MEASURES FOR FIRE SAFETY IN HIGH BUILDINGS

(TO FORM PART OF SUPPLEMENT NO. 3 TO THE NATIONAL BUILDING CODE OF CANADA)

ISSUED BY THE
ASSOCIATE COMMITTEE
ON THE NATIONAL BUILDING CODE
NATIONAL RESEARCH COUNCIL
OTTAWA, CANADA

1973

NRCC NO. 13366

PRICE: $1.00

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SPECIAL NOTE

The measures contained in this Supplement have been prepared to aid those who must develop solutions to the problem of controlling smoke movement in buildings in accordance with the requirements of the National Building Code. The knowledge requirements are well within the capabilities of the competent designer. The designer should appreciate, however, that the successful application of these measures constitutes a design problem requiring a clear understanding of the principles that govern smoke movement, as well as an awareness of the assumptions on which the measures are based. The assumptions regarding building characteristics associated with each measure are included in the text. If the building under consideration has characteristics that are significantly different from these, appropriate adjustments must be made in the design.

This is particularly true of methods employing air-handling systems where, for example, a realistic assessment of the leakage characteristics of the enclosures of spaces into which air is introduced may be critical. In this context, special attention is drawn to the building pressurization approach used in conjunction with a smoke shaft. The recommendations contained in the Supplement for this approach were developed assuming a building with fairly uniform leakage characteristics. Where a building departs substantially from this model, the design must be adjusted to compensate. An example of the latter condition would be a building which contains at the lower levels a large shopping complex of much greater floor area than at the higher levels. Details of the associated problems are given in a paper which is being prepared by the Division of Building Research of the National Research Council.

The designer is cautioned that the tabular and graphical information in this Supplement have been developed for buildings having the characteristics listed in this report. It will be for him to judge the extent to which the building under consideration has characteristics that will allow the application of this information. This is particularly important where a designer intends to develop his own smoke control approach. In some cases the design may prove sufficiently complex to necessitate the use of a computer, and reference should be made to a paper describing a computer approach to this problem which is available from the Division of Building Research.

Finally, it should be noted that the National Building Code requires that a check be made of the smoke control system when requested by the authority having jurisdiction in accordance with the procedures described in Appendix C of this Supplement. This will indicate deficiencies caused by inexact estimates of the leakage characteristics or of air supply requirements, and in all but the most extreme cases will provide an opportunity for appropriate adjustments before the system is put into service.

CONTENTS

INTRODUCTION

Experience with high buildings has shown that the time required for complete evacuation can exceed that which is considered necessary for the safe egress of all occupants. Studies of the 'chimney effect' and observations of smoke movement in fires have shown that present measures for containing a fire on a lower storey will not usually prevent the movement of smoke through elevator, stair and other vertical shafts to the upper storeys of a high building. Occupants of high buildings, and particularly those on upper storeys, may be faced with severe smoke conditions from fires occurring in storeys below them, before their own evacuation is possible.

The measures described in this document are designed as a means of implementing the requirements of NBC Subsection 3.2.6., and are intended to maintain safe conditions for occupants of a high building who may have to remain in the building during a fire, to protect exit routes and to assist firefighters by providing efficient access to the fire floor.

The specific reference to Code clauses in this document apply to the 1970 edition of the National Building Code as revised by Change Series No. 3 issued October 1973.

CHAPTER I

SCOPE OF MEASURES

This document includes a number of detailed measures that may be incorporated in a building in order to comply with the requirements relating to control of smoke that are included in Subsection 3.2.6. of the National Building Code. It is not the intention to exclude other means of attaining the same objectives. Where smoke control methods other than those described in this document are developed, they may be based on the information in Appendix B, Mechanisms of Smoke Movement in Buildings.

Smoke control measures required by NBC Subsection 3.2.6. vary depending on the height and occupancy of a building. In a sprinklered building, the requirements for control of smoke movement are minimal (see Measure A in Chapter 2). In very tall buildings, limits are placed on penetration of smoke into exit stairs, firefighters' elevator and all floor areas other than the one on which fire occurs. This is achieved by Measures B, D, F, H and I in Chapter 2. In certain buildings of lesser height and limited population, exit stairs and firefighters' elevators are protected, and smoke may be expected to enter upper floor areas. This applies where Measures, C, E, G and J, described in Chapter 2, are employed. In other buildings, the spread of smoke into shafts and floor areas is accepted, but areas of refuge are provided that are maintained smoke free, can be reached by all people in the building within a few minutes and are linked to outdoors by safe means of egress. They are described in Measures K and L in Chapter 2.

Where Measures A, B, D, F, H and I in Chapter 2 are applied, it is assumed that in the event of fire occupants of the floor on which the fire occurs will leave by exit stairs immediately following the sounding of a fire alarm, and that occupants of the floor immediately above the floor on which the fire occurs will be advised to leave by the first arriving fire department officer or other person assigned this responsibility. Occupants of all other floors may remain on their floors unless otherwise directed.

Where Measures C, E, G and J in Chapter 2 are applied, it is assumed that occupants of all floors will move immediately into the stair-shafts, and will then proceed slowly to the outdoors following the sounding of a general fire alarm.

Where Measure K in Chapter 2 is applied (i.e., the building is divided vertically into two zones), it is assumed that occupants of the floor on which the fire originates will leave by exit stairs, and that the occupants of all other floors in the zone in which the fire is discovered will move through vestibules or bridges to floor areas on the same level in the fire free smoke control region immediately following the sounding of a fire alarm. Occupants may remain in these areas of refuge until further directed by the fire department officer.

Where Measure L in Chapter 2 is applied, it is assumed that occupants of the floor on which the fire originates will leave by exit stairs, and that occupants of all other floors will move by corridors or stairs to areas of refuge that are distributed throughout the building immediately following the sounding of the fire alarm. Occupants may remain in these areas of refuge until otherwise directed.

In a residential building where reliance is placed on balconies as places of refuge from smoke, as described in Measure M in Chapter 2 occupants may remain in their suites when a general fire alarm is given, but should be prepared to move on to their balconies if conditions in the suite should become untenable.

It is assumed that the population of below grade storeys will not exceed the 300 persons per unit exit width referred to in NBC Article 3.2.6.1., and that occupants of below grade storeys will evacuate the building by the stairshafts immediately after the discovery of a fire in a below grade storey.

It is also important that firefighters are provided with a smoke free access to below grade fire floors. The Measures described as A, B, C, D, E, F, G, L and M include provisions designed to separate the exit stairs serving above grade storeys from those serving below grade storeys, and to limit entry of smoke into these shafts. It is also required that elevator and service shafts be provided with a separation near grade, or be designed to limit their functioning as paths of smoke movement into upper floor areas. In Measures H, I and J no special precautions are necessary to protect shafts in below grade storeys because the system of pressurization plus venting of the fire floor protects all shafts, whether or not these penetrate below grade storeys. In Measure K the separation into two zones is maintained in below grade storeys. Smoke free access will thus be available to any floor on which fire occurs.

SYNOPSIS OF MEASURES FOR LIFE SAFETY IN HIGH BUILDINGS

Each of the measures is illustrated by a sketch with notes describing the applicable conditions (Fig. 1 to 18). These sketches are intended as a guide to the detailed requirements and as an aid to finding the relative clauses, but they are not intended to limit in any way the scope of the detailed provisions which in general provide a wider range of choice than can be shown in the sketches and notes. A summary of requirements applicable to all buildings regardless of the measure being used is given in the following paragraph.

Requirements Common to all Measures for Life Safety in High Buildings

Elevators controlled by keyed switch (NBC Article 3.2.6.3)
Firefighters' elevator required (NBC Article 3.2.6.4)
Means of venting each floor area to outdoors by smokeshaft windows or building exhaust system (NBC Article 3.2.6.5)
Certain floor areas in the building are sprinklered (NBC Articles 3.2.2.8. and 3.2.6.6)
Limits on flamespread and smoke production ratings for interior finish materials in certain locations (NBC Article 3.2.6.7)
Central alarm and control facility required (NBC Article 3.2.6.8)
Voice communication system required if building is over 120 ft. high (NBC Article 3.2.6.9)
Fire protection required for electrical feeders to emergency equipment (NBC Article 3.2.6.10)
Power to operate emergency lighting alarm and communications systems (NBC Article 3.2.6.11)
Emergency power to operate elevators required if building is over 120 ft. high (NBC Article 3.2.6.11)

MEASURE A. FULLY SPRINKLERED BUILDING

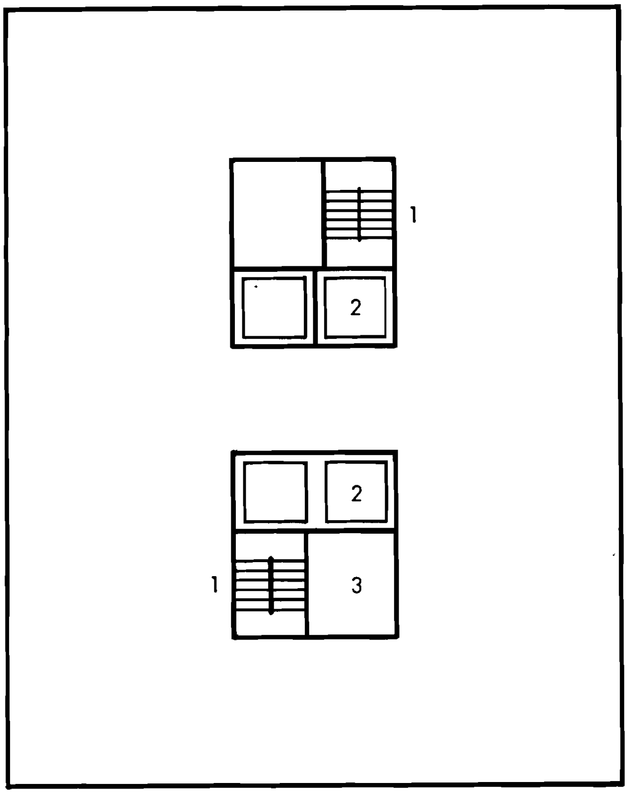


Figure 1 Typical Floor Plan, Measure A

1. Door to outdoors in each stairshaft held open during a fire emergency (2A(2)) *

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that storey (2A(3))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2A(3))

2. Elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2A(5))

3. Vertical service spaces provided with firestops at the first floor below the lowest exit storey or are vented to outdoors at top (2A(6))

   Air moving fans are stopped in a system that serves more than two storeys (NBC Sentence 3.2.6.2.(6))

* First number, 2, indicates Chapter 2. Letter "A" indicates Measure A in Chapter 2. Last number, (2), indicates numbered sentence in Measure A.

Measure A satisfies NBC sentence 3.2.6.2 (6) for groups A, C, D, E, or F, Major Occupancy Classification

No limit on height

All floor areas sprinklered. (NBC sentence 3.2.6.2 (6))

Limits on flame spread and smoke described in NBC article 3.2.6.7 are relaxed.

MEASURE B. OPEN CORRIDOR ACCESS TO STAIRS AND ELEVATORS including restrictions on movement of smoke from floor to floor

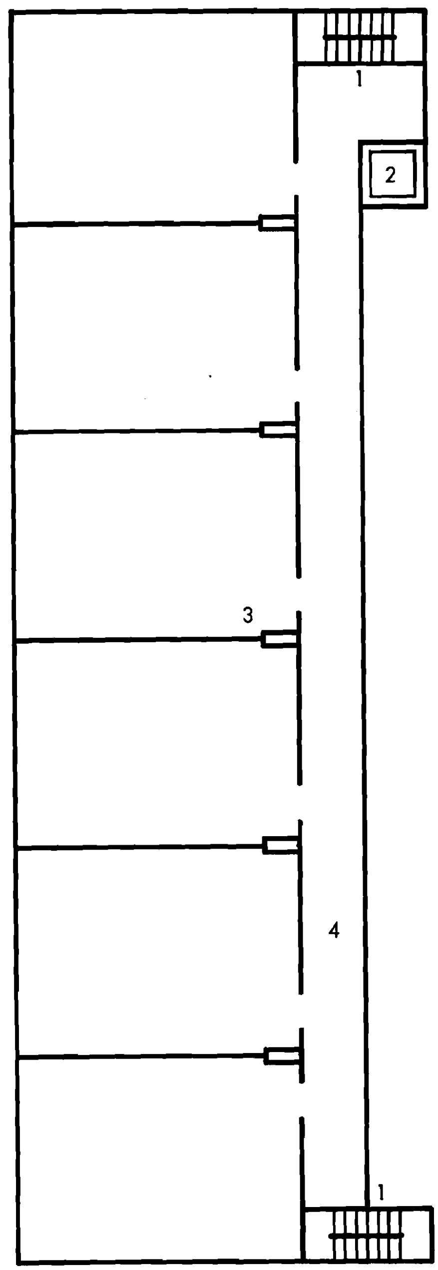


Figure 2 Typical Floor Plan, Measure B

1. Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that storey (2B(3))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2B(3))

2. Elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2B(4))

3. Vertical service spaces provided with firestops at the first floor below the lowest exit storey and at intervals not exceeding five storeys or are vented to outdoors at top (2B(5))

4. Open corridor or balcony providing access to stairs and firefighters' elevator (2B(2))

   Elevator shaft and stairshaft unheated

   Air moving fans are stopped in a system that serves more than two storeys (2B(7))

   Certain dampers close in air handling ducts during a fire emergency (2B(8))

Measure B satisfies NBC sentences 3.2.6.2 (2) (3) and (4) for any Major Occupancy Classification

No limit on height

MEASURE C. OPEN CORRIDOR ACCESS TO STAIRS AND ELEVATORS
no additional restrictions on movement of smoke from floor to floor

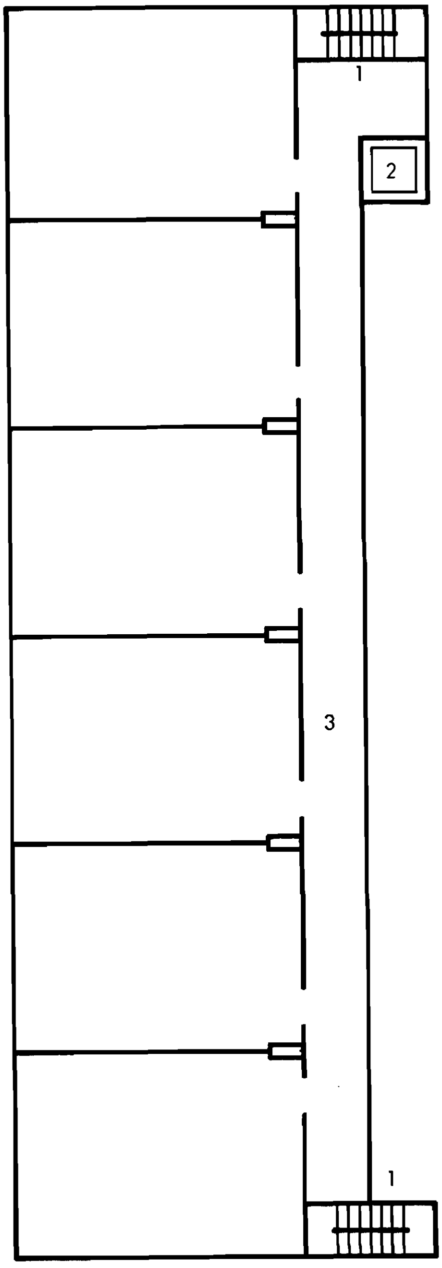


Figure 3 Typical Floor Plan, Measure C

1. Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that storey (2C(3))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2C(3))

2. Elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2C(4))

3. Open corridor or balcony providing access to stairs and firefighters' elevator (2C(2))

   Elevator shaft and stairshaft unheated

   Air moving fans are stopped in a system that serves more than two storeys (2C(5)

Measure C satisfies NBC sentence 3.2.6.2 (7) for groups A, C, D, E, or F, Major Occupancy Classification

Limit on population (NBC sentence 3.2.6.2 (7))

Limited to buildings not more than 250 ft. high (NBC sentence 3.2.6.2. (7))

MEASURE D. PROTECTED VESTIBULE ACCESS TO STAIRS AND ELEVATORS including restrictions on movement of smoke from floor to floor

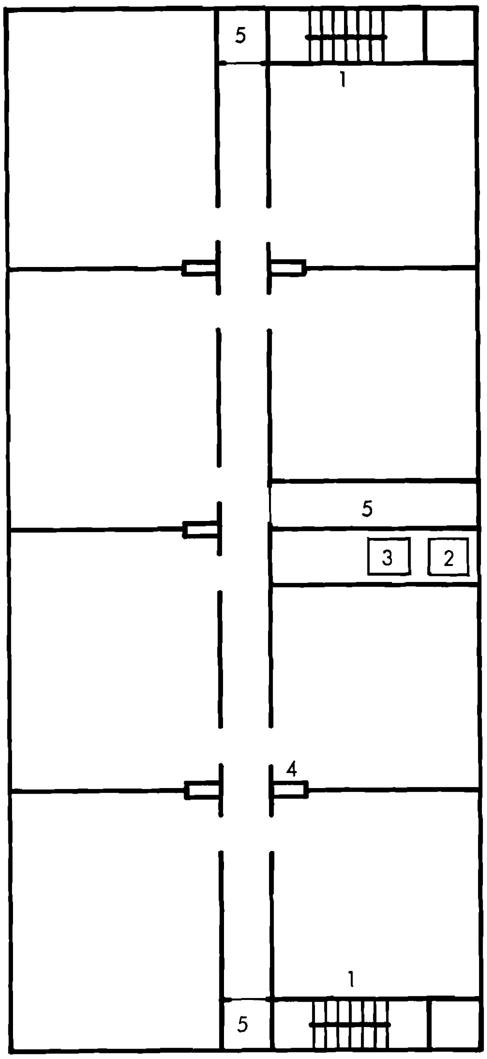


Figure 4 Typical Floor Plan, Measure D

1. Door to outdoors in each stairshaft held open during a fire emergency (2D(7))

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that level (2D(8))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2D(8))

2. Elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2D(13))

3. Firefighters' elevator shaft provided with vent to outdoors at top and bottom during a fire emergency (2D(9))

4. Vertical service spaces provided with firestops at the first floor below the lowest exit storey and at intervals not exceeding five storeys or are vented to outdoors at top (2D(12))

5. Vestibule vented to outdoors during a fire emergency or pressurized (2D(5))

   Vents to vestibules openable from central control facility if building is over 120 ft high (2D(6))

   Air moving fans are stopped in a system that serves more than two storeys (2D(15))

   Certain dampers close in air handling ducts during a fire emergency (2D(16))

Measure D satisfies NBC sentences 2.3.6.2 (2), (3), and (4) for any Major Occupancy Classification

No limit on height

MEASURE E. PROTECTED VESTIBULE ACCESS TO STAIRS AND ELEVATORS no additional restrictions on movement of smoke from floor to floor

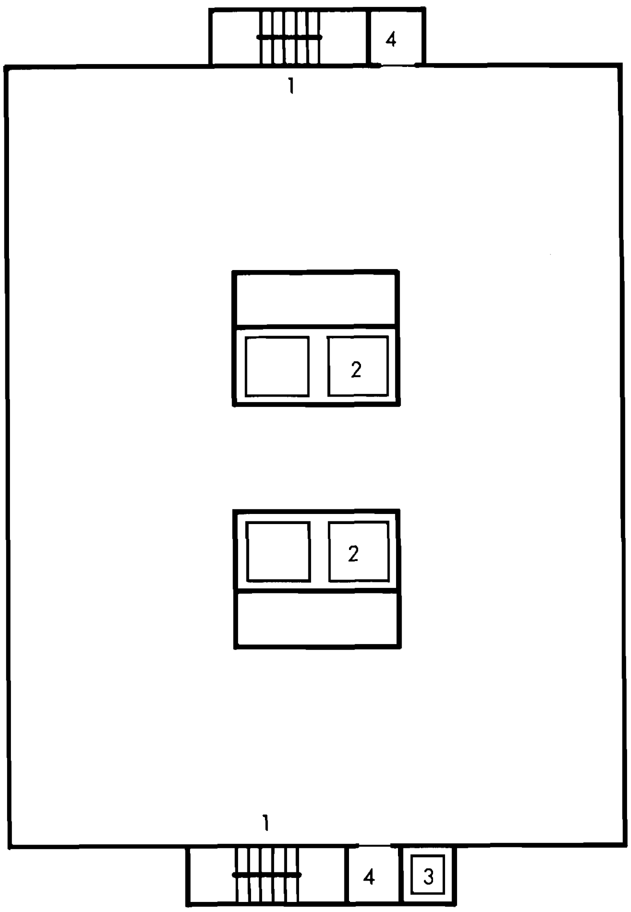


Figure 5 Typical Floor Plan, Measure E

1. Door to outdoors in each stairshaft held open during a fire emergency (2E(6))

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that level (2E(7))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2E(7))

2. Elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2E(11))

   No special protection against smoke for elevator shafts or vertical service spaces other than firefighters elevator

3. Firefighters elevator shaft provided with vent to outdoors at top and bottom during a fire emergency (2E(8))

4. Vestibule vented to outdoors during a fire emergency or pressurized (2E(4))

   Vents to vestibules openable from central control facility if building is over 120 ft high (2E(5))

   Air moving fans are stopped in a system that serves more than two storeys (2E(12))

Measure E satisfies NBC sentence 3.2.6.2 (7) for groups A, C, D, E, or F, Major Occupancy Classification

Limit on population (NBC sentence 3.2.6.2 (7))

Limited to buildings not more than 250 ft. high (NBC sentence 3.2.6.2 (7))

MEASURE F. PRESSURIZED STAIR AND ELEVATOR SHAFTS including restriction on movement of smoke from floor to floor

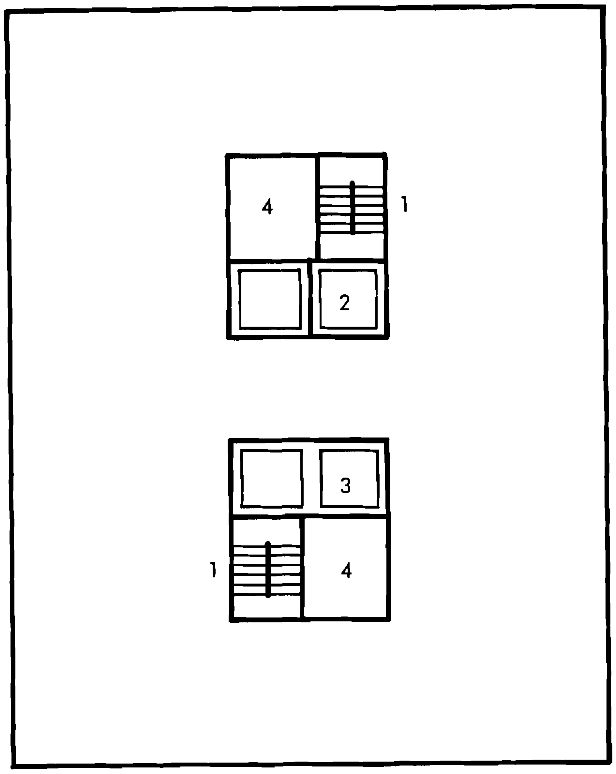


Figure 6 Typical Floor Plan, Measure F

1. Door to outdoors in each stairshaft held open during a fire emergency (2F(2))

   Stairshaft pressurized during a fire emergency (2F(2))

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that level (2F(3))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2F(3))

2. Firefighters elevator shaft pressurized during a fire emergency (2F(4))

3. Elevator shafts other than firefighters' elevator vented to outdoors at top (2F(8))

4. Vertical service spaces provided with firestops at the first floor below the lowest exit storey and at intervals not exceeding five storeys or are vented to outdoors at top (2F(7))

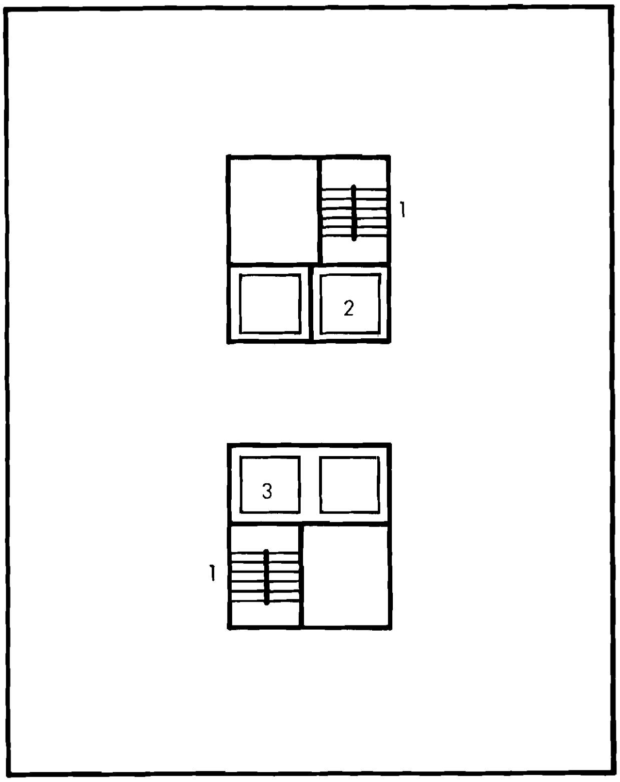
   Air moving fans are stopped in a system that serves more than two storeys during a fire emergency (2F(11))

   Certain dampers in air handling ducts close during a fire emergency (2F(12))

Measure F satisfies NBC sentences 3.2.6.2 (2), (3), and (4) for any Major Occupancy Classification

No limit on height

MEASURE G. PRESSURIZED STAIR AND ELEVATOR SHAFTS
no additional restriction on movement of smoke from floor to floor



1. Door to outdoors in each stairshaft held open during a fire emergency (2G(2))

   Stairshaft pressurized during a fire emergency (2G(2))

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that level (2G(3))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2G(3))

2. Firefighters' elevator shaft pressurized during a fire emergency (2G(4))

3. No special protection against smoke for elevator shafts or vertical service spaces other than firefighters' elevator

   Air moving fans are stopped in a system that serves more than two storeys during a fire emergency (2G(7))

