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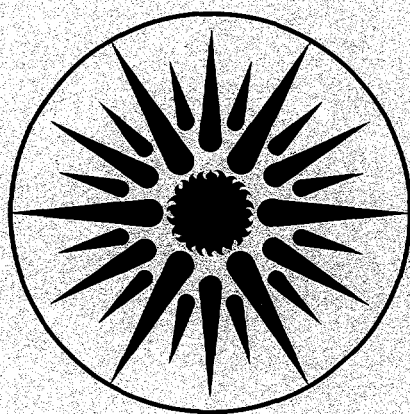
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Ventilation and Infiltration in High-Rise Apartment Buildings

R.C. Diamond, H.E. Feustel, and D.J. Dickerhoff

March 1996



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Ventilation and Infiltration in High-Rise Apartment Buildings

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Synopsis: Air flow, air leakage measurements and numerical simulations were made on a 13-story apartment building to characterize the ventilation rates for the individual apartments. Parametric simulations were performed for specific conditions, e.g., height, orientation, outside temperature and wind speed. Our analysis of the air flow simulations suggest that the ventilation to the individual units varies considerably. With the mechanical ventilation system disabled and no wind, units at the lower level of the building have adequate ventilation only on days with high temperature differences, while units on higher floors have no ventilation at all. Units facing the windward side will be over-ventilated when the building experiences wind directions between west and north. At the same time, leeward apartments did not experience any fresh air--because, in these cases, air flows enter the apartments from the corridor and exit through the exhaust shafts and the cracks in the facade. Even with the mechanical ventilation system operating, we found wide variation in the air flows to the individual apartments. In addition to the specific case presented here, these findings have more general implications for energy retrofits and health and comfort of occupants in high-rise apartment buildings.

1.0. Introduction & Literature Review

Quantifying the impact of infiltration on energy use in buildings has stymied researchers and practitioners alike. And while the difficulties of measuring and modeling its effect are widely acknowledged, there is agreement on its importance. The effect of infiltration on energy use in a high-rise apartment building can be seen directly in **Figure 1**. The figure plots annual energy consumption per floor in a 12-story apartment building in Pittsburgh, Pennsylvania. The energy consumption on the lower floors is 28% higher than the mean, and decreases with height until the next-to-the-highest floor where the consumption is 32% lower than the mean. (Energy consumption on the top floor is higher due to conduction losses through the roof.) The reason for this variation in energy use is the infiltration due to stack effect--because of pressure differentials due to inside-outside temperature differences, air in the building rises up the vertical shafts (stairs and elevators) and draws in colder outdoor air at the base of the building. So lower apartments get a greater burden of outdoor air which poses an energy penalty in winter, while the upper units get warm air from below, but the lack of outdoor air to these units poses an indoor air quality penalty.

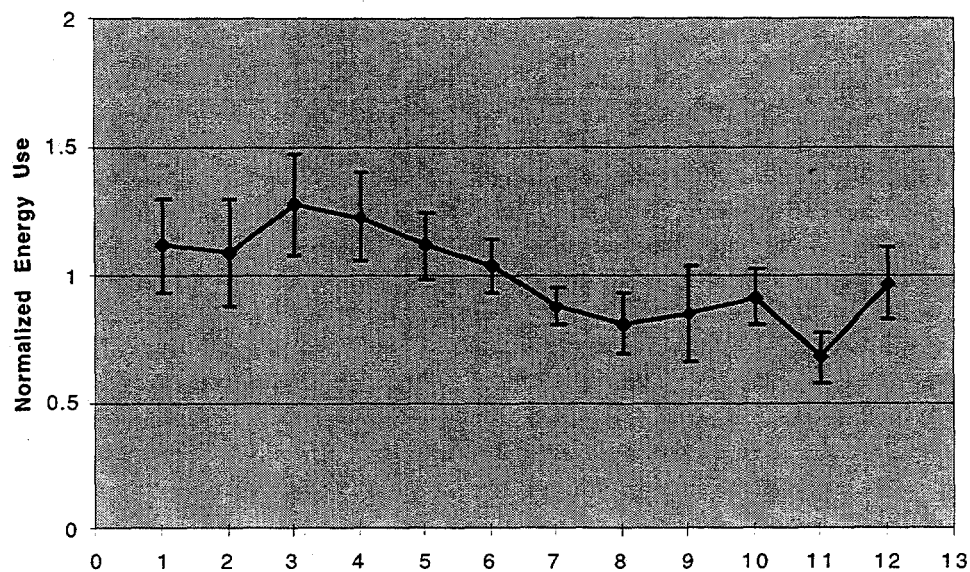


Figure 1. Annual electricity consumption per floor for a 12-story apartment building in Pittsburgh, Pennsylvania. Consumption data have been normalized by mean values. Error bars show one standard deviation above and below the mean.

To address these issues of balancing energy efficiency and health, multi-story residential buildings often have mechanical ventilation systems to provide adequate outside air for comfort and health. The performance of these systems, however, is often less than satisfactory, due to poor design, sporadic maintenance, and interactions with both natural infiltration and occupant behavior.

The literature on air flow and air leakage measurements in high-rise multifamily buildings is quite limited. As we are not aware of any review of these topics for North American multifamily buildings (both highrise and lowrise), we present a brief chronological summary of the research on these topics below.

A pioneering study by Tamura and Wilson measured the pressures across the exterior envelope of a nine-story building in Ottawa, Canada (Tamura and Wilson, 1966). They made measurements with the mechanical ventilation system both on and off, and

concluded that the pressure differences across the building envelope depends on the distribution of the openings in the envelope and the ratio of resistance to air flow inside the building to that across the exterior wall.

An early study on measurements of air leakage in multistory apartment buildings was performed by C.Y. Shaw in 1980. He conducted small-scale pressurization tests on the exterior walls of apartments in a multi-story building and found floor-wall joints, windows and window sills to be the major leakage sites (Shaw 1980).

One of the first measurements of both air leakage and infiltration in a high-rise apartment is reported by Feustel et al. (1985), where fan pressurization, tracer gas and pressure measurements were made in a 9-story dormitory building in Berkeley, California. The measurements were then used in an airflow simulation model to study the importance of both wind and stack effect in determining air infiltration.

Using tracer gas measurements in three typical low-income apartment buildings in New York City, Commoner and Rodberg found natural infiltration rates of 1.08, 0.58 and 1.01 ACH, about twice the leakage calculated from window dimensional measurements. They determined that the "extra" leakage was to adjacent apartments and common spaces (Commoner and Rodberg, 1986).

Modera et al., working with staff from the Minneapolis Energy Office, measured air leakage in a six-unit building in Minneapolis (Modera et al., 1986). Using six blower doors simultaneously they showed that the average leakage for each apartment was 1600 cm^2 ($13 \text{ cm}^2/\text{m}^2$) and that only 40% of the air leakage was directly through the exterior envelope. The remainder was either to the adjacent units or in the interstitial spaces between the apartments. These leakage areas were used in conjunction with a multizone air infiltration model to determine the air flows between apartments and to the outside.

Two blower doors were used to measure air leakage in two three-story apartment buildings in Chicago (Diamond et al., 1986). Leakage areas of 2460 cm^2 and 1880

cm² were measured for the two apartments, which when normalized by floor area were both 19 cm²/m². While the apartments were significantly leakier than the one measured by Modera, roughly the same fraction (60%) of the leakage was to the other apartments.

