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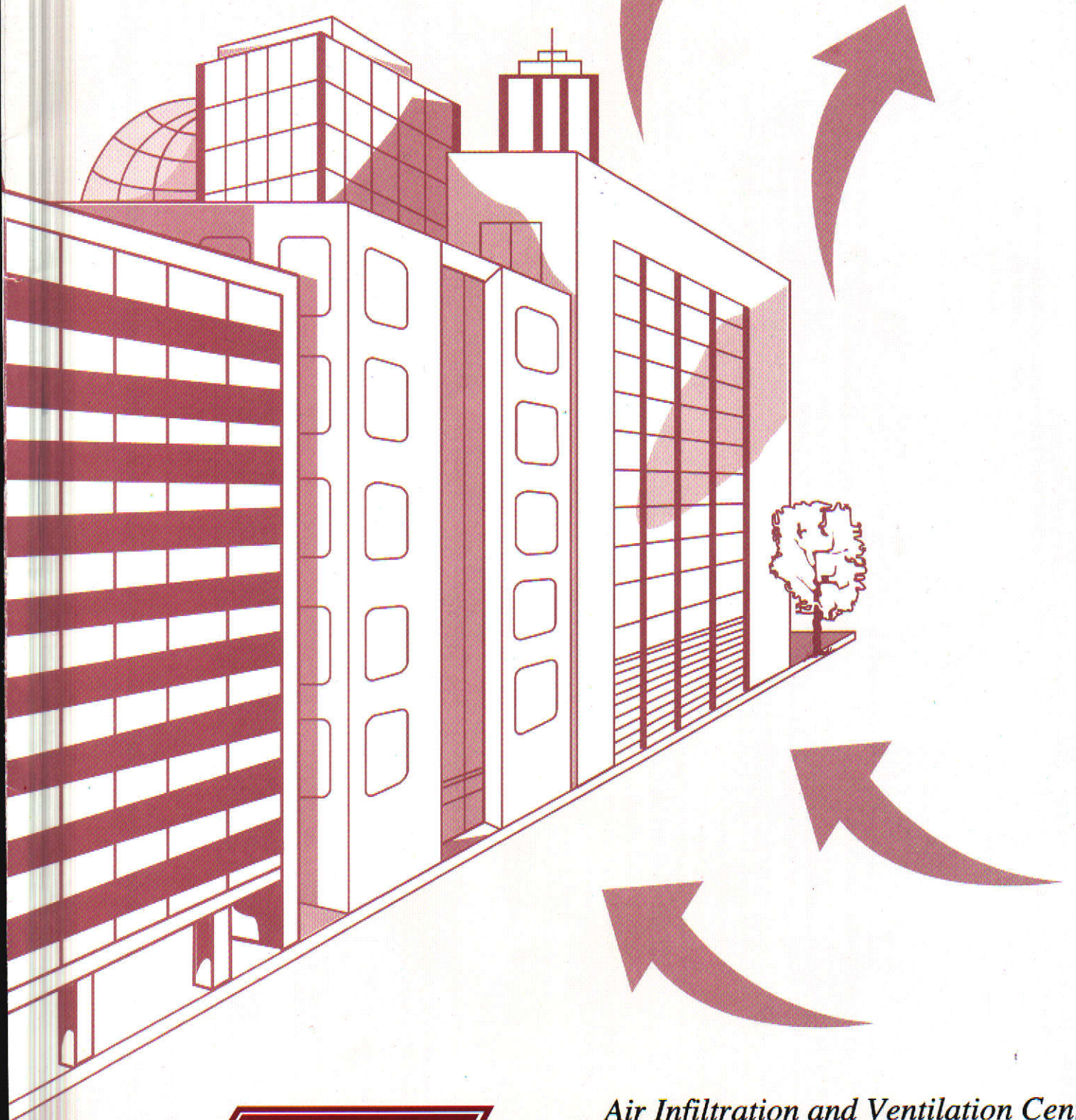

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Ventilation and Infiltration Characteristics of Lift Shafts and Stair Wells - A Selected Bibliography

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1. Introduction

The stack effect provides the driving force for vertical air movement within buildings. Its effects are especially pronounced in high rise developments, where the air leakage associated with elevators, stairs and service shafts can be a major concern. Stairwells and lift shafts themselves provide occupant access to those floors above or below ground level as well as providing routes for the movement of air. A knowledge therefore of the air movement characteristics of such shafts is vital in understanding the ventilation and leakage patterns in medium and high rise buildings. Such work has been particularly helpful in the predication and evaluation of smoke control procedures.

This review attempts to outline the main areas of research that have been undertaken in the evaluation and understanding of air leakage characteristics of both stairwells and lift shafts.

2. Ventilation of stair wells

Air driven by stack and wind pressures cause vertical air movement between floors, through corridors and vertical shafts. Such air movement has serious comfort, energy and indoor air quality implications, and much work has been undertaken in order to understand and model these air movements. These are briefly outlined below.

2.1 Air movement and infiltration

A number of studies restrict their work to the movement of air within stairwells only. Such work investigates the buoyancy driven recirculating flows in stairwells and their associated energy transfer, usually between two or more zones. This includes Reynolds et al (1986, #2959), Riffat et al (#3131), Zohrabian et al (#3583), Balcomb and Yamaguchi (#3826), Jones and Balcomb (#3835), van der Maas and Roulet (#4680), Edwards and Irwin (#4845), and Ergin-Ozkan et al (#6029). The main aim of these investigations is to develop mathematical and theoretical procedures to model thermal air movements, in what can be a rather complex geometrical confined.

Several investigations on the other hand, deal with the combined stack and wind pressure effects on tall buildings and their associated infiltration and pressure effects these include studies by Maszczynski (#50), Karulak (#121), Zuercher and Feustal (#1255), and Achakji and Tamura (#3906). One such study attempt to predict infiltration rates in high rise buildings. In order to use air flow calculations to estimate possible energy savings from reductions in infiltration actual pressure distributions along the building facade is needed. Zuercher and Feustal (#1255) argue that local pressure coefficients can only be obtained from wind tunnel experiments, where the wind velocity profile as well as the surrounding building pattern matches the real situation as close as possible.

A study by Karulak (#121) focuses on the overall nature of infiltration and air movement in multi-storey buildings. In conclusion the author identifies the significance of the vertical temperature flows and states that proper design of mechanical ventilation systems is essential. The unsteadiness of balanced systems in tall buildings can be exploited by the stack effect, resulting in large amounts of vertical heat transfer. This conclusion is echoed in a study by Rydberg (#1489) which examines disturbances in ventilation systems. In tall buildings stack pressures can often override the ventilation system causing the system to fail.

2.2 Air heat and moisture transfer

A number of studies investigating the nature of air, heat and moisture transfer throughout a building have identified stairwells as a major route of transfer. These include Tamura and Wilson (#140), Railio (#784), Rydberg (#1489), Jun and Sheung (#2712), Bahac (#2880), Vitstrom (#3893), Shaw et al (#5125,

#5265). Pressurisation and tracer gas studies have been used in these investigations, to test the leakage characteristics of individual rooms and stairwells. Under certain conditions these studies have found that the stack effect in medium and high rise buildings plays a vital role in air and heat transport. These flows can be minimised according to Tamura (#140) by providing supply air in excess of the exhaust, ie by pressurising the stairwell area. However a number of problems are associated with positive pressure buildings including possible condensation damage.

Another area of focus has been the pollutant transportational capabilities of air movement within the stairwell. The migration of moisture from the ground to first floor in a two-story dwelling has been studied by Edwards and Irwin (#4845) and micro-organism migration in hospitals via stairwell air flows by Munch et al (#2360) are two examples. A more generalised investigation (Grot et al (#3609) concerns the indoor air quality in a modern high rise office building. This study considered the spread of a number of pollutants including carbon dioxide, carbon monoxide and radon by lift and stairwell are flows. All three of these investigations demonstrate the significance of the stack effect, with higher concentrations of moisture, office and hospital pollutants and micro-organisms in the air circulating around the upper floors of the building.

2.3 Smoke control and fire safety

The effects of air flows within stairwells has generated much interest especially in the area of smoke control and fire safety; Tamura (#2057, #2058, #4560, #5145, #5633), Ostatek et al (#2527), Klote (#3459, #3904), Said and MacDonald (#5123). Klote #3904 has identified two control measures which are currently used to limit the spread of fire and smoke out of the building. Zoned control is where a building is divided into a number of smoke zones, each separated from the others by partitions and floors. In the event of a fire pressure differences and airflows produced by mechanical fans can be used to limit the spread of fire and smoke.

However the main control mechanism is to pressurise the stairwell itself, several papers discuss such pressurisation systems these include Tamura and Shaw (#299), Klote (#3459), Clark and Harris (#3376), Grot et al (#3906), Chow et al (#5582), Mung (#5589), McNemar J (1975), and Shaw and Tamura (1976). The aim of such systems is to ensure that stairwells can act as escape routes in the case of a fire. The stairwell is pressurised by the injection of outdoor air into the shaft so that the direction of air flow is from the shaft to its surroundings. ASHRAE have identified two pressurisation systems, single and multiple injection systems (ASHRAE, 1987).

Klote (#3904) has identified three major design considerations with these systems. The consequences of stack and wind pressures acting over the height of the building are that under times of excessive pressure differences doors joining the floor corridor and stairwell may stick (Tamblyn 1991). Stair pressurisation systems should be able to reduce the loss of pressure resulting from several stair doors being open simultaneously, while remaining to operate effectively. A final consideration is the location of the supply air inlets and fans.

Attempts to overcome these design problems have led to many investigations including Tamura (#4560, #5145) and to the specification of a variety of codes and standards. These govern air velocities at door openings and specify the required amount of minimum and maximum pressurization. Other papers including Tamura (#5633) recommend that the stair pressurization system should operate together with a mechanical exhaust fan to vent the fire floor. The work done in this area includes theoretical, mathematical and real test investigations. Recently Computational Fluid Dynamics has been used to evaluate air flow and smoke movement in stairwells, such studies include Munch et al (#2360) and Ergin-Ozkan (#6029).

3. Ventilation of lift shafts

The ventilation and leakage characteristics of lift shafts are somewhat different to that of stairwells. Lifts shafts are usually located in the centre of the building and form part of its service core. They not only contain the lift car, but also many pipes, wires and ducts associated with the services of the building. Shafts are usually constructed of concrete and have totally impermeable walls, floors and ceilings. Openings are allowed to secure ventilation, and to act as vents for gases, smoke and fire. A motor room is typically located directly over the shaft and having

vents to facilitate the necessary air movement required by the plant. These vents are not used for the removal of stale air extracted from the building.

Stack driven air movement through lift shafts in tall buildings can be responsible for a variety of pressure problems. An understanding of the stack effect and associated air movement characteristics is essential if designers are to overcome such problems. In response to this a number of studies have investigated the interaction between the pressure generated by the stack effect and the building.

Tamblyn (1991) investigated the size of the stack effect in a 40 story apartment building to demonstrate the importance of such pressure problems. The ability to locate the natural pressure level is emphasised since this can help direct air tightening investigations to the top or bottom of the building. In this study to locate the neutral pressure level smoke was blown against the elevator door. If the smoke lingers, the neutral pressure level will be at that floor, while on other floors the smoke will be blown back from the shaft or drawn into it. In conclusion the author notes that stack pressures can not only cause elevator door opening problems but also indoor air quality problems. These can be controlled within acceptable limits by understanding the problem and modifying the ventilation systems design. Solutions discussed in this study centre around alterations in HVAC design to regulate a lift shaft pressurisation system.

The effect of stack pressures on the operation of mechanical ventilation systems has been investigated by two other studies. Tamura (#140) attempted to measure the pressure differences for a nine story building as a result of the stack effect and ventilation system operation. Finding in conclusion that in order to reduce the pressure differences and infiltration of air at low levels it was necessary to provide supply air in excess of the exhaust. If excess air is supplied uniformly the authors state that there will be a corresponding increase in the pressure differences causing exfiltration at upper levels. However condensation problems may result. While Rydberg (#1489) concentrated on the possible disturbances that a ventilation system has to overcome in tall buildings. Including for example those caused by the interaction of lifts and stairwells with the operation of the ventilation system. In order to counteract such disturbances, changes in the ventilation system and building design are proposed.

The effects of the vertical air movement generated by stack pressures to transfer warm ventilation air throughout a building are discussed by Wallace, (1985). The study compares the leakage characteristics of two high rise buildings. It concludes that air and heat movement via vertical stairwells and lift shafts and the resulting air leakage and infiltration represents a major problem in many high rise buildings. As a result of these findings a number of retrofits have been undertaken on the two buildings examined, including blocking openings in shafts and sealing up leakage routes, although results of these actions is not presented.

A case study which examines the air movement potential of a number of contaminates from sub-floor garage spaces to higher levels is considered by Grot et al (#3609). The authors conclude that if vertical lift and stair shafts were isolated and the ventilation systems of the garage were changed then most problems of pollutant migration in this building would be alleviated.