Figure 7 Typical Floor Plan, Measure G

Measure G satisfies NBC sentence 3.2.6.2. (7) for groups A, C, D, E or F, Major Occupancy Classification

Limit on population (NBC sentence 3.2.6.2 (7))

Limited to buildings not more than 250 ft. high (NBC sentence 3.2.6.2 (7))

MEASURE H. BUILDING FULLY PRESSURIZED

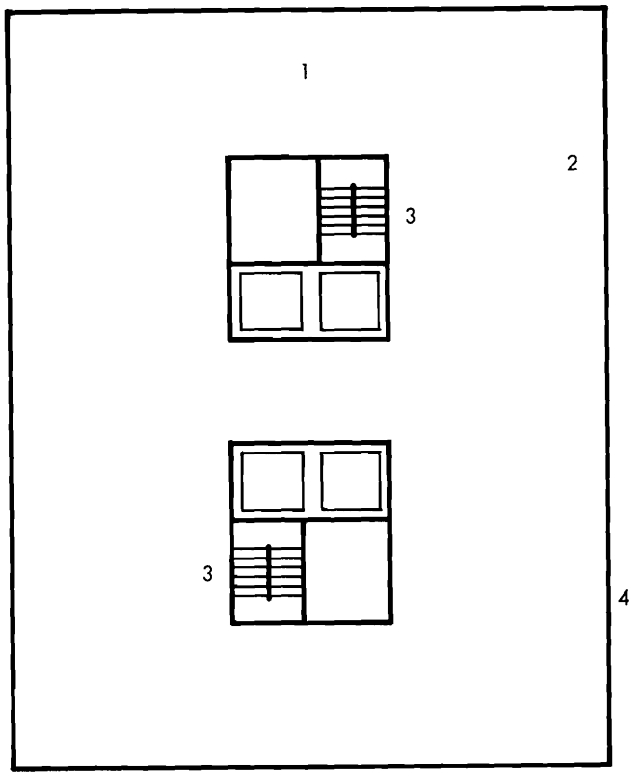


Figure 8 Typical Floor Plan, Measure H

1. All floor areas pressurized (2H(2))

   Provision for modulating air supply for building pressurization during warm weather (2H(3))

2. Fire floor provided with means of venting to outdoors by smokeshaft or windows (2H(6))

3. A proportion of air for building pressurization directed into stairshafts (2H(2))

   Doors to outdoors in stairshafts not held open during a fire emergency (2H(4))

4. Except as required for venting all openings in perimeter walls and roof are kept closed during a fire emergency (2H(4))

   Except as required for pressurization, air moving fans are stopped in a system that serves more than two storeys during a fire emergency (2H(3))

   Certain dampers in air handling ducts are closed during a fire emergency (2H(5))

Measure H satisfies NBC sentences 3.2.6.2 (2), (3), and (4) for any Major Occupancy Classification

No limit on height

MEASURE I. BUILDING CORE PRESSURIZED
including restriction on movement of smoke from floor to floor outside core

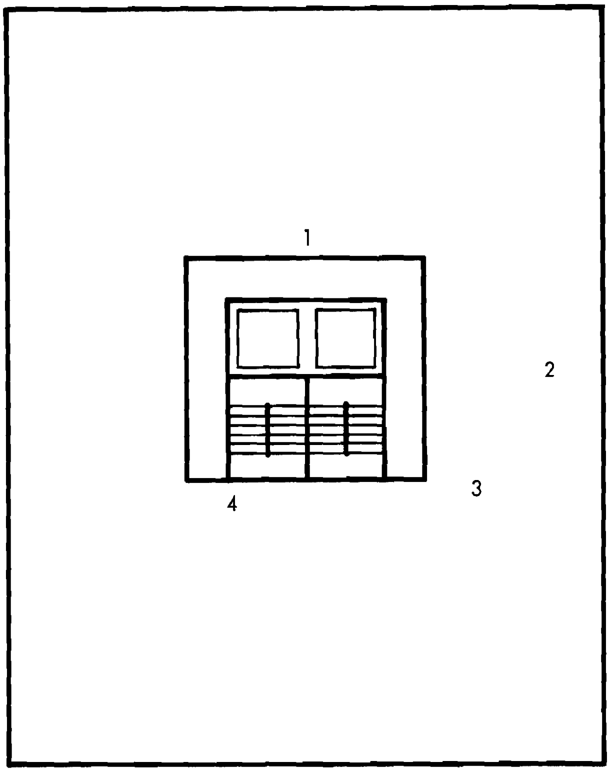


Figure 9 Typical Floor Plan, Measure I

1. Enclosing wall of core is a fire separation with self closing doors

   Central core is pressurized during a fire emergency (2I(2))

   All openings in perimeter walls and roof of core kept closed during a fire emergency (2I(3))

2. Fire compartment is vented to outdoors during a fire emergency by smokeshaft or windows (2I(4))

3. Vertical service spaces outside core provided with firestops at the level of the first floor below the lowest exit storey and at intervals not exceeding five storeys or are vented to outdoors at the top (2I(6))

4. Doors to outdoors in stairshafts not held open during a fire emergency except as required for pressurizing the core (2I(3))

   Air moving fans are stopped in a system that serves more than two storeys in a fire emergency (2I(7))

   Certain dampers in air handling ducts are closed during a fire emergency (2I(8))

Measure I satisfies NBC sentences 3.2.6.2 (2), (3), and (4) for any Major Occupancy Classification

No limit on height

MEASURE J. BUILDING CORE PRESSURIZED
no additional restriction on movement of smoke from floor to floor outside core

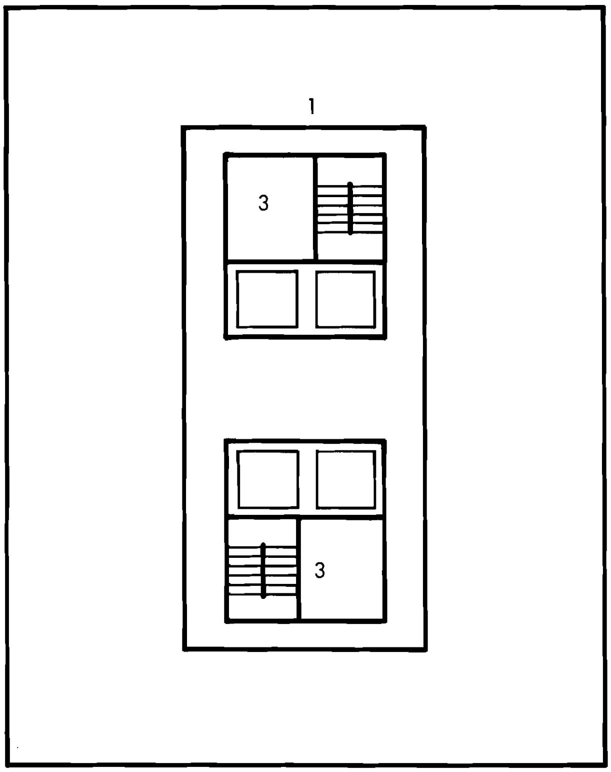


Figure 10 Typical Floor Plan, Measure J

1. Enclosing wall of core is a fire separation with self closing doors

   Central core is pressurized during a fire emergency (2J(2))

   All openings in perimeter walls and roof of core are kept closed during a fire emergency (2J(3))

3. Doors to outdoors in stairshafts not held open during a fire emergency (2J(3))

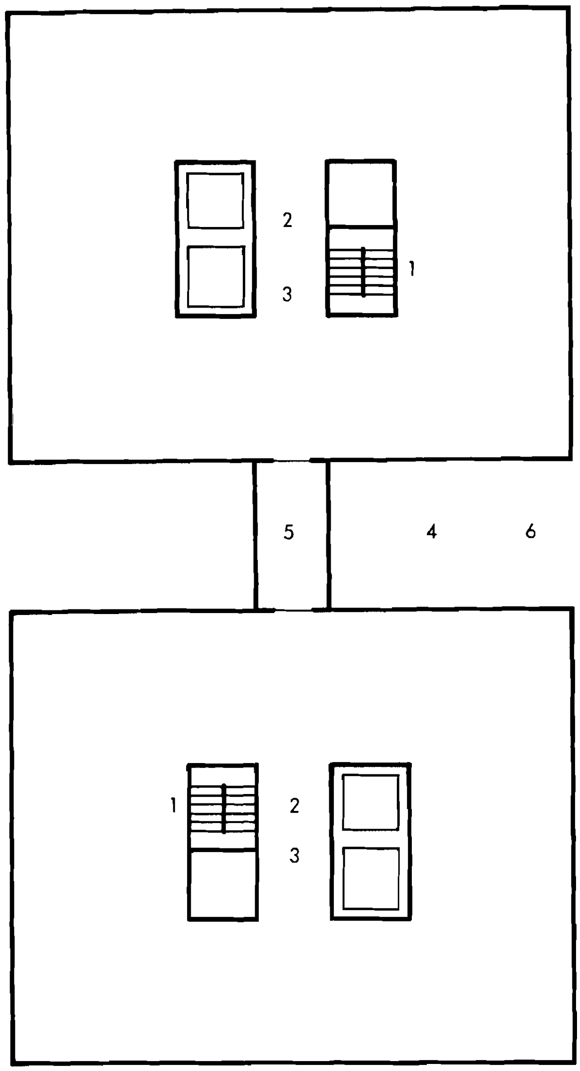
   Air moving fans are stopped in a system that serves more than two storeys (2J(4))

Measure J satisfies NBC sentence 3.2.6.2 (7) for groups A, C, D, E or F, Major Occupancy Classification

Limit on population (NBC sentence 3.2.6.2 (7))

Limited to buildings not more than 250 ft high (NBC sentence 3.2.6.2 (7))

MEASURE K. VERTICALLY DIVIDED BUILDING with spatial separation



1. Door to outdoors in each stairshaft held open during a fire emergency (2K(13))
2. One firefighters' elevator and one stairshaft in each smoke control region (2K(4))
3. If bridges do not occur at each storey two stairshafts are required in each smoke control region (NBC 3.4.2.1.)
4. Building designed as two smoke control regions with spatial separation between (2K(2))
5. Bridge at each storey or at intervals not exceeding five storeys (2K(3))

   Bridge vented to outdoors or pressurized (2K(11))
6. Fire separation in storeys below grade to maintain separation between smoke control regions (2K(15))

   Air moving fans are stopped in a system that serves more than two storeys in a fire emergency (2K(14))

Figure 11 Typical Floor Plan, Measure K

Measure K satisfies NBC sentence 3.2.6.2 (5) for buildings of groups A, D, E, or F, Major Occupancy Classification of any height

Measure K satisfies NBC sentence 3.2.6.2 (5) for buildings of group C Major Occupancy Classification that are not more than 250 ft high

MEASURE K. VERTICALLY DIVIDED BUILDING with fire separation

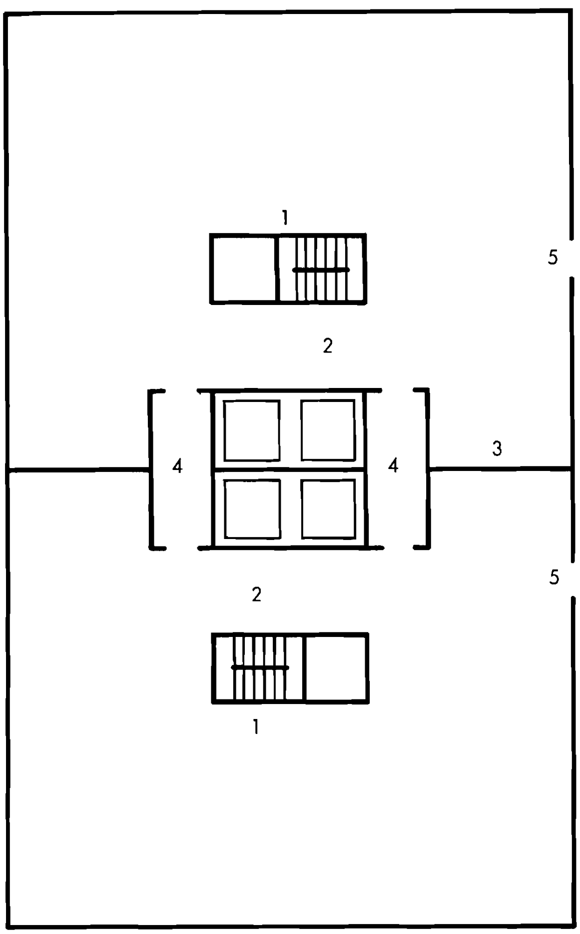


Figure 12 Typical Floor Plan, Measure K

1. Door to outdoors in each stairshaft held open during a fire emergency (2K(13))
2. One firefighters' elevator and one stairshaft in each smoke control region (2K(4))

   If vestibules do not occur at each storey two stairshafts are required in each smoke control region. (NBC 3.4.2.1.)
3. Building designed as two smoke control regions with fire separation between (2K(2))

   Fire separation in storeys below grade to maintain separation between smoke control regions (2K(15))
4. Vestibule at each storey or at intervals not exceeding five storeys (2K(3))

   Vestibules vented to outdoors or pressurized (2K(11))
5. Vent to outdoors in each smoke control region on floors below mid height of building (2K(12))

   Air moving fans are stopped in a system that serves more than two storeys during a fire emergency (2K(14))

Measure K satisfies NBC sentence 3.2.6.2 (5) for buildings or groups A, D, E, or F, Major Occupancy Classification of any height

Measure K satisfies NBC sentence 3.2.6.2 (5) for buildings of group C Major Occupancy Classification that are not more than 250 ft high

MEASURE L. AREAS OF REFUGE
two areas of refuge on each floor

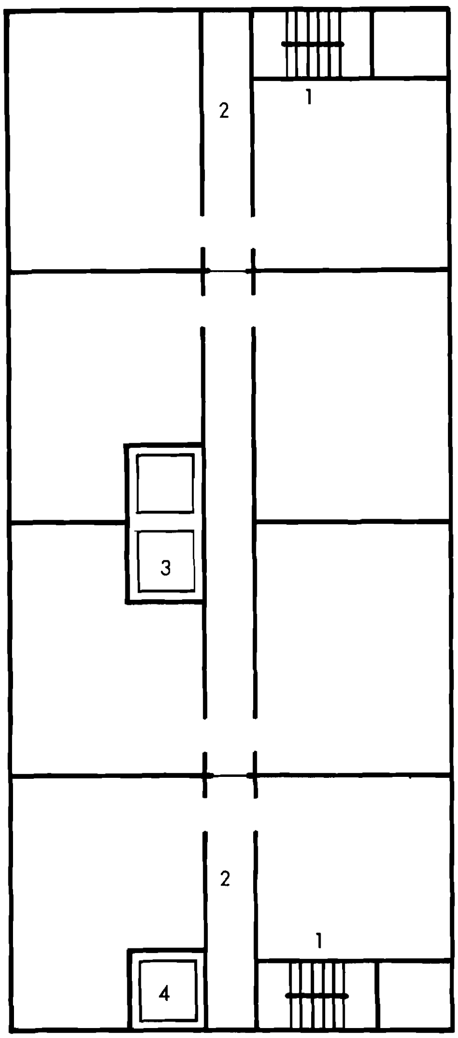


Figure 13 Typical Floor Plan, Measure L

1. Stairshaft and firefighters' elevator shaft protected by area of refuge (2L(10))

   Door to outdoors in each stairshaft held open during a fire emergency (2L(13))

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that level (2L(14))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2L(14))

2. Two areas of refuge on each floor pressurized during a fire emergency (see figure (14) for area of refuge every fifth floor (2L(9))

3. No special protection against smoke for elevator shafts or vertical service spaces other than firefighters' elevator

4. Firefighters' elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2L(12))

   Firefighters' elevator shaft provided with vent to outdoors at top and bottom during a fire emergency (2L(15))

   Air moving fans are stopped in a system that serves more than two storeys during a fire emergency (2L(18))

Measure L satisfies NBC sentence 3.2.6.2 (5) for buildings of groups A, D, E, or F, Major Occupancy Classification of any height

Measure L satisfies NBC sentence 3.2.6.2 (5) for buildings of group C Major Occupancy Classification that are not more than 250 ft high

MEASURE L. AREAS OF REFUGE
duplicate groups of areas of refuge at every fifth storey

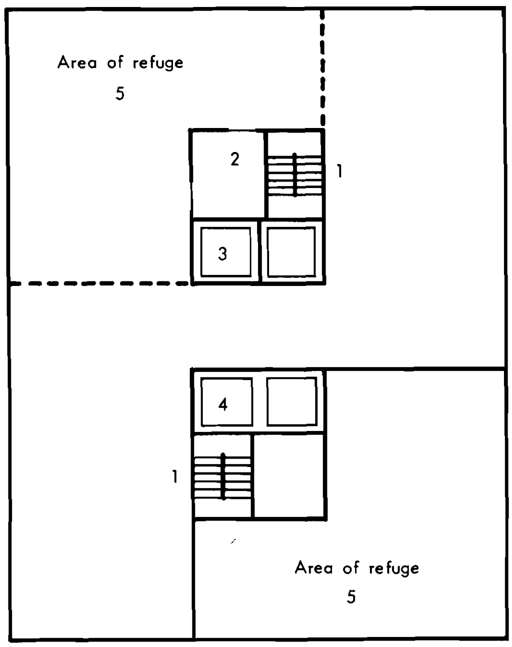


Figure 14 Typical Floor Plan, Measure L

1. Stairshaft and firefighters' elevator shaft protected by area of refuge or vestibule (2L(10))

   Door to outdoors in each stairshaft held open during a fire emergency (2L(13))

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that storey (2L(14))

   Stairshaft serving floors below the lowest exit level is pressurized during a fire emergency (2L(14))

2. Stairshaft and firefighters' elevator shaft protected in intermediate floors by pressurized vestibules (2L(10))

3. Firefighters' elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2L(12))

   Firefighters' elevator shaft provided with vent to outdoors at top and bottom during a fire emergency (2L(15))

4. No special protection against smoke for elevator shafts or vertical service spaces other than firefighters' elevator

5. Two areas of refuge on each fifth floor pressurized during a fire emergency (2L(9)) or areas of refuge may be staggered on intermediate floors see (fig. 15)

   Air moving fans are stopped in a system that serves more than two storeys in a fire emergency (2L(18))

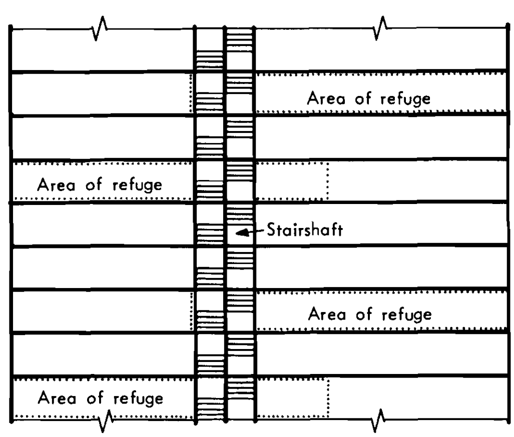


Figure 15 Typical Cross Section showing Areas of Refuge on Intermediate Floors

Measure L satisfies NBC sentence 3.2.6.2 (5) for buildings of groups A, D, E, or F, Major Occupancy Classification of any height

Measure L satisfies NBC sentence 3.2.6.2 (5) for buildings of group C Major Occupancy Classification that are not more than 250 ft high

MEASURE M. BUILDING WITH BALCONIES

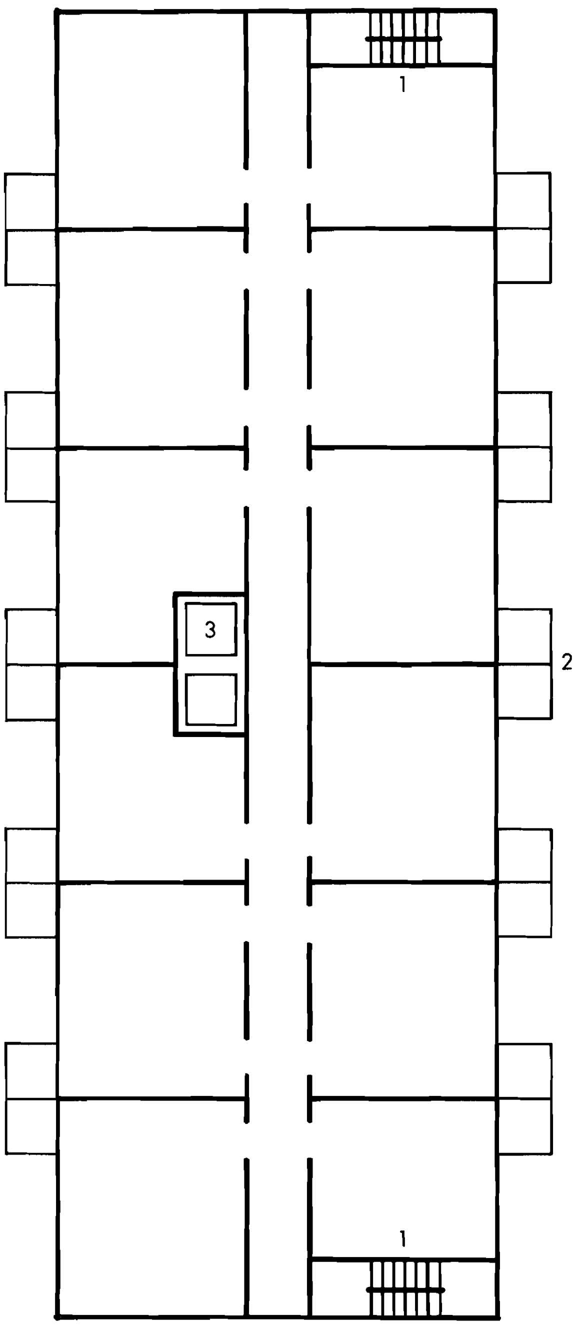


Figure 16 Typical Floor Plan, Measure M

1. Door to outdoors in each stairshaft held open during a fire emergency (2M(2))

   Stairshaft serving floors below the lowest exit level is separate from stairshaft serving floors above that level (2M(3))

   Stairshaft serving floors below the exit level is pressurized during a fire emergency. (2M(3))

2. Each suite provided with a balcony. (NBC 3.2.6.2. (8))

3. Elevator shaft terminates not lower than the first floor below the lowest exit storey or has vestibules at each elevator door in lower storeys (2M(4))

   Air moving fans are stopped in a system that serves more than two storeys in a fire emergency (2M(5))

Measure M satisfies NBC sentence 3.2.6.2 (8) for buildings of group C Major Occupancy Classification that are not more than 120 ft high

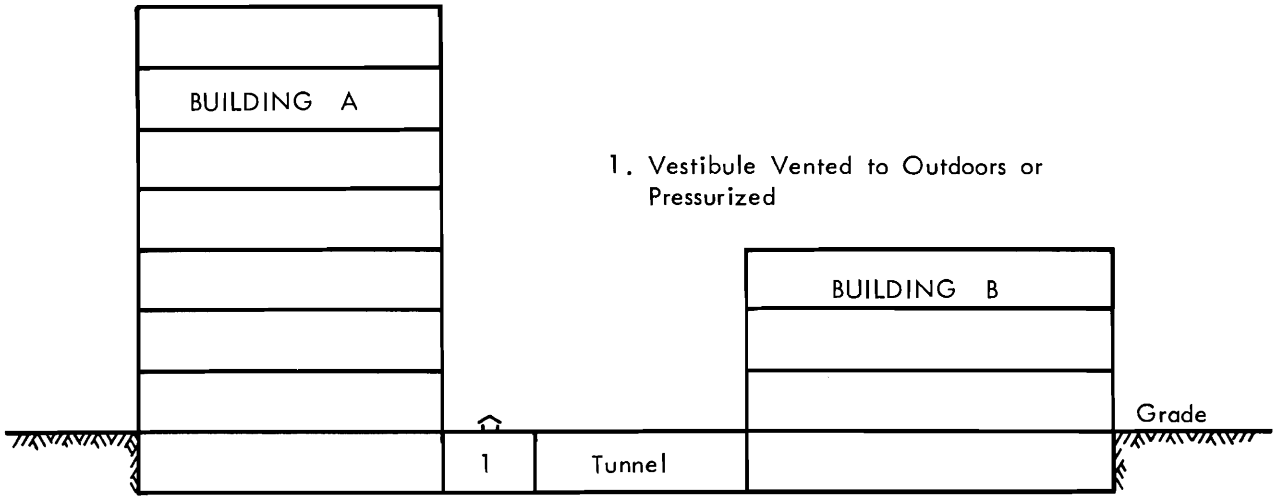


Figure 17 Section through Buildings Linked by Underground Tunnel

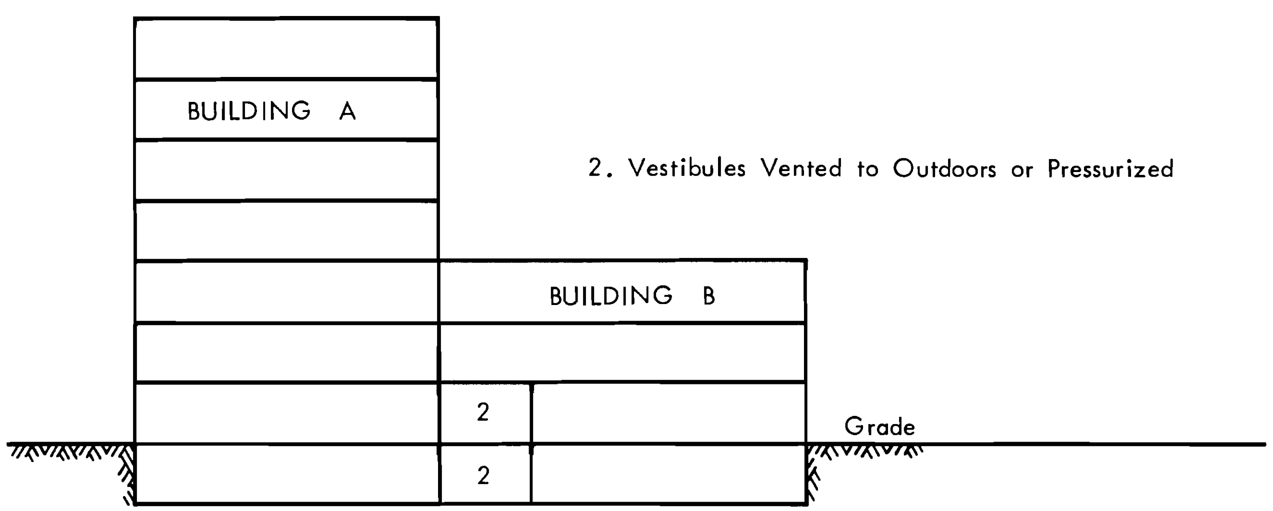


Figure 18 Section through Buildings Joined at Firewall

Measure N satisfies NBC sentence 3.2.6.2.(9) for connected buildings

CHAPTER 2

MEASURES FOR LIFE SAFETY IN HIGH BUILDINGS

Section 2(a)- Fully Sprinklered Buildings

Measure A - General

The measures described in this section may be considered to be an adequate smoke control measure, satisfying the requirements of NBC Sentence 3.2.6.2.(6). Reliance is placed on the full sprinkler installation to limit fire spread and hence the generation of smoke.

