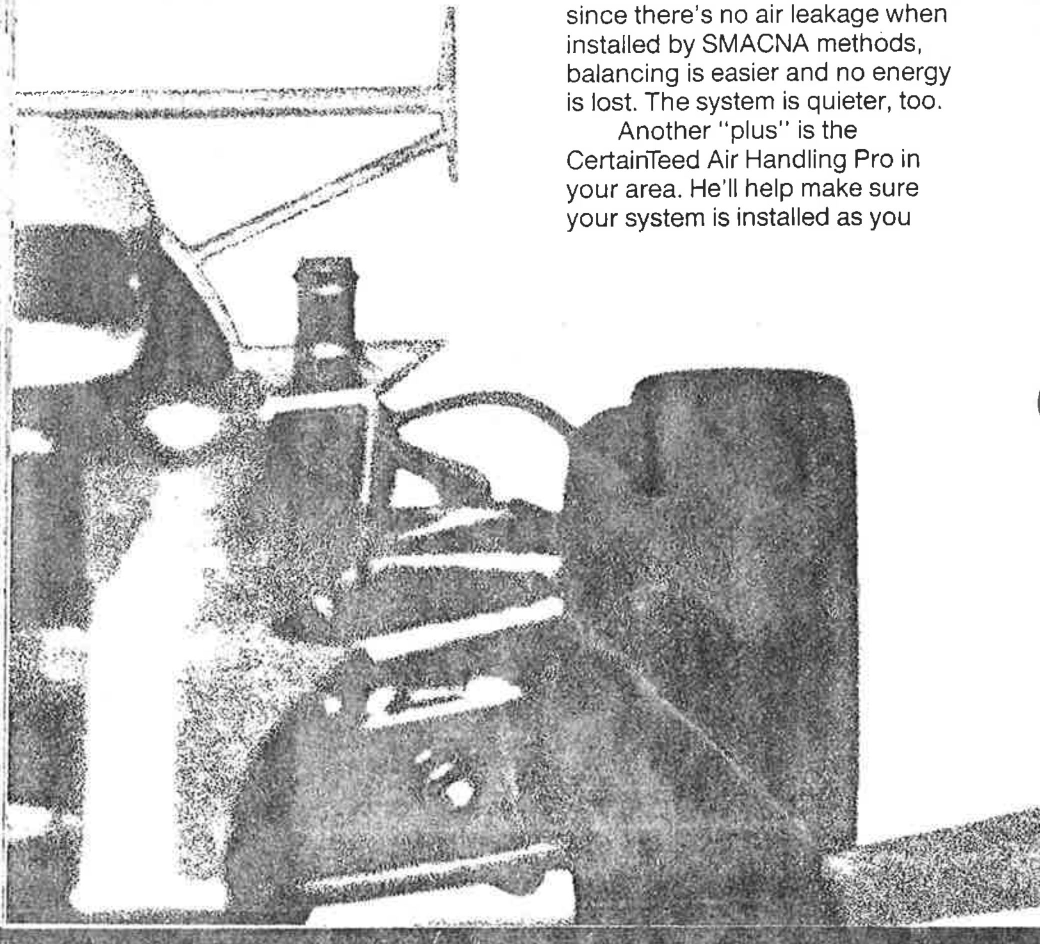

#6111

Exterior Wall Venting for Smoke Control in Tall Office Buildings

Tests conducted on exterior wall venting in the context of a building pressurization approach to smoke control showed that venting rate depends on the amount of building pressurization, vent area, and leakage area of the floor enclosure. The author reviews conditions under which exterior wall venting can be applied effectively to multi-story buildings and gives a guideline for determining the required size of vent openings for controlling smoke movement.

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Member ASHRAE

VENTING of heat and smoke generated by a fire is recognized as an aid to fire fighters and to occupants in gaining access to refuge areas or outdoors. One means of venting the fire region is to provide openable panels or windows in the exterior walls; others are smoke shafts[1] and mechanical venting.[2] The first method, which is the subject of this paper, permits venting of smoke from the fire floor directly to the exterior, whereas the latter methods allow smoke from the fire floor to flow into and out of the exhaust shaft extending above the roof of a building.

EXTERIOR WALL VENTING

Fig. 1 illustrates the smoke movement with exterior wall venting for various fire conditions. For all but the last two cases, it is assumed that the air handling systems are shut down.

Venting (summer). With the inside temperature equal to outside temperature, the inside and outside pressures are the same as shown on the pressure diagram to the right of the simple model building. Under this situation there is little air movement within the building.

With a fire on a floor, the air temperatures on this floor are elevated above those of the surrounding areas resulting in local stack action. This causes air to flow into the fire floor through the lower leakage openings of the walls of the vertical shafts (elevator, stair, service) and outside walls, and causes smoke and hot gases to flow out from the fire floor through the upper leakage openings in these walls. Venting of the fire floor can greatly increase the rate of release of heat and smoke to the exterior, but some smoke is likely to migrate into the elevator and stair shafts.

When wind pressures act on the walls of the building, opening the vents only on the windward wall raises the pressures of the fire floor above those of other floors and, hence, increases, the rate of smoke flow into the elevator and stair shafts. If the vents on the leeward and side walls are also open, the flow of smoke into the shafts may be reduced, depending on the location of the fire region with respect to the wall vents. Opening the vents only on the leeward and side walls can lower the pressures on the fire floor below those of other floors, which will assist in preventing smoke from flowing into the vertical shafts.

Venting of lower floor (winter). Building stack action under winter conditions causes an upward flow of air within the building. Thus with a fire on a lower floor, smoke migrates into and up the vertical shafts to contaminate the upper floors at a much more rapid rate than under the summer condition.[3] The pressure diagram shows that on the lower floors the outside pressures are higher than the inside pressures so that when the vents are opened, air flows from outside into the fire floor. The fire floor pressures are raised and approach the outside pressures with a corresponding increase in the unfavorable pressure differences across the walls of the vertical shafts, resulting in a substantial increase in the rate of smoke contamination of the vertical shafts and upper floors.

Venting of upper floor (winter). As the inside pressures are greater than the outside pressures, venting the fire floor on the upper floors causes an outflow of air from the fire floor to outside, causing a reduction in the fire floor pressures below those of adjacent floors and vertical shafts. Hence, under this condition, smoke is prevented from spreading into adjacent spaces within the buildings.