It is essential that lift shafts do not contribute to the spread of fire throughout a building. A number of precautions are associated with the design of lift shafts to ensure they do not. For example lift shafts are designed to the fire resistance specification of individual countries or localities. The outer shaft and its doors also contribute to added fire protection. The problems of elevator and passenger safety when a fire breaks out have been outlined in a paper by Sumka (#3910).

Several studies deal with lift shafts and the associated effects of fire and smoke. These studies examine ways of controlling the spread of fire and smoke throughout the building by venting the lift shafts and corridors. There are two main preventative methods. Natural venting methods to control fire and smoke spread are examined by Tamura (#2058). The study assumes that smoke migration follows the air flow pattern, which in large multi story buildings is vertical. The provision of openings at the top and bottom of lift shafts this smoke migration can be controlled. Opening the vent at the top of a vertical shaft will raise the level of the neutral pressure plane, increasing air flow into the shaft and correspondingly the

number of stories into which air flows from the shaft is reduced. However the author concludes by noting that top venting increases smoke contamination of the shaft and cannot therefore be used for shafts in which smoke contamination must be restricted, such as stairwells. Such a system could, however assist in the evacuation of smoke from the building. Bottom venting inhibits the flow of smoke into the shaft from adjacent contaminated places. However due to the difficulty in preventing smoke contamination a number of precautions are also discussed.

A more modern method is to mechanically pressurise both the lift shafts and associated corridors in the same way as stairwells. Such systems have been reviewed by Tamura and Shaw (#299), Klote (#3904), Tamura and Klote (#3908). However concern exists regarding the pressure fluctuations resulting from the opening and closing of elevator doors. Pressurisation systems therefore need to have variable supply rates with feed back control or relief dampers in the walls of the elevator shafts or surrounding corridors.

Another area of concern related to smoke and fire safety is the transient pressures produced when the elevators car moves in its shaft. This piston effect can pull smoke into normally pressurised areas. Such effects can be overcome by improved design, a theoretical analysis of the pressures involved are discussed by Klote and Tamura (#3909).

As systems become more advanced integrated ventilation and fire safety equipment is being installed. Such systems include HVAC control systems designed to work effectively with fire management and smoke control systems can now prove a cost effective and highly reliable total system approach to fire safety. These systems have been reviewed by Shavit (#3905).

4. Conclusions

This review has identified the importance of stairwell and lift shaft air flows in tall buildings. Of primary interest is the characteristics and mechanisms of such air flows for the prediction of heat moisture and pollutant transport throughout buildings. The restriction and control of smoke and fire in vertical stair wells and lift shafts has also generated much interest along with the associated effects of stack pressures and the resulting air leakage characteristics especially in tall buildings. The interaction of these concerns with ventilation systems has also been an area of focus. Most papers cited in this review deal with the fundamentals of airflows in stairwells and lift shafts. Many use models to predict these phenomena as well as experimental data from test and real buildings. These examples provide important background guidelines for further research.

5. References

5 (a). Stairwell References

#NO 50 Amount of heat needed to warm air infiltrating under action of wind.
Zapotrzeboivanie ciepla na ogrz anie powietza infittrujacego na skutek dzialania wiatru.
AUTHOR Maszcynski E.
BIBINF Ciep. Ogrz. Went. February 1972, 4, 2, 39-44, 3 diagrs, 1 tab, 8 refs. #DATE 01:02:1972 in Polish
ABSTRACT Presents calculation principles and results of investigation into air infiltrating into a high rise building, based upon assumed equality of pressures on staircases and in the rooms halfway up the building.
KEYWORDS high rise building, air infiltration,

#NO 121 Air exchange in multi-storey buildings
Wymiana poivietrza w budynkach wielokondygnacyjinych
AUTHOR Karulak J.
BIBINF Ciep. Ogrz. Went. March 1970 3/6 p81-85 = H.V.R.A. Translation no.216 price 1.55 pounds #DATE 01:03:1970 in Polish, English
ABSTRACT Discusses the factors affecting air change rates in multi-storey buildings and derives expressions for the air infiltration through walls, windows and doors; air flow through gravity ventilation ducts; pressure pattern on the outside walls of the building and the "chimney draught" in the staircase. Derives mathematical model for calculating the air balance for a building with gravity ventilation ducts. Concludes that chimney draught (stack effect) has a large effect and that proper design of the extraction gravity ventilation system is very important.
KEYWORDS high rise building, stack effect, air change rate, pressure distribution,

#NO 140 Pressure differences for nine-storey building as a result of chimney effect and ventilation system operation.
AUTHOR Tamura G.T. Wilson A.G.
BIBINF ASHRAE trans vol 72 p180-189 #DATE 24:01:1966 in English #AIC 1257
ABSTRACT Discusses theoretical pattern of pressure differences inside a tall building and describes measurement of pressure made on a nine-storey building in Ottawa. Pressure differences were measured across external walls, vertical shafts, stairwell doors and elevator doors with the mechanical ventilation system both on and off. Concludes that pressure differences across external walls depend on the distribution of openings in the exterior wall and of the ratio of resistance to air flow inside the building to that across the exterior wall. These can be measured by the position of the neutral zone and the ratio of actual to theoretical draft.
KEYWORDS pressure difference, stack effect, high rise building,

#NO 299 Air leakage data for the design of elevator and stair shaft pressurization system.
AUTHOR Tamura G.T. Shaw C.Y.
BIBINF ASHRAE trans vol 82 part 2 p179-190 8 figs, 3 tabs, 8 refs. D.B.R. Paper No. 717 #DATE 01:06:1976 in English
ABSTRACT Describes research project to find air leakage values of walls of elevator and stair shafts in order to use these values in the design of pressurization systems. Describes method of test and gives results. Concludes that leakage rates for walls of elevator shafts constructed of masonary units are higher than those of cast-in-place concrete. Variations in the leakage of stair shafts could not be related to the type of wall construction but probably depended on the workmanship in sealing crack openings. Finds that internal flow resistance of a stair shaft is substantial and must be taken into account in designing a stair shaft pressurization system.
KEYWORDS air leakage, elevator shaft, wall, pressurization

#NO 547 Ventilation rates
AUTHOR Nakazawa Y. Narasaki M.
BIBINF Trans.SHASE 54(1) 27-32, 7 figs, 7 tabs #DATE 01:01:1980 in Japanese #AIC 1728
ABSTRACT Treats investigations in office building where 1) flow rates of supply air, return air and ventilation between main office area and adjacent rooms were measured with an anemometer. Return air rates remained constant but ventilation rates varied widely during measurement periods. 2) CO2 was used as tracer gas to determine ventilation rates in offices. Calculates alterations in gas concentrations in rooms adjacent to stairwell and changes in outdoor air concentrations. During air conditioning, ventilation rates in the room were 4-5 room air changer per hour. Without air conditioning, air change rates were 1-2 per hour approximately.
KEYWORDS tracer gas, carbon dioxide, mechanical ventilation, natural ventilation, office building

#NO 784 Heat recovery from the exhaust air in old apartment buildings.
Lammon talteenotto poistoilmasta vanhoissa asuinkerrostaloissa.
AUTHOR Railio J.
BIBINF LVI May 1981 no.5 p.49-52 3 tabs. 3 refs. #DATE 01:05:1981 in Finnish #AIC 426
ABSTRACT In order to investigate the possibilities of installing heat recovery equipment in old apartment houses, a large project has been started. There are 30,000 to 35,000 apartment houses in Finland with an average volume of 6000-7000 cu.m. Possible savings from heat recovery in houses with mechanical exhaust are the transfer of heat to supply air using standard equipment and heat recovery from exhaust air using heat pumps. Applications of the latter method depend on the heating system in the house. The project will investigate the performance of heat recovery, air flows in individual rooms and in the whole apartment, pressure conditions and air leakage in the building, temperature in the apartments and on staircases and the opinions of the inhabitants. Details some problems encountered with heat recovery systems and some advantages of heat recovery.
KEYWORDS heat recovery, heat pump, flat, residential building,

#NO 1255 Air infiltration in high-rise buildings.
AUTHOR Zuercher C.H. Feustel H.
BIBINF 4th AIC Conference "Air infiltration reduction in existing buildings" Switzerland, 26-28 September 1983 p.9.1-9.17 14 figs. 1 tab. 17 refs. #DATE 26:09:1983 in English
ABSTRACT Performs tracer gas measurements and fan pressurization experiments on an 8-storied student residential building in order to determine the influence of wind as well as of stack effect upon air infiltration. Compares pressure and tracer gas distri-

butions with those from a predictive infiltration computer model for high rise buildings. To study the influence of the air flow pattern around the building, adapts the calculated flow pattern in the stairwell to the measured tracer gas concentration with the aid of urban wind velocity profiles and different sets of upwind dependent surface pressure coefficients. A satisfactory correlation is only obtained by application of local pressure coefficients from wind tunnel experiments matching the wind velocity profile as well as the surrounding pattern as closely as possible.
KEYWORDS tracer gas, pressurization, high rise building, prediction, modelling, air flow, wind, pressure coefficient,

#NO 1489 Disturbances in ventilation systems. Part 1 and Part 2
AUTHOR Rydberg J.
BIBINF Heat.Vent.Engr. May 1960, 483-485,489, June 1960, 541-547, 9 figs, 2 refs. #DATE 00:05:1960 in English #AIC 928A and
ABSTRACT The quantity of air in several rooms lying in a stack connected by means of fresh air and exhaust air ducts is considered as a simple model of a multistorey building. Negative pressures set up within the rooms can be equalised by adjusting the valves and resistances of the ducts. The effects of differing air quantities in one of the rooms caused by window opening and thermal forces and the difference in indoor and outdoor temperature, on the pressure distribution and air quantities in the rest of the system is considered. The counteraction of disturbances caused by thermal forces by choking exhaust valves or connecting pipes or throttling the main duct to the fans is discussed. Air leakage into the lowest floor level as a result of negative pressure in the room is quantified. Vertical zoning as an aid to the reduction of pressure driven flow in high buildings is recommended. Noise, air flow in open staircases and lift shafts and disturbances due to wind are also considered.
KEYWORDS ventilation, high rise building, air leakage, air flow, pressure difference, pressure drop, window, air infiltration, mechanical ventilation, air conditioning, wind, modelling, elevator shaft

#NO 1800 Temperature- and wind-induced air flow patterns in a staircase. Computer modelling and experimental verification.
AUTHOR Feustel H, Zuercher Ch, Diamond R et al
BIBINF Energy and Buildings, 1985, Vol 8, p105-122. 15 figs, 3 tabs, 45 refs. #DATE 07:11:1984 in English
ABSTRACT The typical infiltration load for a residential building has been found to range from one-third to one-half of the total space conditioning load. However, most infiltration measurements have been made on single-family houses. Information about the role of infiltration in the energy consumption of large buildings is limited. Furthermore, the prediction of infiltration rates in high rise buildings is a complex problem. The forces that drive this flow result from the superposition of wind pressure on the faces of the building and the stack effect across the height of the building. Infiltration models have shown the latter effect to be significant in single-family residences, particularly in colder climates, and consequently the stack effect is even greater in high rise buildings. For this work, tracer gas and pressurization measurements were performed on a 30 m tall University of California dormitory in order to determine the importance of both wind and stack effect upon infiltration. Measured pressure and tracer gas distributions were compared with those from a predictive infiltration computer model for high rise buildings. To study the influence of the air flow pattern around the building, this model uses various wind velocity profiles characteristic of urban areas and different sets of surface pressure coefficients derived from wind tunnel experiments.
KEYWORDS air infiltration, multi-chamber, air flow, stack effect, surface pressure, mathematical modelling, wind, high rise building, tracer gas, sulphur hexafluoride, pressurization

#NO 2057 Analysis of Smoke Shafts for Control of Smoke Movement in Buildings.
AUTHOR Tamura, G. T.
BIBINF RESEARCH.LOC = Ottawa, Canada; TYPE = REPORT; #DATE 28:06:1970; VOLUME.TITLE = ASHRAE Trans.; VOLUME.NO = 76; PAGES = 290-297; REPORT.NO = 2163; PUBLISHER.NAME = ASHRAE; in English
ABSTRACT A computer analysis of stack effects in a large multi storey building was performed, comparing the air flow (and consequent hypothetical smoke concentrations at higher floors) with and without a smoke shaft. Additionally, tests were performed on one building using one of two stairwells as a smoke shaft. Results indicate that a smoke shaft can be effective in limiting smoke movement to

upper stories, as long as the fire floor is not open to outside air (such as by a broken window), or the smoke shaft is not open to a floor higher than the fire floor.;
KEYWORDS SMOKE, STACK EFFECT; COMPUTER, theoretical modelling, HIGH-RISE BUILDING;