Blower door measurements in a study of eleven multifamily buildings in upstate New York showed an average pre-retrofit leakage rate of 35.5 ACH @ 50 Pa, implying a natural ventilation rate of over 1 ACH (Synertech, 1987).

Bohac and his colleagues tackled a six-story apartment building in Minneapolis, Minnesota in 1987 with several tracer gas and fan pressurization techniques. They were able to estimate airflows between apartments, but concluded that in this building, air exchange was dominated by patterns of window openings (Bohac, 1987).

Researchers in the Pacific Northwest took measurements in nine new motel-style multifamily buildings (where each unit has its own outside door) and reported estimated average leakage rates ranging from 0.08 to 0.30 (median 0.19) ACH, well below the ASHRAE 62 Standard of 0.35 ACH (Baylon and Heller, 1988).

Measurements of low-income rowhouses in Philadelphia showed an extremely high air leakage of 55 ACH @ 50 Pa, with up to 30% of the flow to adjoining units (Cameron, 1990). They attributed the high leakage to the characteristics of the row house construction and the generally poor condition of the houses.

Researchers found that even in a two-story apartment building that ground-floor apartments can have more than double the heating bills of upstairs apartments due to internal air-leakage patterns and heat flow (McBride et al., 1990).

Modera and Herrlin analyzed inter-zonal leakage using two blower doors in a controlled test set-up. These data were used in a computer simulation (Movecomp) to determine air flows in a multifamily building under different wind conditions and

measurement protocols. They found that uncertainties due to wind fluctuations for wind speeds under 5 m/s did not exceed 10% (Modera and Herrlin, 1990).

Shaw and his colleagues in Canada measured two high-rise apartment buildings using a system of two pressurization set-ups and tracer gas equipment. One blower door was used in the individual apartment and the other was used to pressurize the entire building. The pressures between the test unit and the adjacent units were balanced to minimize the air leakage between the party walls (Shaw et al., 1990).

Harrje et al. compared three different tracer gas techniques to measure air infiltration in a high-rise apartment in Princeton, New Jersey. The tests were Constant Concentration Tracer Gas (CCTG), Multi-tracer Mass Spectroscopy (MTMS) and Air Infiltration Monitors (AIMS). The study reports the strengths and weaknesses of the three methods (Harrje et al., 1990).

Hayes reports the results of an audit of a rehab of a four story brick warehouse converted to apartments for the elderly. The new construction consisted of sheet-rocked boxes inside the brick walls of the original building, with large spaces for air flow between the old and new walls. But the individual apartments tested quite tight for air leakage. Hallways tested tight, too. Her conclusions were to focus air sealing on bypasses--especially between old and new building envelopes, and concentrate on improving mechanical ventilation systems with dampers and better controllers (Hayes, 1992).

Mark Kelley (Kelly et al. 1992) measured the air leakage pre-and post-retrofit in a high-rise apartment in Revere, Massachusetts. They found an average pre-retrofit leakage for 17 of the apartments of 532 CFM at 50 pascals, and a post-retrofit leakage of 449 CFM at 50 Pascals, a reduction of 15%.

Perhaps the largest study to date on ventilation in multifamily buildings was conducted by the New York State Energy Research and Development Authority (Shapiro-Baruch, 1993). They developed and tested a ventilation audit in 10 multifamily buildings,

finding measured airflow rates to be on average 32% less than the design values. Energy use for mechanical ventilation varied widely from building to building, from less than 2% to more than 20%. They identified poorly designed and poorly operated supply air systems as the source of many indoor air quality problems.

Monitoring of two multifamily apartment buildings in Chicago, Illinois, was undertaken in the Spring of 1993 by a team of energy researchers from Argonne National Laboratory, the University of Illinois, and Lawrence Berkeley Laboratory. They performed ventilation and infiltration measurements in two multifamily apartment buildings to determine the leakage characteristics for two types of retrofits and adequate levels of ventilation for air quality throughout the building. In one of the two buildings, blower-door measurements showed relatively high air-exchange rates. Pressure measurements in wall cavities indicated that internal and exterior walls experienced pressures close to those outside. Construction details of the walls showed that the use of metal studs, with break-outs for electrical wires, provided holes that connected all wall cavities of a dwelling. Depressurization of one zone caused air flows from the outside through all direct flow paths and through all wall cavities to openings in the walls (e.g., electrical outlets), including interior walls. The building constructed with wooden studs had lower leakage levels. The pressure level for interstitial spaces was much closer to the level of the depressurized zone than to the ambient pressure (Katrakis et al., 1994).

Researchers from LBL used a single-blower-door technique for measuring leakage in multifamily buildings in 1993 in two New York apartment buildings. One apartment was pressurized and depressurized to ± 50 Pa, and the resulting pressures were measured in adjacent apartments. By incorporating the pressures measured in the adjacent apartments (1-15 Pa) into a mass balance equation, they were able to calculate that approximately 50% of each apartment's leakage was to outside in one building, and that a significantly larger fraction was to outside in the other (Dickerhoff et al., 1994).

Vicky Hayes and Ian Shapiro-Baruch report on a recently funded project by the New York State Energy Research and Development Authority (NYSERDA) to assess the types, effectiveness and energy efficiency of ventilation systems in multifamily buildings in New York State. They collected detailed information for ten sites and additional information on another 50 sites. They concluded that much of the uncertainty surrounding ventilation codes and standards could be eliminated if an accurate method of quantifying air flow in a multifamily building was available (Hayes and Shapiro-Baruch, 1994).

What emerges from a review of these studies is the paucity of information characterizing air leakage in multifamily buildings and the typically poor level of control in the provision of ventilation for the building occupants. Several of the articles mention reasons for why there are problems in measuring, modeling and designing ventilation systems for high-rise multifamily buildings, but few offer any solutions. Routine questions from the single-family literature such as how to define a reference pressure for blower door measurements are currently unanswerable for multifamily buildings. And we have little knowledge on how to characterize and determine the leakage distribution in different types of multifamily construction.

2.0 Project Description

Our recent activity in this area came about through the DOE-HUD Initiative, a response to the U.S. National Energy Strategy's directive to improve the energy efficiency in Public Housing. Under the Initiative's guidance a collaborative project was established to demonstrate energy efficiency in Public Housing as part of a utility's Demand Side Management (DSM) Program.

The demonstration site is the Margolis Apartments, a modern 150-unit high-rise apartment building for the elderly and handicapped, located in Chelsea, Massachusetts, in the greater Boston, Massachusetts, metropolitan area (Figure 2).



Figure 2. The Margolis Apartments, Chelsea, Massachusetts.

The Margolis Apartment building was designed and built in 1973-1974 and is typical of high-rise construction from that period. The building has thirteen stories and is of steel-frame construction. The individual apartments have electric-resistance heaters in each room, and double-pane windows and sliding balcony doors. Figure 3 shows a typical floor plan of the building.

