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FIRE IN HIGH BUILDINGS

by

M. Galbreath

Fire Study No. 21
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During the last few years there has been a significant increase in the number of high buildings erected in Canada. The tallest of these to date is 56 storeys, or 736 ft high. Such buildings introduce problems in fire safety that are different in degree and type from those encountered in more traditional buildings, so that safety measures based on accumulated experience alone cannot be expected to cover all innovations in design.

In the hope that the record of fires in high buildings would give some indication of the kind of incident that might occur, a study was undertaken of reports of fires that have occurred since 1950. A high building in this context was assumed to be one 6 storeys or over in height.

The more common fire department aerial ladders generally reach about 80 ft above ground, or about the level of the 6th or 7th floor. If a fire occurs in a floor above this level effective measures to control it and rescue occupants must be conducted within the building. It may also be necessary for those in the upper part of the building to pass through a fire floor on their way to a place of safety. Evacuation of a tall building may involve moving a large number of people, for larger buildings may contain more than 10, 000 people.

References to reports of fires in high buildings that have occurred since 1950 are included in Appendix A. Most of these have appeared in the published literature; a few are the result of visits by DBR staff to building fires. About 60 per cent of the fires occurred in buildings erected since 1950.

The occupancies of the buildings involved were residential (10), office (10), department stores (3), and hospital (1). The deaths of ninety-seven people occurred in six of the fires, the majority in residential buildings. The largest loss of life in one fire occurred in a penthouse restaurant where 25 people died. In the office buildings most of the fires occurred when the buildings were occupied only by cleaners and maintenance staff, and this contributed to the low loss of life in these occupancies. Table I shows the buildings and floors on which deaths occurred.

The figures represent fires in which large loss of life or property occurred. Smaller fires are not usually reported. The numbers are therefore not particularly significant, but the reports may be assumed to illustrate the types of incident that have occurred. Some of the interesting features of these fires are discussed below.

2. SPREAD OF FIRE BETWEEN COMPARTMENTS

Limits can be placed on the extent of probable fire spread by dividing a building into a series of fire-tight compartments. In a multi-storey building it is desirable that each floor should be a separate compartment. In high buildings the involvement of two or more floors may present very considerable problems for fire fighters. In addition, the possibility of fire spread from one floor to another carries with it the possibility of successive spreading to other floors, thus involving the whole of a building above the floor initially on fire. Typical fire incidents are related to the buildings in which they occurred in Table II, which shows that spread of fire to upper floors occurred five times by exterior windows, four times by stair or escalator, and four times by vertical shafts, one of these a refuse chute.

In one building spread of fire to the floor above by way of an exterior window occurred although there was a masonry spandrel 4 ft - 9 in. high between successive windows. In three of the examples noted there was combustible ceiling tile adjacent to the windows. This may have contributed to the size of flame outside the windows, and would provide a readily ignited surface behind the windows on the next floor. It is also noted that all these incidents of spread of fire through windows occurred in the upper half of the building. The air pressures in the building (discussed in Section 3, Spread of Smoke and Toxic Gases) may have contributed to greater flaming outside the windows.

Vertical spread of fire by stairs occurred in older buildings (1922 and earlier), except for one built in 1956 and later converted from an apartment building to a hotel. The more modern design of stairs with self-closing doors and non-combustible interior finishes may be less likely to spread fire.

Spread of fire in shafts is common even in modern buildings. These shafts may be as much as 250 sq ft in area and contain air-conditioning ducts, chilled water, fuel pipe lines and electrical bus bars. Insulation and pipe wrapping contribute a significant quantity of combustible and, in some cases, high flame spread materials.

3. SPREAD OF SMOKE AND TOXIC GASES

It is possible that the greatest danger to life in building fires lies in the smoke and toxic gases produced. Even small quantities of combustible materials can produce large quantities of smoke. Although it may be possible to limit some of these sources, it may be that more success can be achieved by controlling the movement of smoke.

It has been demonstrated by Tamura and Wilson[1] that quite considerable pressure differences exist in high buildings. This tends to force air in at the bottom and out at the top of the building under weather conditions resulting in outdoor temperatures lower than those inside the building. It also creates an upward draught in all vertical shafts such as stairs and elevators. The pressure difference is related to the height of the building, the air tightness of the exterior walls and to the difference in temperature between inside and outside.

These pressures act to draw smoke and toxic gases up through high buildings, as has been demonstrated by the fire reports. Of the 24 fire incidents described in Appendix A there were 16 in which smoke or flame travelled up through the building by various paths.

3.1 Spread of Smoke by Way of Stairs

There is some possibility that smoke will enter stairs through the cracks that exist around doors. If the doors are opened this possibility becomes very much greater. The fire reports in Table II show four instances of smoke being drawn into stairs. Causes noted include doors wedged open, doors held open by firemens' hose, and doors opening and closing as occupants leave. In many buildings it is not possible for firemen to lead a hose to a fire area except by passing it through the stairwell. Some fire departments also make it a standard practice to pass hoses through the stairs.

