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Smoke Control and Fire Evacuation by Elevators

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RÉSUMÉ

Dernièrement, on s'est beaucoup intéressé à la possibilité d'utiliser les ascenseurs comme issue de secours en cas d'incendie. Cet intérêt a été suscité par une plus grande sensibilisation aux problèmes de sécurité des handicapés et aux problèmes généraux d'évacuation des immeubles de grande hauteur en cas d'incendie. L'emploi des ascenseurs comme issue de secours serait une façon de résoudre ce problème. L'obstacle technique principal est la propagation de la fumée aux accès et gaines d'ascenseurs. Ce document traite des systèmes de contrôle de la fumée dans les ascenseurs en précisant les critères servant à les évaluer, et il présente une étude du déplacement de l'air causé par le mouvement des cabines d'ascenseurs. Il comprend une analyse informatique de plusieurs systèmes de protection des ascenseurs contre la fumée pour différentes combinaisons : portes ouvertes-fermées, hiver, été.

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SMOKE CONTROL AND FIRE EVACUATION BY ELEVATORS

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ABSTRACT

In recent years, the possibility of using elevators as a means of fire escape has received considerable attention. This interest has been sparked by an increased awareness of life safety problems of the handicapped and also general fire evacuation problems of high-rise buildings. The use of elevators as a means of fire evacuation is a potential solution to this problem. The major technical obstacle to this is smoke contamination of elevator lobbies and shafts. This paper discusses elevator smoke control systems including criteria for evaluation and presents an analysis of airflow due to elevator car motion. Computer analysis of several elevator smoke control systems are included for several combinations of open and closed doors and for summer and winter conditions.

INTRODUCTION

In most elevator lobbies in North America, there are signs indicating that elevators should not be used in fire situations; rather that stairs should be used. Unfortunately, some people cannot use stairs because of physical handicaps. The use of elevators is a potential solution to this problem. Logistics of evacuation, reliability of electrical power, elevator door jamming, and fire and smoke protection are long-standing obstacles to the use of elevators for fire evacuation. All of these obstacles except smoke protection can be addressed by existing technology as discussed by Klote (1984).

The National Bureau of Standards (NBS) in the United States and the National Research Council of Canada (NRCC) are engaged in a joint project to develop smoke control technology for elevators. This paper is the initial report of this project and it contains discussions of elevator smoke control systems including evaluation criteria. The transient pressures due to "piston effect" when an elevator car moves in a shaft will be addressed in a following paper.

PERFORMANCE CRITERIA

Ideally, an elevator smoke control system should protect the elevator shaft and the elevator lobbies such that smoke contamination in these areas does not present a hazard. It is obvious that a smoke control system can meet this objective, even if a small amount of smoke infiltrates the protected areas. The following general discussion of pressure differences and open doors is presented to form a basis for selection of performance criteria and is included in this paper for discussion only.

Pressure Differences

When the lobby doors (doors between the elevator lobby and the rest of the building) are closed, an overpressure of the elevator lobby with respect to the building will prevent smoke infiltration from the building spaces into the lobby. The extent of this lobby pressurization changes as doors at other locations open and close, as outside air temperature changes, and as wind velocity changes. Therefore, establishment of only one operating pressure difference would be inadequate. More appropriate would be to establish both minimum and maximum allowable pressure differences, so that operation within the range would constitute acceptable peformance.

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The maximum pressure difference should be a value that does not result in excessive door-opening forces. Clearly, a person's physical condition is a major factor in determining a reasonable door-opening force for that person. Section 5-2.1.1.4.3 of the National Fire Protection Association (NFPA) Life Safety Code (NFPA 1981) states that the force required to open any door in a means of egress shall not exceed 50 lb (222 N). However, many smoke control designers feel that a lower value should be used, especially in occupancies involving the elderly, children, or the handicapped. NFPA is currently evaluating proposals to reduce its maximum door-opening force from 50 lb (222 N) to 30 lb (133 N).

For the sake of discussion, if the maximum door-opening force is considered to be 30 lb (133 N), and the force to overcome the door closer is 6 lb (27 N), a hinged door 36 x 84 in (0.91 x 2.13 m) would have a maximum allowable pressure difference of 0.40 in H_2O (100 Pa).