Some additional protection of exit stairs is afforded by the provision of an opening to the outdoors at the foot of the stairshaft. In cold weather, when stack action is likely to be most significant, this measure may give a general increase in air pressure in the stairshaft, thus restricting entry of smoke.

In this section is included the requirement that elevator and service shafts should not be continuous from above to below grade except when vestibules are provided at elevator doors in below grade storeys.

Where Measure A is adopted and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that the occupants of the fire floor will walk down stairs to the street floor or to a safe intermediate floor area. Occupants of other floors may remain until advised to evacuate by the person operating the central alarm and control facility.

Measure A - Requirements in Sprinklered Buildings

(1) The requirements of NBC Sentence 3.2.6.2.(6) may be met by incorporating the requirements in Sentences (2) to (8).

(2) A stairway serving storeys above the lowest exit level has a vent or door to the outdoors at or near the bottom of the stairshaft, as described in Sentence (4).

(3) A stairway serving floors below the lowest exit level

(a) has a vent or door to the outdoors at or near the top of the stairshaft as described in (4)

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level and is separate from a shaft that contains a stairway serving upper storeys, or is enclosed in a shaft that contains a stairway serving upper storeys, but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air introduced at or near the bottom of the stairshaft, at a rate equal to at least 1000 cfm for each storey served by the stairway.

(4) A stairshaft required to be vented to the outdoors by (2) or (3) or by other provisions in this Supplement is provided with a vent or door that

(a) has an openable area of 0. 5 sq. ft. for every door between the stairshaft and a floor area but not less than 20 sq. ft.,

(b) opens directly to the outdoors or into a vestibule or exit corridor that has a similar opening to the outdoors, and

(c) has a door or closure that is openable manually and can remain in this open position during a fire emergency.

(5) An elevator shaft that passes through the floor above the lowest exit storey does not penetrate the floor of the next storey immediately below that storey, except where there is a vestibule between the shaft and each below grade floor area as is described in Sentence (3) of Measure D (p. 36).

(6) A vertical service space, other than an elevator shaft that passes through the floor above the lowest exit storey, is provided with a tight fitting non-combustible seal or fire stop at the floor level of the storey immediately below that storey, except where the vertical service space is vented to the outdoors at the top as described in Sentence 2F(10).

(7) A supply of air required by (3) is carried in ducts as described in Sentence (13) of Measure F (p. 49).

(8) The central control facility required by NBC Article 3. 2. 6. 8. is provided with additional controls capable of

(a) opening closures to vents in shafts that may be required by (6),

(b) stopping air handling systems as required by NBC Sentence 3.2.6.2.(6), and

(c) initiating the mechanical air supply to stairshafts as may be required in (3).

Section 2(b)

Open Corridor Access to Stairs and Elevators

Measures B and C - General

Measures B and C can be applied to a building where habitable floor areas are approached along access ways open to the outdoors.

Each corridor that provides access to stairs or elevators is permanently open to the outside as shown in Fig. 2 and 19. The situation is illustrated by the pressure characteristic diagram shown in Fig. 20. Air flow through openings that may exist in floors is likely to be more pronounced than with other smoke control methods because of the reduction in the influence of vertical shafts, so it is desirable that openings through the floor-ceiling assembly be minimized. This should not, however, present an immediate smoke problem except on the floor directly above the floor where a fire occurs.

Measure C is the same as Measure B except that no steps are taken to limit smoke movement into upper storeys through vertical service spaces or shafts in Measure C.

Where shafts enclosing plumbing and electrical services penetrate floor spaces and a decision has been made to use Measure B for control of smoke movement, these shafts should be sealed at least at every fith storey at a horizontal fire separation and at the floor immediately below the lowest exit storey or have vents to the outside at the top. In the latter case there is still some possibility that smoke may pass into the uppermost floor because the air pressures in these floor areas are in the same range as the outside pressures. It is therefore of importance that any leakage areas in the enclosing walls between floor areas and shaft be kept to a minimum.

In order to avoid creation of pressures that may interfere with the opening of doors to stairs and elevator shafts, it is recommended that the building heating system be so designed that temperatures in stairs and elevator shafts, if heated, will not exceed 20 F degrees above outside air temperature.

Where Measure B is adopted, and a fire is detected by an automatic device, or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that the occupants of the fire floor will walk down stairs to a safe floor area. Occupants of other floors may remain until advised to evacuate by the person operating the central alarm and control facility.

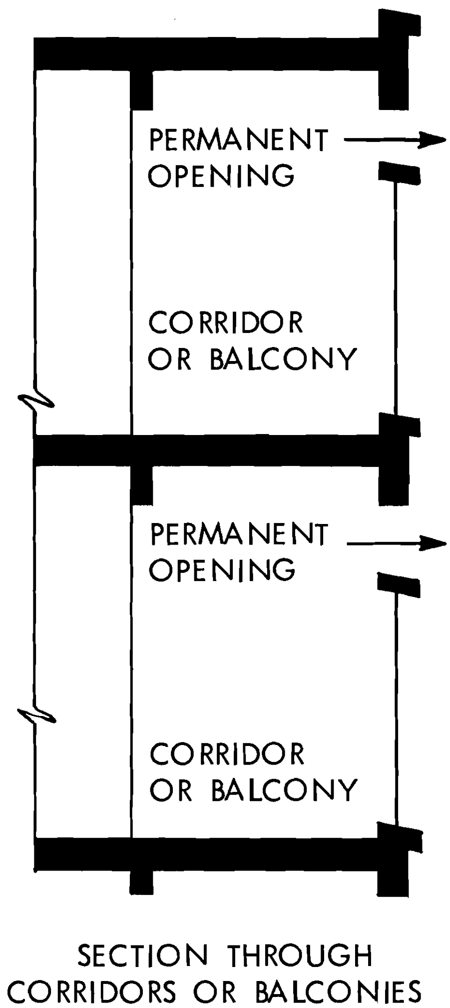


Figure 19

Illustration of Method B and C Design

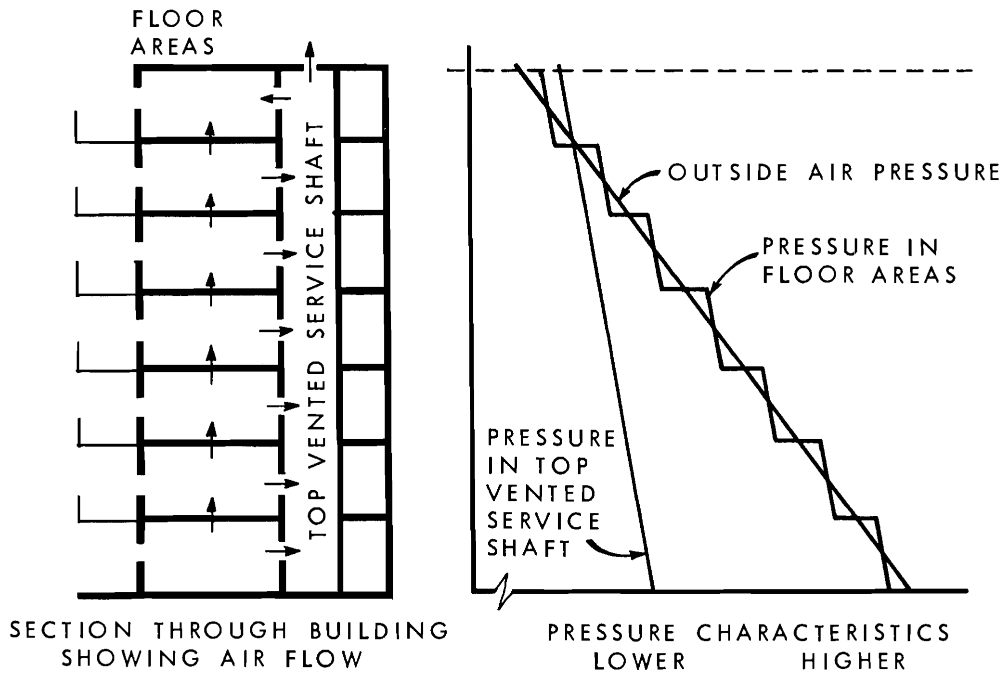


Figure 20

Pressure Characteristics in a Method B Design

Where Measure C is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that occupants of all floors will walk down stairs to the street floor to a safe intermediate floor area.

Measure B - Requirements for Open Corridor Access to Stairs and Elevators (Including restrictions on movement of smoke from floor to floor)

2 (b) (1) The requirements of Sentences (1), (2) and (3) of NBC Article 3.2.6.2. may be met by incorporating the requirements in Sentences (2) to (10).

(2) All public corridors leading to the required exit stairs and firefighters' elevator from every floor area on a floor above the lowest exit storey are provided with permanent openings to the outdoors that

(a) are distributed along the length of the corridor, and

(b) have the top of the opening not more than 10 in. below the ceiling of the corridor, and

(c) have an aggregate open area that is not less than 10 per cent of the floor area of the corridor or 10 sq. ft. whichever is greater.

(3) a stairway serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at the top of the stair-shaft that is as described in Sentence (4) of Measure A (p. 23).

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level and is separate from a shaft that contains a stairway serving upper storeys; or is enclosed in a shaft that contains a stairway serving upper storeys but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air, introduced at or near the bottom of the shaft, at a rate equal to at least 1000 cfm for each storey served by the stairway.

(4) An elevator shaft that passes through the floor above the lowest exit storey does not penetrate the floor of the storey immediately below that storey, except where there is a vestibule between the shaft and each floor area below the lowest exit storey, as described in Sentence (3) of Measure D (p. 36).

(5) A vertical service space within a heated floor area other than an elevator shaft is provided with

(a) tight fitting non-combustible fire stops located at the level of the floor immediately below the lowest exit storey and at the level of certain other floors that are fire separations, provided the space between fire stops does not exceed 5 storeys, or

(b) a vent to the outdoors as described in Sentence (10) of Measure F (p. 48).

(6) An elevator shaft within a heated floor area, other than a shaft that contains a firefighters' elevator, is provided with a vent to the outdoors as described in Sentence (10) of Measure F (p. 48), and is protected against entry of smoke as described in Measure D (p. 36) or Measure F (p. 47).

(7) Except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(8) Supply, return and exhaust ducts exceeding 20 sq. in. in cross-sectional area at the point of entry to a vertical service space in an air handling system that is required to shut down by the provisions of (7) are provided with dampers that will close when the air moving fans are stopped.

(9) Where a supply of air is required by the provisions of Sentence (3) it is carried in ducts described in Sentence (13) of Measure F (p. 49).

(10) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls that are capable of

(a) stopping the air handling systems and closing dampers as required by (7) and (8),

(b) opening closures to vents in vertical service spaces where required by (5) and (6), and

(c) initiating the air supply to stairshafts as may be required by (3).

Measure C - Requirements for Open Corridor Access to Stairs and Elevators (no restriction on movement of smoke from floor to floor)

2(b) (1) The requirements of Sentences (2) and (3) of NBC Article 3.2.6.2., may be met by incorporating the requirements of Sentences (2) to (7).

(2) The public corridors leading to the required exit stairs and firefighters' elevator from every floor area on a floor above the storey on which egress directly to the outdoors occurs are provided with permanent openings to the outdoors that

(a) are distributed along the length of the corridor

(b) have the top of the opening not more than 10 in. below the ceiling of the corridor, and

(c) have an aggregate open area that is not less than 10 per cent of the floor area of the corridor or 10 sq. ft. whichever is greater.

(3) A stairway serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at the top of the stair-shaft as described in Sentence (4) of Measure A (p. 23).

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit storey and is separate from a shaft that contains a stairway serving upper storeys; or is enclosed in a shaft that contains a stairway serving upper storeys,but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air, introduced at or near the bottom of the shaft, of at least 1000 cfm for each storey served by the stairway.

(4) An elevator shaft that contains a firefighters' elevator and passes through the floor above the lowest exit level does not penetrate the floor of the storey immediately below that storey,except where there is a

vestibule between the shaft and each floor area below the lowest exit storey as described in Sentence (3) of Measure D (p. 36).

(5) Except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(6) Where a supply of air is required by (3), it is carried in ducts described in Sentence (13) of Measure F (p. 49).

(7) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls that are capable of

(a) stopping the air handling systems as required by (5) and

(b) initiating the air supply to stairshafts as may be required by (3).

Section 2(c)

Protected Vestibule Access to Stairs and Elevators Shafts

Measures D and E - General

In measures D and E, movement of smoke through stair and elevator shafts is limited by the provision of vestibules that are either open to the outdoors during a fire emergency or have outdoor air injected into them. Stairshafts are further protected by opening a door to the outdoors at the bottom of the shaft. Where vestibules are protected by injection of outdoor air, the elevator shaft is provided with a large opening to the outdoors at the bottom and a smaller opening at the top of the shaft.

Where NBC Article 3.2.6.2. requires that movement of smoke into floor areas to be limited, service shafts are either sealed at intervals or provided with an opening to the outdoors at the top of the shaft as already described in Measure B. A typical plan of a building in which this method of smoke control is appropriate is shown in Fig. 4.

Measure E is the same as Measure D except that no measures are taken to limit movement of smoke into upper storeys in Measure E.

Where a vestibule has a vent or opening to the outdoors that is much larger than the leakage area around doors, etc., between the vestibule and other parts of the building, the air pressure in the vestibule will be approximately equal to the outdoor pressure at the same level. This is illustrated in Fig. 7. In cold weather, in storeys below the neutral pressure plane, air pressure in the vestibule will be substantially higher than that in the floor area. Air will tend to flow from the vestibule into the floor area. In upper storeys, the air pressure in the vestibules will be less than that in the floor area, and air will flow from the floor area to the vestibule. The vent or opening at the foot of the stairshaft referred to above has the effect of increasing pressure in the shaft, so that it approaches outdoor air pressure at ground level (see Fig. 21). On upper storeys the pressure in the stairshaft will be higher than that in the vestibules and smoke that may enter the vestibules will not pass into the stairshaft.

In warm weather when outdoor air may be as warm or warmer than that inside a building, the stack effect is likely to be minimal. In these circumstances, the major problem is expansion of the hot gases on the fire floor. This will tend to force air around doors, etc., into the vestibule. The large vent opening, however, will create a situation where the greater proportion of the air entering the vestibule will pass to the outdoors and a much smaller quantity may enter the shafts. The effect of

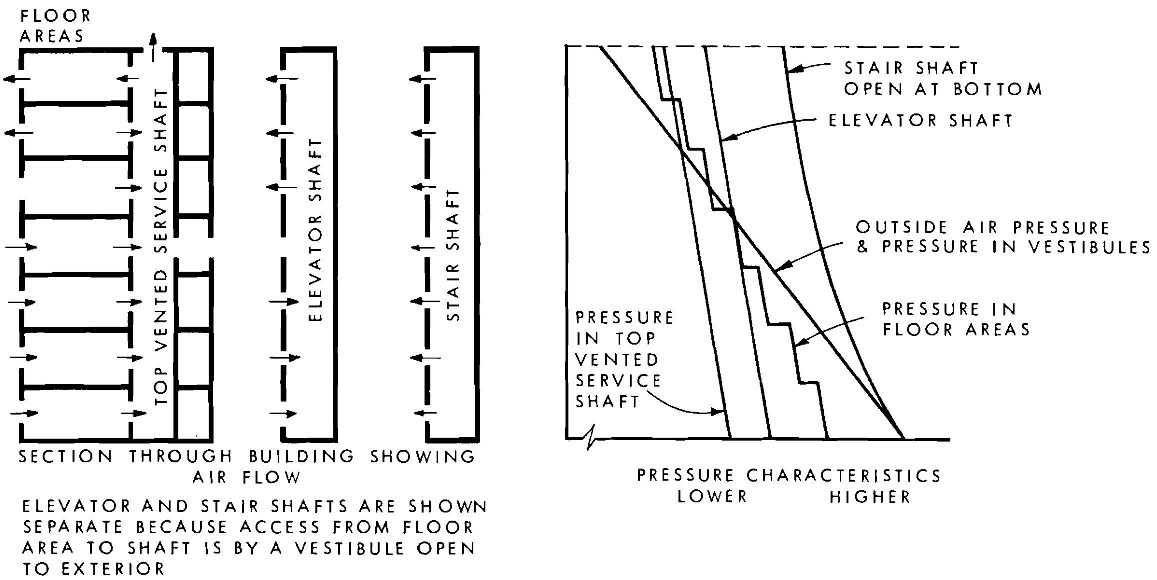


Figure 21

Pressure Characteristics in a Method D Building with Vented Vestibules wind is variable and difficult to predict. In warm weather the effect may be to protect vestibules on one side of the building and allow smoke to enter those on the other side.

Where air is injected into vestibules, the pressure characteristics in cold weather are likely to be as shown in Fig. 22. The rates of air injection should be sufficient to keep the pressures in the vestibules a little higher than the pressure in the shaft. This limits the possibility of movement of smoke into the vestibules from the floor areas. In cold weather, vents at the bottom of the stairs and elevator shafts provide additional protection for these shafts. In addition, the smaller opening provided at the top of the elevator shaft serves to exhaust air that flows into the shaft at the bottom. In warm weather the two openings in the elevator shaft encourage air flow from the pressurized vestibules through the shaft to the exterior, thus providing some dilution of any smoke that may enter the shaft.

Elevator shafts and service shafts that will not be used in a fire emergency are provided with vents at the top to the outdoors where it is required by Measure D (but not Measure E) that movement of smoke into upper floors be limited. The possibility remain, however, that some smoke may pass from top vented elevator and service shafts into the top floor or floors, because air pressures at the top of the shafts and in the floor area of the top storey are approximately equal.

Stack action and the operation of smoke control measures may provide pressures that will interfere with the normal operation of certain doors. Where a vestibule is vented to the outdoors, this may apply to any door between a vestibule and an elevator shaft that is farther above or below the mid-height of a building than the height given by Graph 9 in Appendix A, and to any door between a vestibule and a stairshaft that is farther above grade than the height given by Graph 9.

Where a vestibule is pressurized this may apply to any door between a vestibule and a floor space that is farther above grade than the height shown in Graph 9.

As an alternative to the provision of a mechanical air supply for a vestibule to an elevator shaft, as described in Sentence (5) of Measure D (p. 37), the mechanical air supply can be introduced directly into the shaft as described in Sentence (4) of Measure F (p.47), provided

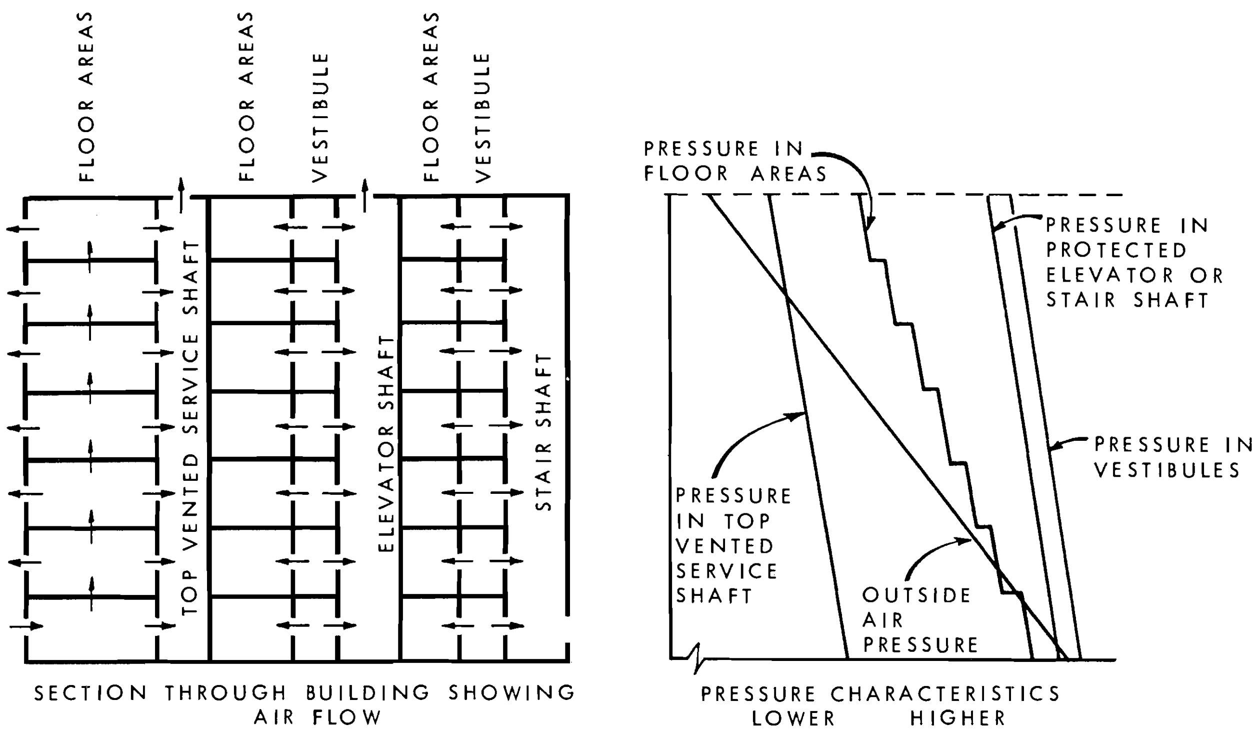


Figure 22

Pressure Characteristics in a Method D Building having Air Injected into Vestibules there are no open vents to the elevator shaft such as described in Sentence (9) of Measure D (p. 38).

Where a mechanical air supply is required by Sentence (5) of Measure D (p. 37) and Sentence (4) of Measure E (p. 40), it may be desirable to heat the air supply and to provide two air intakes in separate locations on the building face as discussed in the general provisions to Measures F and G.

Where Measure D is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously,and that the occupants of the fire floor will walk down stairs to the street floor or to a safe intermediate floor area. Occupants of other floors may remain until advised to evacuate by the person operating the central alarm and control facility.

Where Measure E is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that occupants of all floors will walk down stairs to the street floor or to a safe intermediate floor area.

Measure D - Requirements for Protected Vestibule Access to Stairs and Elevators (including restriction on the movement of smoke from floor to floor).

2(c) (1) The requirements of Sentences (1), (2) and (3) of NBC Article 3.2.6.2. may be met by incorporating the requirements of Sentences (2) to (18).

(2) Between each floor area and each stairshaft or elevator shaft that contains a firefighters' elevator a vestibule is provided that is as described in (3).

(3) Where a vestibule is required by (2) or by other provisions of this Supplement

(a) a fire separation is provided between a public corridor and the vestibule that has a fire resitance rating not less than 3/4 hr.,

(b) a fire separation is provided between a floor area, other than the corridor described in clause (a), and the vestibule that has a fire resistance rating not less than that required for an exit in NBC Article 3.4.5.1., and

(c) a door in the fire separation described in (a) or (b) is provided with a self closing device as required by NBC Subsection 3.1.7., and opens in the direction of travel from the floor area to the <u>exit</u> stairway.

(4) On each floor, any vestibule that has a door to an exit stair may also have a door to a firefighters' elevator, but two exit stairs may not open on to the same vestibule.

(5) Each vestibule described in (2) that provides access to a stair or an elevator shaft

(a) has a vent opening to the outdoors that has an openable area not less than 1 sq. ft. for each door that opens onto the vestibule, but not less than 4 sq. ft., or

(b) has equipment capable of providing a mechanical air supply not less than that obtained from Graph 3 in Appendix A for a vestibule to a stair or an elevator shaft.

(6) The vent to each vestibule referred to in (5) (a) may be provided with a closure that is openable manually, and in a building that is more than 120 ft. in height, it can be opened from the central control facility as provided in (18).

(7) A stairway serving storeys above the lowest exit level is vented to the outdoors at the bottom of the stairshaft as described in Sentence (4) of Measure A (p. 23).

(8) A stairway serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at or near the top of the stairshaft as described in Sentence (4) of Measure A (p. 23).

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level and is separate from a shaft that contains a stairway serving upper storeys; or is enclosed in a shaft that contains a stairway serving upper storeys, but is separated from that stairway at the storey on which egress directly to the outdoors occurs by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air, introduced at or near the bottom of the shaft, at a rate equal to at least 1000 cfm for each storey served by the stairway.

(9) Each elevator shaft protected by a vestibule having a mechanical air supply as described in (5) (b)

(a) has a vent at or near the bottom of the shaft, opening directly to the outdoors or into a vestibule or corridor that has a similar opening to the outdoors, having an openable area not less than 0.25 sq. ft. for every door into the shaft, other than doors at street floor level, and

(b) has a vent at or near the top of the shaft, opening to the outdoors and not into an elevator machinery room, having an openable area that is not less than one-quarter nor more than one-half of the area of the vent at street level required in (a).

(10) The vent at the top of each elevator shaft referred to in (9) may be provided with a closure that is openable manually, and will open on a signal from a products of combustion detector located at the top of the shaft and as provided in (18).

(11) The vent at the bottom of an elevator shaft referred to in (9) may be provided with a closure which is openable manually and is designed to remain open during a fire emergency.

(12) A vertical service space other than an elevator shaft is provided with

(a) a tight fitting non-combustible fire stop at the level of the floor immediately below the lowest exit storey, and at the level of certain other floors that are fire separations, provided the space between fire stops does not exceed 5 storeys, or

(b) a vent to the outdoors as described in Sentence (10) of Measure F (p. 48).