3.2 Spread of Smoke in Shafts

Service shafts are very often open from basement to roof. In some buildings floors are carried across these shafts at intermediate floors. It is common, however, for gaps to be left around pipes and ducts at these points. In eight of the examples noted in Table II there was vertical movement of smoke or flames in the shafts.

3.3 Spread of Smoke by Air-Handling Equipment

Circulation of air through many floors by air handling equipment is a comparatively recent development. The older high buildings were heated by steam or hot water and movement of air was not involved. In one recent building, however, the air conditioning system recirculates air through banks of 10 floors. This type of equipment has caused very rapid distribution of smoke through all floor areas. Table I shows that it has occurred in four of the building fires described.

Standards for heating equipment include provisions for dampers held open by fusible links. These dampers may limit the spread of flame or hot gases, but they are likely to be ineffective if low temperature smoke is being transmitted.

4. FIRES IN BASEMENT AREAS

Fires in basement areas present a particular problem to firemen. The natural air pressures existing in the building tend to direct smoke and gases upward through the stairs and other shafts. It is difficult, therefore, for the firemen to reach the basement level and to locate the centre of the fire in a smoke-laden atmosphere.

There is also a strong chance that a fire can develop unobserved in what is usually the less occupied portion of the building, and one where a high fire load in the form of storage and waste paper collection can frequently be found. Seven of the fires listed in Table I originated in the basement floor.

5. ELEVATORS

Elevators are the principal means of access to floors in high buildings. Few people would consider the possibility of walking up or down 50 floors. The natural reaction of the occupants of a high building on hearing a fire alarm is to attempt to leave the floor by elevators. The danger involved in this practice is illustrated by many of the reports of fires in Appendix A. In one building it is reported that firemen used the elevator communication system to ask people to leave the elevators and continue their descent by stairs. In a Danish fire it is noted that the elevators functioned throughout the fire. It is also the practice among firemen to take the elevator to the floor immediately below the fire and then to approach the fire by the stair.

There are three instances of elevators stopping out of control at the fire floor:

(a) In a penthouse restaurant firemen took the elevator to the floor immediately below the fire floor; then the fire chief attempted to descend. The elevator rose instead to the fire floor and stopped. A second elevator carrying more firemen also rose to the fire floor and stopped there. The firemen had to climb out of the elevator and slide down the elevator cables to the basement.

(b) In a hospital fire six of the eight elevators in the centre section stopped. One group of passengers trapped at the fire floor had to climb out of the elevator to the floor above.

(c) In an office building fire one fireman died when the elevator door opened on the fire floor. The last incident is reported as a possible mistake by the firemen operating the elevator. In the two other cases there was fire immediately adjacent to the elevator shaft and it is possible that the fire caused a short in the call button or associated wiring, with the result that the elevators were called to that floor.

6. MEANS OF ESCAPE

The method of designing exit stairs required by the National Building Code assumes that people will move to ground level in a steady stream. It can be demonstrated (Appendix B) that this is impractical and that in some circumstances the stairs will only accommodate about half the occupants of the floor. In this situation there is a probability that panic will occur, adding to the danger of the occupants.

7. MEANS OF COMMUNICATION

It is apparent from the reports of fires that one of the major problems in high buildings is lack of communication. In one fire two-way radios were used by firemen to maintain contact. In other buildings radios have not been effective because of masking by the structure or interference.

Another important objective is to reassure the occupants in order to reduce the possibility of panic. On one occasion fire trucks were distributed around a building where they could be seen by the occupants, who would then know that firemen were in attendance. This had the effect of reducing the degree of panic. In the Hartford Hospital fire, people leaning from windows beyond the reach of ladders were advised by firemen using loud hailers of the best action to take while awaiting rescue.

8. CONCLUSIONS

8.1 Fire separations now required between floors in high buildings appear to be satisfactory. No failures of floors are reported apart from results of explosions. Weaknesses do occur, however, in windows, open stairs, or escalators and in vertical service shafts.

8.2 Accepted methods of designing buildings do not prevent accumulation or movement of smoke. Natural air pressures contribute to drawing smoke up through stairs, elevators and service shafts. Air-moving equipment also is responsible for distributing smoke through many floors.

8.3 Elevators are frequently used by occupants to leave a building in an emergency. There is considerable danger in this practice because the elevator may go out of action, be drawn up to the fire floor, or be filled with smoke during a fire. The appropriate measures to be taken will depend on whether or not the elevator is to be used in fire.

8.4 Firemen also use elevators to approach a fire floor. It is unreasonable to expect them to walk up with their equipment. Automatic controls interfere with the efficient use of the elevator by firemen and may place them in danger.

