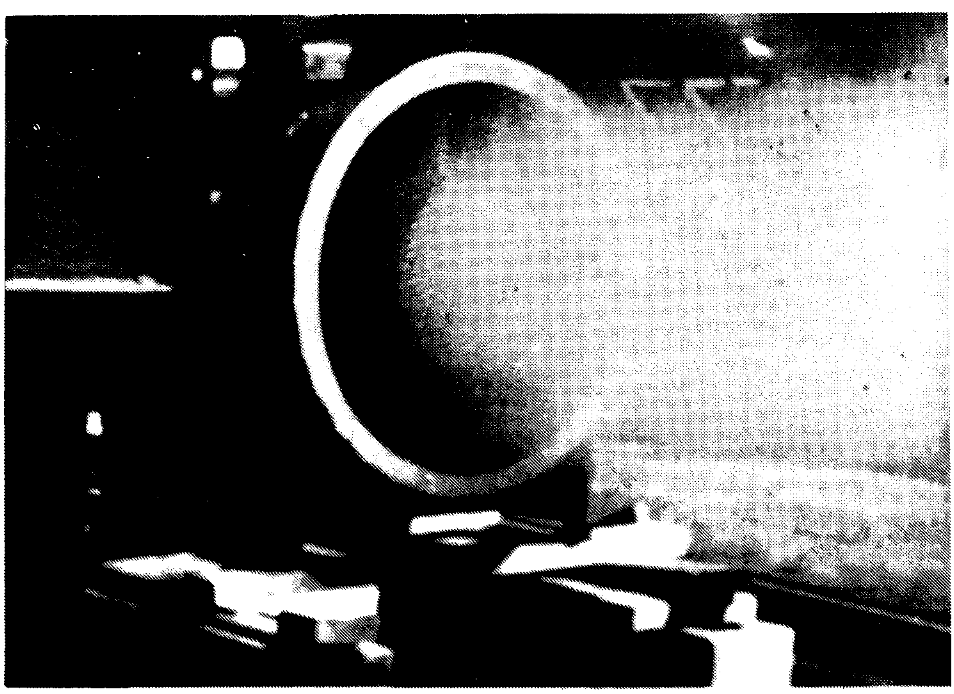
No. 81 - Test No. 4 - bulkhead between center lobby and south end of 10th floor west wing retained in place. Only the right hand water spray line was rebuilt and retained.



No. 82 - Test No. 4 fire load in place. Note burned out area of fire for Test No. 2 in background.



No. 83 - Test No. 4 fire ignition by the fire chief.



No. 84 - Test No. 4 showing exhaust from roof blower of smoke generated by 10th floor fire with use of stairwell as a smoke shaft.

APPENDIX C

FIRE DEPARTMENT DIRECTIVE re:

FIRE DRILL AND EVACUATION PLANS

Fire Drill and Evacuation Rules For Office Buildings And Buildings Classified As Occupancy Group E (Business)

(Effective August 7, 1972)

AUTHORITY - Chapter 19, Title A, Section 488 (3)-1.0-Fire Drills. The Fire Commissioner, in cases where provision is not otherwise made by law, is empowered in his discretion to require and compel the regular and periodic performance of a fire drill, including instruction and practice in the use of means of exit, alarm systems, and fire prevention or extinguishing methods and equipment, in all buildings, structures, enclosures, vessels, places and premises where numbers of persons work, live or congregate (except multiple dwellings).

APPLICATION - These rules shall apply to a building classified in section C26-306.1 of the Building Code as occupancy group E, occupied or arranged to be occupied for an occupant load of more than one hundred persons above or below the street level or more than a total of five hundred persons in the entire building and any existing office building with an occupant load as hereinabove provided.

DEFINITION OF FIRE DRILL AND EVACUATION - The method and practice of the systematic, safe and orderly evacuation of an area or building by and of its occupants in case of fire in the least possible time; also the use of such available fire appliances (including sounding of alarms) as may have been provided for the controlling or extinguishing of fire and the safeguarding of human life.

OBJECTIVE - To provide proper education as a part of continuing employee indoctrination and, through a continuing written program for all occupants, to assure the prompt reporting of fire, the response to fire alarms as designated and the immediate initiation of the fire safety procedures to safeguard life and contain fire until the arrival of the Fire Department.

RULE 1 - RESPONSIBILITIES

a. Owner or other person having charge of the building shall:

(1) Be responsible for providing for fire safety and the conduct of fire drills therein in accordance with these rules.

(2) Be responsible for development of a written Fire Safety Plan providing for fire drill and evacuation procedures in accordance with these rules.

(3) Designate an employee as Fire Safety Director, holding a Certificate of Fitness qualifying him to perform duties specified under subdivision b below.

(4) Designate one or more employees holding a Certificate of Fitness qualifying him to perform duties specified in subdivision b below, to act as Deputy Fire Safety Director.

(5) Insure that during normal working or business hours, when the building is occupied by more than one hundred persons above or below the street level or more than a total of five hundred persons in the entire building, there shall be at least one person on duty in the building as Fire Safety Director holding a Certificate of Fitness. He shall be qualified to conduct fire drills, evacuations and related activities such as organizing, training and supervising a fire brigade. During fire emergencies, the primary responsibility of the Fire Safety Director shall be the supervision and manning of a Fire Command Station and the direction and execution of the evacuation as provided in the Fire Safety Plan. Such activities shall be subject to Fire Department control.