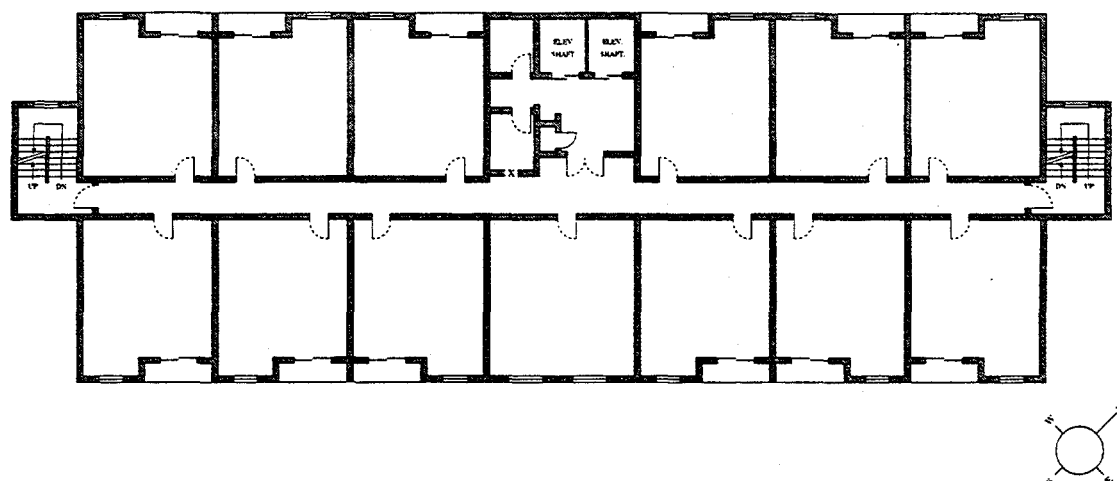


Figure 3. Typical floor plan (floors 6-12), Margolis Apartments, Chelsea, MA. The "x" shows the location of the supply ventilation register for each corridor.

The building has a mechanical ventilation system, with kitchen and bathroom exhaust fans for each apartment leading into separate vertical shafts which have additional exhaust fans located on the roof. The supply air system for the building is provided by a fan and heating unit on the roof that connects to a vertical shaft which has supply registers to the main hallway on each of the floors (Figure 4). Supply air then enters the apartments by a slot under the front door of each unit.

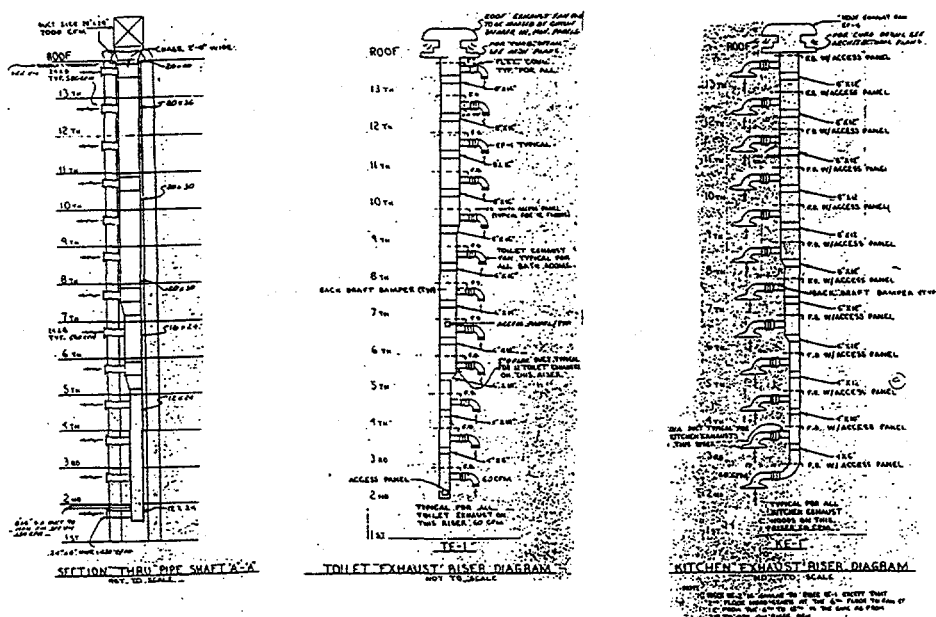


Figure 4. The central ventilation supply trunk and typical exhaust risers from kitchen and bathrooms, Margolis Apartments, Chelsea, Massachusetts.

The building is exposed on all sides to the wind, and is located less than 5 km from the airport weather station. Airport weather data records a mean annual wind speed of 6 m/s with up to 26 m/s wind speeds in winter. The winter wind is primarily from the northwest; the wind in spring through fall is from the southwest.

In December, 1992, the building underwent extensive retrofits. New double-pane, low-e windows replaced the old windows throughout the building. A computerized energy management system was installed that allowed for tracking and controlling of the thermostats in the individual apartments. Efficient light bulbs were installed in the individual apartments and in the parking areas. A new sprinkler system was installed throughout the building. The balconies were screened in to prevent the pigeons from roosting. A second phase of retrofit activity a year later involved improvements to the abandoned ventilation system.

Prior to the window retrofit, drafts were a major complaints expressed by the tenants, but since the retrofit, there have been--according to building management--fewer complaints about window drafts. There was mention of the windows being hard to open for some of the residents, both from the latching mechanism and the effort needed to lift the double-hung sash. No problems with condensation on the windows were reported since the retrofit.

The northwest-facing units (weather side) continue to be the hardest units to maintain thermal comfort. Also the second floor units (above the open parking areas) continue to be a problem in cold weather.

3.0 Measurements & Analysis

The measurements and analysis that we are reporting here consist of four parts: 1) Air leakage measurements of the apartments measured pre- and post-retrofit, 2) Air flow measurements of the apartments pre-retrofit, 3) Pressures and flows between the apartments and the circulation areas and 4) Computer simulations of the air flows in the building under different weather conditions.

3.1 Air Leakage Measurements

We measured the air leakage in nine apartments, before and after the new windows were installed. Figure 5 shows a plot of one of the air leakage measurements. The average pre-retrofit total effective leakage area for the one-bedroom apartments was 241 cm^2 and 256 cm^2 for the two-bedroom apartments. The post-retrofit total effective leakage area for the one-bedroom apartments was 230 cm^2 and 248 cm^2 for the two-bedroom apartments (Table 1).

Table 1: Leakage Areas Pre- and Post-Retrofit

Apartment	Leakage Area @ 4 Pascals(a) [cm ²]	
	<u>pre-retrofit</u>	<u>post-retrofit</u>
301 (2-bdrm)	228	240
313 (2-bdrm)	284	257
704	173	167
1102	280	-
1107	309	293
1211(b)	180	246
1213	238	215
1313(c)	205	278