#NO 2058 Natural Venting to Control Smoke Movement in Buildings Via Vertical Shafts
AUTHOR Tamura, G. T.; Wilson, A. G.;
BIBINF RESEARCH.LOC = Ottawa, Canada; TYPE = REPORT; #DATE 01:07:1970; VOLUME.TITLE = ASHRAE Trans.; VOLUME.NO = 76; PAGES = 279-289; REPORT.NO = 2162; PUBLISHER.NAME = ASHRAE; in English
ABSTRACT Effects of vertical shaft venting on smoke movement in tall buildings are examined in order to obtain conditions for minimum smoke filtration into upper floors, stairways, and elevator shafts during fires. Results show that sufficient bottom venting will nearly eliminate flow of air into shafts, while top venting reduces flow from shafts. Either should reduce smoke transfer between levels. Multiple shaft buildings benefit from top venting some and bottom venting others, reducing necessary vent size for sufficient ventilation.;
KEYWORDS VENTILATION; SMOKE; AIR FLOW; HIGH-RISE BUILDING;

#NO 2360 Flow of microorganisms in a hospital stair shaft - full-scale measurements and mathematical model.
AUTHOR Munch W, Ruden H, et al.
BIBINF Energy Bldgs, Vol 9, No 3, 1986, p253-262, 8 figs, 14 refs. #DATE 00:08:1985 in English
ABSTRACT Measurements of air flow and microorganism concentration have been made in the stair shafts of a hospital, using a diving bell-type of pressure-recording instrument, and a sampler for the microorganisms, respectively. Results of experiments were used to calculate the flow rate of microorganisms between the floors of the hospital. A mathematical model based on simplified transport equations is proposed, which would allow the prediction of the flow field and the distribution of microorganisms in the stair shaft. Comparisons between measurements and numerical calculations indicate that the mathematical model is able to predict the global flow field, qualitatively. The application of the numerical method can help to reduce the experimental work, as well as to investigate the complex exchange mechanisms of microorganisms.
KEYWORDS air flow, hospital, measurement technique, mathematical model, microbiology

#NO 2527 Air movement in buildings: computer programs calculating air pressures and air flows in buildings in which a fire is simulated.
AUTHOR Ostatek E, Phaff J C, De Gids W F
BIBINF IG-TNO/Dept GLB, Report No C411, February 1978, 27p, 2 refs. #DATE 00:02:1978 in English
ABSTRACT Three computer programs calculating air pressures and air flows in buildings have been developed. These computer programs consist of a network of non-linear equations. The IWIS library procedure KNEWTON is used in the iteration process which finds the solution of the system of non-linear equations. Rooms in which several air flows come together are called junctions (for instance a corridor, a central hall or a staircase). The first program is suited for a model with one junction, the second one for a model with one junction and a room in which a fire can be simulated. With the third program it is possible to calculate flows and pressures in a model with one fireroom and nineteen junctions.
KEYWORDS air movement, computer, air pressure, air flow, fire

#NO 2712 The effective and ineffective heat loss by infiltration - field measurement in a dormitory.
AUTHOR Guo Jun, Liu Ming Sheng
BIBINF in: Third International Congress on Building Energy Management; III Ventilation, air movement and air quality: field measurement and energy auditing, held in Lausanne, Switzerland, September 28- October 2, 1987, p52-57, 3 figs, 3 tabs, 2 refs. #DATE 00:09:1987 in English
ABSTRACT It has been argued for a long time in China whether air leakage could be reduced to save energy. Objectors argued that the reduction of air leakage would worsen indoor air quality, as has occurred in "sick" buildings in Europe. But this field test shows that in some buildings, far from benefitting occupants, a large proportion of air leakage serves to decrease the room temperature. This sort of leakage can therefore be reduced with no adverse effects. If the air change rate in a room is reduced,

the fresh air could be felt to be inadequate. But considering air leakage in a whole building we find that a large quantity of air only flows through the outdoors, staircases, and some cracks or other openings in the building envelope, consuming a lot of energy but of little benefit to the occupants. On the other hand, leaked air which flows through rooms and benefits the occupants may be called effective. In fact, the energy consumed by the effective part is not very much in the practice of Chinese design and maintenance. The paper describes a series of measurements carried out on a four storey building.
KEYWORDS air leakage, heat loss, occupancy effects, energy conservation

#NO 2880 Approaches to estimating airflows in large multi-family buildings.
AUTHOR Bohac D L
BIBINF Ashrae Trans, Vol 93, Part 1 1987, p1335-1358, 8 figs, 6 tabs, 19 refs. #DATE 00:00:1987 in English
ABSTRACT Air infiltration can account for a significant part of the heat loss in multifamily buildings. Its magnitude, however, is difficult to determine. In the absence of a central ventilation system, pressurization tests of the whole building are virtually impossible and one-chamber tracer gas measurements become inapplicable. Heating-season-average air infiltration rates can be estimated indirectly by comparing energy consumption data with engineering models of heat loss. However, a large uncertainty is associated with this estimate. We describe various pressurization and tracer gas techniques for characterizing airflows in large multifamily buildings. We applied a number of these techniques to a six-story apartment building. Single and multizone fan pressurization methods enable the measurement of leakage areas of apartments to the outside and to other interior spaces. Single-zone fan pressurization at the apartment building showed that the apartments were relatively tight, with leakage areas dominated by the building's many open windows. Constant-injection tracer gas techniques allow measurement of airflows in the building's vertical shafts, which are likely to be stack dominated. Constant-injection measurements were used to estimate areas in the stairwell. Three variations of the constant-concentration tracer gas technique can be used to measure outside airflows into individual apartments and allow certain interzone airflows to be estimated. These techniquesapplied to the apartment building showed that apartments exchange air primarily with the outside at rates depending heavily on window openings.
KEYWORDS multifamily building, heat loss, energy consumption, pressurization testing, tracer gas measurements, apartment building, fan, constant concentration, window opening

#NO 2959 The modelling of stairwell flows.
AUTHOR Reynolds A J, Mokhtarzadeh-Dehghan M R, Zohrabian A S
BIBINF Building and Environment, Vol 23, No 1, pp 63-66, 1988, 1 tab, 1 ref. #DATE 00:01:1988 in English
ABSTRACT This paper extends an earlier investigation of scale effects on buoyancy-driven recirculation flows in stairwells of the kind adopted in domestic accommodation. Further consideration is given to the role of Reynolds number, which proves to have unexpected features, possibly because stairwell flows fall into the range of incipient instability. A technique is developed to introduce explicitly the fraction defining the way in which the energy loss from the system is divided between the regions above and below the stairway. Finally, it is shown that a single empirical constant suffices to complete relationships among key features of the processes of heat and mass transfer. The resulting formulae are suitable for incorporation within computer models balances for complete buildings.
KEYWORDS mathematical modelling

#NO 3131 Zone to zone tracer gas measurements; laboratory calibration and values of air flows up and down stairs in houses.
AUTHOR Riffat S B, Walker J, Littler J
BIBINF in: "Effective Ventilation", 9th AIVC Conference, Gent, Belgium, 12-15 September, 1988. #DATE 00:09:1988 in English
ABSTRACT This work is concerned with measuring air flows between the floors of houses. A simple measuring technique is described in which two portable SF6 systems were employed. The design and construction of the portable system are presented. A comparison of air flow patterns in a superinsulated house and a standard house is made. Results showed that the air flow between the upper and lower floors of the superinsulated house was about 20 m3/h compared with 100 m3/h in the traditionally built house. The method has also been validated in the laboratory by measuring air flows between two small chambers

using both the tracer systems and an independent flow device.
KEYWORDS tracer gas, air flow, sulphur hexafluoride, tight house

#NO 3135 A numerical study of buoyancy-driven flows of mass and energy in a stairwell.
AUTHOR Zohrabian A S, Mokhtarzadieh-Dehghan M R
BIBINF in: " Effective Ventilation", 9th AIVC Conference, Gent, Belgium, 12-15 September, 1988. #DATE 00:09:1988 in English
ABSTRACT This paper describes a two-dimensional numerical study, by finite-volume method of buoyancy-driven flow in a half-scale model of a stairwell. The stairwell forms a closed system within which the circulation of air is maintained by the supply of heat in the lower floor. The heat loss takes place from the stairwell walls. The mathematical model consists of the governing equations of mass, energy, momentum and those of the k - E model of turbulence. The predicted flow pattern and the velocity in the stairway are presented and compared with the authors' experimental data.
KEYWORDS air flow, mathematical model

#NO 3376 Stairwell pressurization in a cold climate.
AUTHOR Clark J A, Harris J W
BIBINF Preprint: Ashrae Transactions, Vol 95, Part 1, 5pp, 3 figs, 3 refs. #DATE 00:00:1989 in English
ABSTRACT The three national model building codes require pressurization systems for high-rise buildings. The goal of stairwell pressurization is to provide a relatively smoke-free evacuation route by maintaining a pressure differential across a stairwell door opening, thereby preventing smoke infiltration. This goal is difficult to attain in cold climates due to weather extremes that relate to stack effect, increased wind effect, and the additional problem of heating the stairwell. This paper discusses the design, construction, testing, and computer modelling of the stairwell pressurization system of a 14-story hotel built in Minneapolis, MN.
KEYWORDS building code, high rise building, pressure differential, smoke movement, stack effect, wind effect, modelling

#NO 3459 Full scale smoke control tests at the Plaza Hotel building.
AUTHOR Klote J
BIBINF ASHRAE Journal, April 1989, pp.28-32, 1 tab, 7 refs. #DATE 00:00:1989 in English
ABSTRACT The objective of this project article is to evaluate the current approach to achieve smoke control for smoke control systems with and without stairwell pressurization. This approach is described in sections on pressure difference and air changes, with particular reference to the Plaza Hotel Building. The interaction between smoke control and the fire is also studied.
KEYWORDS smoke, smoke movement, pressure difference, air change rate

#NO 3583 Buoyancy-driven air flow in a closed half scale stairwell model: velocity and temperature measurements.
AUTHOR Zohrabian A S, Mokhtarzadeh-Dehghan M R, Reynolds A J
BIBINF in:UK, AIVC, 10th AIVC Conference, held at Espoo, Finland, 25-28 September 1989, Volume 2, February 1990, pp167-187, 7 figs, 6 tabs, 18 refs. #DATE 00:02:1990 in English
ABSTRACT This paper describes an experimental study of the buoyancy-driven flow and the associated energy transfer within a closed, half-scale stairwell model. It provides new data on the velocity, temperature, volume and mass flow rates of the air circulating between the upper and lower storeys. The results are presented for various heat input rates from the heater, located in the lower floor. For most of the data presented, heat transfer to the surrounding atmosphere takes place through the side walls. However, the case of insulated side walls is also included and the effects on the parameters of interest are discussed. The velocities were measured using hot-wire anemometers of a temperature compensated type, and the temperatures were measured using platinum resistance thermometers. These measurements were supported by flow visualisation using smoke. The paper also provides data on the rate of leakage through the stairwell joints, measured using a concentration decay method.
KEYWORDS air movement

#NO 3609 Ventilation and indoor air quality in a modern office building.
AUTHOR Grot R A, Persily A, Hodgson A T, Daisey J M
BIBINF in: UK, 9th Conference AIVC, "Effective Ventilation" Gent, Belgium, 12-15 September 1988,

Vol.2, pp303-326, 25 figs, 1 tab, 4 refs. #DATE 00:09:1988 in English
ABSTRACT The new office building study is being investigated in order to establish a long-term record of a modern office building's thermal and environmental performance and to document what parameters in the design, construction and operation of a new office building will effect this performance. Other than initial problems associated with "debugging" the HVAC system and controls, the building has adequate ventilation under most operating conditions. The envelope of the building is not tight for a new office building and infiltration is a significant source of building air exchange. The levels of CO2, HCHO, radon and respirable particles are well within the established guidelines. An area of concern is the airflow from the garage into the occupied space. This airflow can cause high levels of CO2 in the vicinity of elevator shafts and stairwells on the upper levels and near the loading dock. The garage exhaust fans are adequate to reverse this flow, but in the automatic mode they currently do not operate for a sufficient amount of time to do so. A change in their controls, or an attempt to isolate the vertical shafts (stairs and elevators) from the garage, would alleviate these problems. There is no evidence of any significant outgassing of pollutants from the building materials and furnishings. There is however a total of at least 37 volatile organic compounds in the building air which seem to be related to the activities occurring in the building. The levels of all these compounds are of at least two orders of magnitude below established limits (1/10th of the TLV's). However, the vast amount of VOCs found in the building are compounds for which no extensive amount of research has been done to establish irritant levels and therefore these compounds could be a source of complaints from the building's occupants at low ventilation rates.
KEYWORDS office building, indoor air quality, thermal performance, organic compound, pollutant