For purposes of these rules, normal working or business hours shall be construed to mean scheduled or designated periods of time during which work is performed or business is conducted.

(6) Insure that at all times other than normal working or business hours, when there are occupants in the building and there is no Fire Safety Director on duty in the building, there shall be at least one person on duty as Building Evacuation Supervisor. He shall be capable of directing the evacuation of the occupants as provided for in the Fire Safety Plan. During fire emergencies, the primary responsibility of the Building Evacuation Supervisor shall be the manning of a Fire Command Station and the direction and execution of the evacuation as provided in the Fire Safety Plan. His training and related activities shall be under the direction of the Fire Safety Director in accordance with the requirements of these Rules and the Fire Safety Plan. Such activities shall be subject to Fire Department control.

b. Fire Safety Director.

The Fire Safety Director shall:

(1) Be familiar with the written Fire Safety Plan providing for fire drill and evacuation procedure in accordance with these rules.

(2) Select qualified building service employees for a Fire Brigade and organize, train and supervise such Fire Brigade.

(3) Be responsible for the availability and state of readiness of the Fire Brigade.

(4) Conduct fire and evacuation drills.

(5) Be responsible for the designation of a Fire Warden for each floor and sufficient Deputy Fire Wardens for each tenancy in accordance with these rules.

(6) Be responsible for a daily check for the availability of the Fire Warden and Deputy Fire Wardens.

(7) Notify the owner or other person having charge of the building when any designated individual is neglecting his responsibilities contained

in the Fire Safety Plan. The owner or other person in charge of the building shall bring the matter to attention of the firm employing the individual. If the firm fails to correct the condition, the Fire Department shall be notified by the owner or person in charge of the building.

(8) In event of a fire, shall report to the Fire Command Station to supervise, provide for and coordinate:

(a) Manning of the Fire Command Station.

(b) Direction of evacuation procedures as provided in the Fire Safety Plan.

(c) Reports on conditions on fire floor for information of Fire Department on their arrival.

(d) Advise the Fire Department Chief-in-Charge in the operation of the Fire Command Station.

(e) Ensure that the Fire Department has been notified of any fire or fire alarm.

(9) Be responsible for the training and activities of the Building Evacuation Supervisor.

c. Fire Wardens and Deputy Fire Wardens.

(1) The tenant or tenants of each floor shall, upon request of the owner or person in charge of the building, make responsible and dependable employees available for designation by the Fire Safety Director as Fire Warden and Deputy Fire Wardens.

(2) Each floor of a building shall be under the direction of a designated Fire Warden for the evacuation of occupants in the event of fire. He shall be assisted in his duties by Deputy Fire Wardens. A Deputy Fire Warden shall be provided for each tenancy. When the floor area of a tenancy exceeds 7,500 square feet of occupiable space, a Deputy Warden shall be

assigned for each such 7,500 square feet or part thereof.

(3) Each Fire Warden and Deputy Fire Warden shall be familiar with the Fire Safety Plan, the location of exits and the location and operation of any available fire alarm system.

(4) In the event of fire or fire alarm the Fire Warden shall:

(a) Ascertain location of the fire.

(b) Direct the evacuation of the floor in accordance with directions received and the following guidelines:

(i) If the elevators servicing his floor also service the fire floor, they shall not be used. However, elevators may be used if there is more than one bank of elevators, and he is informed from the Fire Command Station that one bank is unaffected by the fire.

(ii) If elevators do not service the fire floor and their shafts have no openings on the fire floor, they may be used, unless otherwise directed.

(iii) Elevators manned by trained building personnel or firemen may also be used.

(iv) In the absence of a serviceable elevator the Fire Warden shall select the safest stairway to use for evacuation on the basis of the location of the fire and any information received from the Fire Command Station. The Fire Warden shall check the environment in the stair prior to entry for evacuation. If it is affected by smoke, an alternate stair shall be selected and the Fire Command Station notified.

(v) The Fire Warden shall keep the Fire Command Station informed of the means being employed for evacuation by the occupants of his floor.

(vi) The most critical areas for immediate evacuation are the fire floor and the floors immediately above. Evacuation from the other floors shall be instituted when instructions from the Fire Command Station or conditions indicates such action. Evacuation should be via uncontaminated stairs. He shall try to avoid stairs being used by the Fire Department. If this is not possible, he shall try to attract the attention of the Fire Department personnel before such personnel open the door to the fire floor.

(vii) Evacuation to two or more levels below the fire floor is generally adequate. He shall keep the Fire Command Station informed regarding his location.

(viii) Fire Wardens and their Deputies shall see that all occupants are notified of the fire, and that they proceed immediately to execute the fire safety plan.

(ix) The Fire Warden on the fire floor shall, as soon as practicable, notify the Fire Command Station of the particulars.

(x) Fire Wardens on floor above the fire shall, after executing the Fire Safety Plan, notify the Fire Command Station of the means being used for evacuation and any other particulars.

d. Fire Brigade.

(1) On the receipt of an alarm for fire, the fire brigade shall:

(a) Report to the floor below the fire to assist in evacuation and provide information to the Fire Command Station.

(b) After evacuation of fire floor, endeavor to control spread of the fire by closing doors etc.

(c) Attempt to control the fire until arrival of the Fire Department, if the fire is small and conditions do not pose a personal threat.