The criterion for selecting a minimum allowable pressure difference across the elevator lobby is that there shall be no smoke infiltration into the lobby. Of particular relevance is whether the smoke control system has pressure difference feedback control. A differential pressure sensor located between the elevator lobby and the building on the fire floor controls the supply of air to the smoke control system so that acceptable performance is maintained. One method to achieve variable supply air is by means of a fan bypass system as used for stairwell smoke control (Klote and Fothergill 1983). For such a system, when the pressure on the fire floor increases due to wind, buoyancy, etc., the sensor reacts, causing increased supply airflow and maintaining the pressure difference. These systems also can prevent excessive pressure differences by reducing supply airflow rate. In order to prevent smoke infiltration, such a system need only maintain a small pressure difference of about 0.02 in H_2O (5 pa). Incorporating a safety factor, a minimum pressure difference value of 0.05 in H_2O (12 Pa) will be used in this paper.

For systems without feedback control, the minimum pressure difference must be sufficient to avoid being overcome by the forces of wind, buoyancy of hot smoke, or stack effect.

Piston effect due to elevator car motion within the shaft is also a concern, and a conservative approach is to select the minimum pressure difference so that the system also will not be overcome by this effect.* An alternate is to design for some infiltration of smoke during the short periods of time when the elevator car is traveling away from the fire floor. Such a design should be based upon an analysis including the quantity of smoke infiltrated, the purging rate of the elevator lobby, and toxicity data about the smoke. Because of the current level of understanding of fire toxicology, such an analysis could at best only be an approximation and is beyond the scope of this paper. For the present case, discussion will be limited to systems where the pressure difference due to piston effect is small enough that it will not overcome the smoke control system.

The pressure difference between a fire compartment and its surroundings can be expressed as

$$\Delta P = K_s \left(\frac{1}{T_O} - \frac{1}{T_F} \right) h \qquad (1)$$

where:

ΔP = pressure difference, in H_2O (Pa)

T_O = absolute temperature of the surroundings, °R (°K)

T_F = absolute temperature of the fire compartment, °R (°K)

h = height above the neutral plane between fire compartment and surroundings, ft (m)

K_s = constant, 7.64 (3460)

The neutral plane is the plane of equal hydrostatic pressure between the fire compartment and its surroundings. For a fire with a fire compartment temperature of 1470F (800°C), the pressure difference 5.0 ft (1.52 m) above the neutral plane is 0.052 in H_2O (13 Pa). Fang

*The second paper of this project will present a method of analysis of piston effect and will demonstrate that for slow moving elevator cars in multiple car shafts, piston effect is not a concern.

(1980) has studied pressures caused by room fires during a series of full-scale fire tests. During these tests, the maximum pressure difference reached was 0.064 in H_2O (16 Pa) across the burn room wall at the ceiling. Water spray from sprinklers cools smoke from a building fire, reducing pressure differences due to buoyancy. Thus the pressure difference that could result from buoyancy is highly dependent upon the fire intensity and its proximity to the elevator lobby.

The pressure difference due to wind can become very large in the event of a broken window in a fire compartment. A wind of 50 mph (22 m/s) can result in a pressure difference on the order of 1.2 in H_2O (300 Pa). Obviously if a system were designed so that it would not be overcome by such a wind pressure, the door-opening forces would be unacceptably high during times of low wind velocity. However, the occurance of such high velocity wind is infrequent. A 15 mph (6.7 m/s) wind occurs far more often and can result in pressure differences on the order of 0.10 in H_2O (25 Pa).

One potential solution to the wind problem is to vent the fire floor on all four sides to relieve such pressures. For a building that is much longer than it is wide, it may be appropriate to vent the fire floor only on the two longer sides. Another possible approach is reliance upon fire sprinklers. Even though little research has been done on the subject, it is likely that the operation of fire sprinklers would reduce the chances of a window breaking in a fire compartment. A third approach might include the use of a vestibule between the elevator lobby and the building in an attempt to provide additional protection against the forces of the wind. Further research is needed with respect to wind and methods to minimize wind effects on pressurized elevator systems.

The state of smoke control technology has not progressed to the point where pressure difference criteria can be based upon engineering data alone. However, for this paper, a minimum pressure difference of 0.10 in H_2O (25 Pa) will be used for systems without feedback control.