#NO 3826 Heat distribution by natural convection.
AUTHOR Balcomb J D, Yamaguchi K
BIBINF in Proceedings 8th National Passive Solar Conference, Sante Fe, NM, Boulder, CO, USA: ASES, 1983. #DATE 00:00:1983 in English
ABSTRACT Natural convection between spaces in a building can play a major role in energy transfer. Two situations are investigated: convection through a single doorway into a remote room and a convective loop in a two-story house with a south sunspace where a north stairway serves as the return path. A doorway-sizing equation is given for the single-door case. Detailed data are given from the monitoring of airflow in one two-story house. and summary data are given for five others. Observations on the nature of the airflow and design guidelines are presented.
KEYWORDS air flow, convection

#NO 3835 Description and preliminary validation of a model for natural convection heat and air transport in passive solar buildings.
AUTHOR Jones G F, Balcomb J D
BIBINF USA, in Proceedings 10th National Passive Solar Conference, 1985. #DATE 00:00:1985 in English
ABSTRACT We have proposed a transient, quasi-two-dimensional, numerical model for interzone heat flow and airflow in passive solar buildings. The paths for heat flow and airflow are through connecting apertures such as doorways, hallways, and stairways. The model includes the major features that influence interzone convection as determined from the results of our flow visualisation tests, and temperature and airflow measurements taken in more than a dozen passive solar buildings. The model includes laminar and turbulent quasi-steady boundary-layer equations at vertical heated or cooled walls which are coupled to a one-dimensional core model for each zone. The cores in each zone exchange air and energy through the aperture which is modelled by a Bernoulli equation. Preliminary results from the model are in general agreement with data obtained in full-scale buildings and laboratory experiments. The model predicts room-core temperature stratification of about 2 deg. C/m (1.1 F/ft) and maximum aperture velocities of 0.08 m/s (15 ft/min.) for a room-to-room temperature difference of 1 deg.F.
KEYWORDS passive solar building, air flow

#NO 3893 Improvement of air quality in schools by enhanced air transfer.
Battre luftkvalitet i skolar genom forcerad overluftsforing.
AUTHOR Vikstrom P
BIBINF Sweden, Stockholm, Swedish Council for Building Research, R77:1989, 28pp.#DATE 00:00:1989 in Swedish

ABSTRACT In certain buildings there are rooms which are heavily loaded from the ventilation standpoint, and at the same time there may be adjoining rooms where the load is light. This may be the case in e.g. classrooms with adjoining corridors and stairways. The quality of air in the heavily loaded room can be improved by using a fan to enhance transfer of air between the adjoining room and the room to be ventilated. The effect of enhanced air transfer is dictated by the size of the adjoining room and the ventilation in this room. The greater the volume of the adjoining room in relation to the room to be ventilated, the longer it takes for an equilibrium concentration to be established. Ventilation in the adjoining room assists in removing contaminants and in this way lowers equilibrium concentration. The aspect of different factors is set out in a chart. Measurements in a school show that in a classroom with a very low extract air flow a substantial improvement is achieved by means of enhanced air transfer. Calculations based on the measurement results show that enhanced air transfer in all classrooms along the corridor would have a limited effect on air quality in the classrooms.
KEYWORDS indoor air quality, school, fan

#NO 3904 Smoke control technology. Overview.
AUTHOR Klote J H
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp1-8, 2 figs, 2 tabs, refs.#DATE 00:00:1989 in English
ABSTRACT Considerable advances in smoke control technology have occurred in the last few decades. However, smoke control is just beginning to take its proper place as a fire protection tool. This paper provides an overview of this technology, including discussions of the fundamental principles, stairwell pressurization, zoned smoke control, elevator smoke control, system activation, and acceptance testing. In addition, the problems of smoke purging are addressed.
KEYWORDS smoke movement, fire, stairwell pressurization

#NO 3906 Pressure drop characteristics of typical stairshafts in high-rise buildings.
AUTHOR Achakji G Y, Tamura G T
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp45-50, 9 figs, 2 tabs, refs. #DATE 00:00:1989 in English
ABSTRACT Little information exists on the pressure drop characteristics in tall buildings. Full-scale tests were conducted, therefore, to develop data on the airflow resistance required for designing a smoke control system for stairshafts by the pressurization technique. Data were obtained for open and closed tread stairshafts, with and without people inside them. The study revealed that the flow resistance inside the stairshaft with people can be double that without people. Also, a simple physical model to stimualte the effect of people on the flow resistance was developed. This paper describes the analytic model, the experimental study, and the data obtained on the airflow resistance for the various stair configurations.
KEYWORDS pressure drop, stairwell, high rise building

#NO 4331 Condensation, heating and ventilation in small houses.
AUTHOR Raw G J, Fox T A
BIBINF Netherlands, International CIB W67 Symposium, "Energy, moisture and climate in buildings", 3-6 September 1990, Rotterdam, pI27, 1 tab. #DATE 00:09:1990 in English
ABSTRACT BRE has investigated condensation in recently built 1-bedroom and bedsit homes in the UK. The study revealed significant condensation problems and gave an indication of the factors related to condensation: ventilation devices (particularly a passive ventilator in the bedroom, a mechanical ventilator in the kitchen and/or bathroom, or an air brick in any inner hall or landing); air movement (via stairs); heating (particularly the heating period and using bottled gas) and insulation. These factors were more important than occupant behaviour and "energy consciousness". It seems therefore that ventilation and heating facilities which depend on occupant behaviour are generally used effectively. The most important occupant characteristics were the number and age of occupants.
KEYWORDS condensation, heating, ventilation rate, residential building

#NO 4560 Stair pressurization systems for smoke control: design considerations.
AUTHOR Tamura G T
BIBINF USA, ASHRAE Transactions, Vol 95, Pt 2, 1989, 9pp. #DATE 00:00:1989 in English
ABSTRACT Literature on the various types of pressurization systems, stair use during evacuation, and

code requirements was reviewed and summarized. Non-fire and fire tests were conducted in the 10-story experimental fire tower of the National Fire Laboratory of the National Research Council of Canada. The flow resistance of an open stair door at various angles were measured. Under fire conditions, the vertical profiles of pressure differences across the stairshaft wall and those of the velocity pressure at the stair door opening were measured. With the stairshaft pressurized, the critical velocities required to prevent smoke backflow at the stair door opening on the fire floor were determined and compared with the calculated values for various fire temperatures.
KEYWORDS pressurisation, smoke control, building design

#NO 4680 Nighttime ventilation by stack effect.
AUTHOR van der Maas J, Roulet C-A
BIBINF USA, Ashrae Transactions, Vol 97, Part 1, 1991, Preprint, 9pp, 7 figs, refs. #DATE 00:00:1991 in English
ABSTRACT In the summer, ventilation at night is used to increase thermal comfort in an experimental three-level laboratory. To this effect, special apertures, which stay open during the summer nights, are provided at ground level and on the roof, allowing natural ventilation of the high-mass staircase and building. this paper concerns a case where the high-mass staircase (all internal doors closed) was cooled by stack ventilation. The temperatures of the inflowing air, the exhaust air, and the wall were measured as a function of time. the time dependence of the exhaust air and wall temperatures is compared with a simple dynamic model that couples air flow, heat transfer, and a thermal model for the wall. The agreement is good. The heat loss rate is an output parameter that can be used in energy calculation. For given openings, the model predicts that the total heat extracted from the building during the night can be maximized by increasing the heat-exchanging surface area (e.g., all internal doors open) and by increasing the thermal effusivity, of the wall materials. Further validation of the model is needed and mechanical ventilationshould be included. However, in principle, a simple design tool can be made showing the effect of opening sizes, wall surface area, and wall thermal properties on the energy consequences of night ventilation for a particular climate.
KEYWORDS stack effect, cooling

#NO 4845 Two-directional air movements in stairwells.
AUTHOR Edwards R, Irwin C
BIBINF UK, AIVC 11th Conference, "Ventilation System Performance", held 18-21 September 1990, Belgirate, Italy, Proceedings published March 1990, Volume 1, pp 379-388, 4 figs, 1 tab, 3 refs. #DATE 00:03:1991 in English
ABSTRACT The predominant route for air movements between the floors of two-storey dwellings is via the stairwell. Such air movements are of significance in the assessment of building performance: for instance, it is possible that moisture could be transferred from ground floor areas to rooms on the first floor, resulting in an increase in condensation risk in such rooms. Severaldomestic heating schemes have been designed such that heating appliances are provided on the ground floor only; the upper floor relying on convective airflows for heating. If the ground floor to first floor airflow induce by such a system is too small, then the upstairs room will not attain the desired temperature, which in turn could lead to condensation problems, quite apart from the issue of occupant discomfort. This paper summarises two case studies of air movement measurements performed by means of the UMIST PCS system, and analyses the data in terms of moisture migration and heat transfer.
KEYWORDS air movement, stairwell, heat transfer, moisture

#NO 5123 An evaluation of a network smoke control model.
AUTHOR Said M N A, MacDonald R A
BIBINF Preprint, USA, ASHRAE Transactions, Vol 97, Pt 1, 1991, 13 figs, refs. #DATE 00:00:1991 in English
ABSTRACT This paper describes the evaluation of the air and smoke movement model developed at a Canadian research institute. To verify the model, predicted data are compared with data from full-scale fire tests involving a pressurized stair shaft smoke control system. The tests were conducted in the 10-story experimental fire tower at the National Fire Laboratory of the National Research Council of Canada. Predicted data exhibit good agreement with measured data. The paper also discusses the effects of large exterior and interior openings and the pressure due to the fire on the building's pressures and on smoke migration.
KEYWORDS smoke control, modelling

#NO 5125 Overall and component airtightness values of a five-storey apartment building.
AUTHOR Shaw C Y, Magee R J, Rousseau J
BIBINF Preprint, USA, ASHRAE Transactions, Vol 97, Pt 2, 1991, 11 figs, refs. #DATE 00:00:1991 in English
ABSTRACT Fan pressurization and balanced fan pressurization tests were conducted on a five-story apartment building to determine its air leakage characteristics. The overall airtightness of the building envelope and the airtightness values of the exterior walls of three individual stories were obtained, as well as the airtightness values of interior partitions, stairwells, and floor/ceiling separations. The methods used to measure the airtightness values are described, and the test results are reported.
KEYWORDS air tightness, apartment building, fan pressurisation

#NO 5145 Stair pressurization systems for smoke control.
AUTHOR Tamura G T
BIBINF USA, Ashrae Journal, July 1991, pp 14-18, 3 figs, 15 refs. #DATE 00:07:1991 in English
ABSTRACT In this article, the results of preliminary studies conducted during the first phase of ASHRAE Research Project 559RP are presented. The studies examined the critical air velocities needed to prevent smoke backflow at an open stair door.
KEYWORDS smoke control, pressurization, stairwell

#NO 5265 Airflow patterns in a five-storey apartment building.
AUTHOR Shaw C, Reardon J, Said M, Magee R
BIBINF UK, AIVC 12th Conference, "Air Movement and Ventilation Control within Buildings", held 24-27 September 1991, Ottawa, Canada, proceedings published September 1991, Volume 1, pp 359-374. #DATE 00:09:1991 in English
ABSTRACT Tracer gas tests were conducted on a five-storey apartment building to determine the air and contaminant flow patterns within the building. The test method involves the injection of a small amount of tracer gas, SF6, into a selected location to create a single source and monitoring the tracer gas concentrations at locations throughout the building. Based on the rates at which the tracer gas concentrations change at various locations, the air and contaminant flow patterns within the building can be determined. Several such tests were conducted. In each test, the tracer gas was injected into one of three locations: a garbage room on the ground floor, a party room in the basement and the supply air duct of the building's heating and ventilating system. This paper presents the results of the tracer gas tests. It also includes measurements of the overall airtightness of the building envelope, the exterior wall airtightness values of three individual storeys, and the airtightness values of interior partitions, stairwells and floor/ceiling separations.
KEYWORDS air flow, apartment building, tracer gas measurements, contaminant

#NO 5582 Field tests on staircase pressurization system in Hong Kong.
AUTHOR Chow W K, Lam Wai L, Cheung K P, Lam K C
BIBINF USA, Ashrae, Far East Conference on Environmental Quality, held Hong Kong, 5-8 November 1991, pp 27-38, 13 figs, 3 tabs, refs. #DATE 05:11:1991 in English
ABSTRACT This paper reports a series of field tests on the performance of staircase pressurization systems. The differential pressurelevels across the doors to the staircase, airflow rate, air temperature, and fan characteristics are measured. A review on the present local fire regulations is also presented. The airflow network program ASCOS was also used to simulate the system. By comparing the measured field test results with those simulated by the computer model, modification to the operation is proposed. Recommendations are made for improving the future design of these smoke control systems.
KEYWORDS stairwell, pressurisation, air flow, temperature, building regulations, smoke control