8.5 It is not possible for all the occupants of upper floors to enter the stairs in an emergency. There is, therefore, need for the provision of a safe place of refuge on each floor connected directly to an escape route leading to the outside.

8.6 There is need for means of communication between firemen and occupants and between firemen on the fire floor and those on the ground, both in order to assist in rescue and firefighting, and to reassure the occupants.

9. MEASURES THAT CAN BE INCORPORATED IN THE DESIGN OF BUILDINGS

The foregoing examination of the kinds of incident occurring in high buildings points to a number of areas in which modifications might be made in design.

9.1 Spread of Smoke

Measures should be taken to reduce the spread of smoke through buildings:

(i) Air pressures in stairwells and elevators that are to be used during a fire can be maintained at about 0.1 in. water gauge above that in the surrounding areas. This is described more fully by McGuire[2] and should be effective in keeping shafts free of smoke.

(ii) Alternatively, a lobby provided with either artificial ventilation or an opening to the outside air may be placed between each floor area and the stair or elevator. This is included in the British Standard Code of Practice for High Flats[3] where a 15-sq-ft opening is specified. An openable window appears to be accepted in Britain as an alternative to a permanent opening. Experiments on smoke movement in stairs have been conducted in France[4] and in Los Angeles[5]. These show that ventilated lobbies and positive air pressures can contribute to a smoke-free stair. The NFPA Building Exits Code[6] also describes, but does not require, a smoke-proof tower. This is a stair approached by a balcony or ventilated space.

(iii) Service shafts may be sealed at each floor, using non-combustible materials to prevent transmission of smoke, or they may be provided with a vent at the top to draw smoke out of the shaft. Shafts differ from stairs in that they are not occupied so that the presence of smoke is not objectionable provided it does not enter the floor areas. This also is referred to by McGuire[2].

(iv) Smoke and gas detectors should be provided in air moving systems to close dampers and shut off fan motors when smoke enters the system. The National Fire Code[7] has provisions for smoke detectors in these systems.

(v) Basement areas and other windowless floors should be provided with ventilation openings at high level or ducts that may be operated by firemen to clear smoke.

9.2 Place of Refuge

Every floor in a high building, including ground floor and basements, should be divided horizontally into compartments by a 1-hr fire separation. This would provide a place of refuge on each floor for all the occupants of the floor. It would also provide an area that could be used for firemen to assemble before entering the fire area. It is, of course, essential that each place of refuge thus formed is connected to stairs and elevators.

The provisions now in the National Building Code[8] for smoke-stop doors in hospital buildings would have somewhat the same effect. What is termed a "horizontal exit" in the National

Building Code is also recognized therein as an alternative means of escape.

Some examples of how this suggestion could be implemented are illustrated in Figures 1, and 2, which show typical plans of high buildings and the suggested means for improving fire safety. The partitions do not need to be in the same position on each floor. They can be placed to minimize interference with the normal use of the floor area. It can be seen that this provides many additional exit routes from any point on the floor.

9.3 Elevators

One or more elevators should be assigned for the emergency use of firemen to enable them to approach the fire. These elevators should have a keyed switch to cut out the automatic controls. They should operate in a smoke-free shaft using positive air pressures, as noted in Section 9.1 (i), and open to a smoke- and fire-free lobby. This system has been adopted in Britain and is illustrated in Figure 3. The British Code of Practice also specifies load and speed of the elevator.

One or two elevators assigned to firemen could be used for evacuation of a number of occupants. It is obvious, however, that if all the occupants are to be moved by elevator the time to evacuate would be a matter of hours. The cost of enclosing all the elevators and lobbies in a fire separation would not be much higher than that of protecting one or two. This would allow all the elevators to be used for evacuation in safety. If all these elevators were to operate under emergency power, however, the additional cost might be excessive.

9.4 Emergency Power

If reliance is to be placed on fans to create smoke-free areas and if elevators are to be used for transporting occupants and firemen, emergency power would have to be provided. Present requirements of the National Building Code cover emergency power only for lighting and exit signs.

9.5 Communications

Many large buildings now have equipment to provide background music in public areas and some apartment buildings have two-way communication between apartments and entrance lobby. This could be extended to provide a public address system to the occupants, and to introduce some form of two-way communication between ground floor and upper floors.

9.6 Spread of Fire by Windows

Some consideration should be given to the design of windows to reduce the probability of vertical spread of fire. This might involve restrictions on the size or placing of windows and on the use of combustible ceiling finishes.

REFERENCES

(1) Tamura, G. T. and A. G. Wilson. Pressure differences for a nine-storey building as a result of chimney effect and ventilation system operation. ASHRAE, Transactions, Vol. 72, Part I, 1966, p. 180-189 (NRC 9467).

(2) McGuire, J.H. Control of smoke in building fires. Fire Technology, Vol. 3, No. 4, November 1967.