Open Doors

When a door in a boundary of a smoke control system is open, smoke may flow through the open door into the space that is intended to be protected. However, the door of an elevator lobby intended for evacuation of the handicapped is a special case. Due to the basic instinct for self-preservation, people inside the elevator lobby will not let smoke flow into the lobby through an open doorway when they can close the door. Obviously, the lobby occupants will see to it that lobby doors are only open for the short periods of time needed for other people to take refuge inside the lobby. Thus smoke infiltration of the elevator lobby will be kept to a minimum provided that positive lobby pressurization is maintained. Small quantities of smoke that do infiltrate when a door is momentarily opened will be purged by the lobby pressurization air. This approach eliminates the need to consider a design airflow through open elevator lobby doorways to prevent smoke infiltration of the lobby.

SMOKE CONTROL SYSTEMS

To evaluate the performance of specific smoke control systems under conditions of different outdoor temperature and with various combinations of doors open and closed, the NBS computer program for analysis of smoke control systems (Klote 1982) was used. A number of different systems were analyzed and evaluated. All of the systems studied succeeded in maintaining adequate pressurization when all building doors were closed; however, many of the systems failed under particular conditions of open doors. These systems are included because they illustrate pitfalls and form a logical pathway to a system with feedback control, which can overcome many problems that can develop when certain building doors are open. However, it should not be inferred that this is the only system that can provide adequate elevator smoke protection under a wide variety of conditions. The analysis of the systems that follow should be viewed as examples of how to evaluate a smoke control system based upon the particular characteristics of the building under consideration.

Example Building

An eleven-story building with a typical floor plan shown in Figure 1 was arbitrarily selected for the analysis. Because the building is symmetric, only half of each floor was analyzed. A discussion of symmetry is provided in Chapter 2 of the ASHRAE smoke control manual (Klote and Fothergill 1983). The flow areas per floor for the example building are listed in Table 1. The flow areas for open and closed elevator doors are based upon field tests done by Tamura and Shaw (1967). These values are for center-opening double-panel doors but would be much smaller for single sliding doors, which have smaller gaps. The leakage area of the first floor exterior wall with doors closed is 0.40 ft^2 (0.037 m^2) larger than other exterior wall leakage to reflect the presence of leakage around exterior doors. The flow area of open stairwell doors was selected as half the geometric area of the opening to reflect the reduced flow due to stationary vortices as described by Cresci (1973).

Because smoke control is to be accomplished by maintaining the shaft and lobby at an overpressure, it is counterproductive to top vent the shaft to the outside as is generally the custom. Accordingly, no shaft vent is incorporated in the model. This represents either an unvented shaft or a vent that is tightly dampered shut during smoke control operation. For this study, winter conditions and summer conditions have been arbitrarily chosen as 5F (-15°C) and 90F (32°C), respectively, and will be simply referred to as winter and summer.

Shaft Pressurization

The system in this example consists of a roof-mounted fan supplying 4700 cfm (2220 L/s) into the top of the elevator shaft. The elevator lobbies are intended to be pressurized indirectly through the shaft, and the system has no automatic control beyond activation. This analysis and all others in this paper are based upon the idealization of a constant flow fan - a fan for which the flow rate is independant of pressure. This is an appropriate and slightly conservative approximation for centrifugal fans used in smoke control systems.

Table 4 lists pressure differences under three different conditions of open doors for both winter and summer. With all of the building doors closed during winter, the system will maintain pressure differences across the elevator lobby doors of 0.13 in H_2O (32 Pa) at the first floor, increasing to 0.17 in H_2O (42 Pa) at the eleventh floor. This increasing pressure difference with height is due to the greater density of the outside air compared to that inside. During summer, the pressure difference tends to decrease with height (Table 2) because of the lower density of air outside than inside.

A large path for airflow from the shaft to the outside exists on the first floor when the elevator doors are open, the elevator lobby doors are open, and the exterior doors are open. The resulting loss in pressurization is dramatic, especially in summer, as can be observed from the data in Table 2. This situation represents a real possibility, especially open elevator doors at the ground floor as required by many codes. When the elevator doors are closed but the exterior doors are open, the pressurization is higher but still not up to the minimum desired pressure difference.

The computer runs summarized in Table 4 are representative of a larger number of runs. Although these other runs are not presented in tables in this paper, some interesting observations are worth noting. Relocation of the supply fan to ground level had a negligible effect on the pressure differences produced across the elevator lobby doors. Another observation was that the large airflow path due to the first floor doors being open is not the only large path that can adversely affect the pressurization system. Another example involves flow through the stairwell due to an open exterior stairwell door and an open interior stairwell door. An open elevator vent to the outside is another path that significantly reduces shaft and lobby pressurization.