Venting with building pressurization (summer). It was seen that venting of the fire floor either intentionally or unintentionally (as by window breakages caused by the heat of the fire) can aggravate problems associated with smoke migration. The pressures inside the building must be raised, therefore, above outside pressures at all levels to ensure that the fire floor pressure decreased when the vents are opened. This can be accomplished by pressurizing all floors with all or some of the supply air systems of the building operating at 100% outside air and the return and exhaust system shut down.

Under summer condition, with equal rates of supply of outside air to all floors, the amount of building pressurization is uniform at all heights of the building. Opening the wall vents on any floor will result in the same amount of reduction in the floor space pressures for vents of equal size on all floors.

Venting with building pressurization (winter). In winter with the building pressurized in the same manner as for the previous case, the amount of the building pressurization is least on the ground floor and greatest on the top floor. This is due to stack action which causes the outside air supplied to the lower floors to flow up through the vertical shafts to upper floors. Consequently, the pressures of the vented floor located at upper levels are reduced more than those located at lower levels. Hence, the venting rates and the pressure differences across the stair and elevator

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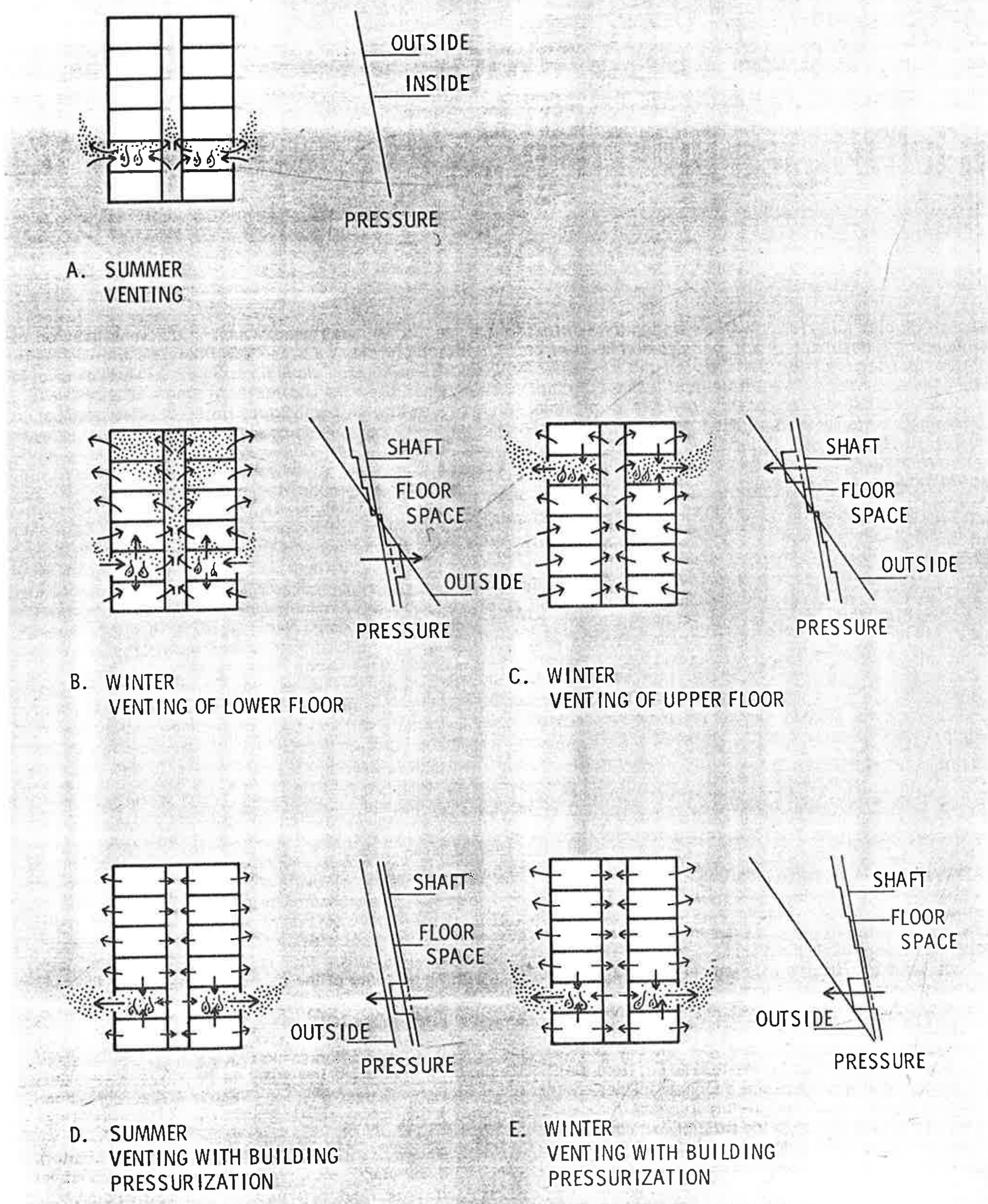

Fig. 1 Pressure and flow patterns with exterior wall venting

doors on the vented floor of the upper floors are greater than those of the lower floors. Except for the case when the vents are opened only on the windward wall, wind action is unlikely to seriously affect the performance of this method of smoke control for office buildings in which the occupants are expected to vacate the fire floor soon after the start of a fire.

VENT SIZE CONSIDERATION

With the building pressurized, opening the wall vents causes air to flow from the adjacent floors into the vented fire floors and out through the vents (Fig. 2). Assuming that the supply air to the vented floor is stopped, it follows that the total air flow rate through the wall vents equals the air flow rate into the vented floor from the surrounding spaces:

$$A_v (P_f - P_o)^{1/2} = A_e (P_i - P_f)^{1/2} \tag{1}$$

A = leakage area in terms of equivalent orifice area
P = pressure

subscript

v = wall vent
f = fire floor
o = outside
e = enclosure of fire floor
i = non-vented floor

The leakage area of the fire floor enclosure (A_e) is the sum of the leakage areas of the walls of the vertical shafts, the floor constructions and the air duct openings (return, exhaust) of the vented floor. Eq 1 assumes that the pressures inside the vertical shafts and air ducts are equal to P_i. They are less than P_i but are likely to be close to it as air flows into the shafts and ducts from all floors except the vented floors where it flows out.