(3) British Standard Code of Practice. CP3 Chapter IV, Precautions Against Fire. Part 1, Fire precautions in flats and maisonettes over 80 ft in height. British Standards Institution, London 1962.

(4) Col. Beltramelli, Capt. Clement and J.P. Fackler. Problems raised by smoke in fires in tall blocks of flats. Fire International, 1 July 1963 and 2 October 1963.

(5) Degenkolb, J.G. Smoke Proof Enclosures. Building Standards Monthly, Vol. XXXV, No. 10, Part 1, October 1966.

(6) National Fire Prevention Association. The Building Exits Code, NFPA 101, 1963.

(7) Associate Committee on the National Building Code. National Fire Code. National Research Council, Ottawa, Canada.

(8) Associate Committee on the National Building Code. National Building Code 1965. National Research Council, Ottawa, Canada.

TABLE I

DEATHS FROM FIRES IN HIGH BUILDINGS

Ref. No. See Appendix A	Occupancy	Age of Building	Floor of Origin	Floor on Which Death Occurred	No. of Deaths on Floor	No. of Deaths in Fire	Contributary Circumstances
24	Penthouse Restaurant	1951	11	11	25	25	Combustible ceiling cut off access to stair. Elevators stopped at fire floor.
11	Hotel	older*	1	6 9 10 11 12 13	1 2 2 4 4 9	22	Smoke passed up vertical shafts.
3	Hospital	1948	B	9	16	16	Fire passed up refuse chute spread on combustible ceiling tile in 9th floor corridor. Elevators stopped at fifth floor.
22	Hotel	1898	B	1 2 11	9 1 1	11	Explosion damaged first floor. Smoke passed up elevator shaft to 11th floor
8	Department Store	older*	7	7 8	4 3	7	Workmen spraying flammable insecticide on carpets. Fire passed up open stair to 8th floor.
7	Hotel	older*	6	6	4	4	Combustible wall linings spread fire in corridor.

TABLE I (cont'd)

Ref. No. See Appendix A	Occupancy	Age of Building	Floor of Origin	Floor on Which Death Ocurred	No. of Deaths on Floor	No. of Deaths in Fire	Contributary Circumstances
17	Hotel	1922	1	1 12	2 2	4	Smoke filled stairs.
13	Hotel	1956	B	1 2 Not known	1 1 1	3	Smoke filled stairs and elevator shaft. One man jumped from window and died.
2	Office	older*	3B	22	2	2	Smoke passed up vertical shafts.
18	Office	recent**	6	6	1	1	Elevator opened on fire floor.

* older indicates unknown date in early 1900's.

** recent indicates unknown date since about 1950.

TABLE II

VERTICAL SPREAD OF SMOKE OR FLAME

NUMBER REFERENCE SEE APPENDIX A	DATE OF CONSTRUCTION	HEIGHT IN STOREYS	FLOOR OF ORIGIN	COMBUSTIBLE CEILINGS	SPREAD OF FIRE BY WINDOWS	SPREAD OF FIRE BY STAIRS OR ESCALATORS	SPREAD OF SMOKE BY STAIRS	SPREAD OF FIRE BY SHAFTS	SPREAD OF SMOKE BY SHAFTS	SPREAD OF SMOKE THROUGH ELEVATOR	SPREAD OF SMOKE THROUGH VENTILATION SYSTEM
2	1898	11 + B	B						*		
2	older	25 + 4B	3B							*	
8	older	8 + 2B	7	*	*	*				*	
9	older	-	26					*			
1	older	14	1						*		
7	older	8 + 2B	6	*					*	*	
4	1914	7 + B	2			*					
0	1921	24 + B	13	*	*						
7	1922	12 + 2B				*					*
3	1948	13 + 2B	1B	*				*			
4	1951	11 + 2B	11	*							
3	1956	12 + B	B	*		*				*	
2	recent	7	5		*						
5	recent	13 + 2B	12								
6	recent	-	2						*		*
8	recent	13 + B	6	*	*						
3	recent	7 + B					*				*
4	recent	16	roof								
6	recent	8 + 3B	3B					*			
1	1960	12	1								
5	1962	36	2B				*	*		*	*
1	1962	6	5		*		*				
0	1963	12	4				*				
9	1965	-	1	*							
		Totals		8	5	4	4	4	4	5	4

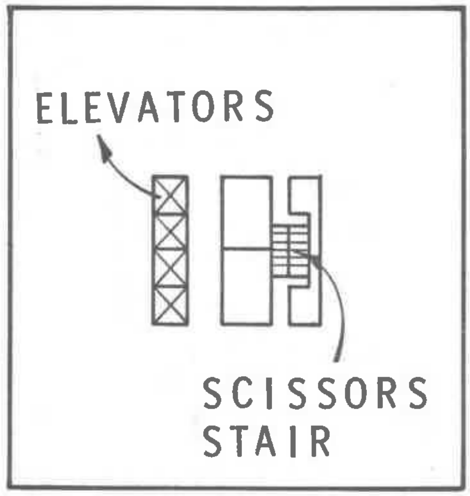

FIGURE 1(a)