If the stairwell were pressurized, the effect of open stairwell doors to the building would be such that they would raise the pressure of the floor spaces and thereby reduce lobby pressurization only on the floor with the open stairwell door. Such a combination of systems would need to be analyzed to determine fully the effect of interactions.

Lobby Pressurization

The system in this example consists of a roof-mounted, constant-flow fan supplying 4700 cfm (2220 L/s) into the top of a supply shaft connected to all of the elevator lobbies. Air from this shaft pressurizes the lobbies directly and then indirectly pressurizes the shaft. Again, this system has no automatic control beyond activation.

Comparison of the pressure differences (Table 3) produced by this system with those (Table 2) produced by elevator shaft pressurization shows that for the situation with all doors closed and the situation with the exterior door, first floor elevator, and elevator lobby doors open, the two systems produce essentially identical results. This is true for both winter and summer and can be accounted for by the fact that the flow area from the elevator shaft to the lobby is relatively large compared to that from the lobby to the building, even with the elevator doors closed (Table 1). Thus, in most cases, the shaft can be thought of as being at almost the same pressure as the lobby. An exception is when the exterior door and first floor elevator lobby door are open but the elevator doors are closed (Tables 2 and 3), which results in reduced lobby pressurization for both winter and summer. A direct path exists from the lobby to the outside, which allows greater loss of pressurization air. As with shaft pressurization, this system cannot maintain adequate pressurization with certain building doors open.

Zoned Smoke Control

Zoned smoke control most commonly used in the United States consists of using the building heating, ventilating, and air-conditioning (HVAC) fans to exhaust the smoke zone (zone in which a fire is located) and to pressurize surrounding zones. When the smoke zone is one or more floors of the building, a resulting overpressure of the building shafts to the smoke zone can exist. Zoned smoke control was examined to see to what extent it might be used to achieve elevator smoke control. However, the system described below failed to produce adequate levels of pressurization.

For this analysis, the smoke zone consists of the fire floor and the floor above, which are exhausted at a rate of 5000 cfm (2360 L/s) per floor. The floors directly above and below the smoke zone are supplied (pressurized) at the same rate. This system was selected because of its ability to control smoke movement under a variety of conditions of open stairwell doors. When stairwell doors are open to both the smoke zone and to pressurized nonsmoke zones, the pressure difference across the ceiling of the smoke zone can drop to as low as 0.01 in H_2O (2 Pa). Such a low level of pressurization may be sufficient to control smoke from a fire in a sprinklered building or from a smoldering fire, but it would not control movement of hot, buoyant smoke. Smoke that reaches the floor above the fire floor is cooled due to dilution and heat transfer. Thus, by including the floor above the fire floor in the smoke zone, it is much less difficult to control smoke movement.

Pressure differences across the elevator lobby for three conditions of open and closed stairwell doors, during winter and summer, and when the second floor is the fire floor are listed in Table 4. With all doors closed, a significant pressure difference is maintained for both floors of the smoke zone (0.29 in H_2O (72 Pa) during winter and 0.37 in H_2O (92 Pa) during summer). However it can be observed from Table 3 that positive pressurization of the elevator lobbies was not maintained on non-smoke-zone floors.

The performance criteria for systems where the fire floor is identified should be extended. While it is obvious that the minimum pressure difference of 0.10 in H_2O (25 Pa) still applies to the fire floor, other floors are subjected to lower temperature, less buoyant smoke, or no smoke at all. Therefore, much lower pressure differences would prevent smoke from entering the shaft. For discussion, a minimum pressure difference on nonfire floors of 0.02 in H_2O (5 Pa) will be used unless the floor itself is pressurized. With a zoned smoke control system, a pressurized floor will have air flowing through its elevator lobbies, into and through the elevator shaft, and from there into the elevator lobby on the smoke zone (which is an exhausted space). Thus the airflow resulting from this zoned smoke control system, which indirectly pressurizes the elevator lobby on the fire floor, also makes it impossible to pressurize the elevator lobbies on some other floors.