(d) Leave one member on the floor below the fire to direct the Fire Department to the fire location and to inform them of conditions.

(e) On arrival of the Fire Department the fire brigade shall report to the Fire Command Station for additional instructions.

RULE 2-ALARMS

Any person discovering fire, heat or smoke shall immediately report such condition to the Fire Department unless he has personal knowledge that such a report has been made. No person shall make, issue, post or maintain any regulation or order, written or verbal, that would require any person to take any unnecessary delaying action prior to reporting such condition to the Fire department.

RULE 3-DRILLS

a. Fire drills shall be conducted, in accordance with the Fire Safety Plan, at least once every three months for existing buildings during the first two years after the effective date of these rules, or for new buildings during the first two years after the issuance of the certificate of occupancy. Thereafter, fire drills shall be conducted at least once every six months.

b. All occupants of the building shall participate in the fire drill. However, occupants of the building, other than building service employees, are not required to leave the floor or use the exits during the drill.

c. A written record of such drills shall be kept on the premises for a three year period and shall be ready available for Fire Department Inspection.

RULE 4-SIGNS AND PLANS

a. Signs at elevator landings- A sign shall be posted and maintained in a conspicuous place on every floor at or near the elevator landing in accordance with the requirements of the Fire Department, indicating that in case of fire, occupants shall use the stairs unless otherwise instructed. The sign shall contain a diagram showing the location of the stairways except that such diagram may be omitted provided that signs containing such diagram are posted in conspicuous places on the respective floor.

b. Floor numbering signs- A sign shall be posted and maintained within each stair enclosure on every floor, indicating the number of the floor, in accordance with the requirements of the Fire Department.

c. Stair and elevator identification signs- Each stairway and each elevator bank shall be identified by an alphabetical letter. A sign indicating the letter of identification shall be posted and maintained at each elevator landing and on the side of the stairway door from which egress is to be made, in accordance with the requirements of the Fire Department.

d. Stair re-entry signs - A sign shall be posted and maintained on each floor within each stairway and on the occupancy side of the stairway where required, indicating whether re-entry is provided into the building and the floor where such re-entry is provided, in accordance with the requirements of the Fire Department.

e. Fire Command Station shall be provided with floor plan of the building and other pertinent information relative to the service equipment of the building.

RULE 5-FIRE SAFETY PLAN

a. The Fire Safety Plan shall include but not be limited to the requirements of these Rules.

b. Within ninety days after the adoption and publication of these Rules the owner or other person having charge of an existing office building or an existing building in occupancy Group E as classified in the Building Code, and designed to be occupied by more than 500 people or by more than 100 people above or below street level, shall submit their Fire Safety Plan to the Fire Department for approval.

c. The owner or other person having charge of a hereafter erected building in occupancy Group E as classified in the Building Code and designed to be occupied by more than 500 people or by more than 100 people above or below street level shall submit their Fire Safety Plan to the Fire Department prior to issuance of temporary or permanent Certificate of Occupancy.

d. The applicable parts of the approved Fire Safety Plan shall be distributed to all tenants of the building by the building management when the Fire Safety Plan has been approved by the Fire Commissioner.

e. The applicable parts of the approved Fire Safety Plan shall then be distributed by the tenants to all their employees and by the building management to all their building employees.

f. Where the owner of the building is also an occupant of the building he shall be responsible for the observance of these Rules and the Fire Safety Plan in the same manner as a tenant.

g. All occupants of the building shall participate and cooperate in carrying out the provisions of the Fire Safety Plan.

h. In the event there are changes from conditions existing at the time the Fire Safety Plan for the building was approved, and the changes are such so as to require amending the Fire Safety Plan, within 30 days after such changes, an amended Fire Safety Plan shall be submitted to the Fire Department for approval.

RULE 6-FIRE COMMAND STATION

A Fire Command Station shall be established in the lobby of the building on the entrance floor. Such command station shall be adequately illuminated.

RULE 7-COMMUNICATIONS AND FIRE ALARM

A means of communication and fire alarm for use during fire emergencies shall be provided and maintained by the owner or person in charge of the building.

RULE 8-VARIATIONS

In buildings where compliance would cause practical difficulty or undue hardship, the Commissioner, at his discretion, may waive or modify the requirements of these Rules and accept alternatives fulfilling the intent of these requirements consistent with public safety.

NOTE: Pending the adoption of legislation which will contain specific requirements for Fire Command Stations, Communications and Fire Alarm Systems, the Fire Department will accept the following:

Fire Command Station

A location on the ground floor with communication to the mechanical equipment room, elevator control room and each floor of the building.

Communication & Alarm Systems

Telephones, walkie talkies or other means of communication which will allow tenants to report a fire directly, notify other occupants of the alarm, and will allow the Fire Safety Director to direct the evacuation and receive status reports of the fire.

Building owners should not install any communication and alarm system or fire command station equipment without consulting the Fire Department. This is designed to avoid the unnecessary expense involved with installing equipment that may not be acceptable under the proposed legislation.