(13) Except as provided in (16) an elevator shaft, other than a shaft that contains a firefighters' elevator

(a) is provided with a vent to the outdoors as described in Sentence (10) of Measure F (p. 48), or

(b) is protected against entry of smoke by a vestibule as described in Sentence (5).

(14) The provisions in (13) are waived for an elevator shaft that serves floor areas below the lowest exit storey and does not penetrate the floor immediately above that storey.

(15) Except for air moving fans supplying vestibules as provided in (5) (b), and except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(16) Supply, return and exhaust ducts exceeding 20 sq. in. in cross-sectional area at the point of entry to a vertical service space in an air handling system that is required to shut down by the provisions of Sentence (5) are provided at that point of entry with dampers that will close when the air moving fans are stopped.

(17) Where a supply of air is required by the provisions of (5) and (8) it is carried in ducts described in Sentence (13) of Measure F (p. 49).

(18) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls that are capable of

(a) opening closures to vents to the outdoors in vestibules on all floors as required by (6) and in elevator shafts as required by (9) and (13).

(b) stopping air handling systems and closing dampers in ducts as required by (6) and (7),

(c) initiating the mechanical air supply to vestibules required by (5) (b), and,

(d) opening closures to vents in vertical service spaces where required by (12).

Measure E - Requirements for Protected Vestibule Access to Stairs and Elevators (no restriction on movement of smoke from floor to floor)

2(c) (1) The requirements of Sentences (2) and (3) of NBC Article 3.2.6.2., may be met by incorporating the requirements in Sentences (2) to (14).

(2) Between each floor area and each stairshaft, or each elevator shaft that contains a firefighters' elevator, a vestibule is provided as described in Sentence (3) of Measure D (p. 36).

(3) On each floor any vestibule that has a door to an exit stair may also have a door to a firefighters' elevator but two exit stairs may not open on to the same vestibule.

(4) Each vestibule described in (2) that provides access to a stair or an elevator shaft,

(a) has a vent opening to the outdoors that has an openable area not less than 1 sq. ft. for each door that opens onto the vestibule, but not less than 4 sq. ft., or

(b) has equipment capable of providing a mechanical air supply not less than that obtained from Graph 3 for a vestibule to a stair or an elevator shaft.

(5) The vent to each vestibule referred to in (4) (a) is provided with a closure that is openable manually, and in a building that is more than 120 ft. in height can be opened from the central control facility as provided in (13).

(6) A stairway serving storeys above the lowest exit level is vented to the outdoors at the bottom of the stairshaft as described in Sentence (4) of Measure A (p. 23).

(7) A stairway serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at the top of the stair-shaft as described in Sentence (4) of Measure A (p. 23)

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level and is separate from a shaft that contains a stairway serving upper storeys; or is enclosed in a shaft that contains a stairway serving upper storeys but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air, introduced at or near the bottom of the shaft, at the rate of at least 1000 cfm for each storey served by the stairway.

(8) Each elevator shaft protected by a vestibule having a mechanical air supply as described in (4) (b)

(a) has a vent at or near the bottom of the shaft opening directly to the outdoors, or into a vestibule or corridor that has a similar opening to the outdoors, having an openable area not less than 0.25 sq. ft. for every door into the shaft other than doors at street floor level, and

(b) has a vent at or near the top of the shaft opening to the outdoors, and not into an elevator machinery room, having an openable area that is not less than one-quarter nor more than one-half of the area of the vent at street level required in (a).

(9) The vent at the top of each elevator shaft referred to in (8) may be provided with a closure which is openable manually and will open on a signal from a products of combustion detector located at the top of the shaft and as provided in (14).

(10) The vent at the bottom of an elevator shaft referred to in (8) may be provided with a closure that is openable manually and is designed to remain open during a fire emergency.

(11) An elevator shaft that contains a firefighters' elevator and passes through the floor above the lowest exit storey does not penetrate the floor of the storey immediately below that storey, except where there is a vestibule between the shaft and each floor area below the lowest exit storey as described in Sentence (3) of Measure D (p. 36).

(12) Except for air moving fans supplying vestibules as provided in (4) (b),and except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(13) Where a supply of air is required by the provisions of (4) and (7) it is carried in ducts described in Sentence (13) of Measure F (p. 49).

(14) The central alarm and control facility required by NBC Article 3.2.6. is provided with additional controls that are capable of

(a) opening closures to vents to the outdoors in vestibules on all floors as required in (5), and in elevator shafts as required by (9),

(b) stopping air handling systems as required by (12) and

(c) initiating the mechanical air supply to vestibules as required by (4) (b).

Section 2(d)

Pressurized Stair and Elevator Shafts

Measures F and G - General

Measures F and G are suitable for use in buildings that have central cores containing elevator and stair shafts, and also in those that have a spine corridor. The objective is to inject sufficient air from outdoors to provide air pressures in stairshafts and in one or more protected elevator shafts that will be at least equal to the outdoor air pressure at ground level. Protected elevator shafts may, in addition, be provided with vestibules on each floor in order to reduce the effect of the large leakage areas around elevator doors, which may otherwise require injection of excessive quantities of air in order to achieve the desired pressurization. An opening to the outdoors at the bottom of each stairshaft is required in conjunction with air injection in order to maintain the desired pressure conditions, though some doors on upper floors may be held open for a time, and to provide for dilution of smoke that may enter the stairshaft. A typical plan of a building where this method of smoke control is appropriate is shown in Fig. 6.

Measure G is the same as Measure F except that no provisions are made to limit movement of smoke into upper floors in Measure G by way of service shaft and unprotected elevator shafts.

Where it is required by NBC Article 3.2.6.2. that movement of smoke into floor areas be limited, service shafts are either sealed at intervals or vented to the outdoors at the top as described in the general provisions of Measures B and C. Elevator shafts that are not protected by injection of air, and will not be used during a fire emergency, are also provided with vents to the outdoors at the top in order to limit movement of smoke into upper floors as described in the general provisions of Measures D and E. This system is, however, likely to be more efficient than that achieved by Measure D because injection of air into some shafts has the effect of increasing the air pressure in all floor areas. This is illustrated in Fig. 23, where it can be seen that the pressure in the floor area of the top storey is greater than that at the top of the vented shaft.

Treads and landings in a stairshaft present an obstacle to free flow of air. Where air is injected only at the top of a stairshaft, there is likely to be a pressure gradient between top and bottom of the stair. This may produce pressure differences of sufficient magnitude to interfere with the opening of doors into the stair shaft in the upper part of the building. This is discussed more fully in Appendix B.

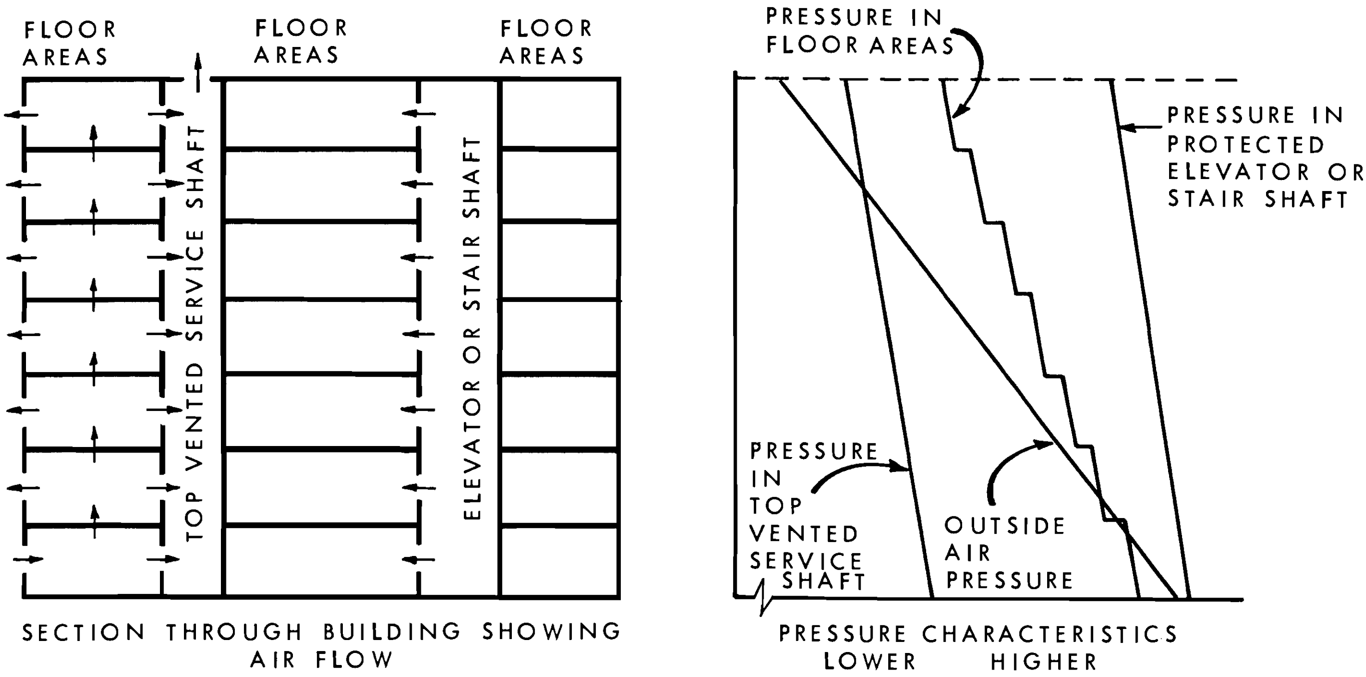


Figure 23

Pressure Characteristics in a Measure F Building

Stack action and the operation of smoke control measures may produce pressures across certain doors that will interfere with their normal operation. This may apply to any door between a floor space and a stairshaft, or an elevator vestibule that is farther above grade than the height shown in Graph 10 in Appendix A.

In order to avoid excessive pressures across doors when outdoor temperatures are appreciably above the January design temperature, it is recommended that the air flow into elevator shafts in a building employing measure F or G be reduced in the proportion shown in Graph 7 in Appendix A of the air flow referred to in Sentence (4) in Measure F (p. 47), and Sentence (4) of Measure G (p. 50), to a lower limit that is not less than that obtained by the factor F_5 = 1100.

The limits are such that no modulation is required in the following situations:

TABLE 1

Minimum Winter Design Temperature	Maximum Height of Building
+20°F	310 ft.
0°F	230 ft.
-20°F	180 ft.
-40°F	150 ft.

Heating of the air supply referred to in Sentences (2) and (4) of Measure F (p. 47) or Sentences (2) and (4) of Measure G (p. 50) may be necessary, since to maintain the efficiency of the smoke control measures the temperature of the incoming air should be not less than the mean of indoor and outdoor temperatures at the time. To avoid damage to water systems, the temperature of air entering critical locations should be not less than 32 degrees F. To maintain tolerable conditions for occupants, the temperature of air entering occupied spaces should be not less than 50 degrees F.

Where mechanical air supply is specified in Sentences (2) and (4) of Measure F (p. 47), or Sentences (2) and (4) of Measure G (p. 50), it is desirable that the air be drawn from at least two remote locations, each on a different face of the building. Each air intake should be provided with a damper that will close on a signal from a products of combustion detector in the duct following 30 sec exposure to smoke or products of combustion. The damper should have a manual override to reopen it when the smoke condition that caused it to close has cleared.

Where Measure F is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that the occupants of the fire floor will walk down stairs to the street floor or to a safe intermediate floor area. Occupants of other floors may remain until advised to evacuate by the person operating the central alarm and control facility.

Where Measure G is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that occupants of all floors will walk down stairs to the street floor.

Measure F - Requirements for Pressurized Stair and Elevator Shafts (including restriction on movement of smoke from floor to floor)

2(d) (1) The requirements of Sentences (1), (2) and (3) of NBC Article 3.2.6.2., may be met by incorporating the requirements in Sentences (2) to (14).

(2) A stairshaft serving storeys above the lowest exit level has

(a) a vent or door to the outdoors at or near the bottom of the stairshaft, as described in Sentence (4) of Measure A (p. 23), except that the vent or door will open when the air supply referred to in (b) is initiated, and

(b) equipment capable of providing a mechanical air supply to the shaft of not less than 15, 000 cfm plus 100 cfm for every weather stripped door into the stairshaft and 200 cfm for every non-weather stripped door into the stairshaft.

(3) A stairway serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at or near the top of the stairshaft as described in Sentence (4) of Measure A (p. 23), and

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level and is separate from a shaft that contains a stairway serving upper storeys; or is enclosed in a shaft that contains a stairway serving upper storeys but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air, introduced at or near the bottom of the shaft, at a rate equal to at least 1000 cfm for each storey served by the stairway.

(4) An elevator shaft that contains a firefighters' elevator is provided with equipment capable of maintaining a flow of air to the shaft that is not less than that obtained from Graph 5 in Appendix A.

(5) Where an elevator shaft referred to in (4) is provided with a vestibule on every floor, the vestibule enclosure conforms to Sentence (3) of Measure D (p. 36).

(6) An elevator shaft that contains a firefighters' elevator and passes through the floor above the lowest exit storey does not penetrate the floor of the storey immediately below that storey, except where each floor area below the lowest exit storey is provided with a vent to the outdoors that

(i) has a net area of at least 2 sq. ft. for every 10,000 sq. ft. of floor area,

(ii) will remain open during a fire emergency, and

(iii) may be incorporated in the conventional exhaust duct system serving below grade storeys.

(7) A vertical service space other than an elevator shaft is provided with

(a) a tight fitting fire stop at the level of the floor immediately below the lowest exit storey and at the level of certain other floors that are fire separations provided the space between fire stops does not exceed 5 storeys, or

(b) a vent to the outdoors as described in (10).

(8) Except as provided in Sentence (9), an elevator shaft, other than a shaft that contains a firefighters' elevator, is provided with a vent to the outdoors as described in (10) or is pressurized as described in (4).

(9) The provisions of (8) are waived for an elevator shaft that serves floor areas below the lowest exit storey and does not penetrate the floor immediately above that storey.

(10) Where a vent to the outdoors is required by (7), (8) or (9) or other provisions of this Supplement, the vent,

(a) if it is in a vertical service space, other than an elevator shaft in a building in which other shafts are not mechanically pressurized, has an openable area that is not less than that obtained from Graph 1 in Appendix A, or if it is in a mechanically pressurized shaft, has an openable area that is not less than that obtained from Graph 2 in Appendix A,

(b) if it is in an elevator shaft, has an openable area that is not less than that obtained from Graph 4 in Appendix A,

(c) if it is in a shaft serving floor areas above the lowest exit storey, is located at or near the top of the shaft where the top of the shaft is above the mid height of the building, or at or near the foot of the shaft where the top of the shaft is below the mid height of the building,

(d) if it is in a shaft serving floor areas below the lowest exit storey, is located at or near the top of the shaft, and

(e) if it is provided with a closure, is openable both manually and on a signal from products of combustion detector, located at or near the top of the shaft,and by a control device located at the central alarm and control facility referred to in NBC Article 3.2.6.8.

(11) Except for air moving fans supplying stairs and elevators as provided in (2), (3) and (4),and except for exhaust from kitchens, washrooms and bathrooms in dwelling units,air-moving fans are stopped in an air handling system that serves more than two storeys.

(12) Supply, return and exhaust ducts exceeding 20 sq. in. in cross-sectional area at the point of entry into a vertical service space in an air handling system that is required to shut down by the provisions of (12),are provided with dampers that will close when the air moving fans are stopped.

(13) Where a supply of air is required by the provisions of (2), (3) or (4) or by other provisions of this Supplement, the duct system is installed in a service space conforming to Section 3.5 of NBC 1970, or is otherwise protected against the effect of fire from the point of fresh air intake to the shaft or to the storey that contains the protected floor area, vestibule or area of refuge that is required to be so protected.

(14) The central alarm and control facility required by NBC Sub Section 3.2.6. is provided with additional controls that are capable of

(a) stopping air handling systems and closing dampers in ducts in (12) and (13),

(b) initiating the mechanical air supply to stairshafts and elevator shafts required in (2), (3) and (4), and

(c) opening closures to vents in vertical service spaces where required in (7), (8) and (9).

Measure G - Requirements for Pressurized Stair and Elevator Shafts (no restrictions on movement of smoke from floor to floor)

2(d) (1) The requirements of Sentences (2) and (3) of NBC Article 3.2.6.2., may be met by incorporating the requirements in Sentences (2) to (9).

(2) A stairshaft serving storeys above the lowest exit level has

(a) a vent or door to the outdoors at or near the bottom of the stairshaft, described in Sentence (4) of Measure A (p. 23), except that the vent or door will open when the air supply referred to in (b) is initiated, and

(b) equipment capable of providing a mechanical air supply to the shaft of not less than 15, 000 cfm, plus 100 cfm for every weatherstripped door into the stairshaft and 200 cfm for every non-weatherstripped door into the stairshaft.

(3) A stairway serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at or near the top of the stairshaft as described in Sentence (4) of Measure A (p. 23),

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level, and is separate from a shaft that contains a stairway serving upper storeys; or is enclosed in a shaft that contains a stairway serving upper storeys, but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air introduced at or near the bottom of the shaft at a rate of at least 1000 cfm for each storey served by the stairway.

(4) An elevator shaft that contains a firefighters' elevator is provided with equipment capable of maintaining a flow of air to the shaft that is not less than that obtained from Graph 5 in Appendix A.

(5) Where an elevator shaft referred to in (4) is provided with a vestibule on every floor, the vestibule enclosure is as described in Sentence (3) of Measure D (p. 36).

(6) An elevator shaft that contains a firefighters' elevator and passes through the floor above the lowest exit storey does not penetrate the floor immediately below the storey, except where each floor area below the lowest exit storey is provided with a vent to the outdoors that,

(a) has a net area of at least 2 sq. ft. for every 10,000 sq. ft. of floor area,

(b) will remain open during a fire emergency, and

(c) may be incorporated in the conventional exhaust duct system serving below grade storeys.

(7) Except for air moving fans supplying stairs and elevator shafts as provided in (2), (3) and (4), and except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in and air handling system that serves more than two storeys.

(8) Where a supply of air is required by (2), (3) and (4), it is carried in ducts that are described in Sentence (13) of Measure F (p. 49).

(9) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls that are capable of,

(a) stopping air handling systems as required by (7), and

(b) initiating the mechanical air supply to stairshafts and elevator shafts required by (2), (3) and (4).

Section 2(e)

Building Fully Pressurized

Measure H - General

Measure H is appropriate for buildings having central cores that contain stair and elevator shafts and windows that are not normally opened, as shown in Fig. 8. The air pressure in the whole building is increased so that at grade level it is at least equal to outdoor air pressure. When a vent to the outdoors is provided on the fire floor by a window in an exterior wall, or an opening into a smoke shaft as described in Chapter 3, or by the building mechanical exhaust system if the building is sprinklered, the pressure in the floor area is reduced substantially, as is shown in Fig. 24. Air will then flow from the shafts and other floor areas into the fire floor. The combination of building pressurization and venting of the fire floor provides that smoke will not pass into other floor areas or shafts, other than the smoke shaft.

It is important that air be uniformly distributed throughout the building. This may be achieved by supplying the air through the conventional duct system or through vertical shafts. A minimum proportion of the air is required to be injected directly into stair shafts. This is designed to reduce the possibility, particularly in warm weather, that a substantial drop in pressure in these shafts will occur when a door to the outdoors at grade is opened, with the consequent danger that smoke will enter the shafts.

It is also recommended that where venting is by smoke shafts, the air supply to the floor on which fire occurs should be cut off by closing the dampers on that floor in order not to overload the smoke shaft.

The total air flow for building pressurization is modulated relative to outdoor air temperature. This is intended, in part, to limit the magnitude of the potential pressure drop in stair and elevator shafts referred to above, and in part to avoid excessive pressures across doors to stair and elevator shafts that would interfere with their normal use.

This requirement for modulation of air flows applies generally to higher buildings. The conditions described in Sentence (3) of Measure H (p. 55) are such that no modulation is required where the January design temperature and the building height are as shown in Table 1 on p. 45.

In Toronto, for example, where the Winter Design Temperature is $1^{\circ}F$, no modulation of air flow would be required for a building not exceeding 230 ft. in height.

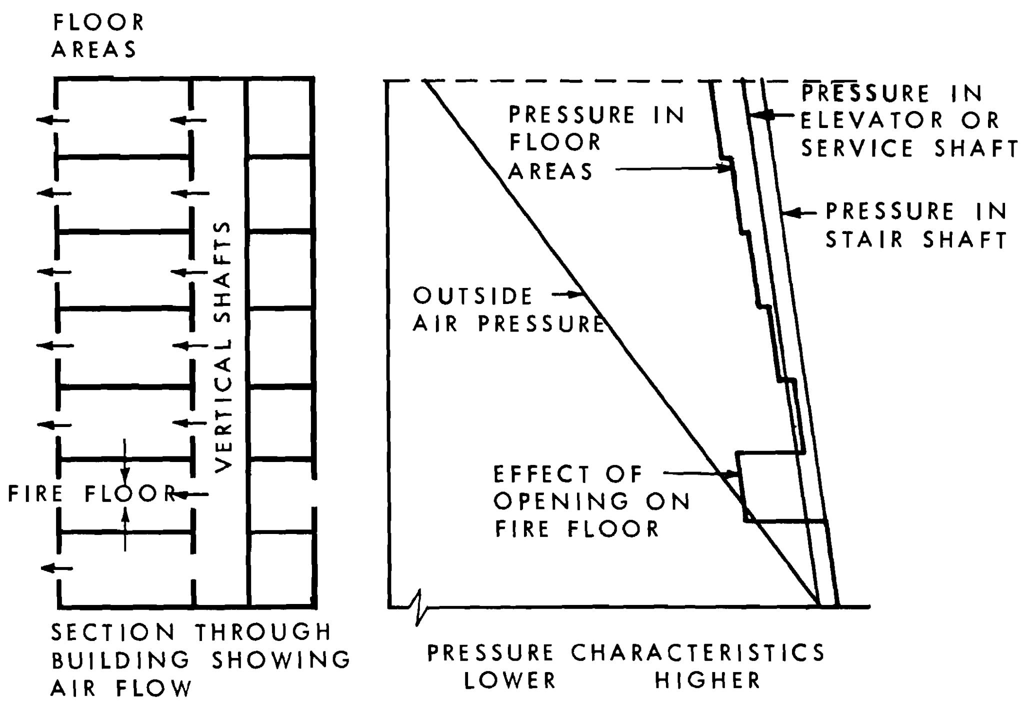


Figure 24

Pressure Characteristics in Measure H Building

This measure is not appropriate for a building where windows may normally be held open. The air flow requirements in Graph 6 in Appendix A are based on an assumed air leakage through the external walls that is appropriate to modern air-conditioned buildings having reasonably tight fitting non-openable windows. If the leakage area is other than that noted above, the air flow requirement must be adjusted proportionately, as described in the notes to Graph 6.

Stack action and the operation of smoke control measures may produce pressures across certain doors that will interfere with their normal operation. This may apply to any door between a floor space and stairshaft or an elevator shaft that is farther above grade than the height shown in Graph 9 in Appendix A.

Where mechanical air supply is required by Sentence (2) of Measure H (p. 55), it may be desirable to heat the air supply and to provide two air intakes in separate locations on the building face as discussed in the general provisions to Measure F and G.

Where a floor area is subdivided by walls, provision should be made for a free air passage from any part of the floor area to the vent or vents required by Sentence (6) of Measure H (p. 56). Such provisions for venting need not apply to public corridors or washrooms that normally have a minimum of combustibles.

There is not likely to be a problem where vents are on outside walls, and each room or space can be vented directly to the outdoors. Where a smokeshaft is used, however, a fire may occur in a space adjacent to a stair or elevator shaft and separated by partitions from the smoke shaft vent. The solution may be to vent each space to the smoke shaft through the ceiling plenum or to provide suitable openings in the partitions. Where each room or space opens on to a corridor leading to stair and elevator shafts, location of the smoke shaft vent in the corridor will be effective in limiting movement of smoke to other floors, but may also present problems to the firefighter who may have to approach the fire through a smoke filled corridor.

Where measure H is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that the occupants of the fire floor will walk down stairs to the street floor or to a safe intermediate floor area. Occupants of other floors may remain until advised to evacuate by the person operating the central alarm and control facility.

Measure H - Requirements for Fully Pressurized Buildings

2(e) (1) The requirements of Sentences (1), (2) and (3) of NBC Article 3.2.6.2. may be met by incorporating the requirements in Sentences (2) to (8).

(2) The building air handling system is designed and installed so that

(a) supply fans are capable of maintaining an air flow into the building not less than that obtained from Graph 6 in Appendix A when the outdoor air temperature is equal to the Winter Design Temperature on a $2\frac{1}{2}$ per cent basis, and

(b) a portion of the air flow referred to in Clause (a) is directed into each stairshaft in a quantity equal to 200 cfm for every weatherstripped door into the stairshaft and 300 cfm for every non-weatherstripped door into the stairshaft.

(3) When smoke control measures are initiated by the controls referred to in (8)

(a) all main return and exhaust fans are stopped,

(b) supply fans provide the air flow into the stairshafts described in (2) (b), and

(c) supply fans maintain an air flow into the building controlled in relation to outdoor air temperature, so that the total air flow into the building is substantially equal to the proportion shown in Graph 7 of Appendix A of the air flow referred to in (2) (a), but not less than the air flow obtained when the factor F_6 equals 0.5.

(4) All openings in external walls and roofs, including vents to vertical service spaces, other than those referred to in (6), have closures that will close as provided in (8).

(5) All return and exhaust ducts exceeding 20 sq. in. in cross-sectional area at the point of entry to a vertical service space are provided with dampers that will close on the floor on which fire occurs as required by (8), other than those covered by (6).

(6) In order to achieve a reduction in air pressure on the floor on which fire occurs relative to that on other floors, means of venting each floor space to the outdoors are provided as described in Chapter 3.

(7) Where a supply of air is required by (2) it is carried in ducts that are as described in Sentence (13) of Measure F (p. 49).