In the cases with all the doors closed, the zoned smoke control system maintained approximately 0.16 in H_2O (150 Pa) between the smoke zone and adjacent nonsmoke zones. Such a large pressure difference would prevent smoke migration. However, on many nonpressurized floors, where smoke could migrate through building shafts, the pressure difference across the elevator lobby is less than 0.02 in H_2O (5 Pa). Further, when stairwell doors open, the pressurization drops significantly, as can be seen from Table 4. This particular form of zoned smoke control (sometimes referred to as the "pressure sandwich" system) does not produce adequate levels of pressurization.

Zoned System Plus Shaft Pressurization

This system consists of the preceeding system plus elevator shaft pressurization at the same flow rate of the first system discussed. This system maintains acceptable pressure differences across the elevator lobby with stairwell doors open on the first, second, third, and fourth floors when the second floor is the fire floor, as shown in Table 5. However, with only the second floor stairwell door open or all doors closed, unacceptably high levels of pressurization result across the elevator lobby at the smoke zone.

Shaft Pressurization with Feedback Control

This system relies on feedback control to maintain a set pressure difference across the elevator lobby on the fire floor. The flow rate into the top of the elevator shaft is varied by modulating bypass dampers, which are controlled by a static pressure sensor that senses the pressure difference between the elevator lobby and the building. Obviously, these sensors would have to be reliable and be protected from heat or designed to withstand elevated temperatures.

As with zoned smoke control, this system requires identification of the fire floor. Pressure differences from computer analysis of this system with the second floor as the fire floor are listed in Table 6. The system maintains 0.05 in H_2O (12 Pa) across the second floor elevator lobby in all cases, with all doors closed, and with a direct path to the outside during both winter and summer. It accomplishes this by varying the supply rate to the elevator shaft from 2500 to 7750 cfm (1180 to 3650 L/s). Throughout all of this, the pressures at nonfire floors are within the acceptable range. Selection of a fan for such a system should include some safety factor to allow for greater leakage areas in the actual building than those assumed in design analysis. For a 25% safety factor, the fan capacity would be approximately 10,000 cfm (4720 L/s). Feedback control not only maintains the set pressure difference in situations of open and closed doors, but also during conditions of pressure difference due to buoyancy of hot smoke.

SUMMARY

Computer analysis of several elevator smoke control systems was presented under a variety of conditions of open and closed doors. Of these systems, all but one failed to maintain adequate pressurization when some combination of doors were open. The successful one was a shaft pressurization system with feedback control, which maintained a set pressure difference under any condition of open or closed doors. It should be noted that there are probably a large number of systems capable of providing adequate smoke control, and the proceedure followed in the paper can be viewed as an example of how to evaluate the performance of a system to meet the particular characteristics of a building under consideration.

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TABLE 1
Flow Areas Per Floor for the Example Building

Location	Area ft^2	m^2
First floor exterior wall (exterior doors closed)	0.940	0.0873
First floor exterior wall (exterior doors open)	22.0	2.04
Exterior walls (except 1st floor)	0.540	0.0502
Stairwell to building (stairwell door closed)	0.270	0.0251
Stairwell to building (stairwell door open)	10.5	0.975
Building floor	0.270	0.0251
Building to elevator lobby (lobby doors closed)	0.420	0.0390
Building to elevator lobby (lobby doors open)	22.0	2.04
Elevator lobby to elevator shaft (elevator doors closed)	1.60	0.0149
Elevator lobby to elevator shaft (elevator doors open)	8.00	0.743

TABLE 2

Pressure Differences from Computer Analysis of Elevator Smoke Control by Shaft Pressurization

Season	1st Floor Exterior Door Open	Elev. Doors Open on Floors	Elev. Lobby Doors Open on Floors	Pressure Difference in Inches H_2O (Pa) from Elevator Lobby to the Building on Floors:										
				1	2	3	4	5	6	7	8	9	10	11
W	No	N	N	.13 (32)	.13 (32)	.14 (35)	.15 (37)	.15 (37)	.15 (37)	.16 (40)	.16 (40)	.16 (40)	.16 (40)	.17 (42)
W	Yes	1	1	Open	.03 (7)	.04 (10)	.05 (12)	.06 (15)	.06 (15)	.07 (17)	.07 (17)	.08 (20)	.09 (22)	.09 (22)
W	Yes	N	1	Open	.08 (20)	.09 (22)	.09 (25)	.10 (25)	.10 (25)	.11 (27)	.11 (27)	.12 (30)	.12 (30)	.13 (33)
S	No	N	N	.18 (45)	.16 (40)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)
S	Yes	1	1	Open	.02 (5)	.02 (5)	.01 (2)	.01 (2)	.01 (2)	.01 (2)	.01 (2)	0	0	0
S	Yes	N	1	Open	.09 (22)	.08 (20)	.08 (20)	.08 (20)	.08 (20)	.08 (20)	.08 (20)	.08 (20)	.07 (17)	.07 (17)