ROBERT O. LOWERY, Fire Commissioner

FIRE DEPARTMENT
110 Church Street
New York, N. Y. 10007

Revised 7/1/72

Revised Sign Specifications - N. Y. Fire Drill and Evacuation Rules

A. Signs at elevator landings.

A sign shall be posted and maintained on every floor at the elevator landing. The sign shall read " IN CASE OF FIRE, USE STAIRS UNLESS OTHERWISE INSTRUCTED". The lettering shall be at least one-half inch block letters in red and white background or as otherwise approved by the Commissioner. Such lettering shall be properly spaced to provide good legibility. The sign shall also contain a diagram showing the location where it is posted and the location and letter identification of the stairs on the floor. The sign shall be at least ten inches by twelve inches, located directly above a call button and securely attached to the wall or partition. The top of such sign shall not be above six feet from the floor level. The diagram on such sign may be omitted, provided that signs containing such diagram are posted in conspicuous places on the respective floor. In such case, the sign at the elevator landing shall be at least two and one-half inches by ten inches and the diagram signs shall be at least eight inches by twelve inches.

B. Floor numbering signs.

A sign shall be posted and maintained within each stair enclosure on every floor, indicating the number of the floor. The numerals shall be of bold type and at least three inches high. The numerals and background shall be in contrasting colors. The sign shall be securely attached to the stair side of the door.

C. Stair and elevator identification signs.

Each stair and each bank of elevators shall be identified by an alphabetic letter. A sign indicating the letter of identification for the elevator bank shall be posted and maintained at each elevator landing directly above or as part of the sign specified in section A (Sign at elevator landings) above. The stair identification sign shall be posted and maintained on the occupancy side of the stair door. The letter on the sign shall be at least three inches high, of bold type and of contrasting color from the background. Such signs shall be securely attached.

D. Stair re-entry signs.

Signs shall be posted and maintained on the stair door at each floor indicating whether re-entry is provided into the building and the floor where such re-entry is provided. The lettering and numerals of the signs shall be at least one-half inch high of bold type. The lettering and background shall be of contrasting colors and the signs shall be securely attached approximately five feet above the floor. The signs shall read as follows and may be either independent or combined with the corresponding sign required by section B (Floor numbering signs) and section C (Stair and elevator identification signs).

(a) Where no re-entry is provided from the stairs to any floor, the sign shall read "NO RE-ENTRY FROM THIS STAIR" and such sign shall be on the occupancy side of the stair door at each floor. No re-entry sign shall be required on the stair side of the door.

(b) Where re-entry is provided to specified floors:

(1) On the stair side of the door at floors where re-entry is provided, the sign shall read "RE-ENTRY ON THIS FLOOR".

(2) Where no re-entry is provided on that floor, the sign on the stair side of the door shall read "NO RE-ENTRY, NEAREST

RE-ENTRY ON THE ____ AND _____ FLOORS". The floor numbers of the nearest re-entry floor below and the nearest re-entry floor above shall be entered in the blank spaces.

E. Material for signs.

Signs required by these specifications shall be of metal, or other durable material.

The material of the stair re-entry signs may be of temporary nature, pending the passage of applicable legislation.

FIRE DEPARTMENT
110 Church Street
New York, N. Y. 10007

Revised 7/1/72

FIRE SAFETY PLAN GUIDELINES

PLAN PREPARATION GUIDELINES:

Since there are many non-uniform physical characteristics in the varied types of office building a standard single plan can not be specified for all buildings. A specific plan must be developed for each building but basic guidelines can substantially assist in the development of a plan for any particular building. In addition to the Fire Department Rules, some of these guides are as follows:

A. Fire Safety Director

The owner or person in charge shall designate personnel to serve as a Fire Safety Director who shall be responsible for the development of and mainenance of a continuing fire safety program in accordance with the requirement of the Fire Department Rules. In addition, he shall:

(1) Be responsible for training of Fire Wardens and Deputy Fire Wardens.

(2) Establish and supervise a fire prevention program.

(3) In the event of a fire, be prepared to advise the Fire Department Officer in Command relative to controls and operation of the air-conditioning and/or mechanical ventilation system, other service equipment of the building and other application information pertaining to the building.

(4) In planning, evaluate the individual floor layouts, the population of floors, the number and kinds of exits, the zoning of the floor by area and occupants and then determining the movement of

traffic by the most expeditious route to an appropriate exit. He must also determine alternative route for each zone since under fire conditions one or more exits may not be useable and an alternate must be provided.

(5) Make provisions for periodic testing of communication system.

(6) Make provision in Fire Safety Plan for activities of Building Evacuation Supervisor. See section B for such activities and qualifications.

(7) The Fire Safety Director is responsible for a daily check for the availability of the Fire Wardens and Deputy Fire Wardens. If the number of Fire Wardens and Deputy Fire Wardens in the building is such that it is impractical to individually contact each one daily, a suggested method to satisfy the requirement is to make provisions for the Fire Warden, or a Deputy Fire Warden in the absence of the Fire Warden, to notify the Fire Safety Director when the Fire Warden or required number of Deputy Fire Warden is not available. In order to determine the compliance by the Fire Warden and Deputy Fire Wardens when this method is used, the Fire Safety Director shall make a spot check of several different floors each day.

B. Building Evacuation Supervisor

A Building Evacuation Supervisor is required at all times, other than normal working or business hours, when there are occupants in the building, and there is no Fire Safety Director on duty in the building. His activities and training are part of the responsibilities of the Fire Safety Director.

(1) Responsibilities: Conduct fire emergency evacuation; Supervise a fire brigade, where applicable; Supervise and man a fire command station for implementation and direction of evacuation

procedures in building under his control in accordance with applicable provision of Fire Department Rules and Fire Safety Plan.