Transposing terms in Eq 1,

$$\frac{(P_i - P_f)}{(p_f - P_o)} = \left(\frac{A_v}{A_e}\right)^2 \tag{2}$$

But

$$(P_i - P_o) = (P_i - P_f) + (P_f - P_o)$$

Let

$(p_i - P_o) = \Delta P_b$ (amount of building pressurization)

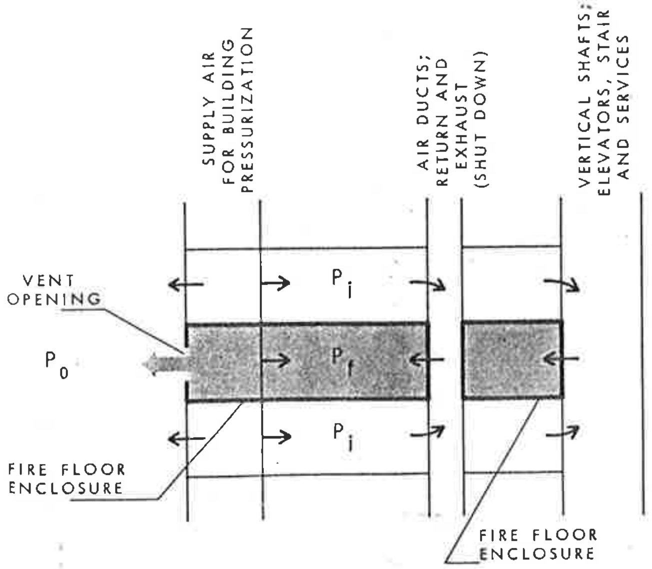

Fig. 2 Flow pattern with venting of fire floor

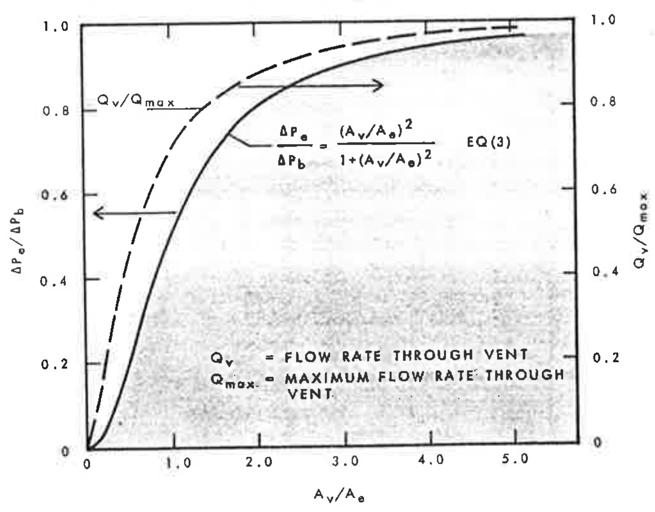

Fig. 3 Variation of floor space pressures and venting rates with vent size

$(P_i - P_f) = \Delta P_e$ (pressure difference across the floor enclosure)

$(P_f - P_o) = \Delta P_v$ (pressure difference across the wall vent)

then

$$\Delta P_b = \Delta P_e + \Delta P_v$$

$$\Delta P_v = \Delta P_b - \Delta P_e$$

Substituting above in Eq 2,

$$\frac{\Delta P_e}{\Delta P_b} = \frac{(A_v/A_e)^2}{1 + (A_v/A_e)^2} \tag{3}$$

The plot of Eq 3 is shown in Fig. 3. It shows that as the vent size is increased for a given amount of building pressurization (ΔP_b) and leakage area of the fire floor enclosure (A_e), the pressure differences across the vented floor enclosure are increased asymptotically to a maximum value (ΔP_b). As the flow rate varies directly as the square root of the pressure difference, taking the square root of $\Delta P_e/\Delta P_b$ gives the ratio of the flow rate through the vent over the maximum flow rate (Q_v/Q_{max}). These were also plotted in Fig. 3.

When the vent area is equal to the leakage area of the floor enclosure ($A_v/A_e = 1$), then the pressure differences across the floor enclosure are one-half of the building pressurization ($\Delta P_e/\Delta P_b = 0.50$), and the flow rate through the vent is 70% of the maximum venting rate ($Q_v/Q_{max} = 0.70$). Also, when $A_v/A_e = 3.0$, $\Delta P_v/\Delta P_v = 0.90$ and $Q_v/Q_{max} = 0.95$. Increasing the vent size further will not significantly increase the venting rate.

In the foregoing analysis, it was assumed that the supply air for pressurization was stopped on the fire floor. If not, it would be expected that the required vent size to obtain given value of $\Delta P_e/\Delta P_b$ would be greater than that shown in Fig. 3. Information on the measured values of A_e of a few office buildings are given in Ref 2.

FIELD TESTS

Venting tests were conducted on two multi-story office buildings using the windows as a means of proving vent openings. These tests were conducted to determine the effect of vent size on the venting rate and the pressure and air flow patterns across the designated fire floor enclosure. They were also checked for cases with the stair door open on the vented floor and other floors.

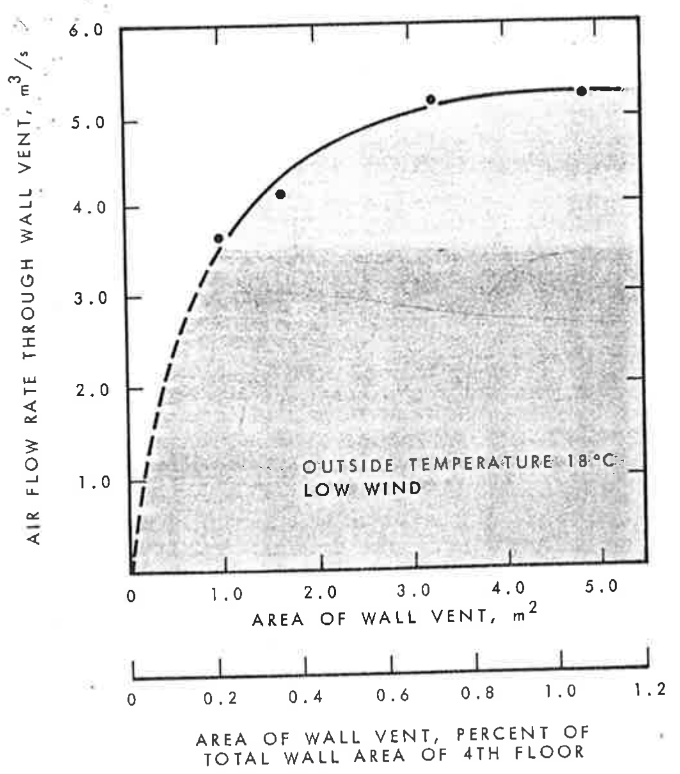

Fig. 4 Venting rate vs vent size opening, Building A

Venting Tests on Building A

Building a is a 17-story government office building with a plan dimension of 26.8 m by 42.7 m and a floor height of 3.35 m, giving an outside wall area per floor of 466 m². The windows are openable casement-type which are normally key locked. When open, each window provided a free area of 1.65 m².