Abbreviations: Elev.-Elevator; E-Exterior; N-None; S-Summer; W-Winter

TABLE 3

Pressure Differences from Computer Analysis of Elevator Smoke Control by Elevator Lobby Pressurization

Season	1st Floor Exterior Door Open	Elev. Doors Open on Floors	Elev. Lobby Doors Open on Floors	Pressure Difference in Inches H_2O (Pa) from Elevator Lobby to the Building on Floors:										
				1	2	3	4	5	6	7	8	9	10	11
W	No	N	N	.13 (32)	.13 (32)	.14 (35)	.14 (35)	.14 (35)	.15 (37)	.16 (40)	.16 (40)	.17 (42)	.17 (42)	.18 (45)
W	Yes	1	1	Open	.03 (7)	.04 (10)	.05 (12)	.06 (15)	.06 (15)	.07 (17)	.08 (20)	.08 (20)	.09 (22)	.10 (25)
W	Yes	N	1	Open	.05 (12)	.06 (15)	.07 (17)	.08 (20)	.08 (20)	.09 (22)	.10 (25)	.10 (25)	.11 (27)	.12 (30)
S	No	N	N	.18 (45)	.16 (40)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.16 (40)
S	Yes	1	1	Open	.01 (2)	.01 (2)	.01 (2)	.01 (2)	.01 (2)	.01 (2)	0	0	.01 (2)	.01 (2)
S	Yes	N	1	Open	.05 (12)	.05 (12)	.05 (12)	.05 (12)	.05 (12)	.04 (10)	.04 (10)	.05 (12)	.05 (12)	.06 (15)

Abbreviations: Elev.-Elevator; E-Exterior; N-None; S-Summer; W-Winter

TABLE 4

Pressure Differences from Computer Analysis of Elevator Smoke Control by Zoned Smoke Control with Second Floor as the Fire Floor

Season	Stairwell Doors Open on Floors	Pressure Difference in Inches H_2O (Pa) from Elevator Lobby to the Building on Floors:										
		1	2	3	4	5	6	7	8	9	10	11
W	N	-.28 (-70)	.29 (72)	.29 (72)	-.27 (-67)	-.04 (-10)	-.02 (- 5)	-.01 (- 2)	0	.01 (2)	.02 (5)	.02 (5)
W	2	-.30 (-75)	.05 (12)	.22 (55)	-.27 (-67)	-.04 (-10)	-.01 (- 2)	0	.01 (2)	.02 (5)	.04 (10)	.04 (10)
W	1,2,3,4	-.03 (- 7)	-.01 (- 2)	-.01 (- 2)	-.02 (- 5)	-.01 (- 2)	0	.01 (2)	.01 (2)	.02 (5)	.03 (7)	.03 (7)
S	N	-.19 (-47)	.37 (92)	-.37 (92)	-.23 (-57)	0	0	0	0	0	-.01 (- 2)	-.01 (- 2)
S	2	-.21 (-52)	.08 (-20)	.28 (70)	-.23 (-57)	0	0	0	0	0	0	0
S	1,2,3,4	0	.01 (2)	.01 (2)	0	0	0	0	0	-.01 (- 2)	-.01 (- 2)	-.01 (- 2)

Abbreviations: Elev.-Elevator; N-None; S-Summer; W-Winter

TABLE 5

Pressure Differences from Computer Analysis of Elevator Smoke Control by Zoned Smoke Control and Shaft Pressurization with the Second Floor as the Fire Floor