(2) Qualifications:

(a) Shall be at least 18 years of age.

(b) Reasonable understanding of English language.

(c) Be of good character, habits and past employment.

(d) Be physically able to perform required duties.

(e) Be sufficiently familiar with the characteristics, service equipment, occupancy, and Fire Safety Plan of the building under his control so as to be able to satisfactorily perform his responsibilities.

C. Fire Wardens and Deputy Fire Wardens

In addition to the requirements in the Fire Department Rules:

(1) Review and study the floor plan for each floor, the number of floor occupants and the number of exits for the purpose of dividing the population into groups or squads and to formulate the traffic pattern for each group or squad to primary and secondary exits.

(2) Daily, throughout the occupancy of the floor, examine and determine that all fire doors to stairs are maintained in the closed position and that no doors are obstructed or inoperable or locked in violation of law, rule or regulations.

(3) Have available an updated listing of all personnel with physical disabilities who cannot use stairs unaided. Make arrangements to have these occupants assisted in moving down the stairs to 2 or more levels below fire floor. If necessary to move such occupants to still lower levels during the fire, move them down

the stairs to the uppermost floor served by an uninvolved elevator bank and then removed to street floor by elevator. Where assistance is required for such evacuation, notify Fire Safety Director.

(4) In case of fire, ascertain if alarm had been transmitted, and Fire Safety Director notified.

(5) Provide for fire warden identification during fire drills and fires, such as using armband, etc.

(6) Take any action necessary to prevent panic.

(7) Assure that all persons on the floor are notified of fire and all are evacuated to safe areas. A search must be conducted in the lavatories to assure all are out. Personnel assigned as searchers can promptly and efficiently perform this duty.

(8) Check availability of applicable personnel on Table of Organization Chart and provide for substitute when position on chart is not covered.

(9) After evacuation, perform a head count to assure that all regular occupants known to have occupied the floor have been evacuated.

(10) When alarm is received, the Fire Warden shall remain at a selected position in the vicinity of the communication station on the floor, in order to maintain communication with the Fire Command Station and to receive and give instructions.

D. Fire Brigade

In addition to the requirements of the Fire Department Rules see function under Item E (2) (Alarm Transmission).

E. Alarm Transmission

In addition to the requirements of the Fire Department Rules

(1) Any person discovering fire or smoke shall without delay cause the transmission of an alarm of fire by any of the following methods available:

(a) Telephone

(b) Building Fire Alarm Box Connected to Fire Department, if building is so equipped.

(c) Street Fire Alarm Box

(d) Interior Fire Alarm System, if building is so equipped. However, also notify Fire Department,

NOTE - Also notify the Fire and/or Deputy Fire Warden that alarm has been transmitted.

(2) A member of the fire brigade shall be assigned the task of alarm box runner who shall know the location of the nearest street alarm box and how to transmit an alarm therefrom. Such member shall immediately, upon receipt of information that there is a fire of evidence of fire, go to the street alarm box, transmit an alarm and await the arrival of the fire department and direct such department to the fire.

F. Fire Drills

In addition to the requirements of the Fire Department Rules:

(1) A record of each drill shall be maintained and each drill evaluated by the Fire Safety Director for the purpose of improving the method of promptly evacuating the floor and/or building.

(2) Emphasis should be placed on orderly evacuation under proper discipline rather than on speed. No running should be permitted.

G. Fire Prevention Program

(1) Periodic formal inspections of each floor area, including exit facilities, fire extinguishers and housekeeping shall be developed:

(a) A daily early check of each exit shall be required to determine that self-closing doors are in the closed position but are not illegally locked in any manner. No obstructions shall be permitted in corridors or aisle spaces.

Necessary exit signs and lights where required, shall be lighted and in good condition.

(b) The location and operation of fire extinguishers shall be known by all personnel. The maintenance shall be controlled by the Fire Safety Director.

(c) Poor housekeeping is a fire breeder. All establishments shall avoid accumulation of combustible debris (paper, cardboard, etc.).

H. Liaison with Fire Department

Develop a close communication with Fire Department for aid in developing and improving the Fire Safety Plan. Keep such department informed about special conditions in the building, the storage of combustibles or chemicals and other related items. In addition to this general guide, additional information can be obtained from the Fire Department.

I. Table of Organization Chart

A chart designating employees and their assignments, shall be prepared and posted in a conspicuous place in each tenancy and on each floor of a tenancy that occupies more than one floor and a copy kept by the Fire Safety Directors. Suggested format for this chart, as attached.

J. Stair Doors

Where presently not required by law, regulation or rule, it is recommended for buildings not constructed under the new Building Code, that doors opening into interior stair enclosures should not be locked from either side with the following exceptions:

(1) Doors may be locked to prevent access to the stair at the street floor.

(2) In buildings less than 100 feet in height, the stair doors may be locked on the stair side on each floor above the street floor.

(3) In buildings 100 feet or more in height, the stair door may be locked on the stair side above street floor except that at intervals of four stories or less, stair doors should remain openable from the stair side without the use of a key to permit re-entry at such floors.

In addition where there are elevators whose lowest terminal landing is above the street floor, the stair doors on the floor of such terminal landing should remain openable from the stair side without the use of a key to permit re-entry at such floor.