#NO 5589 An experimental study of maximum allowable pressure differences for staircases.
AUTHOR Xu Ming
BIBINF USA, Ashrae, Far East Conference on Environmental Quality, held Hong Kong, 5-8 November 1991, pp 163-165, 6 figs, 4 tabs, refs. #DATE 05:11:1991 in English
ABSTRACT When a high-rise building is on fire, a forced draft system must maintain the fire protection staircase at a given pressure difference relative to other parts of the building to prevent smoke from coming in. The volume of forced draft is determined by both minimum smoke-resisting air pressure and the maximum allowable pressure difference for not obstructing the evacuation of people inside. The

latter is connected with national conditions, which are obtained by employing a simulation method and statistics of a 200 person-time experiment measured in various high-rise buildings.
KEYWORDS pressure difference, stairwell

#NO 5633 Assessment of stair pressurization systems for smoke control.
AUTHOR Tamura G T
BIBINF USA, Ashrae, Transactions, Vol 98, Part 1, 1992, 7pp, 5 figs, refs. #DATE 00:00:1992 in English
ABSTRACT An ASHRAE research project (RP-559) was undertaken to investigate the performance of various methods of overpressure relief for stair pressurization systems. The project consisted of four phases-a literature review of stair pressurization systems, field tests, fire tower tests, and computer model studies. The types of overpressure relief systems investigated were exit door relief, barometric damper relief, and feedback control, either with fan bypass, a variable-pitch blade fan, or a variable-speed fan. A related ASHRAE research project (RP-660) was conducted to determine the critical air velocities required to prevent smoke backflow at a stair door opening for various fire conditions. Using the results of these two research projects, this paper assesses the performance of stair pressurization systems and makes recommendations for their suitable application.
KEYWORDS smoke control, stair pressurisation, review, modelling, fan

#NO 6029 Two- and three-dimensional finite-volume predictions of flow in a stairwell and comparison with experiment.
AUTHOR Ergin-Ozkan S, Mokhtarzadeh-Dehghan M R, Reynolds A J
BIBINF Japan, Society of Heating, Air Conditioning and Sanitary Engineers of Japan, 1992, proceedings of the International Symposium on Room Air Convection and Ventilation Effectiveness - ISRACVE, held at the University of Tokyo, 22-24 July, 1992, pp 201-206. #DATE 22:07:1992 in English
ABSTRACT The paper describes a numerical study of three-dimensional buoyancy-driven flow in a stairwell. The HARWELL-FLOW3D computer program which uses the finite-volume method and incorporates the k-e turbulence model was employed. The thermal boundary conditions at the walls are those measured by the authors. The radiation exchanges between surfaces are calculated separately and then incorporated in the numerical computation via the boundary conditions. Two- and three-dimensional predictions of the temperature and velocity fields are presented and the results are compared with experimental data. Comparisons have also been made with two-dimensional predictions.
KEYWORDS numerical modelling, air flow, stairwell

Other References

ASHRAE (1987), Fire and Smoke control. HVAC Handbook. pp58.1 - 58.16.

McNemar J, (1976), Emergancy stairwell ventilation. ASHRAE Journal. July 1975. pp44 - 46.

Reynolds A J (1986), The scaling of flows of energy and mass through stairwells. Building and Environment. Vol 21, pp149-??

Shaw and Tamura (1976), Design of a stairshaft pressurization system for tall buildings. ASHRAE Journal Feb. 1976. pp29 - 33.
ABSTRACT. Pressurization by injecting outdoor air into a stairshaft is one means of maintaining tenable conditions in it during a fir emergenacy. Studies were made on various factors that govern performance of stairshaft pressurization systems. Proposed here is s design for one such systemunder various fire conditions was investigated using a computer model of the building.
KEYWORDS Stairwell, Stair shaft, pressurisation, HVAC system, tall building. SEE REF #299.

5 (c). Lift Shaft References.

#NO 140 Pressure differences for nine-storey building as a result of chimney effect and ventilation system operation.
AUTHOR Tamura G.T. Wilson A.G.
BIBINF ASHRAE trans vol 72 p180-189 #DATE 24:01:1966 in English #AIC 1257
ABSTRACT Discusses theoretical pattern of pressure differences inside a tall building and describes measurement of pressure made on a nine-storey building in Ottawa. Pressure differences were measured across external walls, vertical shafts, stairwell doors and elevator doors with the mechanical ventilation system both on and off. Concludes that pres-

sure differences across external walls depend on the distribution of openings in the exterior wall and of the ratio of resistance to air flow inside the building to that across the exterior wall. These can be measured by the position of the neutral zone and the ratio of actual to theoretical draft.
KEYWORDS pressure difference, stack effect, high rise building,

#NO 299 Air leakage data for the design of elevator and stair shaft pressurization system.
AUTHOR Tamura G.T. Shaw C.Y.
BIBINF ASHRAE trans vol 82 part 2 p179-190 8 figs, 3 tabs, 8 refs. D.B.R. Paper No. 717 #DATE 01:06:1976 in English
ABSTRACT Describes research project to find air leakage values of walls of elevator and stair shafts in order to use these values in the design of pressurization systems. Describes method of test and gives results. Concludes that leakage rates for walls of elevator shafts constructed of masonary units are higher than those of cast-in-place concrete. Variations in the leakage of stair shafts could not be related to the type of wall construction but probably depended on the workmanship in sealing crack openings. Finds that internal flow resistance of a stair shaft is substantial and must be taken into account in designing a stair shaft pressurization system.
KEYWORDS air leakage, elevator shaft, wall, pressurization

#NO 1489 Disturbances in ventilation systems. Part 1 and Part 2
AUTHOR Rydberg J.
BIBINF Heat.Vent.Engr. May 1960, 483-485,489, June 1960, 541-547, 9 figs, 2 refs. #DATE 00:05:1960 in English #AIC 928A and
ABSTRACT The quantity of air in several rooms lying in a stack connected by means of fresh air and exhaust air ducts is considered as a simple model of a multistorey building. Negative pressures set up within the rooms can be equalised by adjusting the valves and resistances of the ducts. The effects of differing air quantities in one of the rooms caused by window opening and thermal forces and the difference in indoor and outdoor temperature, on the pressure distribution and air quantities in the rest of the system is considered. The counteraction of disturbances caused by thermal forces by choking exhaust valves or connecting pipes or throttling the main duct to the fans is discussed. Air leakage into the lowest floor level as a result of negative pressure in the room is quantified. Vertical zoning as an aid to the reduction of pressure driven flow in high buildings is recommended. Noise, air flow in open staircases and lift shafts and disturbances due to wind are also considered.
KEYWORDS ventilation, high rise building, air leakage, air flow, pressure difference, pressure drop, window, air infiltration, mechanical ventilation, air conditioning, wind, modelling, elevator shaft

#NO 2058 Natural Venting to Control Smoke Movement in Buildings Via Vertical Shafts.
AUTHOR Tamura, G. T.; Wilson, A. G.;
BIBINF RESEARCH.LOC = Ottawa, Canada; TYPE = REPORT; #DATE 01:07:1970; VOLUME.TITLE = ASHRAE Trans.; VOLUME.NO = 76; PAGES = 279-289; REPORT.NO = 2162; PUBLISHER.NAME = ASHRAE; in English
ABSTRACT Effects of vertical shaft venting on smoke movement in tall buildings are examined in order to obtain conditions for minimum smoke filtration into upper floors, stairways, and elevator shafts during fires. Results show that sufficient bottom venting will nearly eliminate flow of air into shafts, while top venting reduces flow from shafts. Either should reduce smoke transfer between levels. Multiple shaft buildings benefit from top venting some and bottom venting others, reducing necessary vent size for sufficient ventilation.
KEYWORDS VENTILATION; SMOKE; AIR FLOW; HIGH-RISE BUILDING;

#NO 3609 Ventilation and indoor air quality in a modern office building.
AUTHOR Grot R A, Persily A, Hodgson A T, Daisey J M
BIBINF in: UK, 9th Conference AIVC, "Effective Ventilation" Gent, Belgium, 12-15 September 1988, Vol.2, pp303-326, 25 figs, 1 tab, 4 refs. #DATE 00:09:1988 in English
ABSTRACT The new office building study is being investigated in order to establish a long-term record of a modern office building's thermal and environmental performance and to document what parameters in the design, construction and operation of a new office building will effect this performance. Other than initial problems associated with "debugging" the HVAC system and controls, the building has adequate ventilation under most operating conditions. The envelope of the building is not tight for

a new office building and infiltration is a significant source of building air exchange. The levels of CO2, HCHO, radon and respirable particles are well within the established guidelines. An area of concern is the airflow from the garage into the occupied space. This airflow can cause high levels of CO2 in the vicinity of elevator shafts and stairwells on the upper levels and near the loading dock. The garage exhaust fans are adequate to reverse this flow, but in the automatic mode they currently do not operate for a sufficient amount of time to do so. A change in their controls, or an attempt to isolate the vertical shafts (stairs and elevators) from the garage, would alleviate these problems. There is no evidence of any significant outgassing of pollutants from the building materials and furnishings. There is however a total of at least 37 volatile organic compounds in the building air which seem to be related to the activities occurring in the building. The levels of all these compounds are of at least two orders of magnitude below established limits (1/10th of the TLV's). However, the vast amount of VOCs found in the building are compounds for which no extensive amount of research has been done to establish irritant levels and therefore these compounds could be a source of complaints from the building's occupants at low ventilation rates.
KEYWORDS office building, indoor air quality, thermal performance, organic compound, pollutant

#NO 3904 Smoke control technology. Overview.
AUTHOR Klote J H
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp1-8, 2 figs, 2 tabs, refs. #DATE 00:00:1989 in English
ABSTRACT Considerable advances in smoke control technology have occurred in the last few decades. However, smoke control is just beginning to take its proper place as a fire protection tool. This paper provides an overview of this technology, including discussions of the fundamental principles, stairwell pressurization, zoned smoke control, elevator smoke control, system activation, and acceptance testing. In addition, the problems of smoke purging are addressed.
KEYWORDS smoke movement, fire, stairwell pressurization

#NO 3905 Information-based smoke control systems.
AUTHOR Shavit G
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp37-43, 5 figs,refs. #DATE 00:00:1989 in English
ABSTRACT Until recently fire management and smoke control systems (FM&SCS) provided only the minimum functionality necessary for life safety in buildings. Because of this it was difficult to understand what happened in a building during fire conditions. For example, during a real alarm, users needed to know if the automatic control system performed the necessary functions. Since the FM&SCS did not provide feedback, it was difficult for system operators to understand what happened in a building during fire conditions. The resultant trend was to simplify the automatic smoke control sequences ("keep-it-simple" concept) so that feedback wasn't a necessary function. In parallel, the research and experimental testing of smoke movement in buildings continued and it was found that smoke containment is a dynamic process and building conditions vary during fire situations. Research was also conducted on the use of elevators, not only for firefighting, but also for evacuation of the handicapped and elderly. At the same time, rapid development of microelectronic technology took place to provide cost-effective solutions. Today, with the emergence of new sensor technology and with the opportunities of distributed processing, a systems approach to fire and smoke control may provide the tools to resolve problems with existing systems. HVAC control systems designed to work effectively with FM&SCS can now provide a cost-effective and highly reliable total system approach to life safety.
KEYWORDS smoke movement, fire

#NO 3908 Experimental fire tower studies of elevator pressurization systems for smoke control.
AUTHOR Tamura G T, Klote J H
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp61-72, 6 figs, 8 tabs, refs. #DATE 00:00:1989 in English
ABSTRACT Tests were conducted in the experimental fire tower at the National Research Council of Canada to study smoke movement through elevator shafts caused by a large fire and to determine the effectiveness of mechanical pressurization in keeping the elevator shaft and lobbies tenable for evacuation of the handicapped and for use by firefighters. The tests indicated that pressure control is required

to cope with loss of pressurization due to open doors. Equations were developed to assist in designing pressure control systems involving either a variable supply air rate with feedback control or relief dampers in the walls of the elevator shaft or lobbies. Tests conducted in the tower indicated that for both methods of pressure control, comparison of measured and calculated values of supply air rates and pressure differences are in good agreement.
KEYWORDS fire, elevator shaft, smoke control, pressurisation

#NO 3909 Experiments of piston effect on elevator smoke control.
AUTHOR Klote J H, Tamura G T
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp73-78, 4 figs, 1 tab, refs.
#DATE 00:00:1989 in English
ABSTRACT The transient pressures produced when an elevator car moves in a shaft are a potential problem for elevator smoke control systems. This piston effect can pull smoke into a normally pressurized elevator lobby. This paper presents the results of piston-effect experiments under smoke control conditions. The results of a theoretical analysis and those of the experiments are in good agreement. For most elevators, the piston-effect problem can be overcome by designs that prevent smoke from being pulled into elevator lobbies, and equations for the amount of pressurization air needed to accomplish this are presented.
KEYWORDS elevator shaft, smoke control

#NO 3910 Presently, elevators are not safe in fire emergencies.
AUTHOR Sumka E H
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp79-82, 1 fig, 2 tabs, refs.
#DATE 00:00:1989 in English
ABSTRACT A comprehensive study by elevator experts led to recommendations for code rule to be incorporated into ANSI/ASME A17.1 Elevator Safety Code. Recommendations were approved by the A17.1 code-making body, and operation of elevators in fire emergencies became part of the elevator code that has almost universal acceptance and has become the basis for local, state, and even foreign codes. Background information that supports the emergency use of elevators is provided. This information details elevator operation for purposes of providing insight to the uninitiated. Sprinklers, power supply, smoke, pressurization, entrances, and stack effect are among the topics that are covered. Interface of the A17.1 Elevator Safety Code with the three major Model Building Codes and National Fire Protection Association (NFPA) code committees provides for safe operation of elevators during fire emergencies.
KEYWORDS fire, elevator shaft, smoke, pressurisation, stack effect

New References.