Season	Stair-well Doors Open on Floors	Pressure Difference in Inches H_2O (Pa) from Elevator Lobby to the Building on Floors:										
		1	2	3	4	5	6	7	8	9	10	11
W	N	-.04 (-10)	.52 (129)	.52 (129)	-.07 (-17)	.18 (45)	.22 (55)	.23 (57)	.23 (57)	.23 (57)	.24 (60)	.24 (60)
W	2	-.06 (-15)	.30 (75)	.46 (114)	-.07 (17)	.20 (50)	.25 (62)	.26 (65)	.27 (67)	.28 (70)	.28 (70)	.29 (72)
W	1,2,3,4	.14 (35)	.15 (37)	.15 (37)	.14 (35)	.15 (37)	.15 (37)	.15 (37)	.16 (40)	.16 (40)	.17 (42)	.17 (42)
S	N	-.01 (2)	.57 (142)	.57 (142)	-.06 (-15)	.18 (45)	.20 (50)	.20 (50)	.20 (50)	.20 (50)	.20 (50)	.20 (50)
S	2	-.02 (- 5)	.32 (80)	.49 (122)	-.05 (-12)	.21 (52)	.24 (60)	.24 (60)	.24 (60)	.24 (60)	.24 (60)	.24 (60)
S	1,2,3,4	.15 (37)	.16 (40)	.16 (40)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)	.15 (37)

Abbreviations: Elev.-Elevator; N-None; S-Summer; W-Winter

TABLE 6

Pressure Differences and Supply Airflow Rate from Computer Analysis of Elevator Smoke Control by Shaft Pressurization with Feedback Control for the Second Floor as the Fire Floor

Season	1st Floor Exterior Door Open	Elev. Doors Open on Floors	Elev. Lobby Doors Open on Floors	Supply Air Flow Rate to Shaft cfm* (L/S*)	Pressure Difference in inches H_2O (Pa) from Elevator Lobby to the Building on Floors:										
					1	2	3	4	5	6	7	8	9	10	11
W	No	N	N	3350 (1580)	.04 (10)	.05 (12)	.06 (15)	.07 (20)	.08 (20)	.08 (20)	.09 (22)	.09 (22)	.10 (25)	.10 (25)	.10 (25)
W	Yes	1	1	6950 (3280)	Open	.05 (12)	.06 (15)	.07 (20)	.08 (20)	.08 (20)	.09 (22)	.09 (22)	.10 (25)	.10 (25)	.11 (27)
S	No	N	N	2500 (1180)	.06 (15)	.05 (12)	.05 (12)	.05 (12)	.04 (10)	.04 (10)	.04 (10)	.04 (10)	.04 (10)	.04 (10)	.03 (7)
S	Yes	1	1	7750 (3650)	Open	.05 (12)	.05 (12)	.04 (10)	.04 (10)	.04 (10)	.04 (10)	.04 (10)	.04 (10)	.03 (7)	.03 (7)

Abbreviations: Elev.-Elevator; N-None; S-Summer; W-Winter
*Flow Rate at 70°F (21°C) and one atmosphere