ORGANIZATION CHART FOR FIRE DRILL AND EVACUATION ASSIGNMENT

BUILDING SAFETY DIRECTOR

____

DEPUTY SAFETY DIRECTOR

____

____________________ FLOOR

FIRE WARDEN

____

DEPUTY FIRE WARDENS

________________________ ________________________

________________________ ________________________

SEARCHERS

MALE____________________ FEMALE____________________

________________________ ________________________

ALARM TRANSMISSION:

Any person discovering fire or smoke should without delay cause the transmission of an alarm of fire by any of the following methods available.

1. Telephone (Call#911 to report fire.)
2. Street Alarm Box.
3. Building Fire Alarms. If building fire alarm not connected to central station, also notify Fire Department.

NOTE: Also notify Fire and/or Deputy Fire Wardens that alarm has been transmitted.

APPENDIX D

FIRE DEPARTMENT ADVISORY PROVISIONS

re: OFFICE FURNITURE & FURNISHINGS

ADVISORY SAFETY PROVISIONS

OFFICE FURNITURE & FURNISHINGS

In all offices, conference rooms, waiting rooms, assembly areas and similar spaces, it is recommended that all furniture and furnishings should be of fire resistive quality in accordance with the following requirements.

1. Furniture.

(a) All furniture such as desks, tables, wardrobes, cabinets, bookcases, etc., should be constructed entirely of noncombustible materials or fire retardant treated wood except that a combustible veneer not exceeding one-eight inch may be used on the top surface of such articles.

(b) All free standing chairs, sofas, coat racks, etc., should be constructed with frames of noncombustible materials or fire retardant treated wood.

(c) Wastepaper baskets should be constructed of non-combustible materials with solid sides and bottom.

(d) All upholstery materials including covering, lining, webbing, cushioning and padding, should be self-extinguishing as defined by Federal Specification ccc-T-191 b Method 5903.

(e) All self-supporting plastic materials should be self-extinguishing as defined by the "Standard Method of Test for Flammability of Self-Supporting Plastics," ASTM Designation: D 635-68.

(f) Where the item contains other than noncombustible materials, the manufacturer should submit a copy of a certification* of the service life of the flame retardancy of the treated material or a certification* that the self-extinguishing properties of the material are inherent therein by virtue of the chemical properties of the material. Materials which are not of at least 30 minutes, with no evidence of significant progressive combustion.

(6) In all testing procedures, except as noted in (2) above, the thickness of the materials and of the composite assemblies tested should be the same as the thickness used in the finished item. Certifications submitted by the manufacturer should indicate the thickness of the tested materials.

(b) Draperies and Curtains.

All drapery and curtain materials should meet the requirements of Rules 4.0 (Flameproofing Properties) and Rule 5.0 (Tests) of the Board of Standards and Appeals Rules for Test of Fire Resistive Flameproofed Materials (Cal. No. 294-40-SR). Such tests should indicate that after flameproofing, such processing as ironing, sewing, and normal handling should have no detrimental effects on the treatment of the material and treated materials should have maintained their flameproofed properties after 12 washings and/or dry cleanings. The washing test procedure is to be performed as defined by the Technical Manual of the American Association of Textile Chemists and Colorists (AATCC) Test Method 124-1969 using the wash temperature of 120 ± 5F and the "Tumble Dry" procedure. The dry cleaning test procedure is to be performed by subjecting the material to dry cleaning in a "Coin-Op" machine as manufactured by Norge or Westinghouse or an equal machine.

(c) Carpeting and Rugs

(1) All carpeting, backing and underlayments should pass the methanamine pill test (Department of Commerce Standard FF-1-70).

(2) Only noncombustible floor coverings are recommended for exits, as defined in the Building Code.

(3) Carpeting assemblies representative of the actual installation on floor areas of corridors should not have a flame spread rating greater than 75. The smoke developed rating of carpets in corridors should not exceed 100.

(4) Flame spread ratings for carpet assemblies in general areas should not exceed 150 for areas less than 1,000 square feet and should not exceed 100 for areas over 1,000 square feet. The smoke developed rating should not exceed 200.

(5) The ratings, specified in items (2), (3) and (4) above, should be obtained in accordance with the requirements of ASTM E-84-70 "Standard Method of Test for Surface Burning Characteristics of Building Materials".

However, in lieu of using the ASTM E-84 test method to determine the flame spread rating and/or the smoke developed rating for carpets <u>other than in exits and corridors,</u> the following tests and indices may be utilized. The radiant panel test method, ASTM E162-67, may be used to arrive at the flame spread rating. The rating obtained from using this test should comply with the requirements of paragraph (4) above. However, when the radiant panal test is used to obtain the flame spread rating for carpets other than in exits and corridors, the smoke developed rating should be obtained by the National Bureau of Standards Smoke Density Chamber Test as described in "ASTM Special Technical Publication No. 422." If this test is used, the smoke developed rating, when taken as an arithmetical mean of the "flaming" and "smoldering" tests, should not exceed 300; and the individual results of each test should not exceed 375.

* The certification referred to should be made by an independent

testing laboratory.

If you will retain all manufacturers certifications on your premises, Fire Department personnel will be glad to review them with you.

September 1971

ADVISORY SAFETY PROVISIONS

FIRE LOAD INFORMATION

It is possible to measure and express the relative degree of fire resistance afforded by building materials, assemblies, and systems in terms of length of time, in hours, that a material or a composite is capable of resisting exposure to a standard fire of controlled extent and severity, before a certain critical point is reached.