Tamblyn R T (1991), Coping with Air Pressure Problems in Tall Buildings. ASHRAE Trans. Vol 97, Pt1, pp824 - 827.
ABSTRACT. All buildings exhibit stack effect in cold weather. This is a phenomenon caused by the difference in weight of warm air columns within the building and cold air columns outside. In tall buildings, the stack effect cause unique problems such as elevator sticking and washroom exhaust imbalance. This article explains the cause and outlines HVAC solutions.
KEYWORDS. Stack Effect, Tall building, Pressure

Copies of the documents listed in the previous pages are available from the following address

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Ventilation and Infiltration Characteristics of Lift Shafts and Stair Wells Bibliography Update March 1998

Stair wells

#NO 3906 Pressure drop characteristics of typical stairshafts in high-rise buildings.
AUTHOR Achakji G Y, Tamura G T
BIBINF USA, in: ASHRAE Technical Data Bulletin, Vol 5, No 2, 1989, pp45-50, 9 figs, 2 tabs, refs. #DATE 00:00:1989 in English
ABSTRACT Little information exists on the pressure drop characteristics in tall buildings. Full-scale tests were conducted, therefore, to develop data on the airflow resistance required for designing a smoke control system for stairshafts by the pressurization technique. Data were obtained foropen and closed tread stairshafts, with and without people inside them.The study revealed that the flow resistance inside the stairshaft with people can be double that without people. Also, a simple physical model to stimualte the effect of people on the flow resistance was developed. This paper describes the analytic model, the experimental study, and the data obtained on the airflow resistance for the various stair configurations.
KEYWORDS pressure drop, stairwell, high rise building

#NO 6108 Design of a stairshaft pressurization system for tall buildings.
AUTHOR Shaw C Y, Tamura G T
BIBINF USA, Ashrae Journal, February 1976, pp 29-33, 4 figs, 11 refs. #DATE 00:02:1976 in English
ABSTRACT Pressurization by injecting outdoor air into stairshaft is one means of maintaining tenable conditions in it during a fire emergency. Studies were made on various factors that govern performance of stairshaft-pressurization systems. Proposed here is a design for one such system. The performance of this system under various fire conditions was investigated using a computer model of the building.
KEYWORDS stairwell, pressurization, high rise building

#NO 6102 Air-flow studies in multizone buildings: models and applications.
AUTHOR Herrlin M K
BIBINF Sweden, Royal Inst of Technology, Dept of Building Services Engineering, Bulletin No 23, September 1992, 210pp. #DATE 00:09:1992 in English
ABSTRACT Air-flow studies in multizone buildings have been somewhat limited because simulation programs for interzonal air flows in buildings have not been readily available. The approach in this research was to develop a computer program for simulating air flows and pollutant transports in multizone buildings and to demonstrate its application to a typical Swedish multistory residential building, with emphasis on a comparison of exhaust and exhaust-supply ventilation systems. Studies were performed under different climatic conditions and assumed normal building operations and typical building leakage levels. For floor plans, dimensions, and building materials, excellent statistics are available. A considerable amount of good quality data was also found for duct components and weatherstatistics. As for leakage data, however, very little is available for multizone structures. The steady-state air-flow model described here simultaneously solves the interzonal flows and the flows in ventilation ducts; the fast and reliable solver used stood up well against other methods. At highly turbulent conditions, steady-state assumptions can introduce significant errors; accordingly, the model is better suited for parametric studies than as a tool for evaluating full-scale measurements. The dynamic pollutant transport model was found to be useful for estimating air movements in the building. Even though the absolute air-flow changes were generally small, there were clear differences in the performance of the two ventilation systems. The exhaust-ventilation system allows a pressure hierarchy that is beneficial for controlling interzonal airflows and exfiltration. This hierarchy turns into a disadvantage under some normal building operations, however, and substantially reduces the air-exchange rates in upper-level apartments. The exhaust-supply ventilation system guarantees minimum air-exchange under all conditions. A drawback of this system is that air flows from apartments on the lower levels to apartments on the upper levels via the staircase, and pollutants can also be transported.Because of varying temperatures in the central air-handling unit, variations in exhaust and supply flow rates are fairly large. In both systems, the air-exchange sensitivity to increased leakage levels was small to moderate. The development and application of this program promises to enhance the way we approach air-flow studies in multizone buildings and thereby encourage future research in this and related fields.
KEYWORDS air flow, multizone building, modelling, pollutant

#NO 6112 Field checks on building pressurization for smoke control in high-rise buildings.
AUTHOR Tamura G T, Shaw C Y
BIBINF USA, Ashrae Journal, February 1981, pp 21-25, 6 figs, 4 refs. #DATE 00:02:1981 in English
ABSTRACT Measurements made on two buildings reveal that leaky wall construction of a smoke shaft can seriously affect the performance of a smoke control system. Also revealed is that a stairshaft can be contaminated with smoke, particularly in summer when the stair door on the fire floor andthe exit door of the same stairshaft are opened at the same time.
KEYWORDS smoke control, pressurization, high rise building, wall, air leakage, stairwell

#NO 6114 Emergency stairwell ventilation.
AUTHOR McNemar J L
BIBINF USA, Ashrae Journal, July 1975, pp 44-46, 1 fig. #DATE 00:07:1975 in English
ABSTRACT Gives a detailed appraisal of Brown and Root's emergency stairwell ventilation system at the new Engineering Southwest building in Houston, Texas, USA.
KEYWORDS ventilation system, stairwell, commercial building, high rise building

#NO 6117 The scaling of flows of energy and mass through stairwells.
AUTHOR Reynolds A J
BIBINF UK, Building and Environment, Vol 21, No 3/4, 1986, pp 149-153, 2 tabs, 1 ref. #DATE 00:00:1986 in English
ABSTRACT Simple physical and dimensional arguments are used to determine the laws relating the mass flow induced within a closed recirculating system representative of a domestic stairwell to the energy input driving the flow and the temperature differential established between chambers above and below the stairwell. Appropriate dimensionless groupings are introduced to characterise this kind of system. Experimental results obtained from a one-half scale model of a stairwell are used to validate the simplest analysis and to define the influence of a Reynolds number characteristic of the flow. The results are used to investigate the utility of models of various scales.
KEYWORDS stairwell, air flow, heat loss, modelling

#NO 6221 Air flow and ventilation measured in glazed areas in Narvik.
AUTHOR Eian P, Jensen B, Nielsen A
BIBINF Roomvent '92, Third International Conference, Aalborg, Denmark, September 2-4 1992, Publisher: DANVAK, Lyngby, Denmark, Volume 2, pp 331-342. #DATE 02:09:1992 in English
ABSTRACT In the last decade in Norway it has been normal to build office or shop buildings with glazed spaces. Typical use is for entrance, glass corridors and glazed yards. The heat loss from infiltration cannot be calculated, but must be measured. A special problem is the air change from traffic of persons through a glazed area. In an entrance can the heat loss from door opening be high. For a glass corridor between 2 buildings will traffic give air exchange between the buildings and theglass corridor. Use of traces gas with constant concentration can be used for air change measurements in glazed areas. This is done in a glass corridor, where the air change is found to be approx. 0.4 pr.hour. The influence from traffic can be seen on the results, but to give a expected extra heat loss from that is difficult. Measurement of air change was also done in a staircase with ventilation. Ventilation in the room was expected to give problems, but the results in the glazed staircase showed that was no problem. The worst problem was good mixing of the tracer gas in the larger room. Some of the problems from measurements of air change in glazed spaces are described in the paper. The tracer gas method can be used to evaluate the air tightness of theconstruction system for glass roofs and wall.
KEYWORDS measurement technique, tracer gas, air change rate, commercial building

#NO 6257 The effect of different air inlet sizes on the air flow through a stairwell.
AUTHOR Ergin-Ozkan S, Mokhtarzadeh-Dehghan M R, Reynolds A J
BIBINF Indoor air quality, ventilation and energy conservation, 5th International Jacques Cartier Conference, Montreal, Canada, October 7-9, 1992, publisher: Center for Building Studies, Concordia University, Montreal, Canada, pp 352-359. #DATE 00:10:1992 in English
ABSTRACT An experimental study of the effect of flow through an opening (or a crack) on the natural convection in a stairwell model is presented. The flow is driven by energy input from an electric panel heater located inthe lower floor of the stairwell. The work concentrates on the effect of the size of inlet opening by varying it while keeping the area of the outlet constant. New data are presented for the measured temperatures and velocities at various cross-sections of the stairwell. The results also include gross parameters of the flow, such as the mass flow rates of the through-flow and recirculating flow, heat losses from the lower and upper floors and also from the stairway. The results show that the size of the opening has

a significant effect on the flows of mass and energy within, and through, the stairwell.
KEYWORDS air inlets, stairwell, air flow, modelling, crack

#NO 6522 Comparative performances of mechanical smoke exhaust system, zoned smoke control, and pressurized building method of smoke control.
AUTHOR Tamura G T, MacDonald R A
BIBINF USA, ASHRAE Transactions, Vol 99, Pt 1, 1993, 8pp, 7 figs, 5 tabs, refs. #DATE 00:00:1993 in English
ABSTRACT Non fire and fire tests were conducted in the 10 storey experimental fire tower to evaluate the performance of the mechanical smoke exhaust system, zoned smoke control system, and pressurized building method of smoke control. All three systems have something in common - mechanical exhaust of the fire floor. Tests with fire temperatures of 450 Deg. C and 650 Deg. C indicated that the tower was kept smoke free outside the fire compartment with each system when all stair doors were closed.However, when one or two stair doors were open, including the one on the fire floor, smoke contamination of the stairshaft occurred for all three systems. For the mechanical smoke exhaust system, the entire tower was contaminated when two stair doors were opened. For the zoned smoke control system, only the stairshaft was contaminated, and, for the pressurized building method, the stairshaft and the floor space of the floor above the fire was contaminated. When another stair door was opened, the floor spaces of several floors were contaminated for the zoned smoke control system, whereas the contamination pattern remained unchanged for the pressurized building method of smoke control.
KEYWORDS smoke control, high rise building, stairwell

#NO 6722 A preview of ASHRAE's revised smoke control manual.
AUTHOR Klote J H
BIBINF USA, Ashrae Journal, November 1992, pp 34-37, 4 figs, 16 refs. #DATE 00:11:1992 in English
ABSTRACT New sections of the standard describe systems for stairwell pressurization and zoned, elevator and atrium smoke control.
KEYWORDS smoke control, atrium, stair pressurisation

#NO 7241 Design separately for the pressure requirement and velocity requirement in a "staircase pressurization system" - a case study
AUTHOR Cheung K P; Lam L W; Chow W K
BIBINF UK, CIBSE, proceedings of CLIMA 2000, 1-3 November 1993, Queen Elizabeth II Conference Centre, London, 1993, paper no. 239.
ABSTRACT The publications so far have reported almost no successful cases of staircase pressurization systems. This, and other considerations, have led to a reappraisal on the rationale of the aerodynamics of the current state-of-art of the practice on staircase pressurization systems, leading to an isolation of the sources of air for providing the pressure requirement and the velocity requirement. Out of this isolation process, a possible alternative to the current concept, together with a case study comparison, are presented, as one of a number of other possible, or even better and more reliable, alternatives to the current practice.
KEYWORDS designing stairwells pressurised_stairs pressure case_studies aerodynamics performance reliability

#NO 7259 Fire tower tests on vestibule pressurization for protection of stairshafts.
AUTHOR Tamura G T.
BIBINF USA, Ashrae Transactions, Vol 100, Pt 2, 1994 (preprint), 8 pp, 2 figs, 12 tabs, refs. #DATE 00:00:1994 in English
ABSTRACT A series of tests on various types of stair pressurization systems for providing tenable escape routes during a fire were conducted by the National Research Council of Canada as a joint research project with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Further to this work on protecting the stairshaft from smoke intrusion, the National Research Council of Canada has conducted tests to investigate the performance of (a) a stair vestibule pressurization system alone, (b) a stair vestibule pressurization system incombination with stairshaft pressurization, and (c) a stair vestibule pressurization system in combination with mechanical exhaust of the fire floor. Tests were conducted in the 10-storey experimental fire tower under non fire and fire conditions, with a number of stair and vestibule doors open, including those on the fire floor. For the three systems evaluated, when all stair and vestibule doors were closed, the stairshaft was maintained smoke free. However, when stair and vestibule doors on the second floor (fire floor), third floor, and the exit stair door to the outside were opened, the stairshaft was contaminated with smoke for the vestibule pressurization system alone and for the combination vestibule/stairshaft pressurization system, with

less contamination in the stairshaft of the latter system. Under the same conditions, the stairshaft was essentially smoke free forthe combination of vestibule pressurization and mechanical exhaust of the fire floor, although smoke likely would have entered the stairshaft if additional stair and vestibule doors on the upper floors were opened.
KEYWORDS pressurization, stairwell, smoke control.