Venting tests were conducted on the 4th floor of this building. There was an outside temperature of 18°C and low wind velocity. The building was pressurized by shutting down all return and exhaust fans and operating all supply fans at 100% outside air. The tests involved opening the windows on the south wall of the 4th floor to obtain the required vent area and measuring the air velocities at the window opening to determine the total air flow rate through these windows. The air velocities were measured with a hot-wire anemometer at 12 location for each window, and the readings were averaged for air flow rate calculation. The pressure differences across the elevator door, stair door and across the 4th and 5th floor constructions were measured. Also the pressure differences across the exterior walls of several floors were measured. A diaphragm-type pressure transducer with a silicon peizo-resistive gauge with a static error band of 5% of full-scale output was used.

With a total vent area of about 1% of the wall area (4.94 m²), the stair door on the 4th floor was opened and the flow velocities at this opening were measured. This was repeated with the 4th and 2nd floor doors of the same stair shaft open and, in addition, a test was conducted with the 5th floor stair door also open.

A summary of test results is given in Table 1. Tests No. 1 through 5 were conducted with various vent size openings. Increasing the vent size resulted in a corresponding increase in the venting rate and also the favorable pressure differences across the enclosure of the vented floor. Fig. 4, which gives the venting rate vs vent size, shows that the maximum venting rate is obtained with a vent area of 4.94 m² (slightly greater than 1% of the wall area). The total leakage opening of the floor enclosure of this building was measured and reported in Ref 2 (one of four buildings tested) as 1.30 m² giving the value of A_v/A_e of 3.8. Fig. 3 derived from theoretical considerations shows that for practical purposes the maximum venting rate is reached at about this value. During the tests, the outside supply air to each floor for building pressurization was about 1.20 m³/s.

The vent area which was related to the leakage area of the floor enclosure (A_e) in the previous section is expressed in percent of wall area. The values of A_e can vary from building to building depending on the interior design and construction, but it is likely that they are greater for buildings with larger floor area, which is related to the outside wall area and, hence, the latter might be used to specify the required vent size. If three times the value of A_e is the required vent size, a check on the four buildings[2] measured for their values of A_e gave the required vent sizes as 0.84, 0.76, 0.76 and 1.30% of the wall area. It would seem that there is some validity, as well as from practical consideration, basing the venting requirements on the outside wall area.

Table 1
Results of Venting Tests on the 4th Floor of Building A

Test No	Vent Area m²	Vent Area % Wall Area	No. of Open Stair Doors	Venting Rate m³/s	Flow Rate 4th Floor Stair Door m³/s	Pressure Differences Across Floor Enclosure (Ref. Pressure—4th Floor), Pa 5th Floor	3rd Floor	Stair Door	Elevator Door
1	0	0	0	0	0	−5	0	−5	−5
2	1.00	0.20	0	3.67	0	7	10	5	7
3	1.64	0.35	0	4.13	0	12	15	8	10
4	3.30	0.71	0	5.17	0	19	21	17	18
5	4.94	1.06	0	5.18	0	20	23	18	20
6	4.94	1.06	4th floor	—	1.60	15	17	15	14
7	4.94	1.06	4th, 2nd	—	3.33	11	12	11	10
8	4.94	1.06	4th, 2nd 5th floor	—	4.23	9	10	9	11

1 m² = 10.764 ft²
1 m³/s = 2119 cfm
1 Pa = 0.004016 in. of water

Building pressurization with the vents closed was about 50 Pa as shown in Fig. 5. With vent areas of 1.64 m² and 4.94 m² it was reduced to about 27 and 23 pa for all typical floors other than the vented floor. The maximum pressure differences measured across the fire floor enclosure were about 20 Pa (Table 1) obtained with a vent area of 4.94 m² (1.06% of wall area) which were slightly lower than the amount of building pressurization of 23 Pa obtained with this vent area, or less than half of the original building pressurization with no venting.

The results of the tests conducted with a 1.06% vent area and with some stair doors open are also given in Table 1 (Test No. 6, 7 and 8). When one stair door on the 4th floor (vented) was opened, the rate of air flow into the vented floor through the open stair door was 1.60 m³/s (average velocity of 0.82 m/s) accompanied by a reduction in the pressure differences across the floor enclosure to about 15 Pa. When the 5th floor door of the same stair shaft was also opened, the flow rate increased to 3.33 m³/s, and in addition, when the 2nd floor stair door was opened, the flow rate increased to 4.23 m³/s. Increasing the number of open stair doors resulted in a corresponding reduction in the pressure differences across the floor enclosure. Opening the stair door on the vented floor and other floors, in effect, increased the leakage area of the floor enclosure, A_e. The stair door tests showed that air flows from the stairshaft to the vented floor through the open stair door so that during a fire smoke is inhibited from entering the stairshaft.

With inadequate venting of the fire floor, smoke can enter the stair shaft if another floor is not sufficiently pressurized and the doors of the same stair shaft of both floors are open. This was demonstrated by providing a wall vented area of 1.64 m² (0.35% of wall area) on the 4th and 2nd floors and opening the stair doors on both floors, thus connecting the two floors. Placing a vent opening in the wall of the 2nd floor, in effect, reduced the amount of pressurization on this floor relative to other floors. The direction of flow through the open stair door of the 4th floor was from the floor into the stairshaft at a rate of 0.47 m³/s. This emphasizes the need for adequate venting and equal pressurization of all the floors. Special attention should be given to the pressurization of the ground floor, as this floor usually has a higher exterior wall leakage area than those of the other floors, and it may also have escalator and open stair connection to floors below for offices and shops served by separate air handling systems.