Also, it is possible to express the severity of a fire hazard represented by a given weight of combustible material in the same terms.

Therefore, there exists a means of correlating fire hazard and fire protection.

The National Bureau of Standards (U.S. Department of Commerce), based upon tests conducted many years ago, showed that the relationship between the amount of combustible present (in pounds per square foot of floor area) and the fire severity (in hours of fire exposure according to a standard fire test specification) is approximately as follows:

Average Weight of Combustibles (PSF)	Equivalent Fire Severity (Hours)
5	1/2
7 1/2	3/4
10	1
15	1 1/2
20	2
30	3
40	4 1/2
50	6
60	7 1/2

In estimating combustible contents, wood, paper, cotton, wool, and other similar type materials are taken at their actual weights. This class of materials has a calorific value of about 8, 000 BTU per pound of material

Plastics, petroleum products, and animal or vegetable derivatives are taken at twice their actual weights because their calorific value is about 16,000 BTU per pound. Combustibles enclosed in steel or equivalent incombustible containers (filing cabinets or desks) are taken at a fraction of actual weight.

Prior surveys show that intensity of the fire hazard that may be anticipated in Business Occupancy is usually 10-15 pounds of combustibles per square foot of floor area, average, exclusive of that represented by the building construction itself. The New York City Code is predicated upon these surveys. In effect, the Code is saying that the potential total fire hazard averages less than 20 pounds per square foot of total floor area.

Since there have been no recent surveys by the National Bureau of Standards and because the nature and weight of contents change with time, it is suggested that periodic reviews of contents and an effort to control weight of combustibles be made for each tenancy and floor.

Most manufacturers and suppliers of combustible furniture and furnishings can provide the shipping or actual weight of their products, and most can help estimate the weight of the combustible portion of a product composed of combustible and non combustible components. If this is not possible, estimates can be made by volumetric analysis and rules of thumb established by actual weighting of typical or analogous items in various categories and professional judgment.

Combustible contents in non combustible cabinets such as in steel file cabinets or desks shall be calculated at 10% of its weight when more than 3/4 of the total combustible contents is enclosed in such containers. When less than 1/2 of total combustible contents is so enclosed, the "effective hazard is represented by 40% of its weight; at between 1/2 to 3/4 by 20%.

APPENDIX E

EXTRACT FROM PROPOSED LEGISLATION

re: SMOKE AND HEAT VENTING

construction may be accepted on lieu of the fire separation of two hour fire-resistive construction providing all other requirements of (2) and (3) above are complied with.

(5) Regardless of the floor area, no subdivision of the floor area shall be required under subdivision (c) when complete sprinkler protection is provided in accordance with the construction provisions of article 17.

(6) Existing office buildings 100 feet, or more in height shall comply with the requirements of this subdivision within ten years of the effective date of this local law. If such work is not completed within five years of such effective date, the owner shall submit a statement to the commissioner, with a copy to the fire commissioner, setting forth a plan and time schedule for the performance of the work and completion within the prescribed time. Such plan and time schedule shall be subject to the approval of the commissioner. Notwithstanding the foregoing time for compliance, whenever an alteration is performed which requires filing with the department of buildings, compliance with this subdivision shall be required in that portion of the building being altered. Failure to comply with the provisions of this paragraph, or to perform the work in accordance with the time schedule, as approved by the commissioner, shall constitute a violation.

(7) In existing office buildings 100 feet or more in height where compliance would cause practical difficulty or undue hardship, the commissioner, at his discretion, may waive or modify the requirements of paragraphs (1) through (5) of subdivision (c) and accept alternatives fulfilling the intent of these requirements.

§ 6. Sub-article 504.0 of article 5 of part II title C, chapter twenty-six of such code is hereby amended by adding thereto a new section C26-504.15 to follow C26-504.14 to read as follows:

§ C26-504.15. **Smoke and heat venting.**—(a) Where the floor area of a one-story building classified in occupancy group A, B-1, or D-1 is greater in depth than 100 feet

from a frontage space, that portion beyond 100 feet shall be provided with roof vents and smoke curtains complying with the requirements of reference standard RS 5-11. Where the effective area of vents are glazed with plain glass or plastic not thicker than 1/8 inch, they need not be provided with automatic opening devices.

(b) Buildings classified in occupancy group E, 100 feet or more in height, having air-conditioning and/or mechanical ventilation systems that serve more than the floor on which the equipment is located, shall be provided with at least one smoke shaft by means of which smoke and heat shall be mechanically vented to the outdoors.

(1) Such smoke shaft shall be constructed as required for shafts in section C26-504.6.

(2) Shafts may serve more than a single compartment on a given floor but in all cases shall have at least one wall common to or abutting the compartments served.

(3) The size of the shaft shall be uniform throughout and of such dimensions as to provide 60 air changes per hour in the largest compartment served and at a velocity of not less than 1,600 fpm nor more than 4,000 fpm.

(4) Openings into the shaft shall be provided at each floor and shall be of a size to permit the number of air changes prescribed in (3) above at a maximum air velocity of 3,000 fpm. Such openings shall be located as high as possible and designed to vent the entire compartment. They shall be equipped with an opening protective or closure having a fire protective rating complyng wth table 5.3. Such closures shall be automatically openable individually upon the activation of a detector located at the return shaft of the compartment and upon the activation of any other detectors installed within the compartment.