TYPICAL FLOOR OF
OFFICE BUILDING

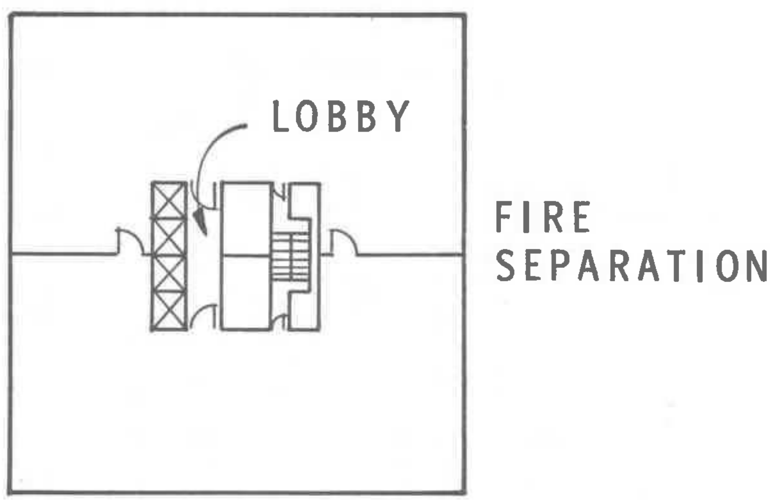

FIGURE 1(b)

FLOOR MODIFIED BY
ADDITION OF PARTITION
AND DOORS

BR 4103-1

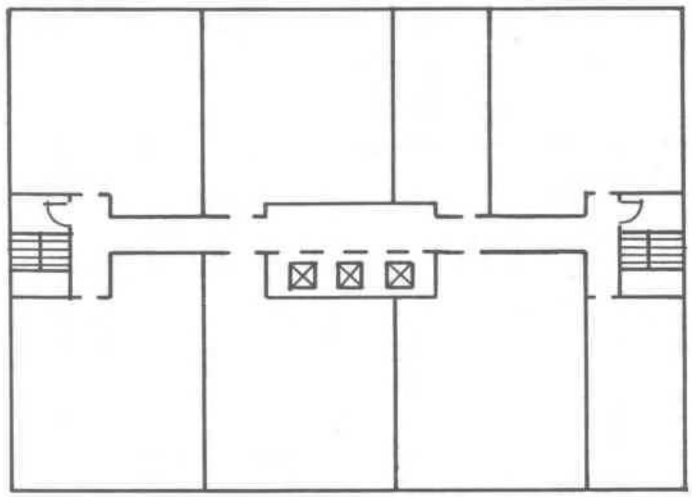

FIGURE 2(a)

TYPICAL APARTMENT FLOOR

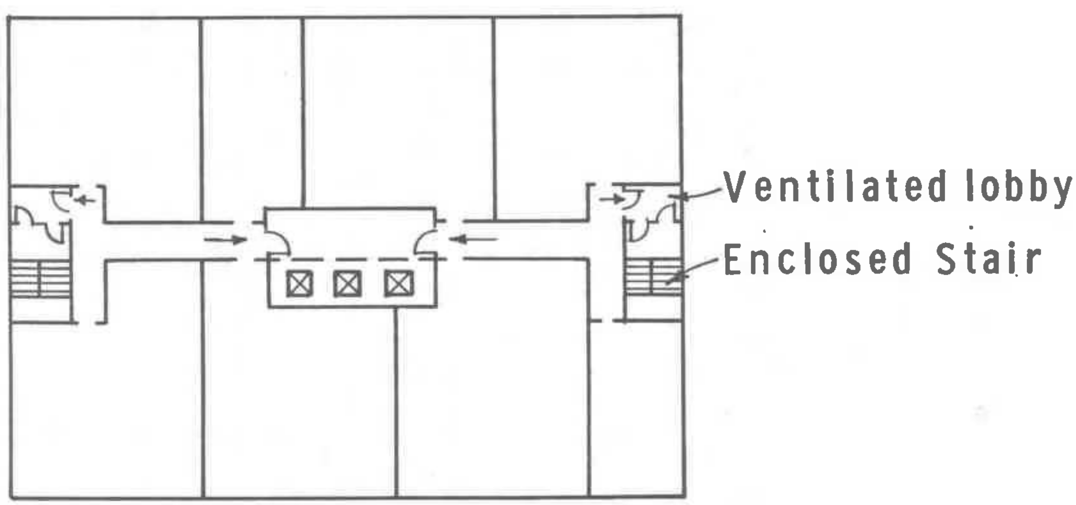

FIGURE 2(b)