(8) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls capable of

(a) Stopping main return and exhaust fans and maintaining the air flow in the supply systems as provided in (2)

(b) Closing the closures and dampers required in (4) and (5) and

(c) Opening the closures to the vent openings on the fire floor as provided in (6).

Section 2(f)

Building Core Pressurized

Measures I and J - General

Measures I and J are very similar to Measure H, except that they may be applied to buildings where windows may be open during normal use. It is thus particularly suitable for controlling smoke movement in residential buildings. Plans of typical buildings where Measures I and J are appropriate are shown in Fig. 9 and 10. The central core that includes exit stairs, elevator shafts and public corridors is separated from the remainder of the floor areas. It is important that the leakage area of walls around the core be less than that of the exterior walls of the building.

Measure J is the same as Measure I except that no provision is made to limit smoke movement into upper floors in Measure J by way of vertical shafts and ducts that are outside the core.

Air is injected into the core so that the air pressure in the core at the ground floor is equal to exterior air pressure at the same level. Provision of a vent to the outdoors in the fire suite will cause air to flow from adjacent parts of the building into the fire suite. This is the only method apart from Measure B that makes it possible for smoke to be confined to the fire suite.

Where movement of smoke from floor to floor outside the central core is to be limited as in Measure I (but not J), all vertical shafts penetrating floor areas must be sealed at intervals or vented to the outdoors at the top, as discussed in the general requirements of Measure D.

The air flow requirements in Graph 6 of Appendix A are based on the air leakage characteristics of typical corridor walls and doors. If the leakage areas exceed those given in the notes to Graph 6, the air flow should be increased in direct proportion.

Stack action and the operation of smoke control measures may produce pressures across certain doors that will interfere with their normal operation. This may apply to any door between a suite and a corridor that swings into the corridor and is farther above grade than the height shown in Graph 9 in Appendix A.

Within a suite that is subdivided by partitions, the space that includes the vent to the outdoors described in Sentence (4) of Measure I (p. 59) should be in the same space as the door to the public corridor or linked to it by a leakage area of at least 0.5 sq. ft.

Where mechanical air supply is required by Sentence (2) of Measure I (p. 59) and Sentence (2) of Measure J (p. 62), it may be desirable to heat the air supply and to provide two air intakes in separate locations on the building face as discussed in the general provisions to Measures F and G.

Where Measure I is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that the occupants of the fire floor will walk down stairs to the street floor or to a safe intermediate floor area. Occupants of other floors may remain until advised to evacuate by the person operating the central alarm and control facility.

Where Measure J is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that a fire alarm will sound on all floors simultaneously, and that occupants of all floors will walk down stairs to the street floor or to a safe intermediate floor area.

Measure I - Requirements for Partially Pressurized Building (Compartmented Floor Area) (including restrictions on movement of smoke from floor to floor)

2 (f) (1) The requirements of Sentences (1), (2) and (3) of NBC Article 3.2.6.2. may be met by incorporating the requirements in Sentences (2) to (10).

(2) The building air handling system is designed and installed so that supply fans are capable of maintaining an air flow into the space that includes stairs, elevator shafts and corridors, not less than that obtained from Graph 6, in Appendix A, when the outdoor air temperature is equal to the January Design Temperature on a $2\frac{1}{2}$ per cent basis.

(3) Any vent at the top of an elevator shaft or vertical service shaft within the central core and all other openings penetrating the space that includes the stairs, elevator shafts and corridors are provided with closures at the point of penetration that will close in the event of fire, as provided in (9).

(4) Means of venting each fire compartment to the outdoors are provided by

(a) an opening in an exterior wall, such as an openable window or panel, having an openable area of at least 4 sq. ft.,

(b) an opening into a smoke shaft, as described in Chapter 3, operated by a products of combustion detector, or

(c) an exhaust system, such as a kitchen or washroom exhaust, that has an air flow to the outdoors of not less than 400 cfm per fire compartment served, provided the exhaust system is designed to function as a smoke shaft and meets the relevant requirements of Chapter 3.

(5) Where a closure is provided in an opening referred to in (4)(a) or (b) it will open

(a) by operation of a fusible link, or

(b) on a signal from a products of combustion detector in the room or suite.

(6) A vertical service space that is outside the pressurized space referred to in Sentence (2) is provided with

(a) a tight fitting non-combustible seal or fire stop

(i) at the level of the floor immediately below the storey in which egress directly to the outdoors occurs, and

(ii) at the level of certain other floors that are fire separations provided the space between fire stops does not exceed 5 storeys, or

(b) a vent to the outdoors as described in Sentence (10) of Measure F (p. 48).

(7) Except as otherwise provided in (2) and (4), and except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(8) Supply, return and exhaust ducts exceeding 20 sq. in. in cross-sectional area at the point of entry to a vertical service space in an air handling system that is required to shut down by (7) are provided with dampers that close when the air moving fans are stopped.

(9) Where a supply of air is required by (4), it is carried in ducts that are described in Sentence (13) of Measure F (p. 49).

(10) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls that are capable of

(a) stopping return and exhaust fans, closing dampers in ducts, and maintaining the air flow in the supply system to the space that includes stairs, elevator shafts and corridors as provided in (2) and (7),

(b) causing dampers and closures in the enclosing walls of the space that includes stairs, elevator shafts and corridors to close as required by (3), and

(c) opening closures to vents in vertical service spaces where required by (6),

(d) opening closures in vents referred to in (4) on any floor, and

(e) initiating the air flow in the exhaust system from any floor where required by (4)(c).

Measure J - Requirements for Partially Pressurized Building (Compartmented Floor Area) (no restrictions in movement of smoke from floor to floor)

2(f) (1) The requirements of Sentences (2) and (3) of NBC Article 3.2.6.2. may be met by incorporating the requirements in Sentences (2) to (6).

(2) The building air handling system is designed and installed so that supply fans are capable of maintaining an air flow into the space that includes stairs, elevator shafts and corridors not less than that obtained from Graph 6 in Appendix A when the outdoor air temperature is equal to the January Design Temperature on a $2\frac{1}{2}$ per cent basis.

(3) Any vent at the top of an elevator shaft or vertical service shaft within the central core, and all other openings penetrating the space that includes the stairs, elevator shafts and corridors are provided with closures at the point of penetration that will close in the event of fire, as provided in (4).

(4) Except as otherwise provided in (2), and except for exhaust fans from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(5) Where a supply of air is required by (2), it is carried in ducts as described in Sentence (13) in Measure F (p.49).

(6) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls that are capable of

(a) stopping return and exhaust fans and maintaining the air flow in the supply system to the space that includes stairs, elevator shafts and corridors as provided in (2), and

(b) causing dampers and closures in the enclosing walls of the space that includes stairs, elevator shafts and corridors to close as required by (3).

Section 2(g)

Vertically Divided Building

Measure K - General

In Measure K a degree of protection to occupants is achieved by providing either a spatial separation or a fire separation between two parts of the building as shown in Fig. 11 and 12. Under these conditions, except as subsequently noted, air pressures on either side of the division will be symmetrical and smoke should not pass from one side to the other. Smoke from fire in one part of the building may be expected to pass into stairs, elevator shafts and floor areas on the fire side, while the equivalent spaces on the other side will remain smoke free. Vestibules and bridges are provided as means of access to refuge areas for occupants of floor areas in the part of the building that is exposed to fire and smoke.

Vestibules or bridges are either vented to the outdoors or pressurized mechanically in order to prevent their acting as paths for the transmission of smoke. In vented vestibules below the neutral pressure plane of the building, air will normally flow from the vestibules to the floor areas and no smoke should enter the vestibules. In vestibules above the neutral pressure plane, air will flow from the floor area to the vestibule and thence to the outdoors.

If a window breaks in the fire area, the pressure in the fire area will be the same as that in the vestibule and no smoke transfer should occur. Where vestibules are mechanically pressurized, it is anticipated that air flow will always be from the vestibule to the floor areas on either side, thus limiting the possibility of smoke entering the vestibule.

Provision of an opening to the outdoors at the foot of a stairshaft will, in winter, increase the air pressure in the shaft and thus reduce the probability of entry of smoke from a floor on which fire occurs.

Where a dividing wall is used to separate the two parts of a building (Fig. 12), breakage of a window in a fire compartment below the neutral pressure plane can be undesirable. The pressure in the fire compartment will increase to a level approximately the same as exterior pressure, and this may cause substantial smoke flow through the dividing wall from the fire side to the other side of the building. This consideration does not apply to a spatial separation as in Fig. 11.

Provisions have been included to allow windows below the midheight of a building on the side away from a fire to be opened manually in order to bring the pressure in that space to the exterior pressure and to eliminate the pressure difference across the dividing wall.

While it is recognized that the most efficient solution to the problem of moving occupants to a place of safety is to have bridges or connecting vestibules at each floor level, the requirements in Measure K are that these be at intervals not exceeding 5 storeys. The approaches to the bridges or vestibules are by stairs and corridors whose width is controlled by Sentence (6) and (7) of Measure K (p. 66). These provisions combine to make it possible for all occupants to reach a place of safety in about 3 min.

Stack action and the operation of smoke control measures may produce pressures across certain doors that will interfere with their normal operation. This may apply where a building has vestibules vented to the outdoors

(a) at any door that swings into a vestibule from a floor space farther below the midheight of the building than the distance shown in Graph 9 in Appendix A,

(b) at any door that swings out of a vestibule from a floor space that is farther above the midheight of the building than the distance shown in Graph 9 in Appendix A,

(c) at any door between a floor space and an elevator shaft that is farther above or below the midheight of the building than the distance shown in Graph 10, in Appendix A,

(d) at any door between a floor space and a stairshaft that is farther above grade than the height shown in Graph 9, in Appendix A.

In a building that has vestibules that are pressurized, pressure that may interfere with the normal operation of doors may occur with any door between a vestibule and a floor space where the rate of air injection exceeds 350 cfm for each weatherstripped door or 700 cfm for each door that is not weatherstripped, and any door between a floor space and an elevator shaft that is farther above or below the midheight of the building than the height shown in Graph 9 in Appendix A.

Where mechanical air supply is required by Sentence (11) of Measure K (p. 67), it may be desirable to heat the air supply and to provide two air intakes in separate locations on the building face as discussed in the general provisions to Measure F and G.

Where Measure K is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually in a smoke control region of the building, it is intended that a fire alarm will sound on all floors in that smoke control region, and that the occupants on all floors will move through the dividing vestibules or bridges to the other smoke control region.

Measure K - Requirements for Vertically Divided Building

2(g) (1) The requirements of Sentences (1), (2), and (3) of NBC Article 3.2.6.2. may be met by incorporating the requirements of Sentences (2) to (17).

(2) The building is designed as

(a) a structure divided into two smoke control regions by a continuous vertical fire separation that has a fire resistance rating not less than that required for a floor in NBC Subsection 3.2.2., or

(b) two or more smoke control regions separated by spatial separations that conform to the provisions of NBC Subsection 3.2.3.

(3) Bridges or vestibules are provided at intervals not exceeding 5 storeys to permit movement of occupants from one smoke control region to the other.

(4) In each smoke control region referred to in (2), there is at least one exit stair and one elevator in a shaft that meets the requirements of NBC article 3.2.6.4. that is not common to both smoke control regions.

(5) The floor area on either side of a bridge or vestibule is of sufficient size to accommodate its own normal population, plus the occupants of the one to five storeys of the adjacent smoke control region, who may have to enter the floor area during a fire emergency, assuming 5 sq. ft. per ambulatory person and 16 sq. ft. per non-ambulatory person.

(6) The width of each bridge or vestibule, and each connecting corridor and door on the same storey, is sufficient to provide one 22 in. unit of width for every 150 persons, who may have to use these passages to reach the floor area referred to in (5) from the adjacent smoke control region.

(7) The width of each stair or ramp that provides access to a floor having a bridge or vestibule from intervening floors is sufficient to provide one 22 in. unit of width for every 100 persons, who may have to use the stair to reach the bridge or vestibule referred to in (6).

(8) Between each bridge or vestibule and public corridor there is a fire separation that has a 3/4 hr fire resistance rating.

(9) Between each bridge or vestibule and a floor area other than the public corridor referred to in (8), there is a fire separation that has a fire resistance rating as required for exits in NBC Subsection 3.4.5.

(10) Each door opening into a bridge or vestibule conforms to the provisions for horizontal exits in NBC Article 3.4.8.12.(5) and for doors in NBC Article 3.4.8.15., and is suitably identified as an access to an area of refuge.

(11) Each bridge or vestibule is provided with

(a) a vent, opening to the outdoors, that has an open area not less than 10 sq. ft. and which may be provided with a closure that is openable manually and will open as provided in (17), or

(b) a mechanical air supply, not less than that obtained from Graph 8 in Appendix A, that will be initiated as provided in Sentence (17).

(12) Where the building is divided into two smoke control regions by a fire separation as described in (2)(a), each floor area below the midheight of each smoke control region is provided with a vent, opening to the outdoors, that has an open area of not less than 16 sq. ft., and which is normally closed but can be opened manually.

(13) Each stairshaft is vented to the outdoors as described in Sentence (4) of Measure A (p. 23).

(14) Except as provided in (11), and except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(15) Floor areas below the lowest exit storey are divided by a fire separation that has a fire resistance rating at least equal to that required in (2)(a), and is in a location corresponding to the fire or spatial

separations required for upper storeys. Doorways are provided in the separations protected by pressurized vestibules as described in (11)(b).

(16) Where a supply of air is required by (11) and (15) it is carried in ducts as described in Sentence (13) of Measure F (p. 49).

(17) The central alarm and control facility required by NBC 3.2.6.8. is provided with additional controls that are capable of

(a) Closing doors in fire separations required by (8), (9) and (15) between floor areas and vestibules,

(b) initiating the mechanical air supply to the vestibules where required by (11)(b) and (15),

(c) stopping air handling systems where required by (14).

Section 2(h)

Areas of Refuge (Smoke free areas)

Measure L - General

Measure L is intended to provide refuge areas which occupants may enter during a fire. It may be used for buildings that have many openings between floors so that it is impractical to confine smoke to one floor level.

This measure is basically the same as described in Measure D, except that larger quantities of air must be injected into each area of refuge than into a comparable vestibule in order to maintain tolerable conditions for the occupants. A typical floor plan is shown in Fig. 13. The area of refuge may include normally occupied space in the building, and it is because fire may occur in one of these spaces that provision is made for alternate groups of areas of refuge.

It is permissible to have areas of refuge on every fifth floor if the access routes are made wide enough to allow all occupants to reach the area of refuge within 3 min. (see Fig. 14). In this case, stairshafts and firefighters' elevators must be protected on intermediate floors by vestibules or by pressurization of the shafts.

Stack action and the operation of smoke control measures may produce pressures across certain doors that will interfere with their normal operation. This may apply to any door between an area of refuge and a floor space that is farther above grade than the height shown in Graph 9 in Appendix A.

Between every area of refuge and the floor space, a vent should be provided fitted with a self-closing damper that will permit air to move from the area of refuge to the floor space but not vice-versa. It should have an openable area not less than 1 sq. in. for every 10 cfm of air injected into the area of refuge in excess of that specified in Measure D for a pressurized vestibule.

Where Measure L is adopted, and a fire is detected by an automatic device, or a fire alarm box is activated manually, it is intended that an alarm will sound on all floors simultaneously, and that occupants of all floors will move to areas of refuge distributed throughout the building and await instructions over the voice communication system.

Where a mechanical air supply is required by Sentence (9) of Measure L (p. 70), it may be desirable to heat the air supply and to provide two air intakes in separate locations on the building face as discussed in the general provisions to Measures F and G.

Measure L - Requirements for Areas of Refuge (Smoke free areas)

2(h) (1) The requirements of Sentences (1), (2) and (3) of NBC Article 3.2.6.2. may be met by incorporating the requirements of Sentences (2) to (20).

(2) Two independent groups of areas of refuge are distributed through the building so that there is an area of refuge in each group at least at every fifth storey, and each group is linked by a common exit stair to exterior at grade.

(3) Each group of areas of refuge referred to in (2) can accommodate all the occupants of above grade storeys at the rate of 5 sq. ft. of floor area per ambulatory person or 16 sq. ft. per non-ambulatory person.

(4) The width of corridors and doors leading to an area of refuge on the same storey is sufficient to provide one 22 in. unit of width for every 150 persons who may have to use these passages to reach the area of refuge.

(5) The width of stairs or ramps leading to an area of refuge from intervening floors is sufficient to provide one 22 in. unit of width for every 100 persons who may have to use the stairs or ramps to reach the area of refuge.

(6) Between each area of refuge and a public corridor there is a fire separation that has a 3/4 hr fire resistance rating.

(7) Between each area of refuge and a floor area other than the public corridor referred to in (6), there is a fire separation that has a fire resistance rating as required for exits in NBC Subsection 3.4.5.

(8) Each door opening into an area of refuge conforms to the provisions for doors in NBC Article 3.4.8.15., and is suitably identified as an access to an area of refuge.

(9) Each area of refuge is provided with a mechanical air supply not less than that required for a vestibule providing access to a stair or an elevator shaft in Sentence (5) of Measure D (p.37), and obtained from Graph 3 in Appendix A, or not less than 5 cfm for each occupant of the area of refuge during a fire emergency, whichever is the greater.

(10) Any door in an exit stairshaft, or in a shaft that contains a firefighters' elevator, that does not open directly into an area of refuge is provided with a pressurized vestibule as described in Sentence (5) of Measure D (p. 37), except where the stair or elevator shaft is pressurized as described in Sentence (2) of Measure F (p.47) and Sentence (4) of Measure F (p.47).

(11) Except as provided in (10) an elevator shaft that contains a firefighters' elevator is provided with a pressurized vestibule as described in Sentences (2), (3) and (5) in Measure D (p. 36 and 37), or is pressurized as described in Sentence (4) of Measure F (p.47).

(12) An elevator shaft that contains a firefighters' elevator or opens into an area of refuge and passes through the floor above the lowest exit storey, does not penetrate the floor of the storey immediately below that storey, except where there is a vestibule between the shaft and each floor area below the lowest exit storey as described in Sentence (3) of Measure D (p.36).

(13) A stairshaft serving storeys above the lowest exit level is vented to the outdoors at or near the bottom of the stairshaft as described in Sentence (4) of Measure A (p.23).

(14) A stairshaft serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at or near the top of the stairshaft as described in Sentence (4) of Measure A (p.23), and

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level and is separate from a shaft that contains a stairway serving upper storeys, or is enclosed in a shaft that contains a stairway serving upper storeys, but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air, introduced at or near the bottom of the shaft, of at least 1000 cfm for each storey served by the stairway.

(15) Each elevator shaft protected by a vestibule or area of refuge having a mechanical air supply as described in Sentences (9) and (10)

(a) has a vent at or near the bottom of the shaft opening directly to the outdoors or into a vestibule or corridor that has a similar opening to the outdoors, having an openable area not less than 0. 25 sq. ft. for every door into the shaft, other than doors at street floor level, and

(b) has a vent at or near the top of the shaft opening to the outdoors, and not into an elevator machinery room, having an openable area that is not less than one-quarter nor more than one-half of the area of the vent at street level required in (a).

(16) The vent at the top of each elevator shaft referred to in Sentence (15) may be provided with a closure that is openable manually, and will open on a signal from a products of combustion detector located at the top of the shaft, and as provided in Sentence (20).

(17) The vent at the bottom of an elevator shaft referred to in Sentence (15) may be provided with a closure which is openable manually, and is designed to remain open during a fire emergency.

(18) Except for air moving fans serving areas of refuge and vestibules as provided in Sentences (9), (10) and (11), and except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(19) Where a supply of air is required by (9), (10), (11) and (14), it is carried in ducts as described in Sentence (13) of Measure F (p. 49).

(20) The central alarm and control facility required by NBC 3. 2. 6. 8. is provided with additional controls that are capable of

(a) closing doors in fire separations required by (6) and (7) between floor areas and areas of refuge or vestibules,

(b) stopping air handling systems as required by (18),

(c) opening closures in vents to the outdoors in elevator shafts that may be required by (11) and (16), and,

(d) initiating the mechanical air supply to the areas of refuge, vestibules and shafts as may be required by (9), (10), (11), and (14).

Section 2(i)

Residential Buildings with Balconies

Measure M - General

In residential buildings not more than 120 ft. in height, the greater part of the requirements for control of smoke movement are waived where each suite has direct access to a balcony. The protective features are limited to stopping air handling systems, providing an opening to the outdoors at the foot of stairshafts serving upper floors, and protection of stairshafts in below grade storeys. A typical arrangement is shown in Fig. 16.

Where Measure M is adopted, and a fire is detected by an automatic device or a fire alarm box is activated manually, it is intended that occupants on the fire floor will evacuate if possible, and that occupants of other floors may remain in their suites to await instructions over the voice communication system.

Measure M - Requirements for Residential Building with Balconies

2(i) (1) The requirements of NBC Sentence 3.2.6.2.(8) may be met by incorporating the requirements of Sentences (2) to (7).

(2) A stairshaft serving storeys above the lowest exit level has a vent or door to the outdoors at or near the bottom of the stairshaft, as described in Sentence (4) of Measure A (p. 23).

(3) A stairshaft serving storeys below the lowest exit level

(a) has a vent or door to the outdoors at or near the top of the stairshaft as described in Sentence (4) of Measure A (p.23),

(b) is enclosed in a shaft that does not pass through the floor above the lowest exit level and is separate from a shaft that contains a stairway serving upper storeys; or is enclosed in a shaft that contains a stairway serving upper storeys, but is separated from that stairway at the lowest exit level by a fire separation, and

(c) is provided with equipment capable of maintaining a flow of air, introduced at or near the bottom of the shaft, of at least 1000 cfm for each storey served by the stairway.

(4) An elevator shaft that passes through the floor above the lowest exit storey does not penetrate the floor of the storey immediately below that storey except where there is a vestibule between the shaft and each floor area below the lowest exit storey, as described in Sentence (3) of Measure D (p.36).

(5) Except for exhaust from kitchens, washrooms and bathrooms in dwelling units, air moving fans are stopped in an air handling system that serves more than two storeys.

(6) Where a supply of air is required by (3) it is carried in ducts as described in Sentence (13) of Measure F (p.49).

(7) The central alarm and control facility required by NBC Article 3.2.6.8. is provided with additional controls that are capable of

(a) stopping air handling systems as required by NBC Sentence 3.2.6.2.(8), and

(b) initiating the mechanical air supply to stair shafts as may be required by Clause (3)(c).

Section 2(j)

Connected Buildings

Measure N - General

The measures described in Section 2N are intended to prevent movement of smoke from one building to another. They are of particular significance where two buildings of unequal height are joined together. The techniques suggested are provision of a large opening to the outdoors in a connecting vestibule so that smoke entering through leakage areas around doors will be vented to the outdoors, or pressurization to maintain a higher pressure in the vestibule than in adjacent spaces as illustrated in Fig. 17 and 18.

The requirements for protection of openings are described in terms appropriate to a doorway. Any other openings should be avoided if possible. Where they occur, they should be protected by provision of an air lock that gives the same standard of protection as the vestibule described in Sentence (3).

Measure N - Requirements for Connected Buildings

2(j) (1) The requirement of NBC Sentence 3.2.6.2.(9) that limits movement of smoke from one building to another may be met by incorporating in the link between the buildings, the requirements in Sentences (2) and (3).

(2) Between one building and the other there is a fire wall as described in NBC Article 3.2.1.1.

(3) Any opening in the fire wall is protected against passage of smoke by a vestibule described in Sentence (3) in Measure D (p.36) and has

(a) a vent to the outdoors that has a net area of 10 (0.25d + 0.00045a) sq. ft.

where d is the number of doors having a perimeter not more than 20 ft. that open into the vestibule

and a is the area in square feet of enclosing walls, floors and ceilings whose outer face is in contact with the outside air,

(Where the outer face of a wall is in contact with the ground or fill it is assumed that there is no leakage through that portion and the value of "a" is assumed to be zero)
or,

(b) equipment capable of maintaining a supply of air into the vestibule sufficient to ensure that the air pressure in the vestibule when the doors are closed is higher by at least 0.05 in. (water gauge) than that in either adjacent floor area when the outdoor temperature is equal to the Winter Design Temperature on a $2\frac{1}{2}$ per cent basis.

CHAPTER 3

VENTING OF FLOOR AREAS

(1) The requirements of NBC Sentence 3.2.6.5.(1) and of Measures H or I are met by incorporating in a floor area windows or wall panels as described in (2), by smoke shafts as described in (3) and (7), or by the use of building exhaust systems as described in (8).

(2) Where windows or wall panels are used for venting as required in (1), they must

(a) be uniformly distributed along the exterior wall of each storey,

(b) have a total area of at least 1 per cent of the exterior wall area of each storey,

(c) be readily openable from the interior without use of wrenches or keys,

(d) be readily identified from the interior, and from the exterior where they are accessible to firefighters, and

(e) be designed so that when opened they will not endanger persons outside the building during a fire.

(3) Where one or more smoke shafts or vertical service spaces are used for venting to meet the requirements of (1), they must

(a) have an opening or openings into each storey with an aggregate area of not less than that obtained from Table 2 for the height of the shaft, the area of the largest floor area served by the smoke shaft, and the leakage characteristics of shaft wall and dampers obtained from Tables 3 and 4,

(b) have an aggregate unobstructed cross-sectional area that is equal to that provided in (a), and

(c) be designed to comply with the requirements of (4).