(a) fit to $n=0.667$

(b) air conditioner in window post-retrofit only

(c) bedroom window not fully closed during post-retrofit test

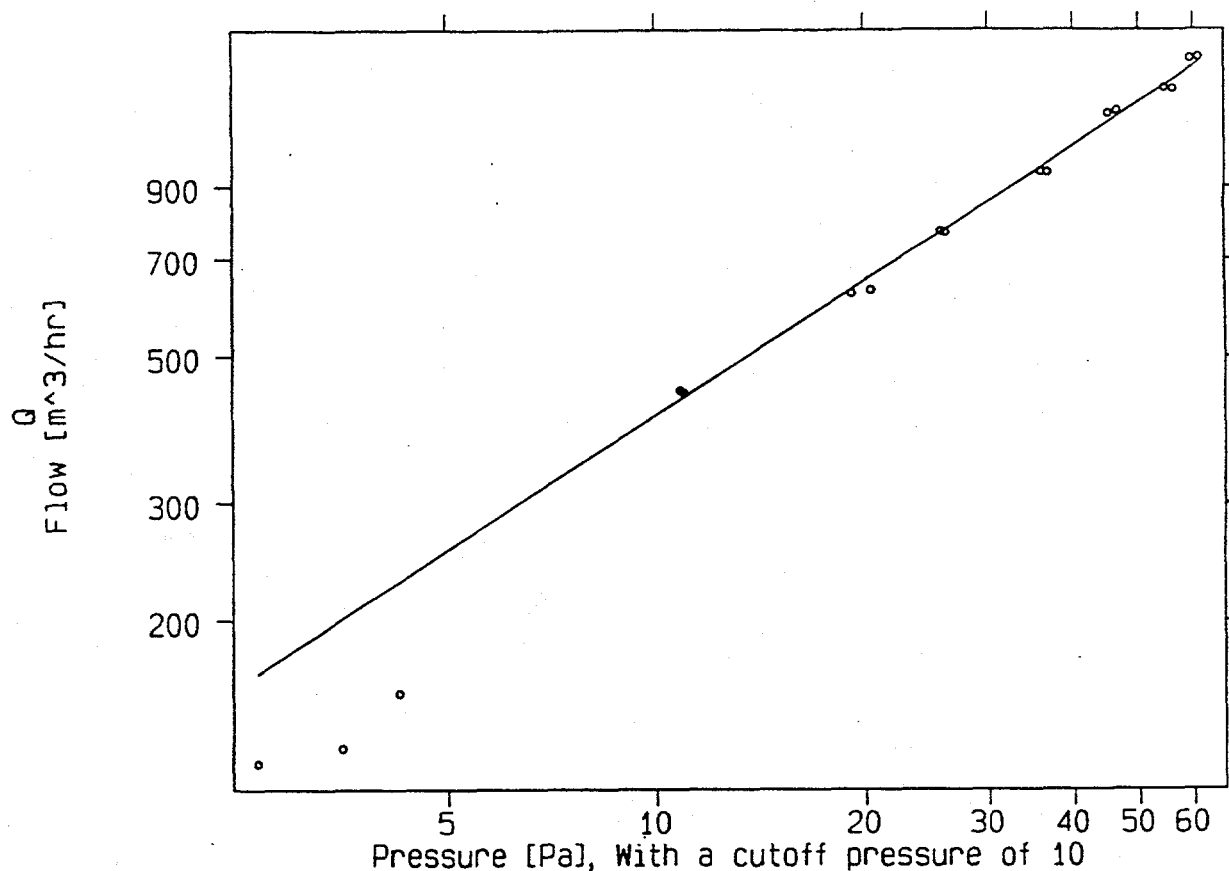


Figure 5. Air flow versus pressure from blower door measurements at an apartment on the 12th floor of the Margolis Apartments. The Effective Leakage Area (ELA) was 237 cm² at 4 pascals and 324 cm² at 25 pascals.

We found little or no reduction in air leakage due to the new windows, which is surprising given that tenants who had previously complained of drafts were now satisfied. One explanation is that tenants were previously experiencing down drafts at the window due to cold surface temperatures, which no longer occur because of the new double-pane, low-e windows.

We also note that these measurements, both pre- and post-retrofit, were made in very windy conditions--beyond the limits allowed for standard blower-door tests. While this problem is not uncommon in low-rise buildings, it is an even bigger problem in high-rise buildings, where wind speeds are often much higher than for buildings at ground level. Furthermore, the measurement technique being used is based on a reference pressure describing the pressure field around the building. In large buildings, it is very difficult to find a pressure point which acts as the reference pressure for the apartment

being investigated. There is also the possibility that the measurement technique itself, i.e., depressurization with a blower door, temporarily seals the windows and distorts the findings.

By way of comparison, Kelley et al. (Kelly 1992) measured the air leakage pre-and post-retrofit in a high-rise apartment in Revere, Massachusetts, a few kilometers north of the Margolis apartment. They found an average pre-retrofit leakage for 17 of the apartments of 904 m³/h at 50 pascals, and a post-retrofit leakage of 763 m³/h at 50 Pascals, a reduction of 15%. The comparable flows at Margolis were higher, and showed no reduction after the retrofit, with an average of 1183 m³/h pre-retrofit and 1214 m³/h post-retrofit (Table 2).

Table 2: Air Flow Pre- and Post-Retrofit

Apartment	Air Flow @ 50 Pascals(a) [m3/hr]	
	<u>pre-retrofit</u>	<u>post-retrofit</u>
301 (2-bdrm)	1140	1204 (+5%)
313 (2-bdrm)	1416	1288 (-10%)
704	864	838 (-3%)
1102	1397	-
1107	1541	1469 (-5%)
1211(b)	901	1233 (+37%)
1213	1188	1076 (-9%)
1313(c)	1025	1394 (-)

(a) fit to $n=0.667$

(b) air conditioner in window post-retrofit only

(c) bedroom window not fully closed during post-retrofit test

3.2 Air Flow Measurements

Ventilation rates were measured using tracer gas in two apartments, pre-retrofit, in various configurations of exhaust ventilation. With no supply or exhaust ventilation we found typical rates to be about 0.2 ACH (Figure 6).

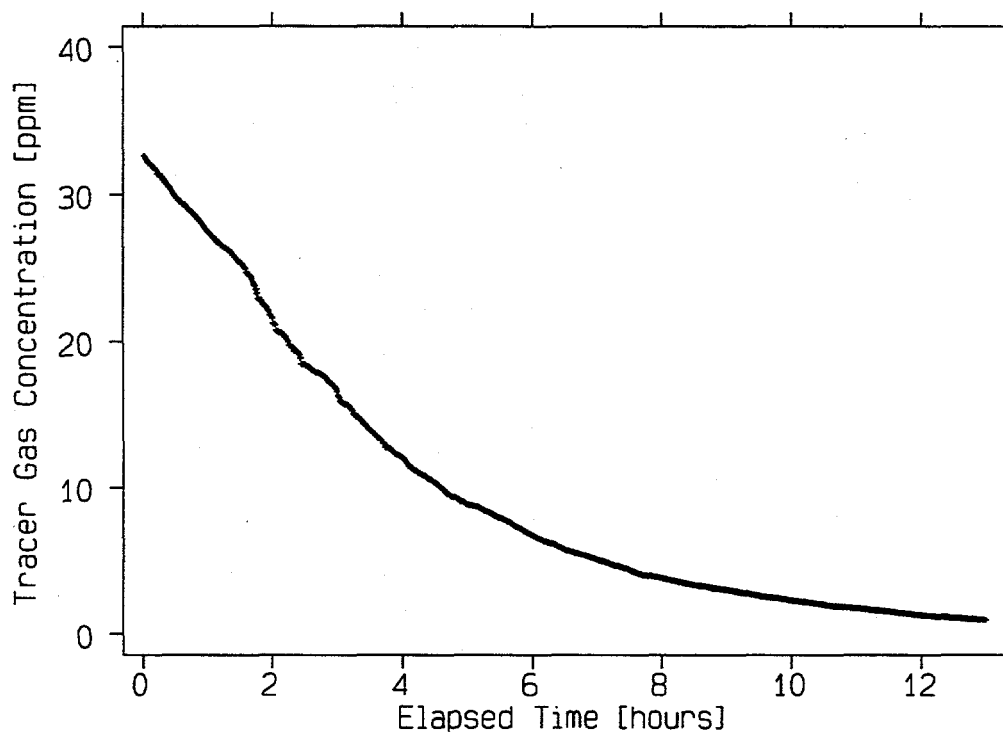


Figure 6. Tracer gas decay **without** supply and exhaust fans in operation for a unit on the 12th floor of the Margolis Apartments (June 12, 1992). The decay corresponds to an air exchange rate of 0.2 ACH.