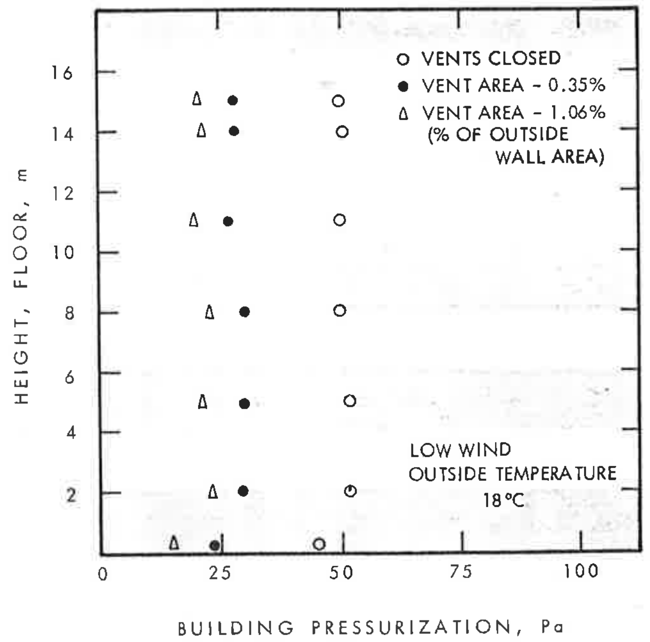

Fig. 5 Building pressurization for various sizes of vent openings, Building A

Venting Tests on Building B

Building B is a 57-story commercial office building with a plan dimension of 34.1 m by 68.3 m and a floor height of 4.0 m, giving an outside wall area per floor of 811 m². Three fixed windows, each located at the mid-face of east, south and west walls of the 22nd floor, were removed and replaced by 2 plywood panel doors of equal size for each window. The area of each door was 1.20 m².

Tests were conducted with the air handling systems in normal operation which pressurized the building sufficiently for the venting tests. The pressure differences across the outside walls of the south, east and west walls on the 22nd floor were −62, −65 and −25 Pa (ref. pressure-floor space) respectively. The weather reported by the local meterological station at the time of the test was −7°C with a west wind of 9 m/s. The lower pressure difference reading across the west wall was caused by the wind acting on the west face of the building which was partially shielded by nearby tall buildings.

Table 2
Results of Venting Tests on the 22nd Floor of Building B

No	Vent Area m²	Vent Area % Wall Area	Venting Rate m³/s	Pressure Differences Across Floor Enclosure (Ref. Pressure—4th Floor), Pa 23rd Floor	21st Floor	Passenger Elevator	Service Elevator	North Stair	South Stair
1	0	0	0	−1	0.5	0.5	−1	−2	−1
2	E. Wall-1.2	0.15	5.65	12	12	12	16	8	9
3	E. Wall-2.4	0.30	9.82	23	21	26	27	20	26
4	E. Wall-2.4 S. Wall-1.2	0.45	11.05	27	32	32	27	22	26
5	E. Wall-2.4 S. Wall-1.2	0.45	—	27	27	28	28	doors open 4.3 m³/s*	24
6	E. Wall-2.4 W. Wall-2.4	—	10.57 −3.10**	20	22	22	24	doors open 3.04 m³/s*	17
7	W. Wall-2.4	—	6.60	14	15	19	16	11	15

*Flow from stairshaft into 22nd Floor
**Flow from outside into 22nd floor

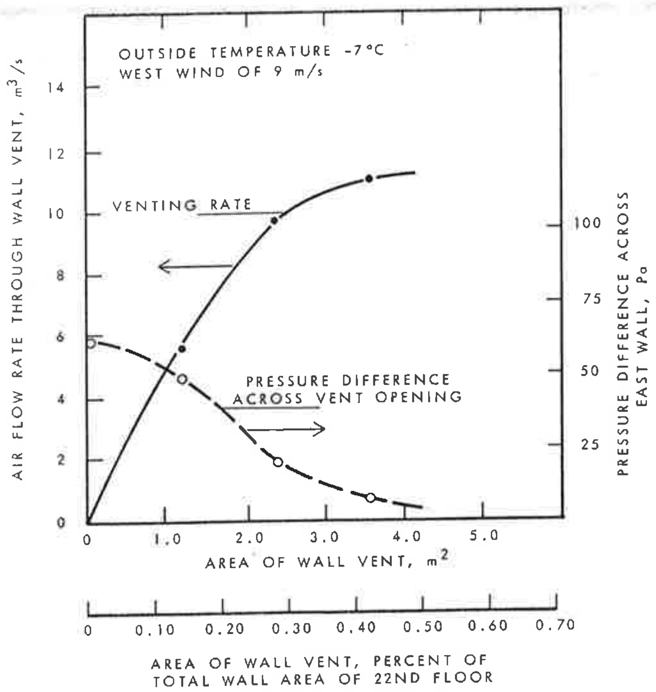

Fig. 6 Venting effect vs vent site opening, Building B

The results of the venting tests are given in Table 2. Test No. 1 through 4 were conducted with various vent size openings in the east wall (leeward wall) and the south wall (side wall). As shown in Fig. 6, the venting rate increased with increasing vent area and approached a maximum venting rate with an area of about 0.5% of the total wall area of the 22nd floor. The pressure difference across the vent openings decreased with increasing vent area, and at near the maximum venting rate it approached the zero value (also shown in Fig. 6). The required vent area in terms of percent wall area at maximum venting for building B is about one-half of that of Building A. This is partly due to the way in which the buildings were pressurized. Building A was pressurized with the supply air systems operating and the return and exhaust systems shut down, whereas Building B was pressurized with the building air handling systems operating in the normal mode. For the latter case, the floor space was vented by the return and exhaust systems as well as by the exterior wall vents, and hence, the required vent area for Building B was considerably lower than that for Building A.

As shown in Table 1, the pressure differences across the floor enclosures increased with increasing wall vent area. The maximum pressure differences measured (27 Pa between adjacent floors and the 22nd floor) were less than one-half of the building pressurization as measured across the east wall (65 Pa) with all vents closed. This was also the case for Building A.

Test No. 5 was similar to Test No. 4 except that the north stair door on the 22nd floor was opened. The measured flow rate across the door opening was 4.30 m³/s into the floor from the stairshaft. When the stair door on the ground floor was also opened, the flow rate increased to 6.50 m³/s.

Test No. 2 through 5 were conducted by opening the vents on the leeward and side walls. Test No. 6 was conducted by opening the vents on the windward wall (west and the leeward wall (east) with vent openings of equal area (0.30% of the total wall area). Air flowed into the floor space through the west wall vent at a rate of 3.10 m³/s and out through the east wall vent at 10.57 m³/s. The flow rate into the floor space through the open door of the north stair-shaft was 3.04 m³/s. Test No. 6 was conducted with only the west wall vent open. The direction of air flow through this vent reversed with air flowing out to the exterior at a rate of 6.60 m³/s, which was about two-thirds of that with the vent of equal area located in the opposite wall (Test No. 3). Venting through the windward wall was possible as the inside pressures were higher than the outside pressures by 25 Pa with all vents closed. It can be expected, however, that under high wind, effective venting may not be possible with vents open only on the windward wall.