#NO 7260 Effect of opening stairwell doors on the performance of a stairshaft pressurization system.
AUTHOR Yuill G K, Haddad K H.
BIBINF USA, Ashrae Transactions, Vol 100, Pt 1, 1994, (preprint), 10 pp, 3 figs, 9 tabs, refs. #DATE 00:00:1994 in English
ABSTRACT Two hypothetical buildings with different leakage characteristics were used to study the effect of the opening of stairwell doors on a top-injection stairwell pressurization system. A flow network program called SMOKESIM was used to perform the simulations. It was found that roof leakage plays a role in whether the design number of open inside stairwell doors should be placed at the top or the bottom of the stairshaft for the most critical design. The data obtained also show that a much bigger fan size is needed when the smoke control system is designed with the outside door open than when a number of inside doors are open. The results also help assess the usefulness of published leakage data in the design of top-injection stairwell pressurization systems.
KEYWORDS stairwell, door, pressurization, roof, air leakage

#NO 7482 The effect of different air inlet sizes on the air flows through a stairwell.
AUTHOR Ergin-Ozkan S, Mokhtarzadeh-Dehghan M R, Reynolds A J.
BIBINF Indoor Environment, No. 2 1993, pp 350-359, 10 figs, 8 refs.#DATE 00:00:1993 in English
ABSTRACT The effect of airflow through an opening (or a crack) on the natural convection in a stairwell model is presented. The flow is driven by energy input from an electric panel heater located in the lower floor of the stairwell. The work concentrates on the effect of the size of inlet opening by varying it while keeping the area of the outlet constant. New data are presented for the measured temperatures and velocities at various cross-sections of the stairwell. The results also include gross parameters of the flow, heat losses from thelower and upper floors and also from the stairwell. The results show that the size of the opening has a significant effect on the flows of mass and energy within, and through, the stairwell.
KEYWORDS Air inlets, air flow, stairwell, crack, openings.

#NO 7753 Experimental investigation of air flows through large openings in a horizontal partition.
AUTHOR Klobut K, Siren K
BIBINF Finland, Helsinki University of Technology, Laboratory of Heating, Ventilating and Air Conditioning, Report B35, 1994, 76 pp, 17 figs, 17 refs #DATE 00:00:1994 inEnglish
ABSTRACT In recent years, a computer simulation has gained considerable attention as a tool for predicting the air flows and an evolution of contaminant concentrations in buildings. Several computer programs, different in degree of sophistication and capabilities, have been developed for this purpose. However, what they all have in common is the lack of a suitable model for predicting the air flows through any large horizontal openings between vertically stacked building zones. Such flows may occur, eg., in a stairwell connecting two floors of a detached house. In order to satisfy an obvious need, the development of such a model has been a long term objective for a project initiated in the Laboratory of Heating, Ventilating and Air Conditioning at Helsinki University of Technology. In the first phase, the laboratory experiments were carried out to explore, for the first time, the influence of several parameters on combined forced and density-driven air flows through large openings in a horizontal partition. The two-way flows in the opening were monitored using a tracer gas technique. Variable parameters included the direction and rate of the net flow, the temperature difference between the zones, and the dimensions of the large opening.
KEYWORDS air flow, openings, wall

#NO 7926 Sensitivity of a stairwell pressurization system to the airtightness of building components
AUTHOR Yuill G K, Haddad K
BIBINF USA, ASHRAE Transactions, Vol 100, Pt 2, 1994, (preprint), 9pp, 3 figs, 5 tabs, refs. #DATE 00:00:1994 in English
ABSTRACT Smokesim is a computer program that can predict the pressure differences to maintained across building partitions by a fan system installed for smoke control. A major input to this program is the airtightness data of the various building components. Since designers do not have these data when they are designing the smoke control systems, the capability of SMOKESIM may not be useful in

the design stage. The purpose of this project was to investigate this issue by studying the sensitivity of the required capacity of the smoke control fan to errors inthe airtightness of building components. Three buildings were simulated using SMOKESIM to do the sensitivity analysis. The published leakage data can be used to form two leakage combinations for the same building that lead to different design decisions concerning the stairwell pressurization system.
KEYWORDS stairwell, pressurization, air tightness, building component

#NO 8416 The evolution of pressurized stairwells
AUTHOR Clark J A, Buckley J S.
BIBINF USA, ASHRAE, 1995, proceedings of ASHRAE Centennial Conference, held 28 January - 1 February 1995, Chicago, USA, 5pp, 3 figs, refs.
ABSTRACT Stairs evolved from climbing devices such as ladders, climbing poles, and ramps into formed structures of steps with railings and landings. At first their need was limited to people's convenience between point A and point B under normal conditions. However, as humans became more civilized, the concept of the internal stairwell developed. Internal stairwells were enclosed as the fireproof building evolved. As the space population increased, there became a need for additional stairwells. Rather than build additional internal stairs, the concept of the external steel fire stairs or "fire escape" was added for emergency egress of the people. When the elevator and the escalator were developed to move people to greater heights, stairs were retained as the backup system. Escape from fire was always a concern in stairwell design; however, the danger from smoke was always present, though it was not considered the primary danger until relatively recently. This paper discusses the evolution of the concept of pressurized stairwells for smoke control from their original concept of building internal stairwells used for normal conveyance of occupants.
KEYWORDS stairwell, pressurisation, smoke control

#NO 8424 Computer simulation of ventilation strategies for maintaining an acceptable indoor air quality in office buildings
AUTHOR Said M Nade A, Shaw C Y, Plett E G, Vaculik F.
BIBINF USA, ASHRAE, 1995, proceedings of ASHRAE Centennial Conference, held 28 January - 1 February 1995, Chicago, USA, 8pp, 11 figs, 2 tabs, refs.
ABSTRACT This paper evaluates the effects of various ventilation strategies on contaminant distribution in a 22-storey office building for two events; 1. a partial renovation event, when a part of an occupied building is renovated, and 2. a scheduled shutdown event, when the HVAC systems are shut down during a holiday or a weekend A multizone air and contaminant flow model was used to predict contaminant distribution in a 22-storey office building. The model calculates pressures, airflows, and the time-varying contaminant concentration in the zones of a tall building. For a partial renovation event, the ventilation strategies included venting the renovated zone using window(s), a stairwell, a smoke control shaft, and mechanical exhaust. For a scheduled shutdown event, typical building operation was assumed with no specific source zone in the building. The objective of the computations was to determine the required start-up time of the HVAC system to diminish accumulated pollutant concentration in the building following a scheduled shutdown. Computations were conducted for winter, spring, and summer outdoor conditions. The effectiveness of various ventilation strategies for minimizing the spread of the contaminant from the renovated zone to the surrounding areas depends on the location of the renovated zone with respect to the neutral pressure plane in the building. For the building used in the study, based on an outdoor air supply rate of 0.94 ACH, a four-hour start-up of the HVAC operation is adequate to diminish accumulated pollutant concentration in the building after a scheduled shutdown.
KEYWORDS simulation, ventilation strategy, indoor air quality, office building

#NO 9004 Building Services Legislation.
AUTHOR Johansson M
BIBINF UK, Building Services Research and Information Association, (BSRIA), June 1995, Reading Guide RG 14/95, 3rd edition, 123pp.
ABSTRACT The purpose of this Directory is to list the UK legislation which should be considered when designing, installing and operating building services. This is taken to cover air conditioning, heating, ventilation, plumbing, controls, lighting, power, security, fire protection, lifts, insulation, acoustics, energy and alternative energy. The subject area is wide and the identification of all relevant Regulations and Acts difficult to achieve. However, the Directory contains the important legislation.
KEYWORDS standard, building regulations

#NO 9034 Development of smoke management systems.
AUTHOR Webb W A
BIBINF USA, Ashrae J, August 1995, pp 36-40, 1 tab, 19 refs.
ABSTRACT This paper describes recent events which have contributed to the current state of smoke management design. It concerns information about fire size, smoke production and assessing the risk of occupants to be used in designing smoke management systems. The information applies especially to atria and other large volume spaces, including covered shopping malls. It is intended to explain work performed since the 1960 s to help understand the current state of smoke management system practice and design. Considers high rise, building pressurization, natural ventilating. stairway pressurization, atria, occupant risk and system evaluation.
KEYWORDS smoke control, stack effect, ventilation system

#NO 9183 Characteristics of buoyancy-driven interzonal airflow via horizontal openings.
AUTHOR Riffat S B, Shao L
BIBINF UK, Building Serv Eng Res Technol, Vol 16, No 3, 1995, pp 149-152, 6 figs, 6 refs.
ABSTRACT Airflow through horizontal openings in buildings e.g. stairwells, ventilation shafts. service shafts and chimneys has important implications for building energy consumption, thermal comfort. contaminant control and fire safety. However, little information is available regarding the characteristics and mechanism of air exchange through horizontal openings, especially that driven by buoyancy. This paper presents a study of buoyancy-driven flow through horizontal openings using time-dependent computational fluid dynamics (CFD). The results reveal that flow patterns in the zones as well as in horizontal openings are highly transient and that the dominant mode of air exchange through openings is that of intermittent pulses. This character of instability and oscillation should be adequately represented in multizone airflow models to improve their prediction accuracy.
KEYWORDS air flow, openings, stairwell, computational fluid dynamics

NO 9697 Scale modelling of the pressure drop in a stairshaft.
AUTHOR Wong Y W, Chan W K
BIBINF USA, Ashrae Transactions, Vol 102, Pt 2, 1996, [preprint], 7 figs, 1 tab, refs.
ABSTRACT This paper presents results of a study of the pressure drop in a scale model of a stairshaft with closed treads. A 1:10 scale model of a 10 story stairshaft was build to study airflow resistance within the shaft under isothermal conditions, including the effect of occupant density. Three cases were investigated: a stairshaft with no occupant, a shaft with medium density, and one with high-density occupancy. In addition, the effects of the distribution of occupants in the stairshaft were studied. The pressure drop through the model stairshaft was measured at each story for a range of volume flow rates between 0.0368 and 0.0901m3/s (1.29 and 3.18 ft3/s) introduced at a single injection point at the top of the stairshaft. The pressure loss coefficient for the scale model with no occupants was found to be approximately 33.2. The results obtained are comparable to published measurements made in full-scale stairshafts with typical floor heights between 3.2m and 3.85m. The pressure drop varies linearly with the height of the stairshaft and varies directly with the square of the supply air rates. Results from the test demonstrate the same trend as reported in the literature - that the pressure loss coefficient is a function of the occupant density in the stairshaft. The loss coefficient increased by a factor of approximately two when the model was populated to simulate occupancy at medium occupant density and by a factor of three at high occupant density when compared to that of the empty stairshaft. The pressure loss coefficients for the scale model at medium and high occupant densities were found to be approximately 65.7 and 95.9 respectively. The results also agree with published results that the distribution of occupants, whether on the landings at each story or between floors, has little effect on the loss coefficients for medium- and high-density occupancy.
KEYWORDS stair pressurisation

#NO 9816 Ventilation behaviour in a void space furnished with gas water heaters.
AUTHOR Ohira N, Omori T
BIBINF Japan, proceedings of the 5th International Conference on Air Distribution in Rooms, Roomvent '96, held Yokohama, Japan, 17-19 July, 1996, Volume 3, pp 255-262.
ABSTRACT Many buildings in Japan are furnished with a large stairwell in the centre, called "void". Gas water heaters are often installed in the void, consuming the air inside and discharging the exhaust gas into the void. The behaviour of the exhaust gas in the void space has become a great concern. Model experiment and three dimensional CFD have been conducted to investigate, in detail, flow characteristics in the void space. The study selects a simple rectangular void space which accommodates gas water heaters discharging exhaust gas from the corners. Good agreement

has been obtained between the CFD results and experimental data regarding the velocity distribution at the top of the void, thereby validating the CFD method employing the k-e model of turbulence. Detailed consideration has been made to identify the flow field in the void space by using the CFD results.
KEYWORDS stairwell, gas appliance, computational fluid dynamics, modelling, air flow, occupancy effects