Table 2. Minimum Size in Square Feet of Vent Opening(1)(2) into Smoke Shaft from Each Floor Area

Floor Area Sq Ft	Leakage Area (3)	Building Height, Ft 60	120	240	360	480	600	720	840	960
2,000		1.0	1.1	1.3	1.5	1.6	1.8	1.9	2.0	2.1
5,000		2.2	2.5	2.9	3.2	3.5	3.8	4.0	4.2	4.4
10,000		4.3	4.8	5.4	5.9	6.4	6.8	7.2	7.5	7.8
20,000		8.3	9.1	10.1	10.9	11.7	12.4	13.0	13.6	14.1
30,000	.0%	12.2	13.4	14.7	15.6	16.8	17.6	18.4	19.2	19.9
40,000		16.1	17.5	19.1	20.3	21.7	22.7	23.7	24.7	25.5
50,000		20.0	21.7	23.5	24.8	26.5	27.6	28.8	30.0	31.0
60,000		23.9	25.8	27.8	29.3	31.2	32.5	33.9	35.2	36.2
2,000		1.0	1.2	1.5	1.9	2.3	2.8	3.5	4.4	5.7
5,000		2.3	2.7	3.4	4.1	4.9	5.8	7.0	8.5	10.6
10,000		4.4	5.1	6.2	7.3	8.7	10.2	12.1	14.5	17.6
20,000		8.5	9.8	11.6	13.5	15.8	18.3	21.3	25.2	30.0
30,000	1%	12.6	14.3	16.8	19.3	22.5	25.8	30.0	35.1	41.4
40,000		16.7	18.8	21.9	25.1	29.0	33.2	38.3	44.5	52.3
50,000		20.7	23.2	27.0	30.7	35.4	40.3	46.4	53.8	62.9
60,000		24.8	27.7	32.0	36.2	41.7	47.4	54.3	62.8	73.2
2,000		1.0	1.3	1.8	2.5	3.8	6.2	13.3	48.8	961.7
5,000		2.4	2.9	4.0	5.3	7.6	11.6	21.7	64.0	1011.4
10,000		4.6	5.5	7.3	9.5	13.2	19.4	33.6	86.2	1087.8
20,000		8.8	10.5	13.5	17.4	23.5	33.4	54.7	125.3	1235.4
30,000	2%	13.1	15.4	19.6	24.9	33.3	46.4	74.1	160.7	1378.0
40,000		17.3	20.2	25.6	32.2	42.7	59.0	92.7	194.6	1509.7
50,000		21.5	25.0	31.4	39.5	52.0	71.3	110.5	226.0	1642.5
60,000		25.7	29.7	37.3	46.6	61.1	83.4	128.2	258.4	1768.0
2,000		1.1	1.4	2.2	3.8	9.1	72.8			
5,000		2.5	3.1	4.7	7.7	16.2	93.8			
10,000		4.7	5.9	8.7	13.5	26.6	124.8			
20,000		9.2	11.3	16.1	24.3	45.4	180.2			
30,000	3%	13.6	16.5	23.3	34.6	63.0	230.9			
40,000		17.9	21.8	30.4	44.7	80.1	279.3			
50,000		22.3	26.9	37.3	54.6	96.6	326.5			
60,000		26.6	32.1	44.2	64.4	112.9	372.2			
2,000		1.1	1.5	2.8	7.2	265.0				
5,000		2.5	3.4	5.9	13.6	309.7				
10,000		4.9	6.4	10.7	23.1	378.7				
20,000		9.5	12.2	19.8	40.4	504.7				
30,000	4%	14.1	17.9	28.6	56.9	622.0				
40,000		18.6	23.5	37.2	72.9	732.8				
50,000		23.1	29.1	45.7	88.7	841.0				
60,000		27.6	34.7	54.2	104.2	944.6				
2,000		1.1	1.6	3.7	35.0					
5,000		2.6	3.7	7.7	52.8					
10,000		5.1	6.9	13.9	79.0					
20,000		99.4	13.3	25.6	126.2					
30,000	5%	14.6	19.5	36.8	170.5					
40,000		19.3	25.6	47.8	213.2					
50,000		24.0	31.7	58.7	254.8					
60,000		28.7	37.7	69.5	295.3					

Notes to Table 2

(1) The minimum size of vent opening into a smoke shaft is obtained from Table 2 for a smoke shaft depending on the floor area and total leakage area of smoke shaft walls and dampers. This total leakage area may be estimated, where cross-sectional area of smoke shaft, opening into shaft and opening to the outdoors at the top of the shaft are equal, by adding the leakage areas for shaft wall obtained from Table 3 and for dampered openings obtained from Table 4.

(2) Where an elevator shaft is used as a smoke shaft, the design is more complicated. The criteria for designing such smoke shafts are discussed in the paper referred to as no 18 in the bibliography.

(3) Leakage area is the total of the leakage area of smoke shaft wall obtained from table 3, and the leakage area of dampered opening in smoke shafts obtained from table 4.

TABLE 3

Leakage Area of Smoke Shaft Wall

Wall Construction	Leakage Area as a per cent of Damper Area
Monolithic concrete	0.5
Masonry wall unplastered	1.5
Masonry wall plastered	0.5
Gypsum wallboard on steel studs	1.0

TABLE 4

Leakage Area of Dampered Opening in Smoke Shafts

Type of Damper	Leakage Area as a per cent of damper area (1)
Single-blade fire damper	2.0
Multi-blade fire damper	2.5
Gasketted damper	1.0

Note (1) to Table 4
(Values include allowance for 0.5 per cent leakage between frame and wall construction.)

(4) Each smoke shaft or vertical service space described in (3) must

(a) be separated from the remainder of the building by a fire separation that has a fire resistance rating at least equal to that required for the floor assembly through which it passes, or be designed as a chimney conforming to Part 6 of the National Building Code 1970, except that flue liners need not be provided,

(b) have an opening to the outdoors at the top that has an area at least equal to the cross-sectional area of the shaft, and which may be protected against the weather, provided the closure can be opened from the outside, and will open automatically by a signal from a smoke detector in the shaft, by operation of the fire alarm system, and when a closure required in (5) opens,

(c) terminate at least 3 ft. above the roof surface where it penetrates the roof, and

(d) contain no combustible material, fuel lines or services that are required for use in an emergency.

(5) Each opening required by (3)(a) must be located so that the top of the opening is not more than 10 in. below the ceiling, except that the opening may be above the ceiling, if the ceiling freely allows passage of air, and is provided with a closure that,

(a) has a fire protection rating conforming to NBC Sentence 3.1.7.1.(4),

(b) can be opened from a remote location such as a stair-shaft or the storey immediately below, or will open automatically by means of a smoke detector located in the vicinity of each doorway to a required exit stairway, and

(c) must not open automatically on any floor, other than the fire floor, when smoke or hot gases pass through the shaft.

(6) A smoke vent opening referred to in (2) or (3) that is less than 42 in. above the floor must be protected by a guard when required by Sentence 3.3.1.12.(3).

(7) An elevator shaft, other than a shaft and associated machinery room that contains a firefighters' elevator and equipment, may be used for venting provided

(a) the building is sprinklered,

(b) the shaft conform to (3),

(c) provision is made for the return of all elevator cars in the shaft to the street floor level on the activation of any fire alarm signal, and

(d) the cars in the shaft are rendered inoperative during a fire emergency.

(8) In a sprinklered building the air handling system may be used for smoke venting provided

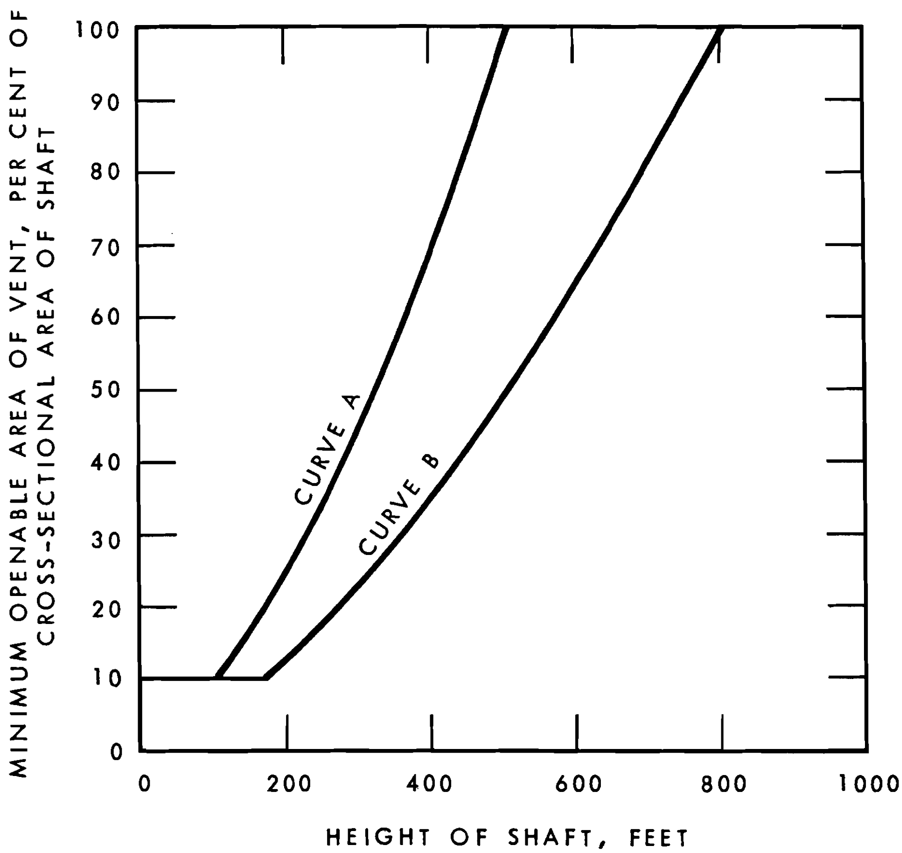
(a) the system can maintain an exhaust to the outdoors at the rate of six air changes per hour from any floor area, and

(b) emergency power to the fans required by (a) is provided as described in NBC Article 3.2.6.11.

(9) Where a damper is required by (5), the leakage area between damper components and between damper and frame must not exceed 3 per cent of the openable area of the damper.

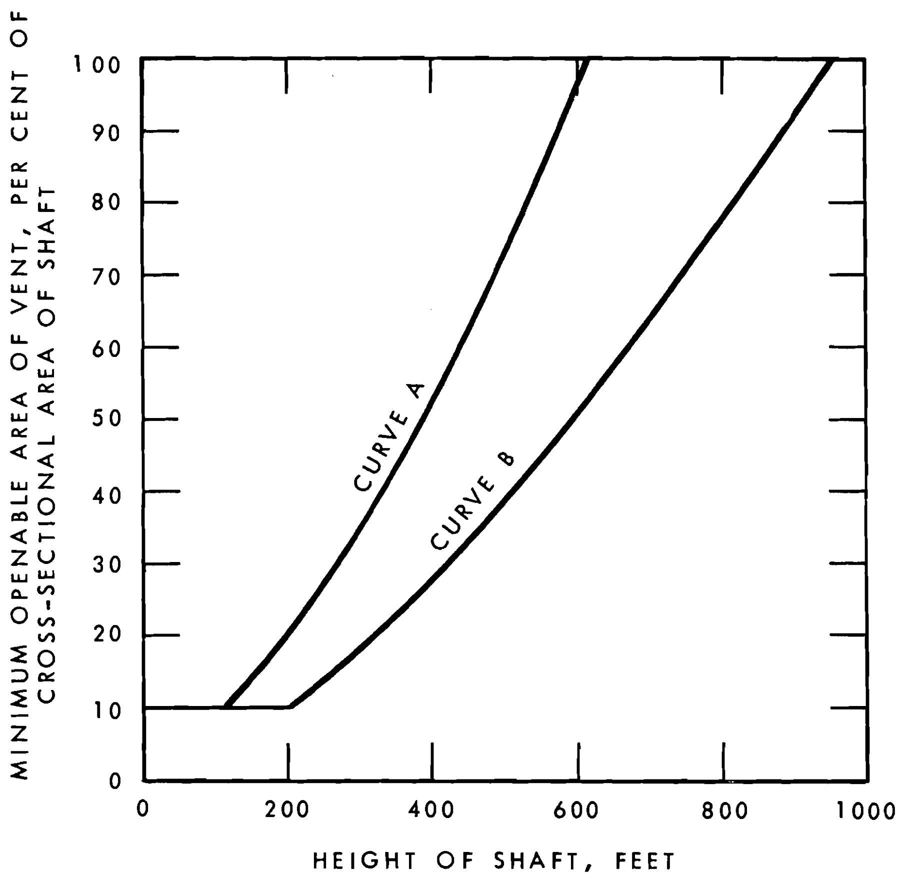
APPENDIX A

GRAPHS FOR APPLYING SMOKE CONTROL MEASURES



Graph 1

Vent to a Vertical Service Space where no other Shaft in the Building is Pressurized



Graph 2

Vent to a Vertical Service Space where other Shafts in the Building are Pressurized

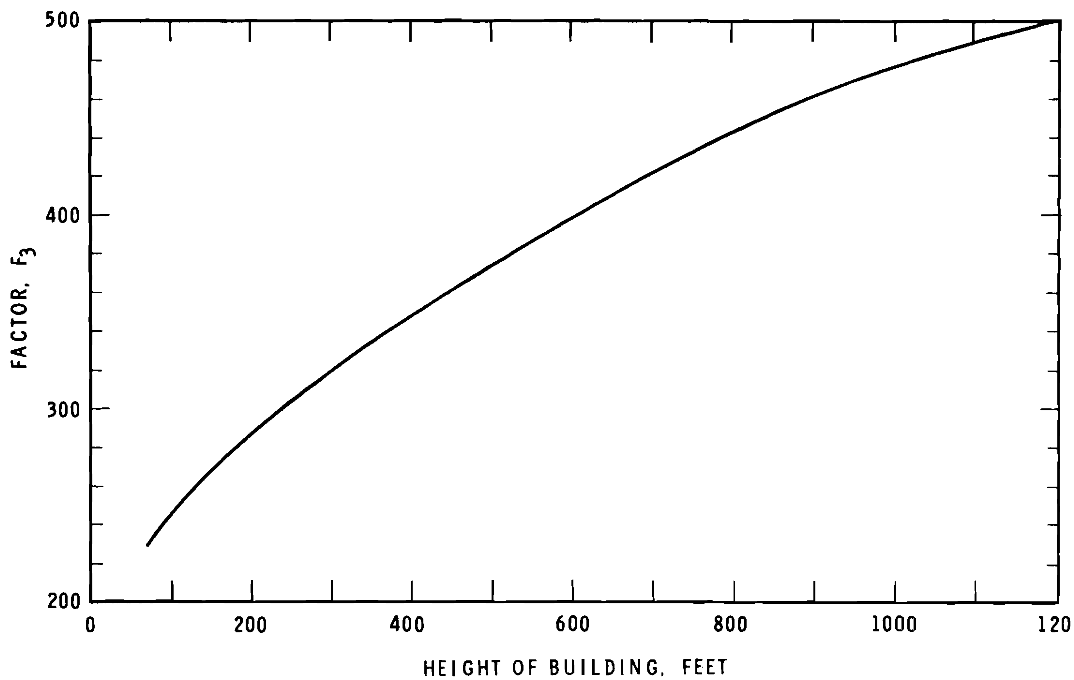
Notes to Graphs 1 and 2

(1) Curve A applies to a vertical service space that is enclosed by unplastered unit masonry or by plaster and steel stud construction with all openings in the shaft sealed to the degree required by Article 3.1.7.6. of the NBC 1970.

(2) Curve B applies to a vertical service space that is enclosed by monolithic concrete or by plastered unit masonry with all openings in the shaft sealed tightly to minimize air leakage.

(3) A shaft having a vent that is 100 per cent of the cross-sectional area of the shaft is acceptable for buildings up to 1.5 times the height shown by the appropriate curve in Graphs 1 and 2.

(4) The total leakage area, based on measurements arrived at in typical high buildings is assumed to be 1/4 sq. ft. for every 100 sq. ft. of shaft wall area in the case of Curve A and 1/8 sq. ft. for every 100 sq. ft. of shaft wall area in the case of Curve B.



Graph 3

Factor for Mechanical Air Supply to a Vestibule

Notes to Graph 3

(1) Air supply to each vestibule in cubic feet per minute

$$= F_3d + 150e + 200s$$

where

F_3 is a factor obtained from Graph 3

d = the number of doors having a perimeter not more than 20 ft. between each vestibule and a floor area.

c = the number of doors having a perimeter not more than 20 ft. between each vestibule and an elevator shaft.

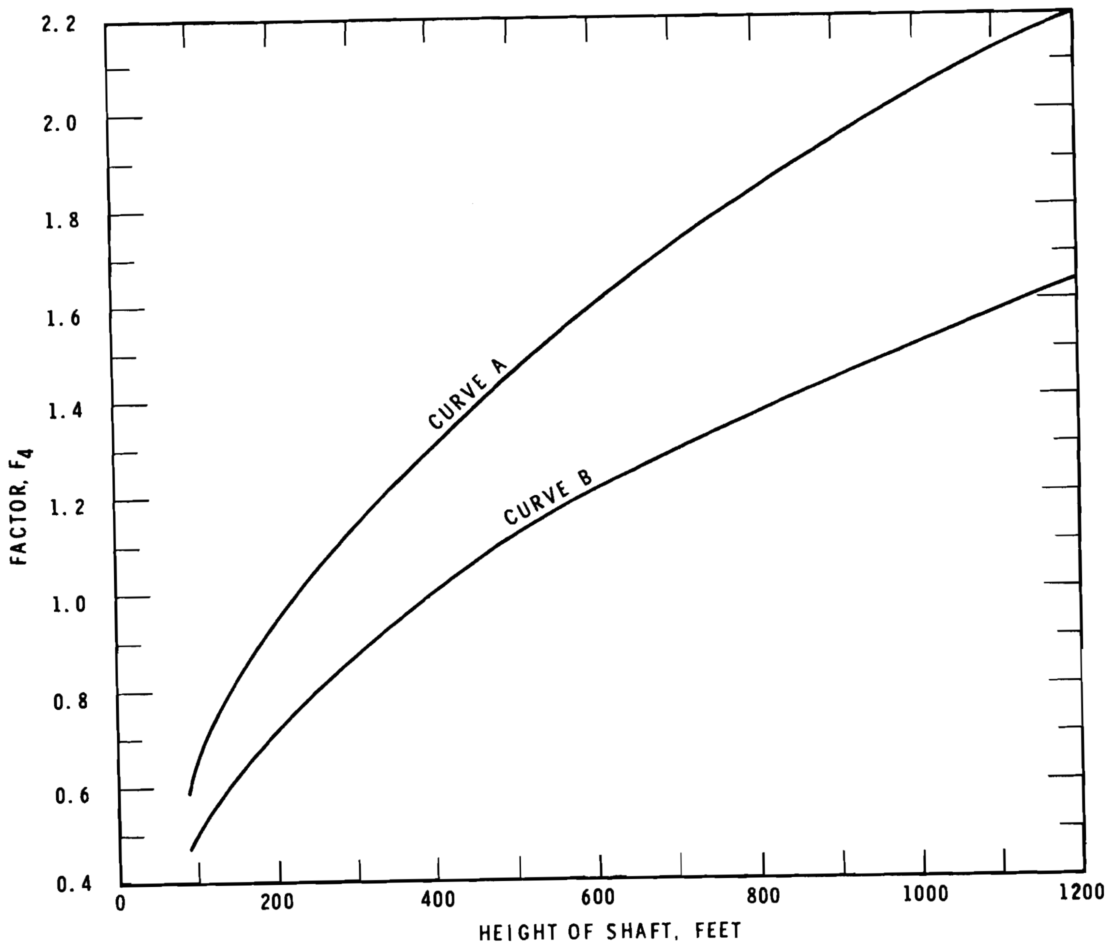
s = the number of doors having a perimeter not more than 20 ft. between each vestibule and a stairshaft.

(2) If the perimeter of a door exceeds 20 ft. the value of d, e or s must be increased in direct proportion to the increase in the perimeter.

(3) A double leaf door is counted as 2 doors.

(4) A door provided with tight fitting weatherstripping is counted as ½ door.

(5) Height of building is the number of feet between the roof and the floor level of the lowest basement floor.



Graph 4

Factor for Area of Vent to an Elevator Shaft

Notes to Graph 4

(1) Curve A applies to a vented elevator shaft where no other shaft in the building is pressurized or where the number of pressurized shafts is less than as described for Curve B.

(2) Curve B applies to a vented elevator shaft where at least two stairshafts and one other elevator shaft in the building are pressurized.

(3) Area of vent opening at top of each vented elevator shaft in square feet $= F_4(0.25d_4 + 0.0014a_4)$ where

F_4 is a factor obtained from Graph 4

d_4 is the total number of doors having a perimeter not more than 20 ft. that open into the elevator shaft

a_4 is the area of the enclosing walls of the elevator shaft in square feet.

(4) If the perimeter of a door exceeds 20 ft., the value of d_4 must be increased in direct proportion to the increase in the perimeter.

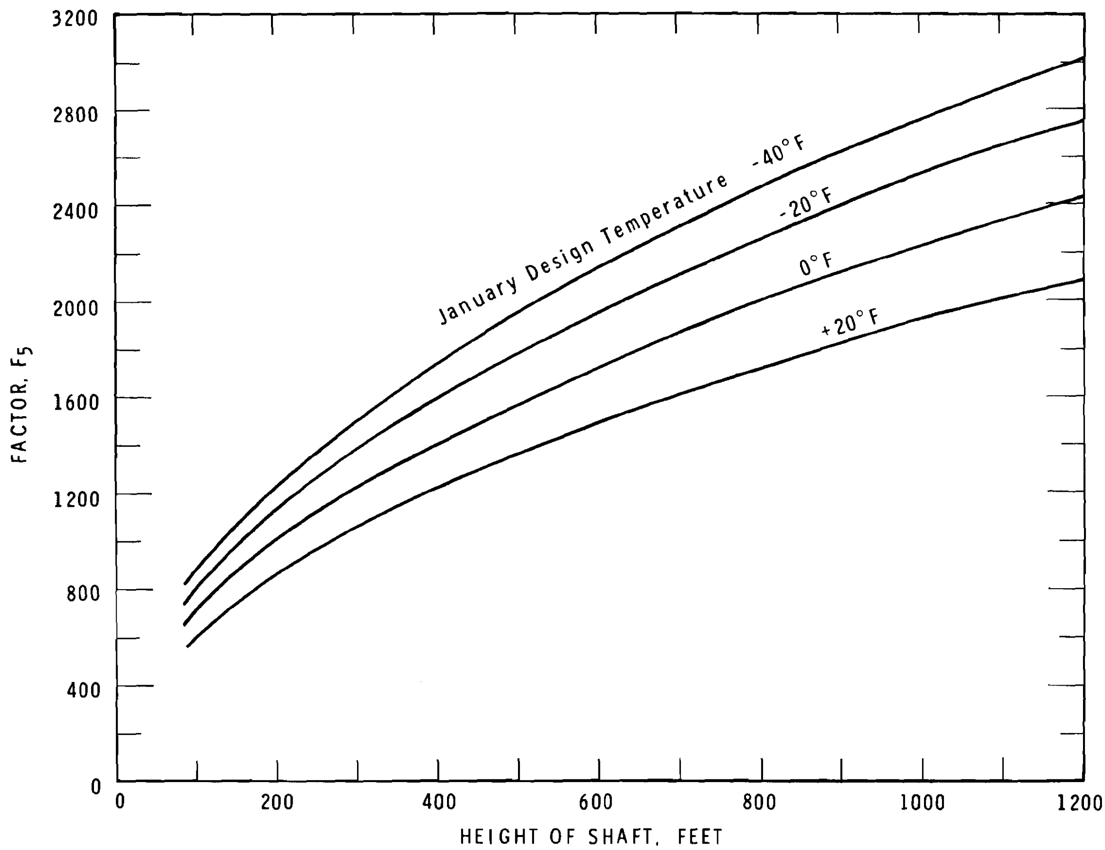
(5) A double leaf door is counted as 2 doors in this formula.

(6) A door provided with tight fitting weatherstripping is counted as $\frac{1}{2}$ door.

(7) If the enclosing walls of the shaft are of monolithic concrete or of unit masonry plastered on one side, the value of a_4 may be halved.

(8) If an elevator shaft is provided with vestibules on each floor, the enclosing walls considered in this formula may be taken as including those of the vestibules if it leads to an economy in air supply requirements. In this case, d_4 above refers to doors between the vestibules and the floor areas, and doors between the elevator shaft and the vestibules do not enter into the calculation.

(9) A top vent area that is 100 per cent of the shaft area is acceptable where calculation by the formula described in Note (3) indicates a need for a vent that is between 100 per cent and 150 per cent of the shaft area. Where the calculation indicates a need for a vent area that is greater than 150 per cent of the shaft area, top venting of the shaft is not acceptable.



Graph 5

Factor for Air Supply to an Elevator Shaft

Notes to Graph 5

(1) Air supply to each elevator shaft in cubic feet per minute

$= F_5 (0.25d_5 + 0.0014a_5)$

where

F_5 is factor obtained from Graph 5

d_5 is the total number of doors having a perimeter not more than 20 ft. that open into the elevator shaft.

a_5 is the area of enclosing walls of the shaft in square feet

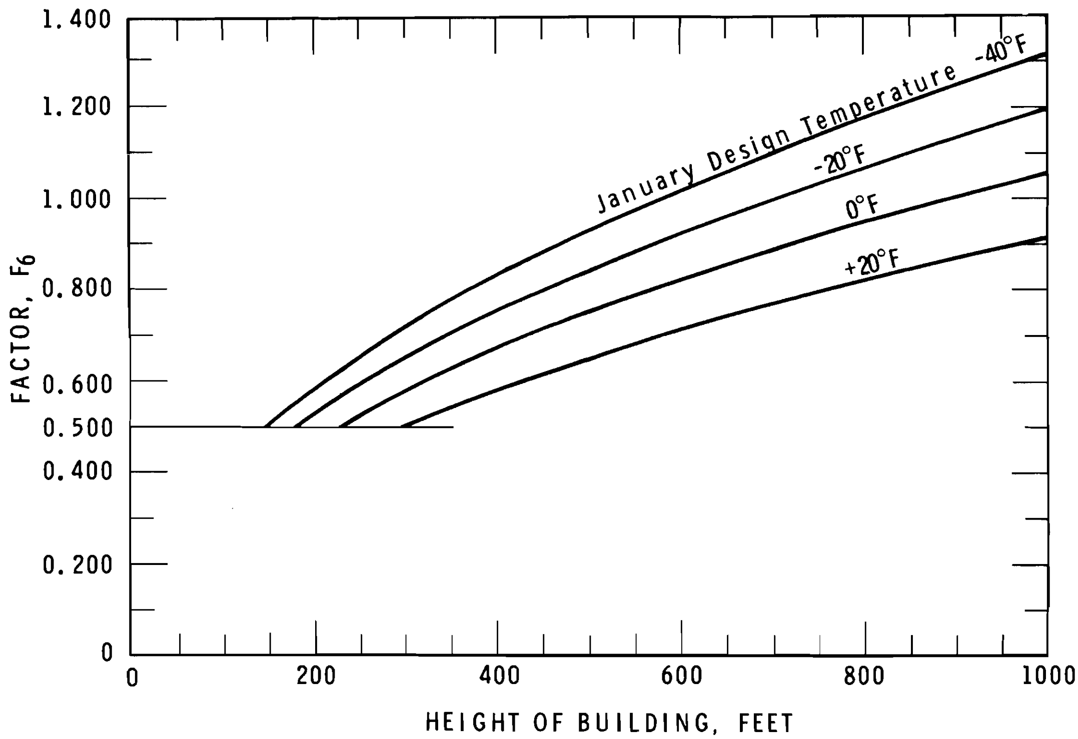
(2) If the perimeter of a door exceeds 20 ft. the value of d_5 must be increased in direct proportion to the increase in the perimeter.