CONCLUSIONS

The following statements can be made from the theoretical studies:

1. Maximum venting rate is obtained with vent area equal to about 3 times the leakage area of the floor enclosure (Fig. 3).
2. The ratio of pressure difference across the floor enclosure and building pressurization ($\Delta P_e/\Delta P_b$) depends on the ratio of the vent area and the leakage area of the floor enclosure (A_v/A_e) (Eq 3).
3. Under summer conditions, as the building pressurization is constant with building height, the venting performance can be expected to be the same for a fire on any floor. Under winter conditions, however, the building pressurization increases with height because of stack action. From statement 2, this would result in a greater venting rate and pressure differences across the floor enclosure of the upper floors compared to those of the lower floors. Hence, excessive pressure differences can develop across the stair and elevator doors of the vented upper floor of a tall building, which may require some limit on the amount of venting.

From the results of tests on two multi-story office buildings, the conclusions are as follows:

1. Maximum venting rate is obtained with wall vent area equal to about 1% of the total outside wall area of the vented floor.
2. At maximum venting, the pressure differences across the floor enclosure are just under one-half of the amount of building pressurization with the vents closed.
3. Opening the stair door on the vented floor causes a substantial flow of air from the stairshaft into the vented floor accompanied by a reduction in the pressure differences across the floor enclosure.
4. Except for the case with the wall vents opened only on the windward wall, wind action is unlikely to seriously affect the venting performance for smoke control.
5. As the flow of hot gases through the wall vents can be substantial, precaution must be taken in the design of the wall construction above the wall vents to minimize the possibility of the exterior spread of fire to upper floors.

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2. Tamura, G. T. and Shaw, C.Y., "Experimental Studies on Mechanical Venting for Smoke Control in Tall Office Buildings." ASHRAE Transactions, Vol. 84, Part I, 1978.
3. ASHRAE Handbook & Product Directory, 1976 Systems Vol., Ch 41, "Fire and Smoke Control"

ACKNOWLEDGEMENT

The author is indebted to the Dept of Public Works and the Canadian Imperial Bank of Commerce for granting us permission to conduct tests in their building and for their assistance during the tests. He also wishes to acknowledge the assistance of C. Y. Shaw and R. G. Evans during discussions and conduct of the field tests. □□

The following was inadvertently omitted from Clifford Dias' article, Stairwell Pressurization in a High-Rise Building (AJ 7/78): "The author acknowledges Dr. J. Prasad for the development of the computer program." Sorry. The Editor.

RESEARCH NOTE 10

THERMAL REQUIREMENTS FOR HUMAN COMFORT

(Part I)

WHY: When designing a Heating, Ventilating, and Air-Conditioning system for thermal comfort and health where human occupancy is concerned, an engineer must use criteria, indicies, and standards developed from human research studies. Over the years, ASHRAE has been sponsoring research to determine the physical parameters for thermal environmental conditions that will produce those combinations of physiological and psychological response in man called "thermal comfort." One study under this project evaluated the extensive data vailable from a study on 1600 subjects by Rohles and Nevins, using refined statistical analysis procedures, both to validate the earlier findings and to supplement them, where appropriate.

HOW: Data from the 1600-subject study by Rohles and Nevins were used as the basis for various analyses. To summarize that study, 10 subjects (5 men and 5 women) were exposed for three hours in the ASHRAE Environmental Test Chamber at Kansas State University, dressed in standard clothing (insulation value of 0.6 clo) to 20 Dry-Bulb Temperatures (DBT) ranging from 60 to 98°F (in 20°F increments) at each of 8 Relative Humidities (RH), 15, 25, 35, 45, 55, 65, 75, and 85%. Their thermal sensations were reported after one hour, and every half-hour thereafter, on a seven point ballot on which 7 was hot, 6 - warm, 5 - slightly warm, 4 - comfortable, 3 - slightly cool, 2 - cool, and 1 - cold. The results were subjected to modern methods of analysis of determine: (1) the relationship between thermal environmental factors and thermal comfort; (2) a predictor of thermal comfort; (3) a simple model for human thermoregulation; and (4) the validity of such a simple regulatory model.

RESULTS: This research resulted in: (1) a manual of psychrometric data for thermal comfort aspects of human factors research; (2) a revision of the boundaries for thermal comfort (the Model Comfort Envelope); (3) increased knowledge on the relationship between relative humidity and thermal comfort; (4) validating the relationships between the new effective temperature index, ET*, and thermal comfort; (5) recognition that comfort cannot be provided to 100% of the population simultaneously; (6) development of a curve for predicting the percentages of people who would be thermally dissatisfied for a given ET*; and (7) a valid prediction of thermal sensation for humans in moderate thermal environments using a simple thermoregulatory model.

Other Notes cover the effect of clothing and the effect of air velocity.

USE: The findings of this, and other phases of the Research Project provided the technical basis for the revision of ASHRAE Standard 55-66, *Thermal Comfort Conditions,* that resulted in ASHRAE Standard 55-74, *Thermal Environmental Conditions for Human Occupancy*. An engineer designing a Heating, Ventilating and Air-Conditioning system, by using this Standard, can select the required parameters of the thermal environment that will produce thermal comfort for an occupant of the space. The results of this research have also been used in updating Chapter 7, Physiological Principles, Comfort and Health, of the 1977 Fundamentals Volume of the ASHRAE HANDBOOK.

ASHRAE RESEARCH PROJECT: RP-118
SPONSOR: TC 2.1, PHYSIOLOGY
AND HUMAN ENVIRONMENT
CONTRACTOR: INSTITUTE FOR ENVIRONMENTAL
RESEARCH, KANSAS STATE UNIVERSITY
PRINCIPAL INVESTIGATORS: Dr. Ralph G. Nevins (deceased); Dr. Frederick H. Rohles, Jr.

FOR ADDITIONAL INFORMATION REFER TO THE FOLLOWING: ASHRAE Technical Papers Nos. 2281, 2300, 2309, 2368, Bulletin AC-75-6 (Humidity Control & Energy Conservation), ASHRAE Standard 55-74 (Thermal Environmental Conditions for Human Occupancy), and "Psychrometric Tables for Human Factors Research," KANSAS State University, Institute for Environmental Research Publication 73-02, Manhattan, Kansas 1973, by J.E. Woods and F.H. Rohles.