#NO 10033 Indoor air pollution as a function of indoor and outdoor sources in a typical Israeli apartment.
AUTHOR Lokshin E, Mamane Y
BIBINF Indoor Air '96, proceedings of the 7th International Conference on Indoor Air Quality and Climate, held July 21-26, 1996, Nagoya, Japan, Volume 1, pp 953-958.
ABSTRACT It is the aim of this study to develop a mathematical model, describing indoor air pollutant concentrations as a function of indoor and outdoor sources. The work was carried out in two directions: development of a multi-zone air flow mode, and a transport model defining the pollutant concentrations in each zone of a building as a function of time. Data for simulation experiments were obtained from a typical Israeli apartments, constant outdoor concentrations, and assumed emission factors. It was found that indoor air quality is affected by meteorological conditions (wind), emissions from indoor sources, and the air tightness of a given building. The configuration of the staircase (open or closed and the presence of the vent top) also affects indoor air concentrations.
KEYWORDS outdoor air, apartment building, pollutant

#NO 10122 Prediction of airflow in subway stations.
AUTHOR Fukuyo K, Shimoda Y, Mizuno M, Onishi J, Kaga A
BIBINF Indoor Air '96, proceedings of the 7th International Conference on Indoor Air Quality and Climate, held July 21-26, 1996, Nagoya, Japan, Volume 4, pp 375-380.
ABSTRACT Numerical simulations are conducted to investigate the airflow characteristics in a subway station. In order to confirm the validity, the calculated results are compared with the measured results obtained by flow vizualization using a scale model. Airflow distribution in the concourse is non-uniform. In some regions within the concourse, stagnations of the air is formed. In the condition that the air flows from the outside to the concourse, vortices are formed over the staircases.
KEYWORDS air flow, tunnel ventilation, numerical modelling

#NO 10211 Airflow design in a staircase to modify it for a clean zone.
AUTHOR Suwa Y, Takita H, Ozaki A
BIBINF Indoor Air '96, proceedings of the 7th International Conference on Indoor Air Quality and Climate, held July 21-26, 1996, Nagoya, Japan, Volume 4, pp 133-137.
ABSTRACT Product defects by airborne particle contaminant should be prevented in manufacturing of electronic devices and pharmaceutical industries. In these manufacturing processes, contamination control is very important not only in cleanrooms but also during product transportations. This paper describes investigations on airflow design in a staircase to modify it for a clean zone. Staircases are sometimes used to connect production lines on different floor levels. To make a suitable design of air-supply system, airflow state and particle behavior in a staircase were numerically simulated under various conditions. Simulated results indicated that an adjustment of airflow direction at each supply filter and a balance of airflow volume at exhaust openings were most important to obtain a smooth uni-directional airflow in the staircase. An optimum design of air-supply system was also investigated using numerical simulations to obtain the most desirable airflow state and enough performance of cleanliness recovery in the staircase. Then, an actual staircase was designed and constructed according to the simulation results, and several measurements on airflow distribution, partile counts and cleanliness recovery time, were conducted. Results of these measurements showed good agreements with predictions by numerical simulations, and the staircase satisfied the requirements.
KEYWORDS stairwell, cleanroom

#NO 10218 Thermal and acoustical performance of "buffer rooms".
AUTHOR Mahdavi A
BIBINF USA, Ashrae Transactions, 1993 (1), pp 1092-1105, 12 figs, refs.
ABSTRACT The term "buffer room" refers in this context to spaces built between thermally, visually and acoustically "controlled" indoor rooms and the "noncontrollable" outdoor environment. Examples of buffer rooms are sunrooms, atria, (enclosed) staircases, and air locks. In a long-term research effort carried out in Austria, buffer rooms were studied with regard to their hygrothermal and acoustical performance within a human-ecological framework. Special attention was paid to the problems of temperature fluctuations and risk of

overheating, ventilation rates, and humidity control as well as sound transmission. The research agenda included studies under controlled conditions in SHA, a facility dedicated to building physics research in Vienna, Austria, as well as field investigations. Gives a summarised overview of the content and results of some of these studies, focusing on the issues of thermal performance as well as the acoustical insulation effect of sunrooms and its relationship to natural ventilation.
Keywords thermal performance, noise pollution, sunspace, atrium, natural ventilation

#NO 10599 Airflow through horizontal openings.
AUTHOR Peppes A A, Santamouris M, Asimakopoulos D N
BIBINF UK, Air Infiltration and Ventilation Centre, proceedings of "Ventilation and Cooling", 18th Annual Conference, held Athens, Greece, 23-26 September 1997, Volume 2, pp 513-522.
ABSTRACT This paper deals with the interzonal air movement in a building, through horizontal openings, under natural convective conditions. There airflow phenomena are investigated experimentally, through a series of experiments in the stairwell of a full-scale building, using tracer gas technique. The resulting time-dependent concentration evolution offers a means of analyzing the flow field. These cases are also simulated by a CFD code, that uses the finite-volume method and incorporates a low-Reynolds k-e two equation turbulence model. The simulations results regarding the concentration and velocity, are in good agreement with the experimental data. Results indicate that the contaminant transmission and consequently the airflow pattern is quite complex and is affected by geometry, location of heat and contaminant sources, building materials and microclimate. The study also discusses the effectiveness of CFD modeling to describe airflow phenomena through horizontal openings, under various conditions. The results could be used to develop accurate algorithms for inclusion in existing mathematical models.
KEYWORDS air flow, openings

#NO 10680 Winter ventilation monitoring at the Portland Building.
AUTHOR Kolokotroni M, Shaw R, Webb B, Perera E
BIBINF UK, Building Services Journal, July 1997,k pp 47-49, 6 figs.
ABSTRACT Winter ventilation performance of the Portland Building, the recently completed low energy building at the University of Portsmouth, UK has recently been monitored by the UK Building Research Establishment as part of the "NatVent" project, which aims to provide solutions to technical barriers preventing the uptake of natural ventilation and low energy cooling for office-type buildings in countries with moderate and cold climates. The monitoring results will be used to gain a better understanding of the applicability and limitations of natural ventilation strategies. During winter, the main focus of the tests is to examine whether acceptable indoor air quality is provided, whether airflow rates are kept within a certain range to avoid discomfort due to draughts and to minimise any excess energy which may be needed to heat the incoming air. The results showed that the natural ventilation strategy provides a satisfactory indoor air quality, as the design intended. CO2 and humidity level are acceptable, and comfortable temperatures were recorded with appropriate fresh air ventilation rates. There are also positive indications for the performance of thermal mass for summer cooling and the role of the staircases for providing stack ventilation.
KEYWORDS monitoring, natural ventilation, building design

Liftshafts

#NO 6110 Smoke control for elevators.
AUTHOR Klote J H
BIBINF USA, Ashrae Journal, April 1984, pp 23-33, 12 figs, 9 tabs, 14 refs. #DATE 00:04:1984 in English
ABSTRACT In most elevator lobbies in the United States, there are signs which have statements similar to the following: - WARNING- Elevator shall not be used in the event of the fire. Use marked exit stairways. Unfortunately, some people cannot use stairs because of physical disabilities. This problem has led the Veterans Administration (VA) to sponsor a project at the National Bureau of Standards (NBS), Center for Fire Research (CFR), to investigate the feasibility of using elevators as a means of fire exit for the physically handicapped. The ultimate goal of this project is to provide information which can be used by building designers. This is the second report on this project. The first report [1] contained a brief discussion of the problem, presentation of a conceptual solution and a report of field tests on four buildings which have smoke control systems intended to protect elevators during fire situations. Information from the first report is presented herein as a convenience to the reader. In addition, thisarticle contains a report of field tests on two other buildings. A simple relationship is

developed for the pressure differences across an elevator shaft and the elevator lobby, and vertical pressure profiles are also discussed. Some of the buildings tested had other types of smoke control systems in addition to systems for elevator protection.These systems are discussed in terms of their interaction with the elevator protection system.
KEYWORDS smoke control, elevator shaft

#NO 7741 Elevator design for the 21st century: design criteria for elevators when used as the primary means of evacuation during fire emergencies
AUTHOR Chapman E F
BIBINF USA, Elevator World, vol 41, No 2, February 1993, pp 43-46 #DATE 00:02:1993 in English
ABSTRACT presents thirteen proposed design requirements to ensure lift safety during fire emergency evacuations. The elevator for use in the 21st century must be designed for safety under all conditions that may be expected in the building for which they are to be installed. the integration of smoke control and fire protection systems along with evacuation procedures for the use of elevators during fire emergencies is examined and recommendations are made to bring elevator systems to a level of safety that can permit their use during fire emergencies. It is suggested that by introducing a number of safety measures existing and practical elevators can become the primary means of egress just as they are the primary means of ingress to a building
KEYWORDS elevator shaft, fire

#NO 8032 Case studies of air-leakage effects in the operations of high-rise buildings.
AUTHOR Wallace J R
BIBINF USA, ASHRAE (DOE) BTECC ,"Thermal Performance of the Exterior Envelopes of Buildings III" conference proceedings, held Clearwater Beach, Florida, 2-5 December 1985, pp 229-235.
ABSTRACT This paper is a comparative study of two 26-storey high-rise buildings with hidden air leakage anomalies--a building envelope problem that may exist in a high percentage of commercial buildings today. Thermography revealed extreme exfiltration problems at top floor mechanical room levels of both buildings. Further investigations affirmed the presence of a severe stack effect fed by air infiltrating into each building's exposed central core through elevator and mechanical shafts, chaseways, and stairways.
KEYWORDS (air leakage, high rise building, commercial building, thermography, stack effect, stairwell, elevator shaft)

#NO 8189 Stack effect in tall buildings
AUTHOR Lovatt J E, Wilson A G
BIBINF USA, ASHRAE Transactions, Vol 100, Pt 2, 1994, (preprint), 12pp, 3 figs, 3 tabs, refs. #DATE 00:00:1994 in English
ABSTRACT Buoyancy forces due to the density difference between cold outdoor air and warm indoor air are known to cause problems in tall buildings in cold climates. Such problems as Elevator doors that do not close and prevent the car from moving, unbalanced ventilation and exhaust air flows in vertical shafts, lobby entrance doors that are difficult to open in cold whether, and discomfort on lower floors due to large quantities of cold infiltrating air are usually a direct result of buoyancy forces acting on these elements of the building during cold whether. The ASHRAE Task Group on Tall Buildings commissioned Research Project 661, Field Verification of Problems Caused by Stack Effect in Tall Buildings. With the objectives of measuring the magnitude of specific problems related to stack effect in a tall building exposed to cold weather and testing the effect of modifications to the heating, ventilating, and air-conditioning (HVAC) system designed to reduce these problems. The measurements indicated that the stack effect caused few observable problems in the specific building measured. Simulations showed that these problems were strongly dependent on the envelope air leakage area. Stack-induced pressures across fire exit doors required to open the doors. Maintaining an airtight envelope above the lobby level minimizes all the problems related to stack effect. Differential pressurization of floors to counteract stack effect was found to be inappropriate for the great majority of buildings. Airtight vestibules around entrance, elevator, and stairwell doors or automatic door openers can reduce door-opening problems due to high stack pressures where envelope leakage is difficult to address problems of modern housing, and guidelines on how to solve them simply and efficiency without undue expense.
KEYWORDS (stack effect, high rise building)

#NO 9620 Controlling stack pressure in high rise buildings by compartmenting the building.
AUTHOR Rousseau M J
BIBINF Canada Mortgage and Housing Corporation, March 1996, 40pp.
ABSTRACT An investigation was conducted of the effect of decreasing the air leakage area across internal partitions of a typical modern high-rise apartment. The objective of this work was to study the practicality of increased compartmentalization or separation of the living

units from each other and from the corridors and vertical shafts in the building. Typically, the main barrier to air movement through a high-rise apartment building is the exterior skin or envelope. Walls and doors between corridors, units and elevator shafts and stairwells are much less airtight, and significant volumes of air can move between these different areas of the building interior under relatively small pressure differences. Some disadvantages of this arrangement are that individual occupants can affect air movement through the entire building by leaving windows or balcony doors open in their units, odours and pollutants produced in one area of the building may be transferred to other areas, exterior walls and windows have large pressure differences across them which drives air and rain through any defect, and special measures to control smoke migration during fires must be provided. The objectives of this study were to measure the actual pressure differences across various separations within a high-rise apartment building, to generate and analyze potential ways of reducing the air leakage through these separations, and to draw conclusions on their effects on air movement in the building, including changes in operation of typical current ventilation strategies and fire and smoke control measures.
KEYWORDS stack effect, high rise building

#NO 10671 A solution to lift shaft air leakage.
AUTHOR Lawson D
BIBINF UK, Building Envelope News, Vol 14, March 1997, pp 1-3.
ABSTRACT Describes how an analysis of problems and proposed remedial work were carried out successfully on an office block with severe ingress problems around the service lift doors.
KEYWORDS elevator shaft, air leakage

AIVC Air Infiltration and Ventilation Centre

The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote an understanding of the complex behaviour of air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.