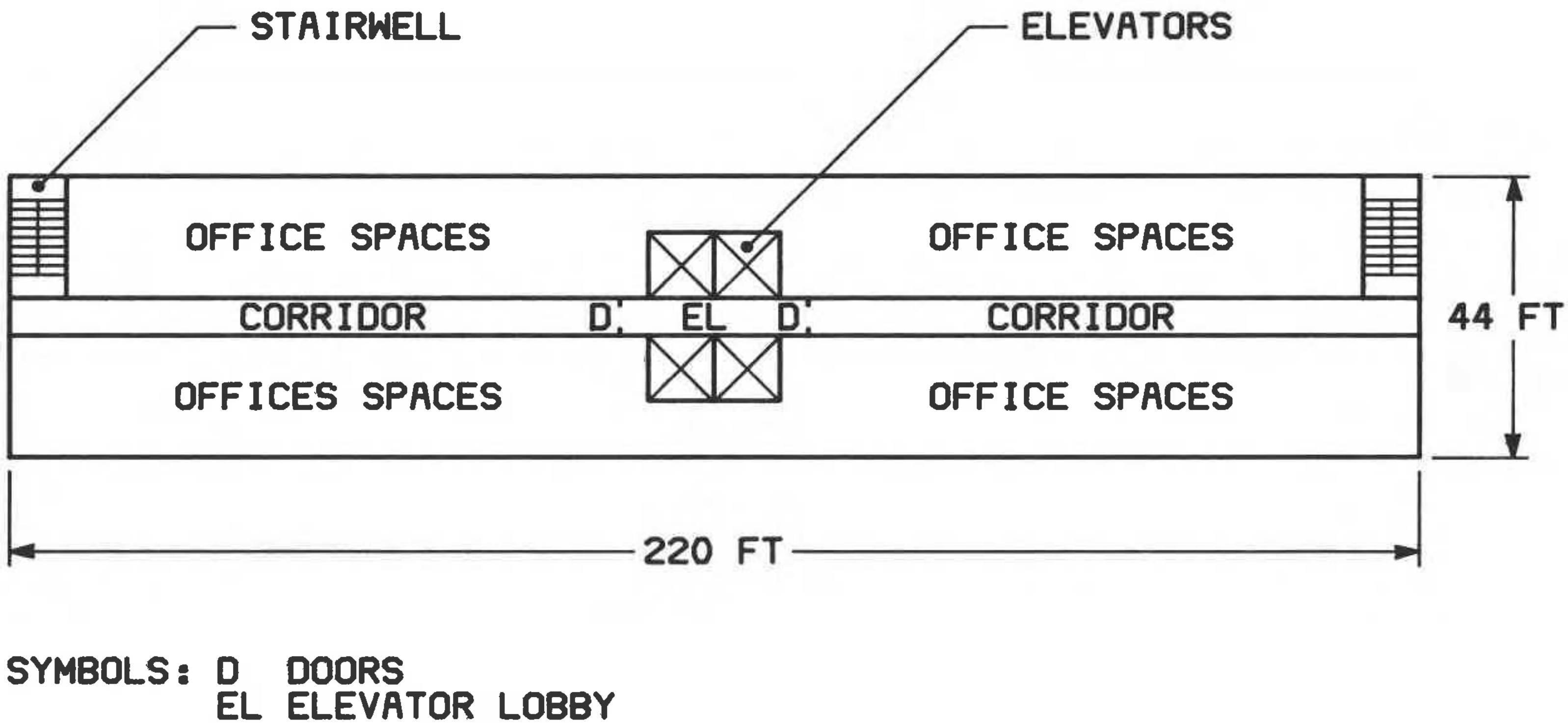

Figure 1. Typical floor plan (above first floor) of example building

Discussion

C. HEDSTEN, OPUS Corp., Minnetonka, MN: How do you correlate 10 story to 40-50 story? UBC calls for 0.25" P on doors in stairwell; are these too high since you require 0.1 on fire floor or .02 on all others? Why the difference? Is UBC too high?

KLOTE: The intent of the paper was to demonstrate the feasibility of smoke control systems for elevator evacuation of the handicapped. This was demonstrated for an eleven story building. The methods of computer analysis used in this paper can be applied to both taller and shorter buildings.

The pressure differences used for evaluation in the paper were values that we felt would provide protection from an intense fire during evacuation. There are many other values of pressure difference which could be used.

R. MASTERS, Jaros, Baum & Bolles, New York, NY: In lieu of feedback control, why not use barometric damper control for simplicity and reliability?

KLOTE: I have made some computer runs of stairwell systems with barometric dampers for pressure relief. During this work, it became apparent to me that a very large number of computer runs would be required for my particular application. At that point I switched to analysis of a bypass fan system with feedback control, and it was very simple to find a system that met my objectives. I feel that feedback control systems are both easier to design and more likely to function as desired in a fire situation. For this reason, feedback control systems were included in the study that is described in this report.

It may be that barometric damper systems can perform well. Clearly, these systems should be studied in greater detail.

E.F. CHAPMAN, Deputy Chief, Fire Department, Brooklyn, NY: How would the system react to a fire located in the elevator lobby or elevator car?

KLOTE: This question can be stated more generally as how we should be prepared for a fire in any means of egress. I know that this has been a concern to fire protection professionals, and that the concerns go beyond those of most ASHRAE members. Cost effective and reliable methods of detecting fires in egress routes and of going into appropriate smoke control modes are needed. The appropriate smoke mode may be just system shut down or something more complicated.

R.R. HENRY, General Dynamics, Groton, CT: You stated that the same results/conclusion resulted from your study in the shaft pressurization and lobby pressurization. If the smoke were to migrate into the lobby or start in the lobby, wouldn't the lobby pressurization method be hazardous to other occupied spaces, including elevator occupants that were being evacuated? And wouldn't this condition be safer if the shaft pressurization method were used?

KLOTE: When I stated that the performance of the two systems was about the same, I meant with regard to the pressure differences produced between the elevator lobby and the building. Smoke movement is very complicated, and it is difficult to say what degree of hazards exists with either system in the case of fire in the elevator cab or shaft. However, in such a case, going into shutdown or a special smoke mode may be the most appropriate approach.

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