(3) A double leaf door is counted as 2 doors in this formula.

(4) A door provided with tight fitting weatherstripping is counted as $\frac{1}{2}$ door.

(5) If the enclosing walls of the shaft are of monolithic concrete or of unit masonry plastered on one side, the value of a_5 may be halved.

(6) If an elevator shaft is provided with vestibules on each floor, the enclosing walls considered in this formula may be taken as including those of the vestibules if it leads to an economy in air supply requirements. In this case d_5 above refers to doors between the vestibules and the floor areas, and doors between the elevator shaft and the vestibules do not enter into the calculation.



Graph 6

Factor for Air Supply for Building Pressurization

Notes to Graph 6

(1) If Measure H is used.

Air supply delivered to whole building in cubic feet per minute

$= F_6 \times a_6$

where

F_6 is a factor obtained from Graph 6

a_6 = the area of all exterior wall surfaces of the building in square feet measured between ground level and underside of the roof.

(Where the outer face of a wall is in direct contact with the ground or fill, it is assumed there is no leakage through that portion and the value of "a_6" is assumed as zero.)

(2) Graph 6 is based on an air leakage rate of 0.6 cfm per square foot of exterior wall at a pressure difference of 0.3 in. of water, based on the measured leakage rate in high buildings having fixed windows and curtain wall panels.

(3) This is equivalent to a leakage area in exterior walls of 0.45 sq. ft. per 1,000 sq. ft. of wall area. If the leakage area in a building differs significantly from this, the air supply should be adjusted in direct proportion.

(4) Height of building is measured between the underside of the roof and the floor level of the lowest basement floor.

(5) If Measure I is used.

Air supply delivered to the space that includes stairshafts, elevator shafts and corridors in cubic feet per minute.

$= F_6 (a_7 + 550d_7)$

where

F_6 is a factor obtained from Graph 6 that is not less than 0.5

a_7 = the area in square feet of the walls enclosing the space that includes stairshafts, elevator shafts and associated corridors on all floors.

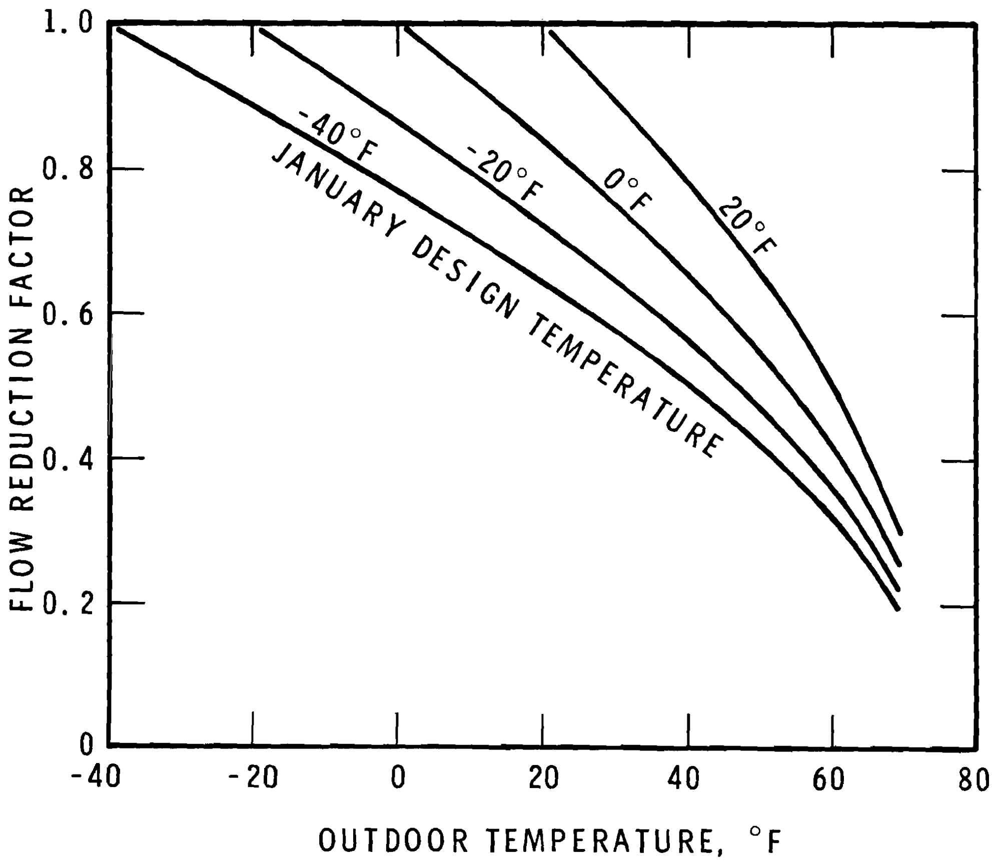
d_7 = the total number of doors having a perimeter not more than 20 ft. in the wall area described in a_7.

(6) If the enclosing walls described above is of monolithic concrete or of unit masonry plastered on one side, the value of a_7 may be halved.

(7) If the perimeter of a door exceeds 20 ft., the value of d_7 must be increased in direct proportion to the increase in the perimeter.

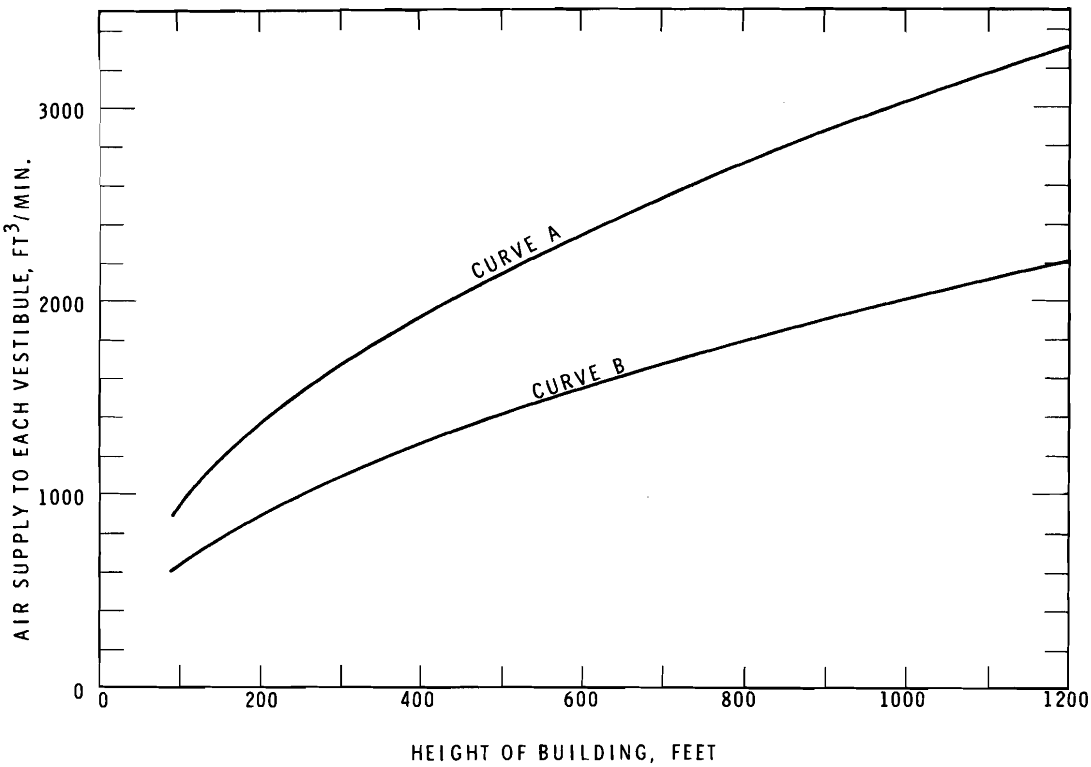
(8) A double leaf door is counted as two doors in this formula.

(9) A door provided with tight fitting weatherstripping is counted as $\frac{1}{2}$ door.



Graph 7

Flow Reduction Factors



Graph 8

Air Supply to Vestibule in a Vertically Divided Building

Notes to Graph 8

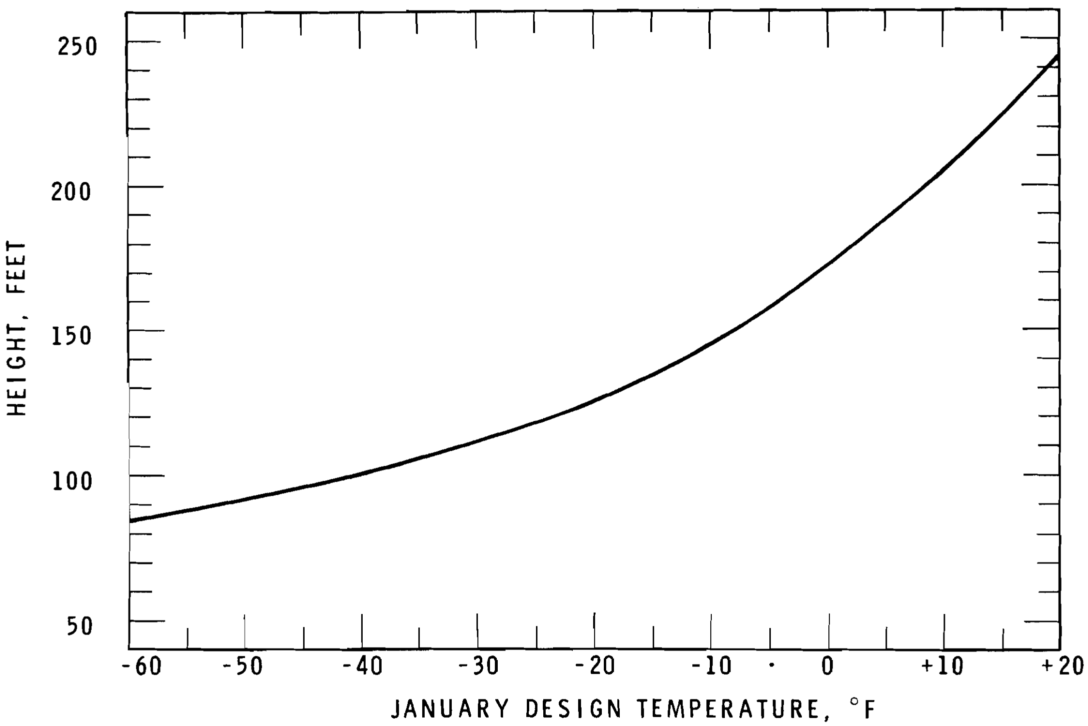
(1) Curve A shows the air supply to each vestibule in cubic feet per minute for a vestibule that has 4 doors (or two double doors) each door having a perimeter of not more than 20 ft. between the vestibule and the floor areas in either side of the building.

(2) Curve B shows the air supply to each vestibule in cubic feet per minute for a vestibule that has 2 single doors each door having a perimeter of not more than 20 ft. between the vestibule and the floor areas on either side of the building.

(3) If the perimeter of a door exceeds 20 ft., the air supply must be increased in direct proportion to the increase in the perimeter.

(4) If the doors are provided with tight fitting weatherstripping, the air supply may be halved.

(5) Height of building is the number of feet between the roof and the floor level of the lowest basement floor.



Graph 9

Height of Shaft Relative to Grade, or the Neutral Pressure Plane at which Pressure across a Door may exceed Two Pounds per Square Foot

ASSUMPTIONS USED IN DEVELOPING FIRE SAFETY MEASURES

The objectives of the measures for fire safety in high buildings are

(a) to provide for the safety of occupants of a building, either by maintaining the occupied floor spaces tenable during the period of a fire emergency or by making it possible for occupants to move to a place of safety,

(b) to maintain tenable conditions in exit stairs leading from floor spaces in which occupants may remain to the outdoors,

(c) to maintain tenable conditions in an elevator that can be used to transport firefighters and their equipment from the street floor to the floor immediately below the fire floor.

It is assumed that the firefighters will use one of the protected stairshafts referred to in (b) to walk up from the floor below the fire to the fire floor.

It has been assumed that the first of these objectives may be met by evacuation of all occupants to the outdoors within about 7 to 10 min. (as provided in NBC Article 3. 2. 6. 1.), by movement of occupants to safe areas within the building within 3 to 5 min. (as in Measures C E G J K L and M), or by maintaining all floor areas tenable except those on the fire floor and the floor immediately above the fire floor (as in Measures A B D F H and I).

The requirements that have applied in the National Building Code covering widths of exits and travel distances to exits make it possible for occupants of a floor on which a fire occurs to leave that floor within 1 or 2 min. provided their escape route is not cut off bv the fire.

The objectives of the measures are to maintain certain spaces substantially smoke free for a significant period of time during a fire emergency, and hence some criterion of tenability is called for. It has been agreed that the criterion for long term tenability should be that a space shall not include more than 1 per cent by volume of the contaminated atmosphere from the fire region. The criterion of tenability is based on considerations of visibility and carbon monoxide concentration.

Mechanisms of Smoke Movement in Buildings

Movement of a smoky atmosphere within a building is not significantly different from that of a normal atmosphere at the same temperature.

The principal constituent of both is nitrogen. The fact that the concentration of various other component gases will differ, together with the feature that a smoky atmosphere will contain particulate matter, will not influence its overall density to an extent that will significantly affect movement. The mechanisms to be discussed do, therefore, relate to the movement of a smoky atmosphere as well as air.

Air Circulating Systems

Reviewing the various mechanisms that can be responsible for the dispersal of smoke within a building, an obvious one is the action of a recirculating air handling system. Assuming that the system has been competently engineered, the approximate extent of the recirculation under any particular circumstances is known, and hence the build-up in one area of contamination from another can be predicted.

Effect of Wind

Exterior winds create pressure differentials within buildings, and hence internal air movement, principally horizontal. Some upward movement also results, however, from the non-uniformity of the wind profile up the side of a building in combination with the fact that, if one side of the building is facing the wind, only that face will be subjected to a positive pressure, the remainder experiencing negative pressure.

Expansion

Another smoke movement mechanism, which is of considerable significance during the early stages of any fire that is not well vented to the outdoors, is the expansion process associated with heating. The leakage characteristics of virtually any building are such that the rate of temperature rise occurring in the fire region cannot create pressure differentials greater than an inch or so water gauge. Instead, the volume of the atmosphere increases linearly with absolute temperature. During the development of a fire in a compartment, absolute temperature may be expected to triple, and the volume of gas will increase by approximately the same factor. At least two-thirds of the original atmosphere in the fire region will, therefore, be displaced by this mechanism.

Generation of gases as a result of combustion has also been considered. The volume created by this phenomenon cannot, however, exceed 20 per cent of the original volume, and is likely to be insignificant compared to expansion due to temperature rise.

Stack Effect

Whenever a temperature differential exists between the interior and exterior of an enclosure, a phenomenon known as stack or chimney effect prevails. Fig. B-1 illustrates the case where the interior temperature is higher than the exterior, and there is an inflow of cold air at low levels and a corresponding outflow at high levels.

This can result from building heating and from temperature differentials created by the fire itself, and is of particular importance in the context of Canadian buildings because of the cold conditions that exist in winter. The pressure differentials generated by stack effect can be calculated from consideration of the densities of the internal and exterior atmospheres.

Fig. B-1 represents a simplified model in which air flows in at a low level and out at a high level, while there is an intermediate level where there is no pressure differential between interior and exterior. This level is referred to as "the neutral plane". Taking the pressure at the neutral plane as P_o, the pressures at the lower or upper openings can be derived, for they are associated with the weights of the columns of gas above them.

The resulting expression for the pressure difference across the lower opening is

$$\delta p = h_1 g \rho_\theta \theta / T_o$$

where δp = pressure difference

h_1 is defined in Fig. B-1

T_o = the absolute outdoor temperature

θ = the difference between indoor and outdoor temperature

ρ_θ = density of indoor air

and g = the acceleration due to gravity

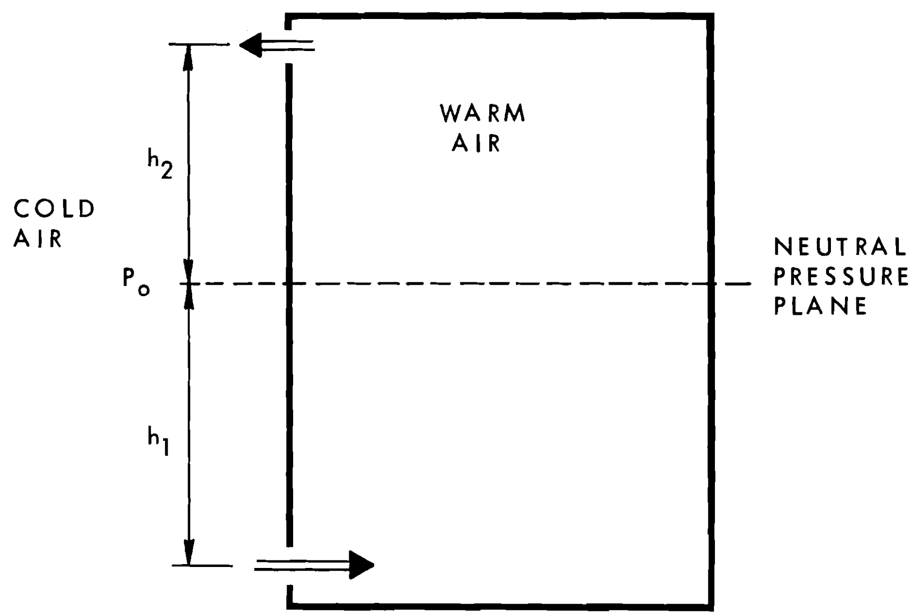


Figure B-1

Stack Action

Substituting $H = (h_1 + h_2)$ will give the total of the pressure head (the sum of the pressure differentials across the upper and lower openings) generated by stack effect.

Relative Importance of Mechanisms Responsible for Smoke Movement

Expansion due to heating of the atmosphere in a fire compartment is largely a transient phenomenon occurring at the development stage of a fire. Two-thirds of the atmosphere of the fire region is likely to be displaced and, if the region were not vented to the exterior, there could be a significant movement of smoke laden atmosphere to other parts of the building. Dispersed evenly throughout the building and taking into account leakage to outdoors, this volume could render untenable a space equal to about fifty times that of the fire region.

Pressures Due to Stack Effect

In discussing the steady state conditions responsible for smoke movement, total pressure heads generated may be compared. These are tabulated in Table B-1 together with the flow rates that these pressure heads will create beneath a typical door having a free space of 3' 0" x 1/2" beneath it. Considering columns 2 and 3, it will be seen that the total head given by stack action resulting from a fire in a single storey is also given by stack action associated with building heating during cold weather in a building three to four storeys in height.

Assuming that a building is compartmented, fire other than one in a shaft should be confined to a single storey. The total pressure head generated by the fire is thus not likely to exceed about 0.1 in. water gauge. As buildings are generally heated in their entirety, stack effect associated with building heating can give a total head significantly more than 0.1 in. water gauge if the building is more than about four storeys in height. It can thus be seen that combating stack action associated with building heating in high buildings is likely to pose more of a problem than combating stack action directly associated with a fire. An examination of the flow pattern created by the two phenomena further demonstrates that in high buildings emphasis should be placed on the building heating rather than the fire stack action problem.

Effect of Wind

Column 4 of Table B-1 indicates that pressures resulting from winds can be substantial. As mentioned earlier, the greatest component of

TABLE B-1 MAGNITUDES OF PRESSURES DEVELOPED BY THERMAL AND WIND EFFECTS

Pressure Head (in. of water)	Height of heated compartment (ft)		Windspeed (MPH)	Flow beneath a door (cfm)(Gap 3'0" x 0.5")
	1440F°(800C°) above ambient (i.e. on fire)	90F°(50C°) above ambient		
0.1	9.5	33.9	14.4	95
0.2	19.1	67.7	20.4	135
0.5	47.7	169.3	32.2	212
1	95.5	339	45.6	301
2	191	677	64.5	425

the resulting airflow is horizontal. This does not create as great a hazard as vertical movement via the shafts in a building. An upward component does exist, however, and its effect is virtually identical to that of stack action associated with building heating. Combating the latter will therefore take account of the more hazardous influence of winds.

Contribution of Air Handling Systems

The effect of recirculating air handling systems is not shown in Table B-1,but it is of substantial significance and hence it must,of necessity,be considered when smoke control techniques are being devised for buildings including such systems.

Significance of Smoke Movement Mechanisms

From the considerations just discussed it has been concluded that the most significant smoke movement mechanisms to be combated are

(1) operating recirculating air-handling systems,

(2) the expansion process occurring during the initial stages of a fire,

(3) stack action associated with building heating.

Techniques for Avoiding Widespread Smoke Contamination

Techniques for avoiding wide-spread smoke contamination in a high building can be divided into the following categories:

(1) Avoidance of any significant fire. The first approach falling in this category is to exclude or limit combustible materials from a building. Calculations of air movement due to stack effect, however,have indicated that the destruction in fire of very small quantities of combustible material can produce enough smoke to produce untenable conditions in upper floors and vertical shafts of a high building. Limits on the use of smoke producing materials are thus unlikely to be adequate as a sole means of smoke control. Automatic extinguishment of a fire can also be considered as an approach to limiting smoke generation,provided the quantity of combustibles destroyed is held within strict limits.

(2) Compartmentation. Where a floor area is divided into a number of fire compartments, the potential size of a fire will be limited to the contents of one compartment. In addition there will be, in some circumstances, dilution of smoke moving from the fire compartment to other floors.

Where the fire occurs below the neutral plane, in cold weather, the path of smoke travel may be along a corridor to stair and elevator shafts. In this case the smoke in the corridor will be diluted by clean air coming from other compartments. In an ideal situation (uniform compartments, no expansion, no wind), dilution of the smoke laden air will be in proportion to the number of compartments. Breaking of a window in the fire compartment will, however, increase the pressure in that space, and reduce the effect of dilution.

Where smoke travel occurs through a vertical shaft from a compartment involved in fire to higher compartments, the level of contamination will not be related to the number of units on one floor, but will likely be restricted to units on other floors that are adjacent to the vertical shaft.

The result of compartmentation is therefore likely to be beneficial, but does not eliminate the need for smoke control measures.

(3) Location of Shafts Outside the Building Envelope. The vertical transfer of smoke to upper storeys of a building from fire on a lower storey occurs largely by the vertical shafts in a building rather than through the floors, to the extent of about 95 per cent or more in the case of a typical 20-storey building. Separation of the shafts from the building would thus largely solve the problem. This approach constitutes one of the suggested methods of smoke control.

(4) Dilution. Dilution by a factor of about 100 of the smoke gases issuing from a fire region will provide a tenable atmosphere. This feature could form the basis of a smoke control method, air being injected into the building at appropriate rates at those locations where smoke is being discharged from the fire region into adjacent parts of the building. When cold weather conditions are considered, however, dilution alone is not likely to be very practical. In general, it would be better if the injection of air were directed to modifying

the pressure pattern within a building in order to limit undesired movement of smoke.

The value of dilution as a means of reducing smoke pollution should,nevertheless,be considered as an important secondary factor governing a designer's choice of smoke control method. Its importance is in dispersing contamination that might develop as a result of delay in implementing smoke control measures,or of other occurrences such as the opening of a number of doors that might interfere with the operation of a smoke control measure. The amount of air required to dilute a contaminated atmosphere to a tenable level can be calculated approximately. If no mixing were to occur between the contaminated and clean air, and the contaminated air were to move out ahead of the clean air,one volume of clean air injected into a compartment would produce a smoke free atmosphere. In practice, however, some mixing does occur. If perfect mixing is assumed in a compartment that has reached a level of contamination equivalent to that of the fire compartment,and no more smoke is entering, the amount of clean air needed to create the one per cent tenable atmosphere discussed would be five times the volume of the compartment. If, however, we are considering a compartment isolated from the fire compartment by a fire separation and self closing doors,it is more reasonable to assume that the level of contamination likely to occur is about one fifth of that in the fire compartment. In these circumstances,injection of three volumes of clean air would be sufficient to produce a tenable atmosphere. If clean air is injected at the rate of one volume every 2 min., the atmosphere in the compartment would be satisfactory in about 6 min.

Note These figures are based on the expression

$$c = C_o e^{-at}$$

where c_o = initial concentration of contaminant

c = final concentration of contaminant

a = rate of diluent air flow air change/minute

t = time in minutes between occurrence of initial and final concentration

e = is a constant 2.718

Based on this calculation, assuming perfect mixing of the contaminated air and the diluent air,

c/c_o	=	0.368 after injection of 1 volume of clean air
		0.135 " " " 2 " " " "
		0.050 " " " 3 " " " "
		0.018 " " " 4 " " " "
		0.007 " " " 5 " " " "

(5) Adjustment of Pressure Differential Distribution. This category of smoke control technique involves modification of pressure pattern within the building. The pressure distribution within a building is illustrated by the pressure characteristic diagrams in Fig.B-2. The graphs represent, in an exaggerated manner, the pressure differences between floor areas, shafts and exterior at the same height above ground. The pressure difference shown amount to little more than 2 in. water gauge, whereas the total pressures involved are about 400 in. water gauge. The graphs do relate pressure to heights, and thus cannot be used to determine pressure difference between one floor and another at a different height. Given any set of characteristics as in Fig.B-2, the important feature is that, during cold weather, air flow from one region to another at the same level will be towards the region that is at a lower pressure. In the typical building whose characteristics are illustrated, smoke generated at a low level will flow into shafts, up through the shafts and out into floor spaces at the higher levels.