(Part II)

WHY: Studies in the field of thermal requirements for human comfort have been conducted primarily in the laboratory, where subjects have either been clothed in a standard ensemble (insulation value of 0.6 clo) or nude (clo value 0.0) Chapter 7, *Physiological Principles, Comfort and Health,* 1972 Fundamentals Volume of the ASHRAE HANDBOOK included discussions based on the findings of previous research, of how to modify the thermal environmental conditions for various values of clothing insulation. However, at about this same time there was a radical change in the types of clothing materials and clothing ensembles generally worn; this necessitated additional studies.

HOW: Thermal insulating values for a wide range of clothing were measured using an electrically heated

(Continued on page 50)

copper manikin. The manikin was dressed in each of the ensembles to be tested and placed in the ASHRAE Environmental Test Chamber at Kansas State University; the chamber was maintained at 70°F Dry-Bulb, 65% relative humidity, 35 fpm air velocity, with the MRT approximately equal to the DBT. Power to the heaters of the manikin was electronically controlled to produce an average temperature of the copper skin approximately equal to that for man in a comfortable indoor environment. The power required to maintain skin temperature, and the air temperature measurements were then used to determine the insulating (clo) value for the ensemble. A general analysis of this method and its results, led to the development and validation of a model that can predict thermal insulation values of garments from the physical data of their fabrics.

RESULTS: Thermal insulation values were obtained for most of the clothing ensembles that people have worn while conforming to fashion trends over the years. Since clothing fashions and materials are subject to change, the validation of a method for predicting thermal insulation values of garments from the physical data of their fabrics provides a method of obtaining clo values without further testing of ensembles.

Other Notes cover the model comfort envelope and the effect of air velocity.

USE: The findings of this part of the Research Project have been used as the technical basis for the information on thermal insulation values of clothing incorporated in the manuscript of Chapter 7, Physiological Principles, Comfort and Health, of the 1977 Fundamentals Volume of the ASHRAE HANDBOOK. The data has also been used by the Federal Energy Agency in developing approaches to energy conservation. From a practical standpoint, thermal comfort for people can generally still be achieved even when the indoor thermal environmental conditions are adjusted for efficient utilization of energy by choosing the proper clothing ensembles.

ASHRAE RESEARCH PROJECT: RP-118
SPONSOR: TC 2.1, PHYSIOLOGY
AND HUMAN ENVIRONMENT
CONTRACTOR: INSTITUTE FOR ENVIRONMENTAL RESEARCH, KANSAS STATE UNIVERSITY
PRINCIPAL INVESTIGATORS: Dr. Ralph G. Nevins (deceased); Dr. Frederick H. Rohles, Jr.

OTHER INVESTIGATORS: C.H. Sprague, D.M. Munson, and N.Z. Azer

FOR ADDITIONAL INFORMATION REFER TO THE FOLLOWING: ASHRAE Technical Papers Nos. 2283, 2299, 2385.

(Part III)

WHY: ASHRAE Standard 55-66 specified that air movement in an occupied zone should be less than 45 fpm. Chapter 7, Physiological Principles, Comfort and Health, of the 1972 Fundamentals Volume of the ASHRAE HANDBOOK included information that, if the air movement in the occupied zone was greater than 45 fpm, it would be necessary to raise the DBT above the designated 72-77°F range to insure thermal comfort; the elevation in DBT was dependent on how much the air motion exceeded 45 fpm. However, field observations indicated that DBT compensation for air motion was not necessarily required at all velocities above 45 fpm. In order to better define the threshold velocity, a study of the effect of air motion and temperature on the thermal sensation of sedentary people was undertaken.

HOW: Ten subjects, 5 men and 5 women, were exposed to each experimental condition for three hours in the ASHRAE Environmental Test Chamber at Kansas State University. Three air velocities were studied: 40, 80 and 160 fpm, at each of three temperatures: 72.0, 78.6, and 85.2°F; relative humidity was maintained at 50% at all times, and MRT was approximately equal to the DBT. The subjects wore a standard clothing ensemble (insulating value 0.6 clo). Activity was kept as near sedentary as possible. Three skin thermistors were affixed to each subject's chest, forearm, and calf. Three ballots were used to measure subjective responses. The first was the traditional 7 point thermal sensation ballot, the second a 7 point ballot designed to measure a subject's response to air motion, and the third was a 7 point ballot designed to measure a subject's response to sound. After one hour, and every half hour thereafter, votes were taken on the thermal sensation ballot. Votes on the sound and air motion ballots were taken at the end of the first, second and third hours. Skin temperatures were recorded after 10 minutes during the three-hour exposure. The data was then subjected to various statistical analyses to determine the significance of the relationships observed.