We also measured the leakage from one apartment to another, using tracer gases, and found little communication between units--less than 4% of the total leakage was to adjacent apartments. This was not altogether surprising given the concrete construction of the building.

These ventilation rates are below the recommended 0.35 ACH given in ASHRAE Standard 62 . Operation of the building supply system and the exhaust systems increased the ventilation rate to 0.44 ACH (Figure 7). If the mechanical ventilation systems were operating at their designed flows, the apartment ventilation rates might well meet the ASHRAE standard without excess ventilation.

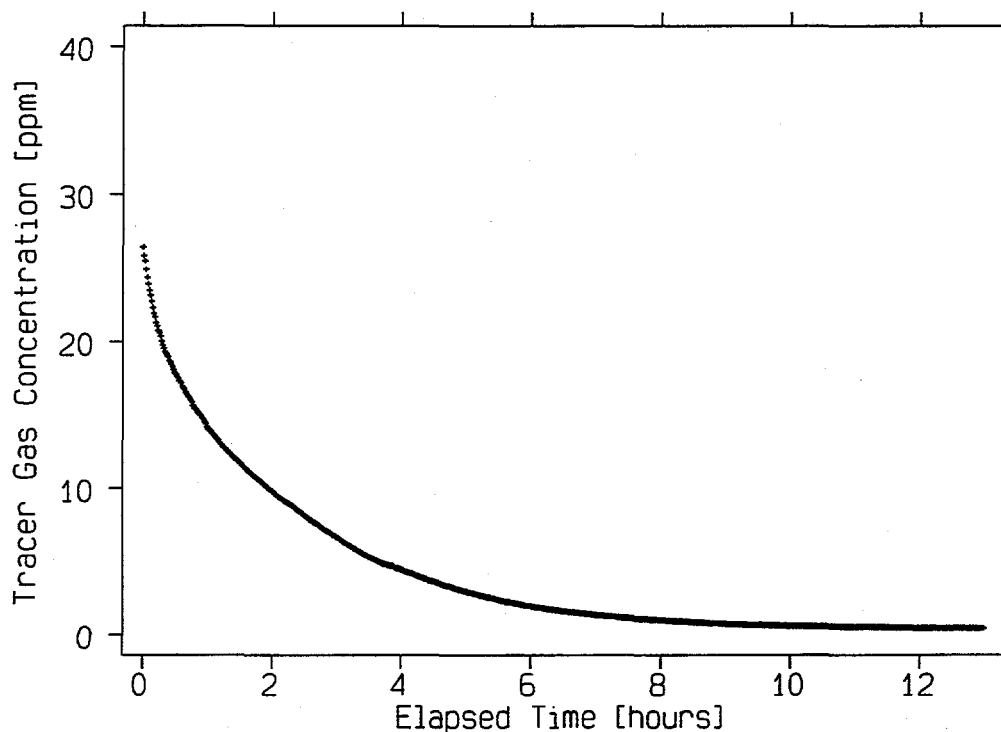


Figure 7. Tracer gas decay **with** supply and exhaust fans in operation for a unit on the 12th floor of the Margolis Apartments (June 13, 1992). The decay corresponds to an air exchange rate of 0.4 ACH.

We measured the exhaust air flow from the kitchen hoods and the bathroom vents using a hot-wire anemometer. The filter area of the kitchen hood was divided into 5 sub-areas and an average velocity for each area was determined. From the air velocity, the flows were then calculated. The air velocity was also measured for several locations in the three-slot arrangement of the bathroom exhaust.

The exhaust flows of the seven apartments investigated showed the following characteristics: 1) air flow at the kitchen exhaust register with both the roof exhaust fan and the building supply on, but with the local exhaust fan off, ranged from 50 to 170 cfm, with a mean value of 92 cfm, significantly higher than the design value, (see Figure 8), 2) air flow at the bathroom exhaust register was smaller than the kitchen exhaust flows, and ranged from 40 to 86 cfm, with a mean value of 53 cfm, 3) With the addition of the local exhaust fan operating, kitchen exhaust flows reach values between 170 to 200 cfm (mean = 188 cfm) and, 4) the air flow at the bathroom register with the local bathroom fan operating (together with the roof top exhaust fan) produced 110 to 140 cfm (mean = 122 cfm).

Under normal operating conditions, i.e., the local bathroom and kitchen exhaust off, the total exhaust flow in the apartments would be between 100 and 260 cfm (mean = 145 cfm). The mean air flow supplied to the apartments from the corridor was measured at 22 cfm, so on average, under these weather conditions, the apartment would be drawing in an additional 120 cfm of outside air through the exterior wall and windows. This over-ventilation suggests the need for lowering the roof exhaust fan flow rates.

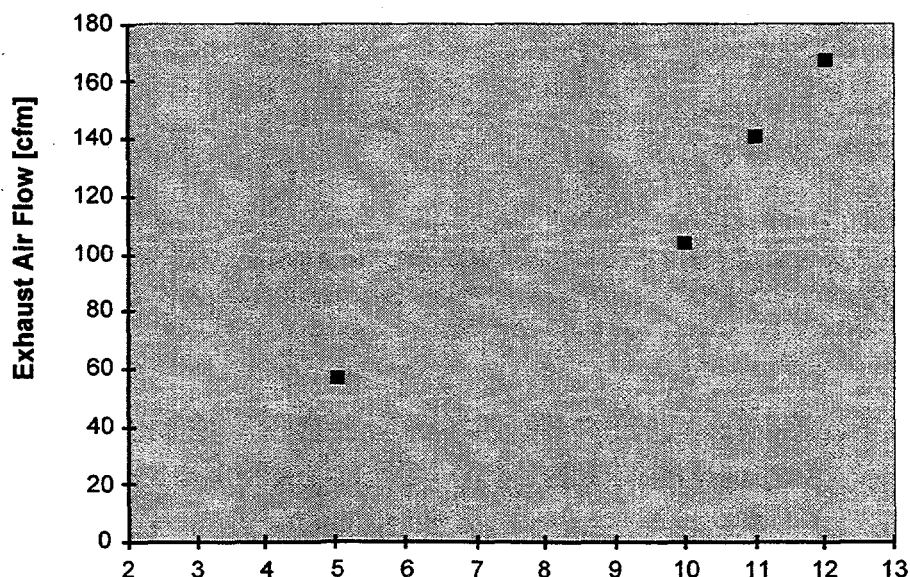


Figure 8. Kitchen exhaust air flow with the local exhaust fans off. Measurements were made at the same exhaust shaft at floors 5, 10, 11 and 12.

3.3 Temperatures, Pressures and Flows

We measured the temperature of the supply air at the hallway registers for floors 2-13, and they were all in the range of 28-30 °C (83-86) °F (see Figure 9). These temperatures were higher than the setpoint in the EMCS for the air supply, which is surprising, but in fact it serves as a more efficient strategy by providing air heated with the gas system than the individual electric units in the apartments and, it avoids cold drafts along the floor!