Shafts provide the major paths for the spread of smoke within a building, so one should note the effect of venting on their characteristics. Fig.B-3 shows the characteristics of a simple heated shaft under three different venting arrangements, the second and third (Fig. B-3(b) and B-3(c)) having obviously useful advantages in controlling smoke movement in buildings.

In Fig.B-3 the shaft is vented to the outdoors at the top, and smoke entering the shaft at any level would not leave it until it reached the top opening. If a corresponding condition were established within a building, the shaft would therefore not constitute a path for the transmission of smoke from low level to high level floor spaces.

In Fig. B-3 the shaft is vented to the outdoors at the bottom, fresh air enters the shaft at the lowest level, and leaves it through any leakage area at any other level in the shaft. Such a condition for a shaft in a building would be most valuable, for as well as being eliminated as a path for smoke dispersal, the shaft also has a clear atmosphere. These conditions, however, may not be sustained long as the atmosphere in the shaft will cool as a result of the influx of cold air, and the characteristic will approach that of the exterior atmosphere. Injection of warm air into the shaft is necessary to maintain these conditions over a prolonged period.

Where a smoke control method is concerned with changing the pressure pattern within a building, many of the measures involved are based on the preceding concept of changing the pressure characteristic of a shaft. Since shafts are the principal paths by which smoke disperses throughout a building, the aim will be either to decrease or to increase shaft pressures substantially. Both measures will eliminate vertical smoke transfer by the shaft between floor spaces. Top venting the shaft as in Fig. B-3, or use of mechanical exhaust to approach these pressure characteristics will however also result in the entry of smoke into the shaft, while pressurizing the shaft such as by mechanical injection will maintain a tenable atmosphere in the shaft.

(6) Smoke Shafts. A smoke shaft differs from a vented service shaft in that an opening is provided into the shaft from the fire floor in addition to the opening to the outside at the top of the shaft.

Until windows in outer walls are broken, a smoke shaft alone can be an effective means of limiting movement of smoke into other floors and shafts. In cold weather, the shaft is warmer than outdoor air and will begin to function as a vent shaft as soon as the dampers are opened. During warm weather there will be some delay, as the smoke shaft cannot function as a vent until hot air has entered the shaft as a result of initial expansion in the fire region. The pressure conditions that prevail during cold weather are shown in Fig. B-4. The air pressure on the fire floor, having an opening into the smoke shaft, is below that in adjacent unvented shafts and adjacent floor areas. Air flow will be from the adjacent floor areas and shafts into the fire floor, and from the fire floor into the smoke shaft. If, however, a window is broken on a fire floor at a lower level, the air pressure in the fire region will be increased to approximately that of outdoor air pressure at the same level. Smoke may then flow into stair and elevator shafts and adjacent floor areas. During warm weather , breaking of a window will allow venting of smoke to the outdoors for a fire on any floor, except when wind is blowing towards the open window. In this event, breaking of the window will cause the action of the smoke shaft to be overwhelmed. The smoke shaft, therefore, is not fully effective as a sole method of smoke control in a floor area with windows, but can be used in conjunction with building pressurization as part of a smoke control method. The size of a smoke shaft is related to conditions to be established in the event of a fire at a lower level of the building, and is dependent on the leakage characteristics of the building. Any increase in the air leakage through the walls of the building and the shafts requires a corresponding increase in the size of the smoke shaft. In Fig. B-4 the idealized smoke shaft pressure characteristic is indicated by a dotted line, and assumes no pressure losses inside the shaft. As the smoke shaft is open to the outside at the top, pressure at the top level of the smoke shaft is equal to that of outside.

Assuming an air temperature inside a smoke shaft equal to that of the building as may occur in the case of a small fire, the slope of the smoke shaft pressure characteristic is the same as those of the vented shafts. In Fig. B-4 the total pressure (ΔP_T) acting across the vent opening at the bottom is represented by the horizontal distance between floor space and smoke shaft pressure characteristics. The value of ΔP_T is about one-half of the total pressure head generated by stack action over the height of the building. The values of ΔP_T are plotted against building height for various outside temperatures in Fig. B-5. The movement of air through the smoke shaft causes a decrease in building pressures, which results in the shifting of the floor space pressure characteristic to the left in the pressure diagram. This results in a lower effective value of ΔP_T. The values of ΔP_T in Fig. B-5 have been adjusted to take this factor into account. So far it has been assumed that no pressure losses occur inside the smoke shaft. Friction, momentum and dynamic pressure losses can, however, occur inside the smoke shaft, as a result of air flow through the open vent of the fire floor, as well as through leakage openings in the walls of the smoke shaft. The smoke shaft pressure characteristic including pressure losses is also shown in Fig. B-4 as a solid line. The actual pressure difference across the open smoke vent ΔP_V is less than ΔP_T; the difference between the two values representing the pressure losses inside the smoke shaft. The flow requirement to achieve the desired venting action depends on the pressure differences across the fire floor enclosure caused by stack action, and on the air tightness of the various interior and exterior separations of a building. The flow rates shown in Fig. B-6 were calculated initially in relation to a 20-storey building having a floor plan 120 ft. x 120 ft., with assumed leakage through walls and floors consistent with results of air movement measurement obtained in several multi-storey buildings. Extrapolation was made for buildings of various heights, floor areas and outside temperatures using the following relationships.

(1) QV is proportional to FA

(2) QV is proportional to $(H)^{\frac{1}{2}}$

(3) QV is proportional to $\left(\frac{Ti - To}{To}\right)^{\frac{1}{2}}$

Where QV is the required flow rate through floor vent of smoke shaft,

FA is the flow area of a typical floor

H is the height of building in feet

Ti is the indoor absolute temperature

To is the outdoor absolute temperature.

Other Considerations

There are a number of other considerations that may have to be taken into account in applying measures for control of smoke movement.

Breaking of Windows on the Fire Floor

Where the room in which a fire occurs has windows, it is likely that they will be broken at a fairly early stage. This will result in a change of pressure in the fire region to a value that is substantially that of outdoor air pressure at that level. In Fig. B-2 it can be seen that for a fire at a low level in the building during cold weather, breaking of windows will greatly increase the pressure in the region involved. As a result more smoke may be expected to pass into adjacent floors and vertical shafts. This has been taken into consideration in the measures described in Chapter 2.

Pressures across Doors

Problems may occur where air pressures across typical hinged doors and sliding elevator doors interfere with their normal use. This may occur when the pressure across a door exceeds 0.4 in. water gauge.

Pressure differences of this magnitude may occur in cold weather where a door communicates with a space that is substantially at outdoor air pressure. This commonly occurs at the entrance doors to high buildings during normal use. The problem is resolved in this case by use of revolving doors or by special hinges which permit the door to rotate about the centre until a sufficient opening is formed to relieve the pressure on the door. It may also occur when windows on a fire floor are broken or where vestibules vented to the outdoors are employed as in Measure D in Chapter 2. Situations where such problems may arise are indicated in the explanatory notes to each smoke control measure.

Possibility of Explosions in Smoke Shafts

There is a possibility that an explosion may occur in a smoke shaft during a fire. The maximum over-pressure predicted on the basis of a British report would probably not exceed about 2.4 psi. This has been considered and because it is a somewhat remote possibility no special precautions are recommended.

Pressure Drop in Stairs

Recent studies have shown that flow requirements for stairwells with an open door at grade level can be sufficiently great to give substantial friction loss pressure drop. If the air is injected only at the top of particular designs of stairwell in a high building, a non-uniform pressure distribution over the height of the stair shaft may occur. This may produce an undesirably high pressure differential across stairwell doors at high levels. This problem may be avoided by injection of the air at several levels rather than only at the top.

Warm Weather Conditions

The smoke control techniques have been developed to function under cold weather conditions, their performance under warm weather conditions has however been carefully considered. Undesirable pressures may be created across certain doors,and there is a possibility of contamination of certain spaces such as a stairshaft at times when the door to the outdoors is open. Where air injection is used, modulation of the supply with exterior temperature can be a solution to the problem,although such action reduces the effect of the air supply in diluting transient smoke contamination. Where no interior-exterior temperature differential exists, the influence of building heating caused stack action as a smoke movement mechanism disappears and, assuming air handling systems to be shut down, expansion becomes a major factor in spreading smoke throughout a building. Under these conditions the influence of a simple vent opening in an external wall can be readily assessed. Flow through all openings in the walls around the fire region will be roughly in proportion to their area. If the area of the vent to the exterior is 10 times the area of the openings communicating to the remainder of the building, it can be assumed that only about 10 per cent of the displaced smoke laden atmosphere will pass into other parts of the building.

During cold weather, expansion may be considered as being responsible for a slight overall increase in pressure of about 0.1 in. water gauge in the fire region for a period of about 20 min.

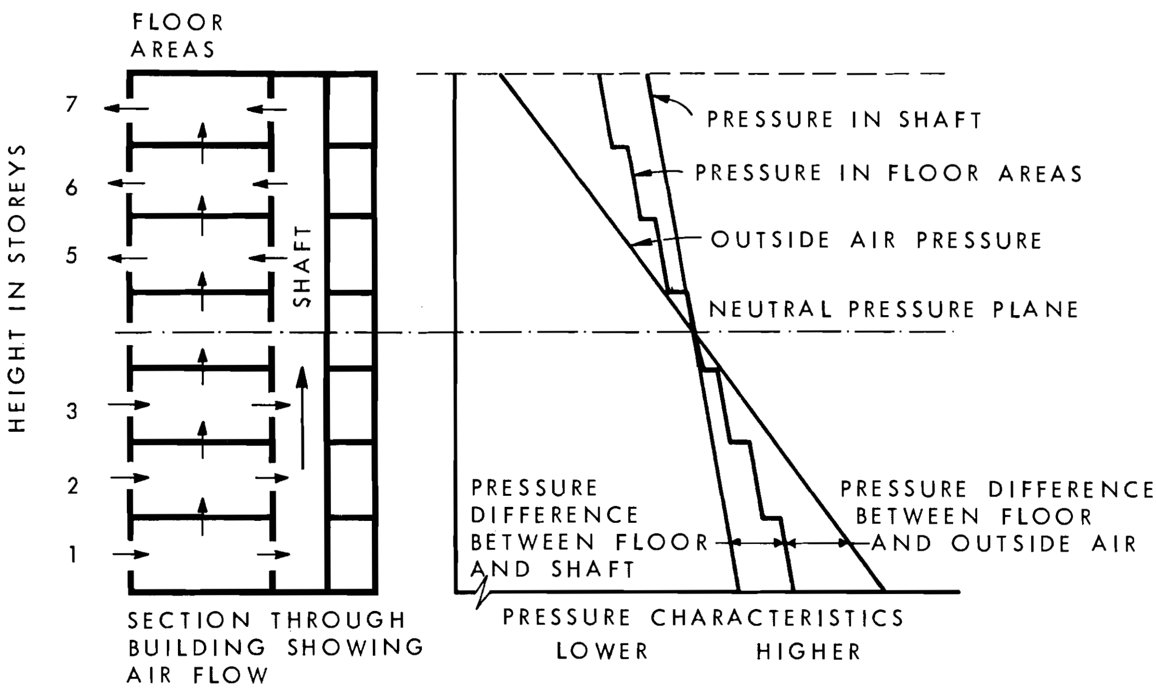


Figure B-2

Pressure Characteristics of a Typical Building

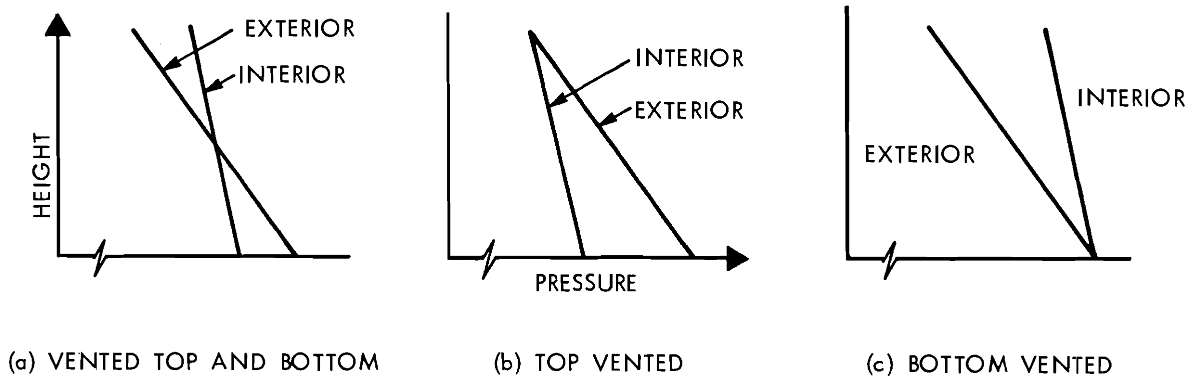


Figure B-3

Shaft Characteristics

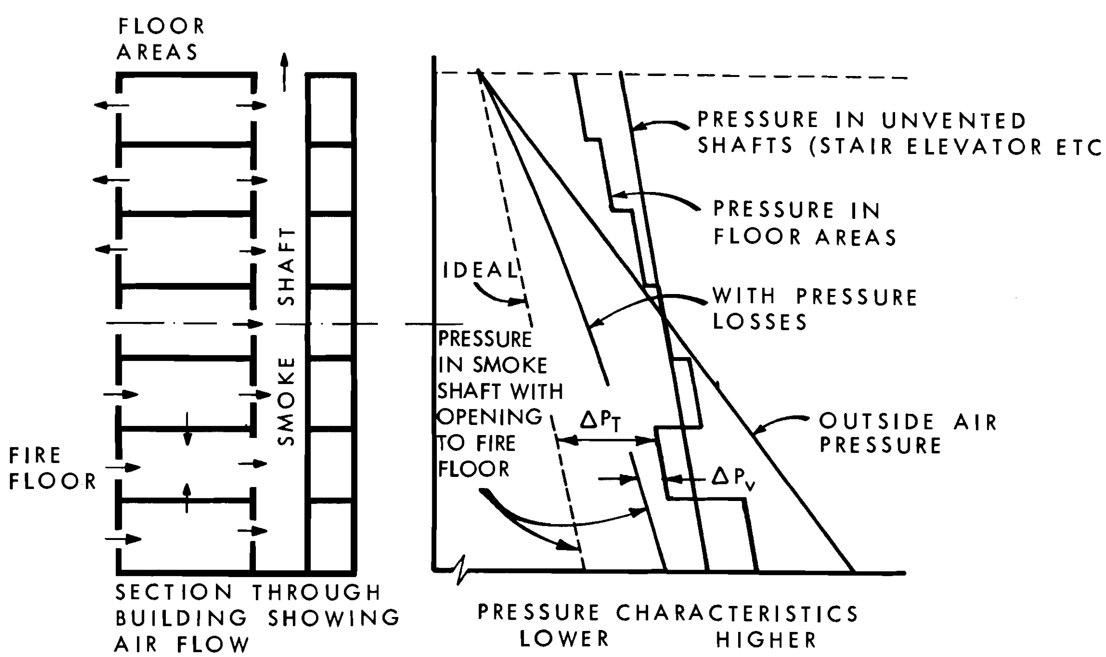


Figure B-4

Pressure Differences Produced by a Smoke Shaft

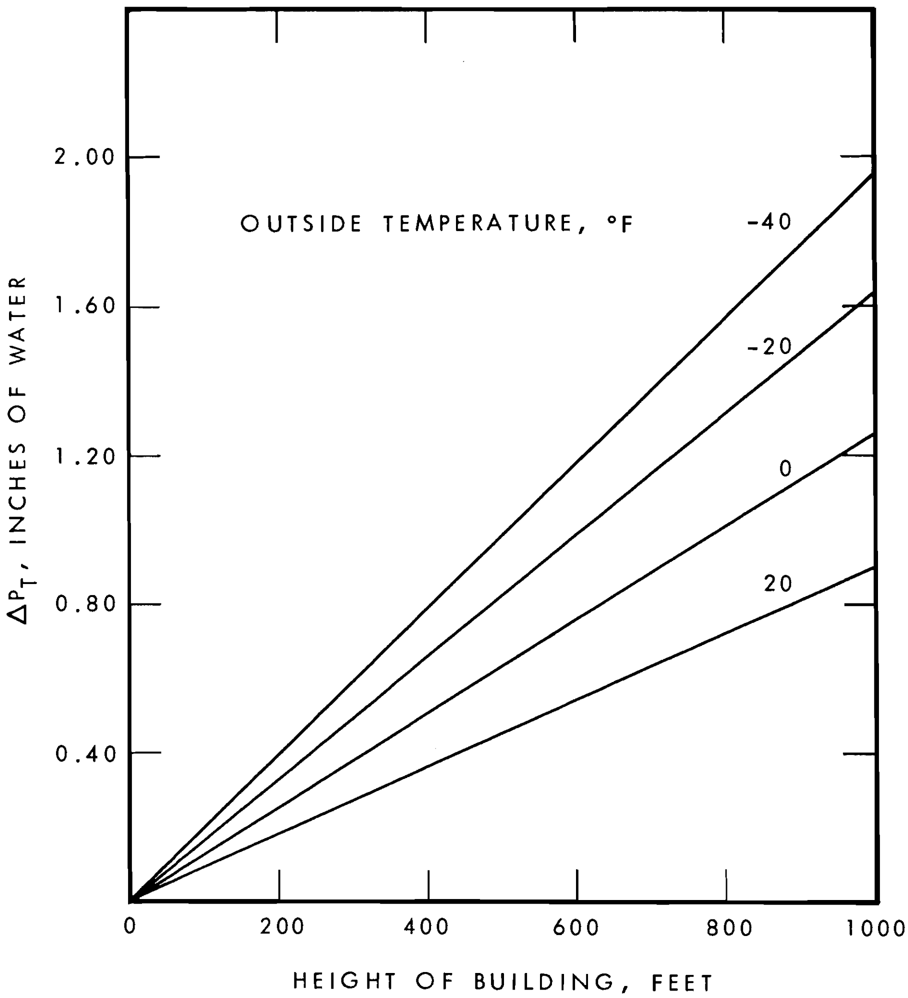


Figure B-5

Available total Pressure Vs Building Height

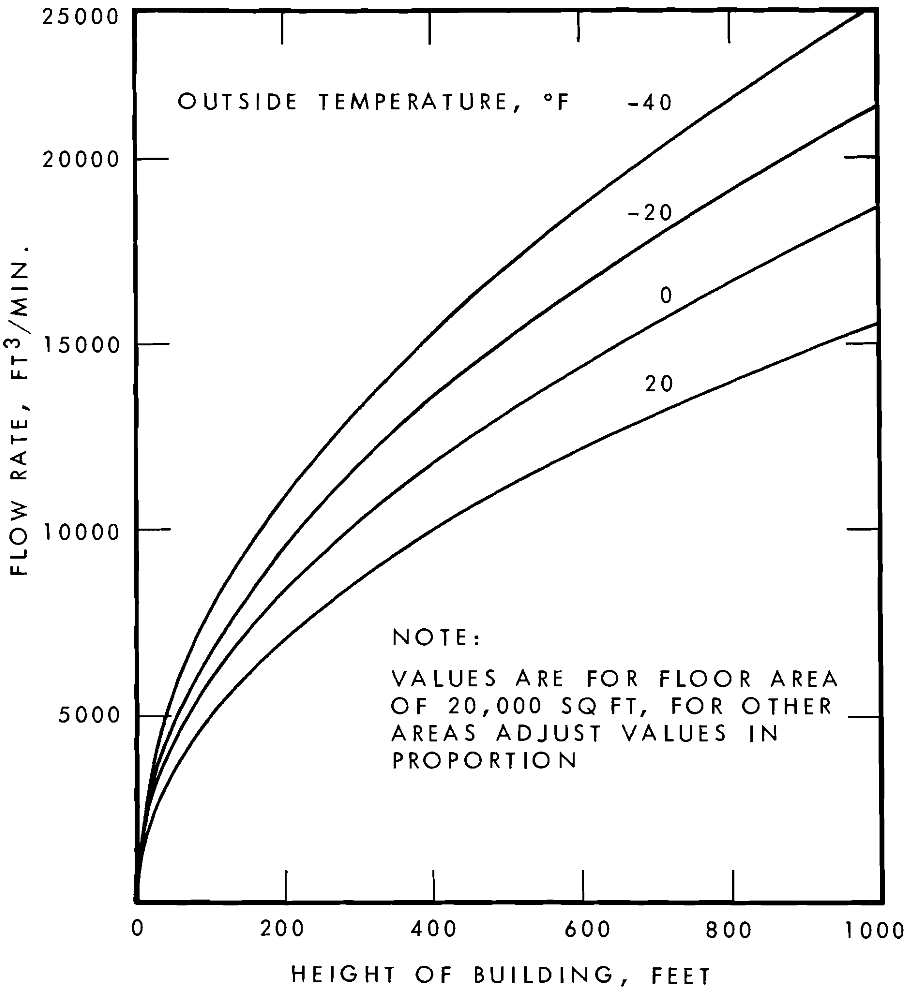


Figure B-6

Required Venting Capacity of Smoke Shaft

CHECK OF A SMOKE CONTROL SYSTEM

Where the efficiency of a smoke control system is to be checked, it may be done by measuring pressure differences and direction of air flow around doors and through separating walls of compartments. A pressure meter can be used to measure pressure differences on either side of a door or partition. Where this is impractical, a punk stick or the smoke from a cigarette held near a crack will give an indication of the direction of air flow. Measurements of air flow may be taken on the intake side of supply fans or in supply ducts to determine whether the specified air flow is being provided.

In general air flow should be from the spaces which may be occupied during a fire emergency, e.g., stairshafts, toward the space in which fire is assumed to have occurred. For each method of smoke control there are certain critical locations where measurements may be taken to check the overall efficiency of the system.

In buildings designed by Measures B, C, D or E, where protection is by venting corridors or vestibules to the outdoors, inspection of the building to determine whether the requirements have been met should be sufficient. In buildings incorporating measures B, C, D, E, F, or G, there may be service shafts vented to the outdoors at the top. In this case, a check may be made of the wall between the shaft and the uppermost occupied floor areas, to ensure that the direction of flow is from each floor area into the shaft, when the vent to the outside is open and the outdoor air temperature is significantly less than that indoors. In a building incorporating Measures D or E, where mechanically pressurized vestibules are used, and in a building incorporating Measure L, a check may be made to ensure that the pressure in each vestibule or area of refuge is greater than that in the adjacent floor areas at each floor level.

In a building incorporating Measure F or G, the efficiency of a protected elevator shaft can be checked by using a meter to measure pressure differences between the shaft and the outdoors at grade, before and after activation of the air injection system. The difference between the two readings gives the magnitude of mechanical pressurization of the shaft, which should be at least equal to one half the calculated pressure difference caused by stack action over the height of a building for the winter design temperature and the design flow rate specified in Sentence (4) of Measure F (p. 47) or Sentence (4) of Measure G (p. 50). Where the air flow is modulated, the magnitude of mechanical pressurization should vary between 0.2 in. of water when the outdoor temperature is equal to that indoors, and one half of the pressure difference noted above when the outdoor temperature is equal to the winter design temperature. Flow rates into the elevator shaft may be checked against that specified in Sentence (4) of Measure F (p. 47) and Sentence (4) of Measure G (p. 50). Stairshafts may be checked with the air injection system operating and the door or vent to the outdoors open. Flow rate through the shaft should be equal to that required by Sentence (2) of Measure F (p. 47) and Sentence (2) of Measure G (p. 50). Top vented elevator and service shafts may be checked as described for a building incorporating Measures B, C, D or E.

In a building incorporating Measure H, the efficiency of the system may be checked by measuring pressure differences between floor areas at grade and outdoors, before and after activation of the air injection system. The magnitude of the mechanical pressurization is obtained as described above in the case of elevator shafts in a building incorporating Measure F or G, and should be equal to half the pressure difference caused by stack action over the height of the building for the winter design temperature and the design flow rate specified in Sentence (2) of Measure H (p. 55). The effect of modulating air flow for different temperature conditions is also as described for elevator shafts. Flow rates into the building may be checked against those required in Sentence (2) of Measure H (p. 55). A check may be made on each floor individually, with the air injection system operating and the damper to the smoke shaft or panel to the outdoors open. Under these circumstances, air flow should be from the stair, elevator and service shafts into the floor area that has a damper or panel open.

In a building incorporating Measure I or J, pressure differences should be measured between the central core at grade and a suite that has a number of windows open to the outdoors before and after activation of the air injection system. The magnitude of mechanical pressurization is obtained as described above in the case of elevator shafts in a building incorporating Measure F or G, and should be equal to half the pressure difference caused by stack action over the height of the building for the winter design temperature and design flow rate specified in Sentence (2) of Measure I (p. 59). The effect of modulating air flow for different temperature conditions is also as described for elevator shafts. Flow rates into the central core may be checked against those required in Sentence (2) of Measure I (p. 59).

In a building incorporating Measure K,inspection should indicate whether or not there is a continuous separation between two parts of the building, extending from the roof through below grade storeys. Where pressurized vestibules are used, a check may be made to ensure that the direction of air flow is from each vestibule into adjacent floor areas at each level. The check should also be made on a low level floor with the floor space vents referred to in Sentence (12) of Measure K (p. 67), or other windows in the two halves of the building open on that floor. This represents the condition when the fire has broken windows in one half of the building and the compensating vent in the other half of the building has been opened manually.

In a building incorporating Measure L, the method of checking is the same as in a building incorporating Measure D or E,except that flow rates into areas of refuge should be measured to ensure that they meet the requirements of Sentence (9) of Measure L (p. 71).

Doors to stairs, elevator shafts and vestibules that are indicated in the notes relating to each Measure as being in locations subject to pressure differences that may interfere with normal opening, should be checked when outdoor temperature is near the winter design temperature, with the air injection system operating and a number of windows open to the outdoors, on each floor in turn.

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