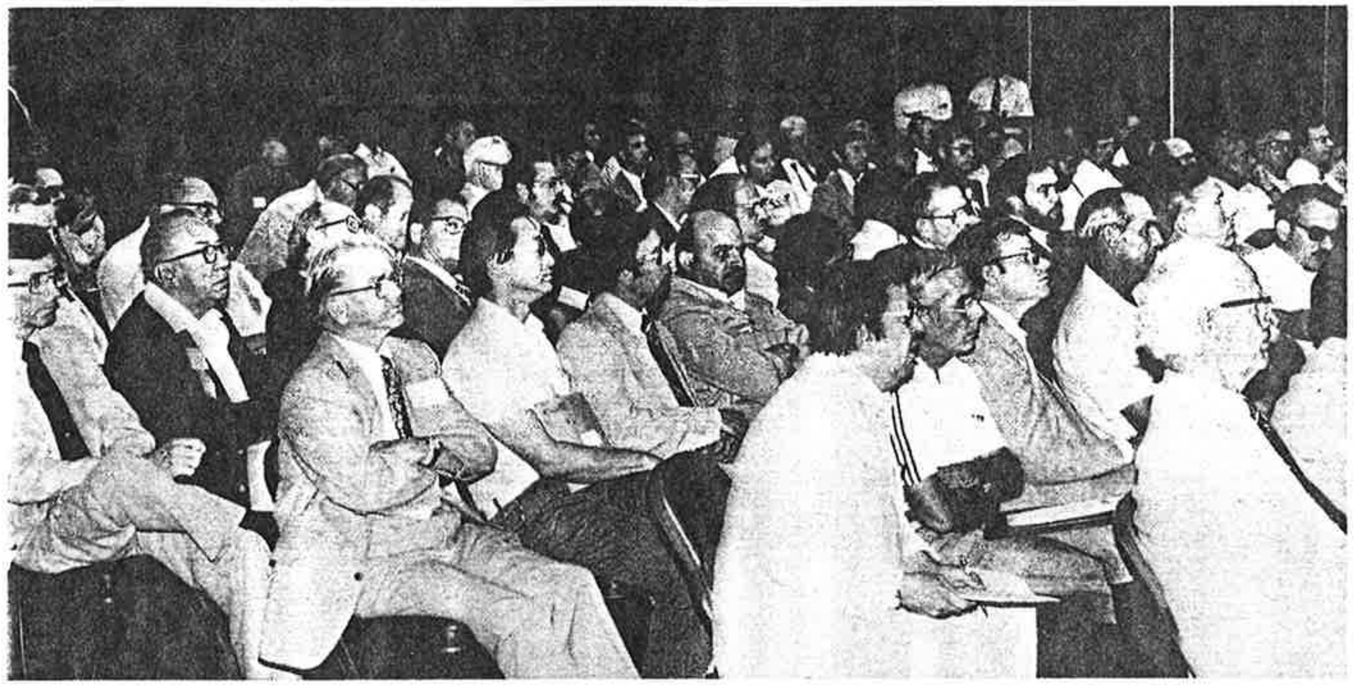
RESULTS: This study demonstrated that the threshold velocity where the DBT should be elevated to compensate for air motion is greater than 45 fpm, but less than 80 fpm. Thermal sensations, air motion and sound level affectivities, and weighted mean skin temperatures all demonstrate significant exposure period adaptations. Significant differences exist between sound level affectivities of men and women during exposure to the three air movement conditions; these differences increase with increasing sound levels, but not significantly. Thermal sensations linearly correlate with the new ASHRAE Effective Temperature (ET*) and with air motion.

Other Notes cover the model comfort envelope and the effect of clothing.

USE: The findings of this, and other parts of the research, were used as the technical basis for the revision of ASHRAE Standard 55-66, *Thermal Comfort, Conditions,* that resulted in ASHRAE Standard 55-74 Thermal Environmental Conditions for Human occupancy. An engineer designing the Heating, Ventilating, and Air-conditioning system of a structure, by using this Standard, can specify the required parameters of the thermal environment to produce thermal comfort for its occupants. In addition, the results of this research have been incorporated in the revision of Chapter 7, Physiological Principles, Comfort and Health, for the 1977 Fundamentals Volume of the ASHRAE HANDBOOK.

ASHRAE RESEARCH PROJECT: RP-118
SPONSOR: TC 2.1, PHYSIOLOGY
AND HUMAN ENVIRONMENT
CONTRACTOR. INSTITUTE FOR ENVIRONMENTAL RESEARCH, KANSAS STATE UNIVERSITY
PRINCIPAL INVESTIGATORS: Dr. Ralph G. Nevins (deceased); Dr. Frederick H. Rohles, Jr.

FOR ADDITIONAL INFORMATION REFER TO: ASHRAE Technical Paper No. 2298.



STANDARDS PROJECT COMMITTEE NEWS

THE ASHRAE Standards Committeeis seeking qualified individuals to participate in the revision of the standards listed below. If you are interested and can actively participate—attend meetings, pay meticulous attention to correspondence and cover your own travel expenses, please send a copy of your resume (or request a Standards Committee Date Form) to Charles T. Zegers, ASHRAE Manager of Standards,345 East 47th Street, New York, NY 10017.

Standard 55-74R (ANSI B193.1-76)—Thermal Environmental Conditions for Human Occupancy—Scope and Purpose: This standard specifies desirable and generally acceptable thermal environmental conditions for comfort for sedentary and slightly active, healthy, normally clothed people in the United States and Canada at altitudes from sea level to 7,000 feet.

This Standard does not specify values for the non-thermal environmental factors such as air quality noise, and illumination.

Standard 62-73R (ANSI B194.1 1977)—Standards for Natural and Mechanical Ventilation—Scope and Purpose: This standard defines ventilation requirements for spaces intended for human occupancy and specifies minimum and recommended ventilation air quantities for the preservation of the occupants' health, safety, and well being and consistent with maximum levels of energy conservation.

Good ventilation practice exists when clean ventilation air is provided in sufficient quantities to maintain the required oxygen, carbon dioxide, and other air quality levels in the space under consideration.

The Standard does not specify the air quantities required for the control of temperature and humidity or the exhaust quantities required for source control of domestic or industrial wastes. The specifications are based on the current state of knowledge and acceptable practice related to air filtration, odor control and environmental physiology. □□

ASHRAE Helps Coordinate U.S. Participation in International Standards

USA Technical Advisory Group, ISO/TC 86—Refrigeration. Call for members.

The American Society of Heating Refrigerating, and Air-Conditioning Engineers, Administrator of the Technical Advisory Group of ISO/TC 86, invites participation of concerned organizations as members of the TAG to direct expanded US involvement in activities of ISO/TC 86.

Scope: Standardization in the field of refrigeration, including air conditioning and cryogenics.

Subcommittees: TC 86.
SC.1-Safety—Secretariat, USA. Sponsor, ASHRAE.
SC.2-Terminology, Definitions and Symbols—No Secretariat. Sponsor, ASHRAE.
SC.3-Testing of Refrigerating Systems—No Secretariat. Sponsor, ASHRAE.
SC.4-Testing of Refrigerant Compressors—Secretariat, U.K. Sponsor, ARI.
SC.5-Construction and Testing of Household Refrigerators—Secretariat, France. Sponsor, AHAM.
SC.6-Testing of Factory Assembled Air-Conditioning Units—Secretariat, USA. Sponsor, ARI.
SC.7-Construction and Testing of Refrigerated Commercial Display Cabinets—Secretariat, U.K. Sponsor, CRMA.
SC.8-Refrigerants and Lubricants for Use in the Refrigeration Industry—Secretariat, USA. Sponsor, ASHRAE.
Working Group 2-Test Packages for Performance Testing—Convener, USA. Sponsor, CRMA.
Working Group 3-Air C9olers, Test Methods Convener—Netherlands. Sponsor, ARI.
Working Group 4-Thermodynamic and Thermophysical Properties of Refrigerants Convener—Czechoslovakia. Sponsor, ASHRAE.

Information may be obtained from Charles T. Zegers, ASHRAE, 345 East 47th Street, New York, NY 10017. □□