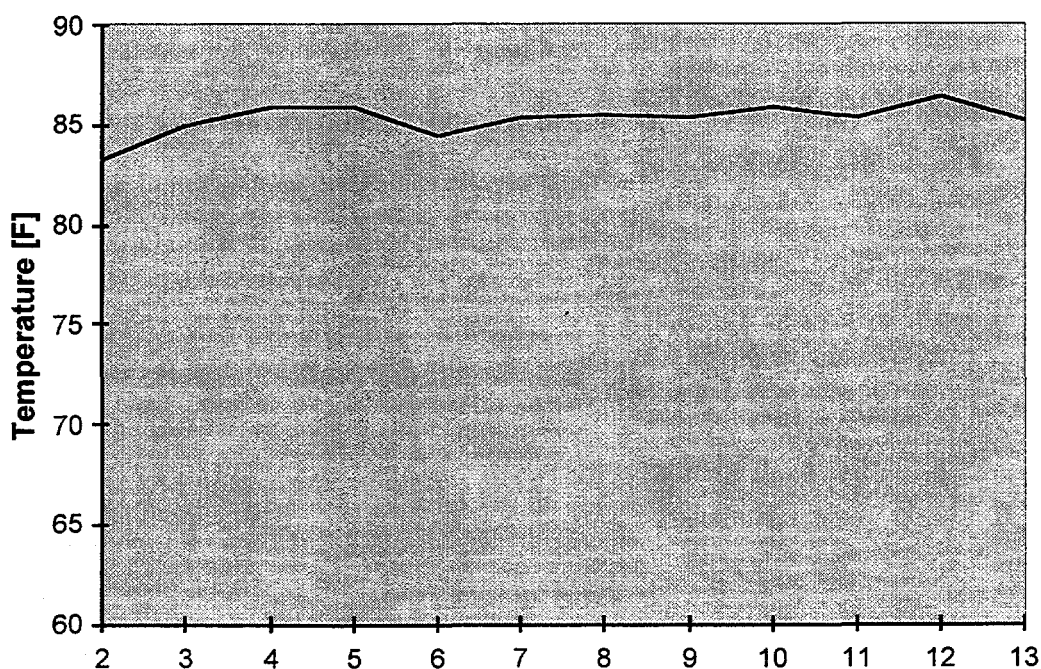


Figure 9. Supply air temperature measured at the hallway registers.

We also measured the supply air flows at the hallway registers and they were all within a range of 900-1300 m³/hr (530-760 cfm) per floor, with the average matching the design specification for the supply air flow (Figure 10).

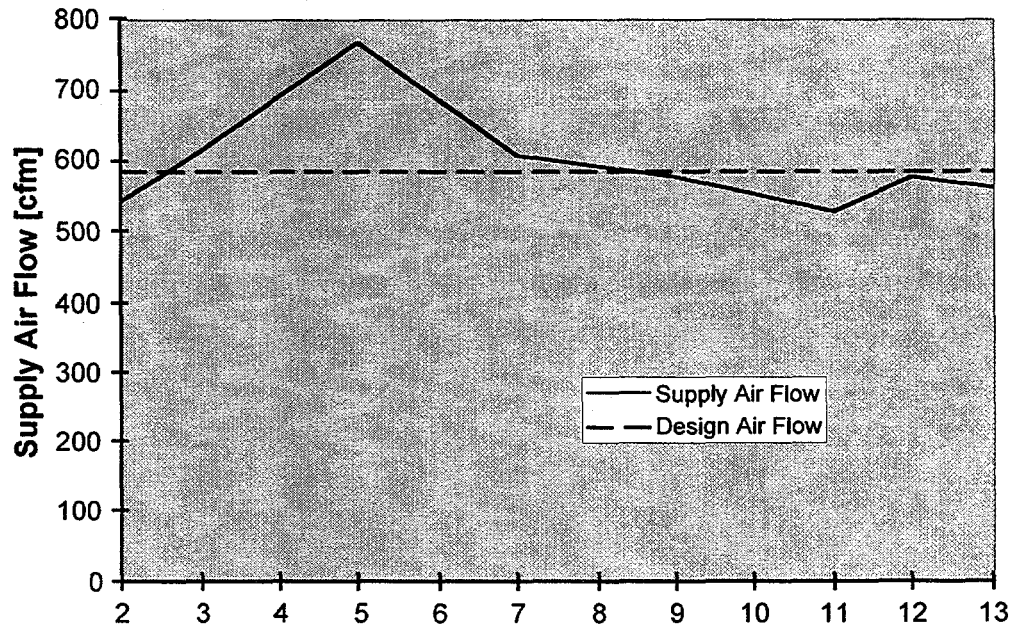


Figure 10. Supply air flow measured at the hallway registers.

The air velocity in the elevator shaft was measured at the top of the shaft at the floor of the penthouse elevator room (which has a large opening to the leeward side). The air velocities ranged between 0.7 and 1.5 m/s with both cabs running (regardless of direction) suggesting the air flow is determined more by wind and stack effect than by the movement of the cabs. The air flow at the top of the elevator shaft during the first measurement was out of the shaft, reversing direction later in the day, i.e., down the shaft, when the wind shifted direction from the northwest to the northeast.

Inside the building, the air velocity from the elevator shaft into the corridor ranged from 2 m/s at the 13th floor down to 0.7 m/s at the 3rd floor. The temperature in the elevator was 19 °C (66 °F) when the outside temperature was 7 °C (45 °F). The air velocity at the trash chute at the 13th floor, with the door open, was 4 m/s, upwards, another indicator of the stack effect in the building.

The pressures from the stairwells to the hallway follow the expected pattern of positive pressures to the outside above the neutral pressure level (roughly the midpoint of the building) and negative pressures below, with the profiles of both the north and south towers being similar. The pressure range from -4 to +8 pascals is relatively small, due to the relatively mild temperatures outside during the measurement 7 °C (45 °F) and the low wind speeds (Figure 11).

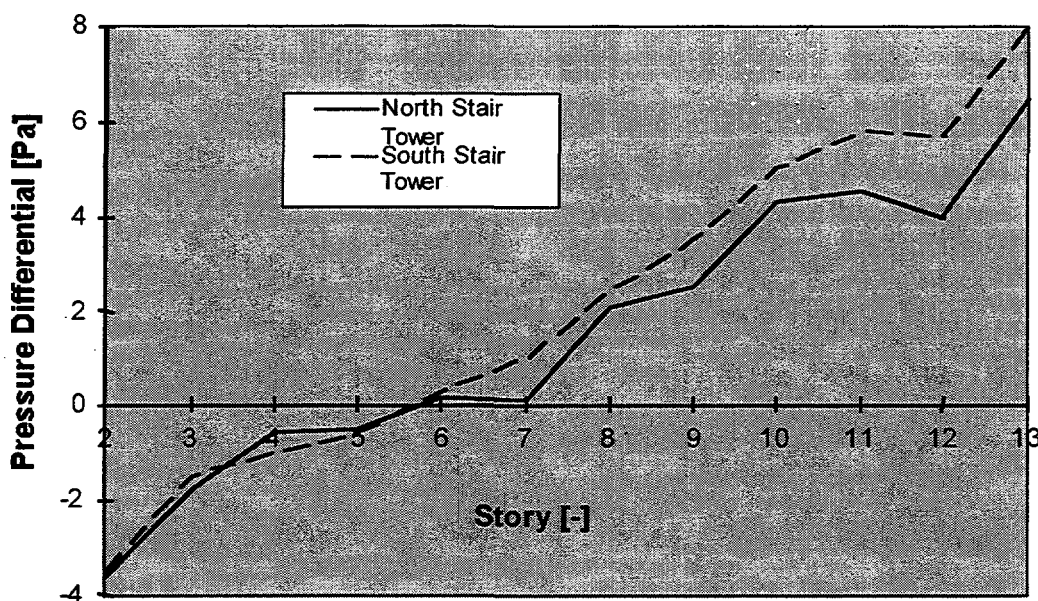


Figure 11. Pressure differences between the stair towers and the hallways.