(5) An approved, automatically controlled, exhaust fan of such capacity as to exhaust 60 air changes per hour from the largest compartment served by the shaft and capable of maintaining not less than a 2-inch negative static pressure at its inlet under flow conditions shall be installed in the shaft.

a. The fan shall be located so that the bottom of the fan inlet is located not less than 3 feet above the top of the automatic protective closure in the highest fire floor served by the shaft.

b. The shaft shall terminate at least 3 feet above the roof level where it penetrates the roof and shall be provided with a protective weather closure which can be opened manually from the outside.

c. When the closure in the required opening on a floor opens, this shall automatically open the weather closure and start the fan.

d. The shaft exhaust fan shall also be controlled from a local start-stop station at the fan, and at either the mechanical control center or the fire command station.

e. The fan shall be operated from circuits that are separate from the general lighting and power circuits, either taken off ahead of the main switch or connected to an emergency power source when such source is provided.

(6) Buildings that are sprinklered throughout shall be exempt from the above smoke shaft requirements.

(c) Existing office buildings, 100 feet or more in height, having air-conditioning and/or mechanical ventilation systems that serve more than the floor on which the equipment is located, shall be provided with at least one smoke shaft by means of which smoke and heat shall be vented to the outdoors.

(1) Such smoke shaft shall be constructed as required in parts (b) (1) to (b) ~~(4)~~ (5) above.

(2) In lieu of such smoke shaft or shafts, all enclosed, interior stairs may be provided with a system of pressurization for fire emergency use. Such pressurization shall be provided by means of a system or systems described herein.

(3) Each stair other than access stairs shall be provided with fresh air in an amount not less than 15,000 cfm plus 10 cfm per square foot of door entering the stair, mechanically supplied at its lowest level.

a. The stair shall have direct relief connection with the outdoors at its lowest level, of 0.25 square foot per door entering the stair at that level but not less than a total of 2.5 square feet or more than 15 square feet.

b. The direct relief connection shall be of fire-resistive construction with a rating not less than the fire protection rating of the stair enclosure. It shall be provided with an opening protective closure complying with table 5.3, and an approved smoke detector located between the outside air intake and the supply fan. Upon activation of this detector, the system will shut down.

c. The protective closure shall open and the supply fan shall start upon activation of any detector in the building except that in (3) b. above.

(4) Each stair shall also be equipped with a smoke exhaust fan with a capacity one-quarter that of the air supply fan. The inlet to the exhaust fan shall be located and equipped as provided in (b) (5) a. and b. above.

a. The weather closure of the exhaust fan shall open automatically and the exhaust fan shall start upon the activation of any detector in the building except the detector in the direct relief connection provided in (3) b. above.

(5) Other operating requirements.

a. All closures shall normally be in closed position.

b. All exit doors more than 150 feet above the outside air intake shall be of an approved type designed to open against pressure, or pressure sensing devices at the top and bottom of each stair shall maintain not more than 0.3 inch water column pressure between the stair shaft and the bottom and top floors of the building.

c. Both stair fans shall also be controlled from a local start-stop station at the fans, and from either the fire command station or from the mechanical control center.

d. The fans shall be operated from circuits that are separate from the general lighting and power circuits, either taken off ahead of the main switch or connected to an emergency power when such source is provided.

(6) Existing office buildings 100 feet or more in height shall comply with the smoke and heat ventiug requirements herein within three years of the effective date of this amendment. If such work is not completed within eighteen months of such effective date, the owner shall submit a statement to the commissioner,

with a copy to the fire commissioner, setting forth a plan and time schedule for the performance of the work and completion within the prescribed time. Such plan and time schedule shall be subject to the approval of the commissioner. Failure to comply with the provisions of this paragraph, or to perform the work in accordance with the time schedule, as approved by the commissioner, shall constitute a violation.

(d) The exhaust fan required in (b) (5) above and the air-supply and smoke exhaust fans required in (c) (3) and (c) (4) above shall be exempt from the provisions of sub-article 1208.0.

(e) Existing buildings that are sprinklered throughout shall be exempt from the above smoke shaft and stair pressurization requirements.

§ 7. Section C26-600.1 of title C, part II, chapter twenty-six of such code is hereby amended to read as follows:

§ C26-600.1. **Scope.**—The provisions of this article shall control the design, construction, protection, location, arrangement and maintenance of required exit facilities to provide safe means of egress from all buildings hereafter erected, altered or changed in occupancy, except that exit requirements for special uses and occupancies, as provided in articles 7 and 8, shall take precedence over the provisions of this article *and except further that existing buildings shall comply with the applicable requirements of section C26-600.3, section C26-604.4 and sub-article 607.0 and 608.0.*

§ 8. Subparagraph b of paragraph (l) of subdivision (j) of section C26-604.4 of such code, as amended by local law number fifty-four for the year nineteen hundred seventy, is hereby amended to read as follows:

b. Doors opening into interior [enclosed stairs] *stair enclosures* shall not be locked from either side [except that doors may be locked to prevent access to the stair at the street floor.] *with the following exceptoins:*

1. Doors may be locked to prevent access to the stair at the street floor.

2. In buildings classified in occupancy group E, less than 100 feet in height, the doors may be locked on the stair side on each floor above the street floor.

DETAILS OF BUILDING AND

TEST EQUIPMENT

Note: Some of the details shown were developed to fit the characteristics of the test building and are not intended to represent generally accepted practice.