FLOOR MODIFIED TO PROVIDE SEPARATION INTO TWO AREAS VENTILATED LOBBY ACCESS TO STAIRS AND ELEVATORS

BR 4103-2

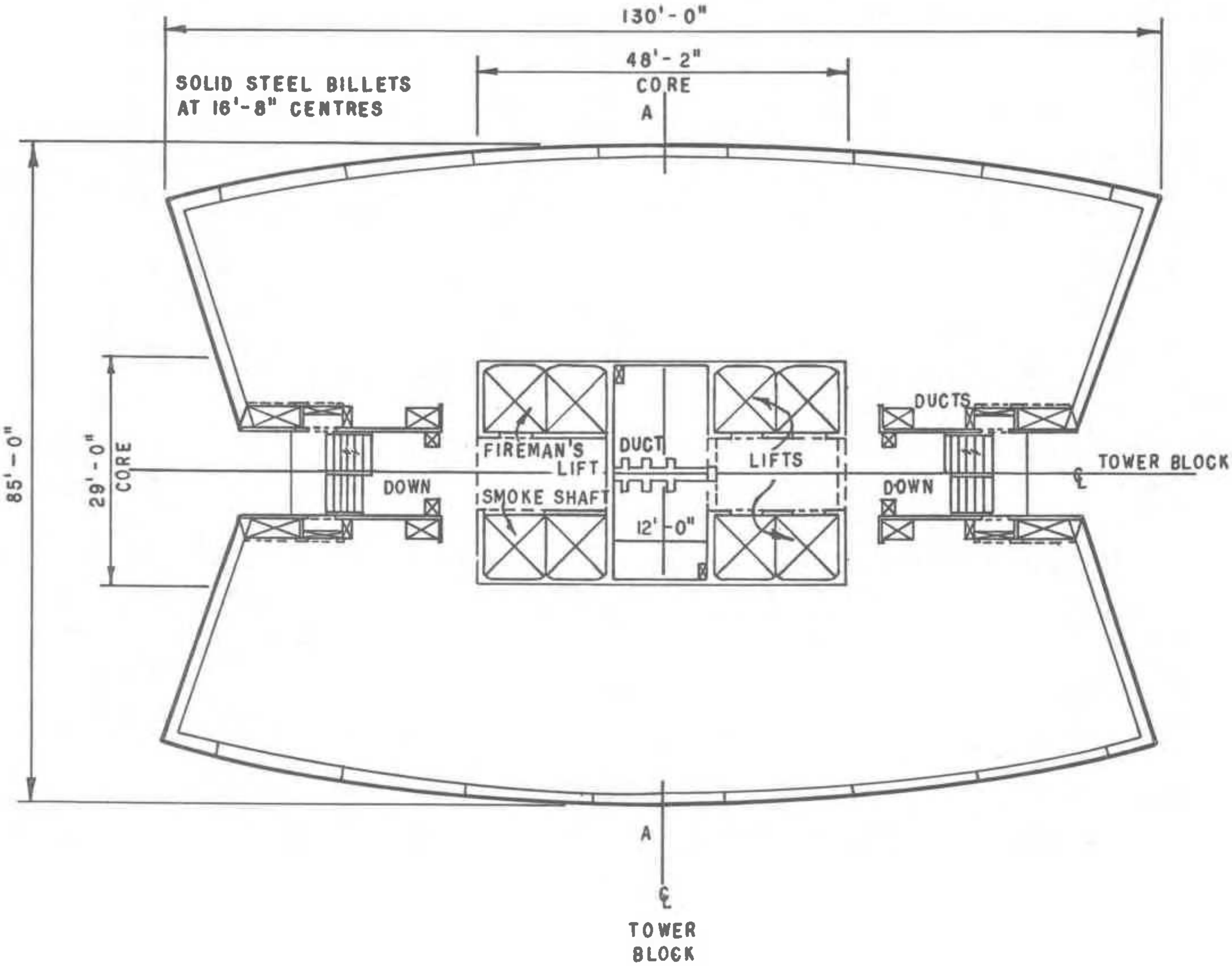

FIGURE 3

PLAN OF BRITISH HIGH OFFICE BUILDING

BR 4103-3

APPENDIX A

LIST OF FIRES IN HIGH BUILDINGS

	Building Involved	Reference
(1)	Office building under construction London England	FPA Journal, No. 51, Oct. 1960. Fire Protection Association, Aldermany House, Queen St., London EC4, England.
(2)	Office building, New York	Institution of Fire Engineers Quarterly, Vol XXIII, No. 52, Dec. 1963. The Institution of Fire Engineers, 148 New Walk, Leicester, England.
(3)	Hospital, Hartford Conn.	NFPA Quarterly, Vol. 55, Jan. 1962. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(4)	Apartment building, Denmark	FPA Journal, No. 58, Jan. 1963. Fire Protection Association, Aldermany House, Queen St., London EC4, England.
(5)	Office building, Montreal	NFPA Quarterly, Oct. 1963. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.