3.4 Ventilation Simulations

Based on the measured air leakage data from the building we conducted extensive air flow modeling of the apartments using the multizone air flow model COMIS, a simulation tool, developed at Lawrence Berkeley Laboratory, which calculates air flows based on mass balance calculations for individual zones (Feustel, 1990). To make the simplified model, each floor was divided into four corner zones (one apartment each), one zone describing five apartments on the southeast facade, one zone describing four apartments on the northwest facade, one zone describing the

hallway and one zone each for the staircases and the elevatorshaft. The supply shaft and the exhaust shafts were modelled as additional zones. Over one hundred zones were defined in the model (see COMIS input file "CHELSEA.CIF" in the Appendix) with 138 outside pressure points (windpressure distribution) and 565 flow paths were necessary to describe the air flow patterns within the building. (CPU-time for nine different wind velocity / temperature difference combinations is 66 seconds on a SUN SparC ELC computer.) In order to limit the amount of input needed for the simulation model, each apartment was modeled as one zone, assuming the internal doors to be open. To account for the stack effect and the inter-zonal flows between the floors, all 13 floors were modeled.

The results show, that with wind blowing perpendicular to the windward side and no stack effect present, air moves from the windward side facade through the corridors into the leeward side apartments. Under the previous conditions with no ventilation system present, only a small portion of the infiltration air is exhausted through the vertical shafts of the exhaust system. Dampers at the apartment level and on top of each of the shafts restrict the exhaust flow.

When the building is operating without the mechanical ventilation system, the air mass flow distribution for windward side apartments on different floors follows a predictable pattern (Figure 12). With increasing wind speed, the distribution of infiltration becomes more pronounced, showing a minimum at the level of the third floor and a maximum at the 11th floor. The leeward side apartments do not experience any infiltration.

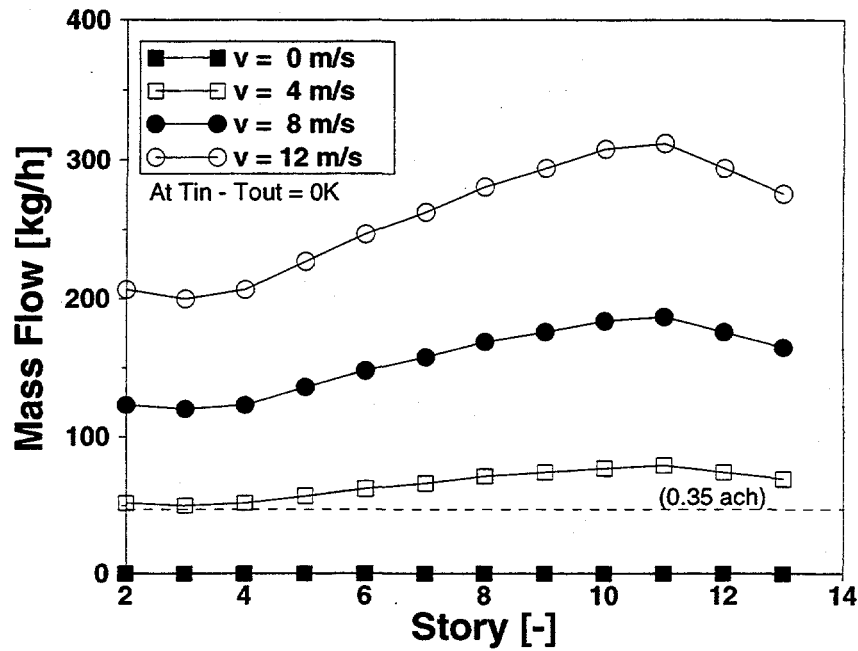


Figure 12. Mass air flow into **windward** apartments at different wind speeds, with no inside/outside temperature difference and the mechanical ventilation system **off**.

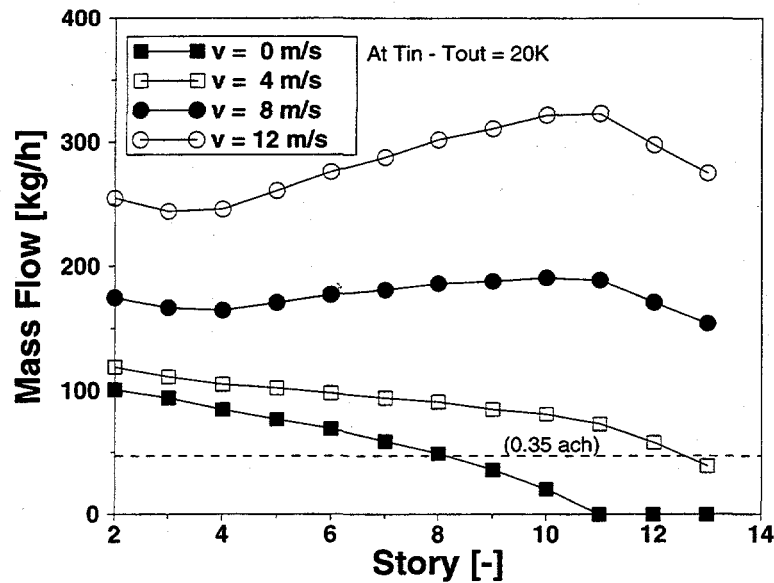


Figure 13. Mass air flow into **windward** apartments, at different wind speeds with an inside/outside temperature difference of 20 K and the mechanical ventilation system **off**.

With a larger inside/outside temperature difference of 20 °C and zero wind speed, the air flow for the windward apartments decreases with height above ground from 100 kg/h (50 cfm) on the second floor to zero at the level of the 11th floor. With increasing wind speed the air flow curves show a more balanced air flow distribution until the velocity driven air flows override the stack effect (Figure 13). As the pressures forcing the air flow can be added, the air flows for any given wind speed are higher if stack pressure is present.

The air flows for the leeward side is shown in Figure 14. With increasing wind speed the air flow entering the apartments through the outside wall is getting smaller. The zero wind speed curve is the same for the windward side and the leeward side. The top floors do not experience any infiltration. Higher wind speeds cause higher negative pressures on the facade, which lower the level for the neutral pressure. At wind speeds of 12 m/s no infiltration occurs at the apartments facing the leeward side.