Building Involved	Reference
(6) Office building, London England	FPA Journal, No. 61, Oct. 1963. Fire Protection Association, Aldermany House, Queen St., London EC4, England.
(7) Hotel, Boston, Mass.	NFPA Quarterly, Vol. 57, July 1963. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(8) Dept. store, Tokyo, Japan	NFPA Quarterly, Jan. 1964. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(9) Office building, New York	Society of Fire Protection, Engineer's Bulletin, April 1966. Society of Fire Protection Engineers, 60 Batterymarch St., Boston 10, Mass.
(10) Air terminal building under construction, London, England	FPA Journal, No. 64, Nov. 1964. Fire Protection Association, Aldermany House, Queen St., London EC4, England.

Building Involved	Reference
(11) Hotel, Jacksonville, Florida	NFPA Quarterly, No. 57, April 1964. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(12) Dormitory, Washington, D. C.	The Evening Star, Washington D. C., USA, Mar. 16, 1964.
(13) Hotel, Ottawa	DBR Fire Investigation.
(14) Dept. store, Dallas, Texas	Fire Journal, Vol. 59, May 1965. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(15) Apartment building, Ottawa	DBR Fire Investigation
(16) Hotel, New York	News Bulletin, National Automatic Sprinkler and Fire Control Association Inc., No. 224, Jan.-Feb. 1966. 277 Park Ave., New York, N. Y.
(17) Hotel, Newark, N. J.	Fire Journal, May 1966. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(18) Office building, Toronto	DBR Fire Investigation.

	Building Involved	Reference
(19)	Office building under construction. Johannesburg, S. Africa	Construction in South Africa, Aug. 1966. The Pithead Press Ltd., 91 Mooi St., Johannesburg South Africa.
(20)	Office building, New Orleans	Fire Journal, July 1966. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(21)	Dept. store, Bristol, England	FPA Journal, No. 73, Dec. 1966. Fire Protection Association, Aldermany House, Queen St., London EC4, England.
(22)	Hotel, Boston, Mass.	Fire Journal, May 1966. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.
(23)	Apartment building, Ottawa	DBR Fire Investigation
(24)	Restaurant and apartment building, Montgomery, Alabama	Fire News, No. 571, Mar. 1967. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass.

APPENDIX B

MEANS OF ESCAPE

Building regulations generally contain provisions for exits and specify a limit to the number of people per unit exit width (22 in.). The figures used by the principal North American Codes are all about the same. They appear to have their origin in studies conducted by the National Bureau of Standards, Washington in the 1930's.*

Studies were made of rate of evacuation of a number of buildings and counts were taken of traffic flow through Grand Central Station in New York during rush hours. The study concluded with recommendations for design of exits based on rate of flow of 60 persons per unit exit width per minute through doorways, and 45 persons per unit exit width down stairs. The report notes that people may be expected to move in a steady flow from low buildings, but that in high buildings this is not practicable. The figures recommended for high buildings were determined by assuming that the occupants of each floor will stand on the stairs, between the floor they have left and the one immediately below. It was thought, however, that to provide space for all the occupants of each floor to stand in the stairwells would be uneconomic. It was therefore suggested that there should be provision for half the occupants of each floor above the first to stand on the stairwells.

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* Design and Construction of Building Exits. Misc. Pub. M151, U.S. Dept. of Commerce, National Bureau of Standards, Washington, 1935.

A more recent study by the London Transport Board** has demonstrated how the degree of crowding can affect rate of travel. The optimum spacing suggested for movement of people in level corridors is 7.7 sq ft per person which corresponds to a forward speed of 2.3 mph (202 ft/min). For the same speed more width is needed on stairs than in corridors. An interesting observation, however, is that local restrictions in the corridor, not more than 10 ft in length, can be accommodated without reduction in speed. Thus it is the recommendation of the British study that connecting corridors be not less than 2/3 the width of the stairs and that local reductions in the corridor be not less than 1/2 the width of the stairs.

When the space is 5 sq ft per person on both corridors and stairs the forward speed is 1.5 mph (132 ft/min). This appears to be close to that required for emergency exit and corresponds to a rate of 40 persons per unit exit width per minute. At 2.5 sq ft per person flow is impeded and at 2.0 sq ft per person all forward movement stops.

The National Building Code suggests 100 sq ft per person as the occupancy load of an office floor area. Exit stairs must

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** Second Report of the Operational Research Team on the Capacity of Footways. Research Report No. 95, London Transport Board, London, August 1958.

Also described in:

Information Sheet 1194, Internal Circulation, Architects' Journal, Information Library, 20 March 1963. Architectural Press Ltd., 9-13 Queen Anne's Gate, London SW1 England.

be provided to allow 60 persons per unit exit width (22 in.). There is also a minimum provision of at least two stairs not less than 3 ft wide. A normal stair well might be about 15 ft by 6 ft or 90-sq-ft floor area. I we assume that people will stand in the stairwell between any floor and the one immediately below in a floor space of 2 sq ft per person each stair will accommodate 45 people. In an office floor area 9, 000 sq ft in area with 90 occupants there will be room on the stairs for everyone to stand. For a larger floor area and a greater number of people there may be insufficient space in the stairs. Figure B-1 shows the ratio of people on the floor for office buildings to NBC and standing space in stairs for different areas of floor.

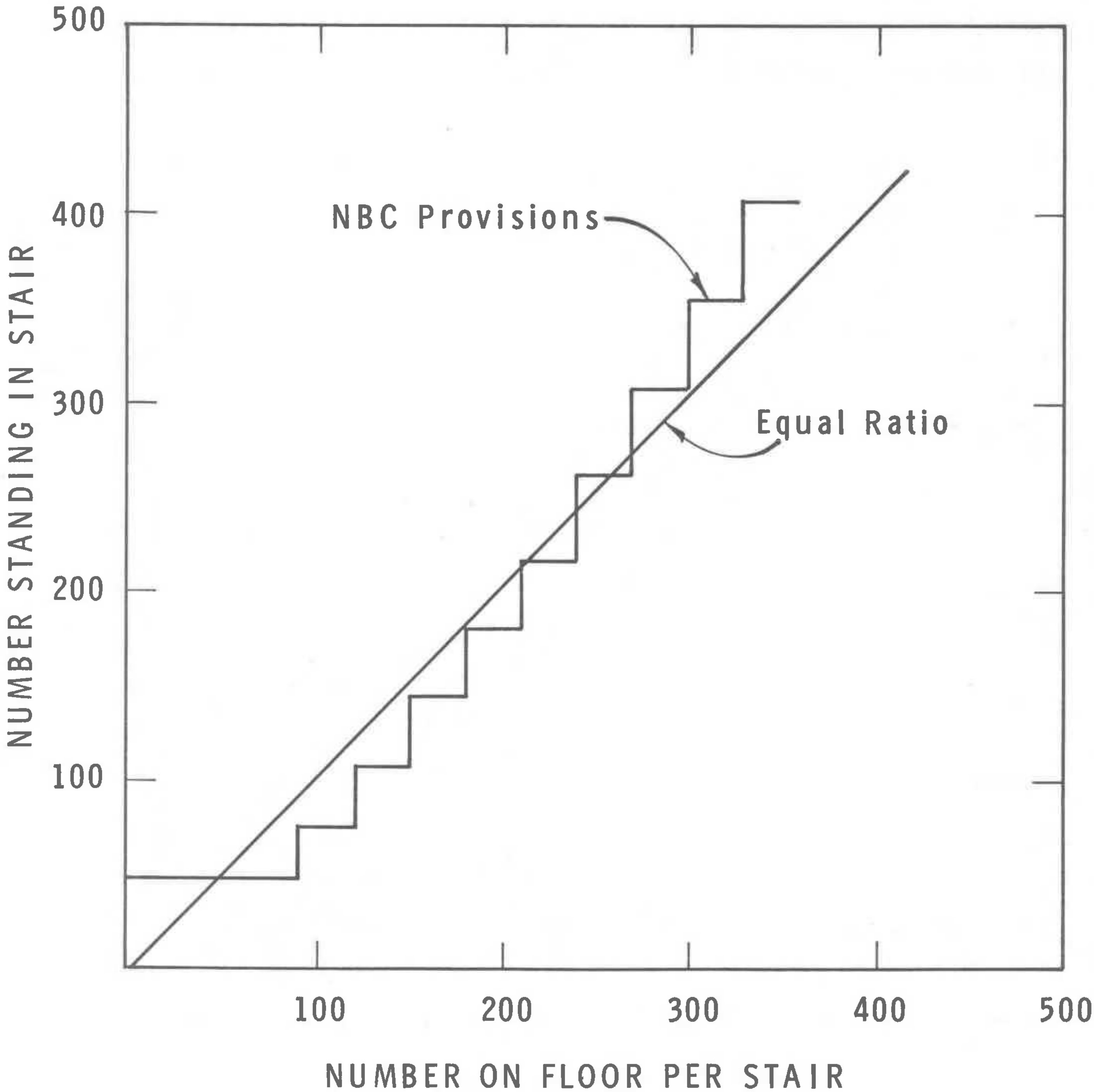

FIGURE B-1

NBC RATIO OF PEOPLE ON FLOOR TO STANDING ROOM IN STAIR FOR OFFICES

BR 1103-A