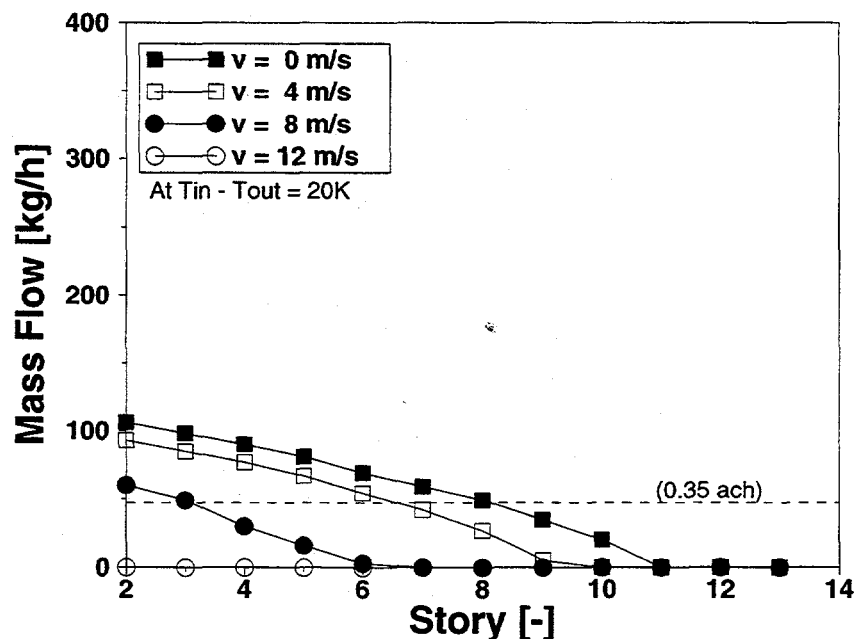


Figure 14. Mass air flow into **leeward** apartments, at different wind speeds with an inside/outside temperature difference of 20 K and the mechanical ventilation system **off**.

Air flows into the apartments are slightly higher when the ventilation system is in operation. Figure 15 shows the air flows entering the apartments located on the windward side through the facade for different wind speeds when no stack effect is present. At low wind conditions, infiltration is almost independent of the height above ground. With higher wind speeds, we see that the infiltration flows follow the wind pressure profile.

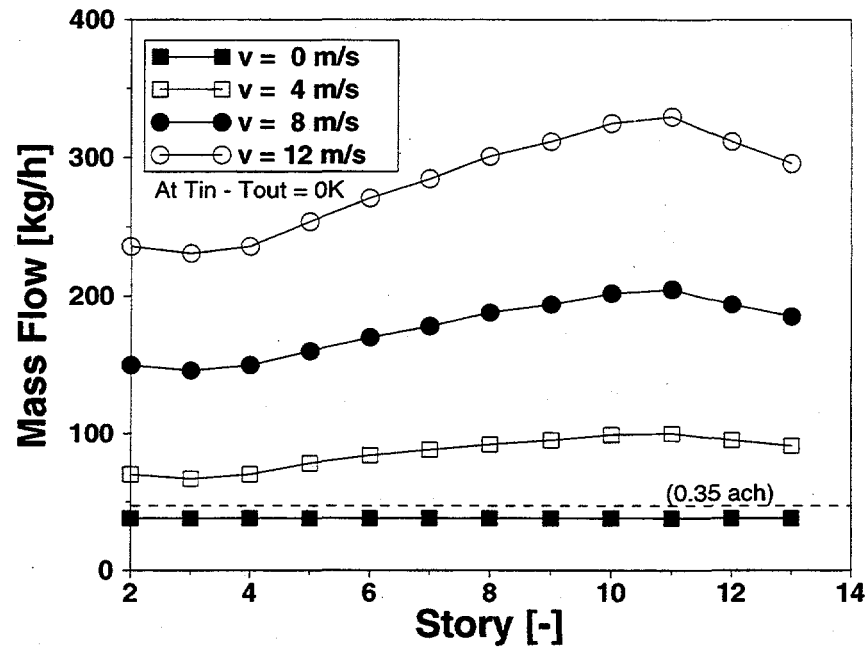


Figure 15. Mass air flow into **windward** apartments at different wind speeds, with no inside/outside temperature difference and the mechanical ventilation system **on**.

The infiltration for the leeward side apartments is quite different (see Fig. 16). For the case of no wind and no inside/outside temperature difference, approximately 75 kg/h are sucked by the exhaust system into the apartment through the exterior building components. With increasing wind speeds, the infiltration is reduced. At wind speeds of 4 m/s, approximately 0.35 ACH are still reached, but with higher wind speeds, the infiltration rate is further reduced, until no outside air enters the apartments when the wind velocity exceeds 12 m/s.

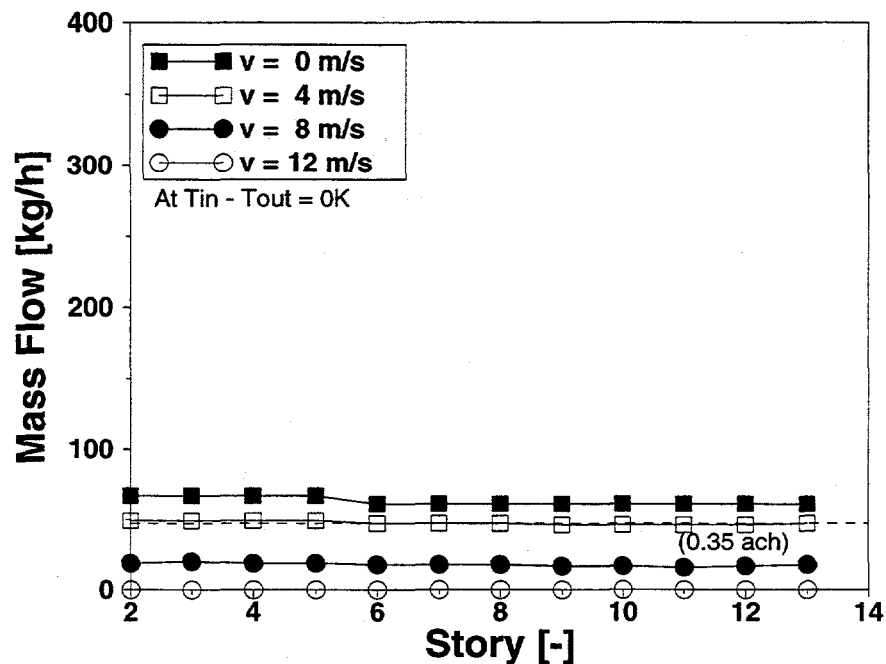


Figure 16. Mass air flow into **leeward** apartments at different wind speeds, with no inside/outside temperature difference and the mechanical ventilation system **on**.

The ventilation system is designed to provide the necessary “fresh” air by means of supplying the air to the corridor. The direction of the air flow through the doorway of the apartment determines whether the supplied air is entering the apartments. For the two higher wind speeds, the air flow passing through the doorways are shown for the apartments on both sides of the corridor (Figure 17). We see, that at higher wind speeds the windward side apartments do not receive any of the air supplied to the corridor. At lower wind speeds, the windward side apartments located on the lower floors participate slightly in the air exchange provided by the supply system. This means, that at lower wind speeds about all the air entering through the facade is being exhausted directly into the vertical exhaust shafts. At higher wind speeds, air from these apartments is forced into the corridor.

All leeward side apartments receive between 50 and 75 kg/h air from the corridor (see Figure 17). With higher wind speeds, the amount of air entering from the corridor increases, however, the air flow being supplied to the corridor via the windward side

apartments is much bigger than the air entering the leeward side apartments. The excess air is leaving the corridor through the elevator shaft. The pressure difference between the corridor and the air intake on the roof could significantly reduce the supply air flow to the corridors.

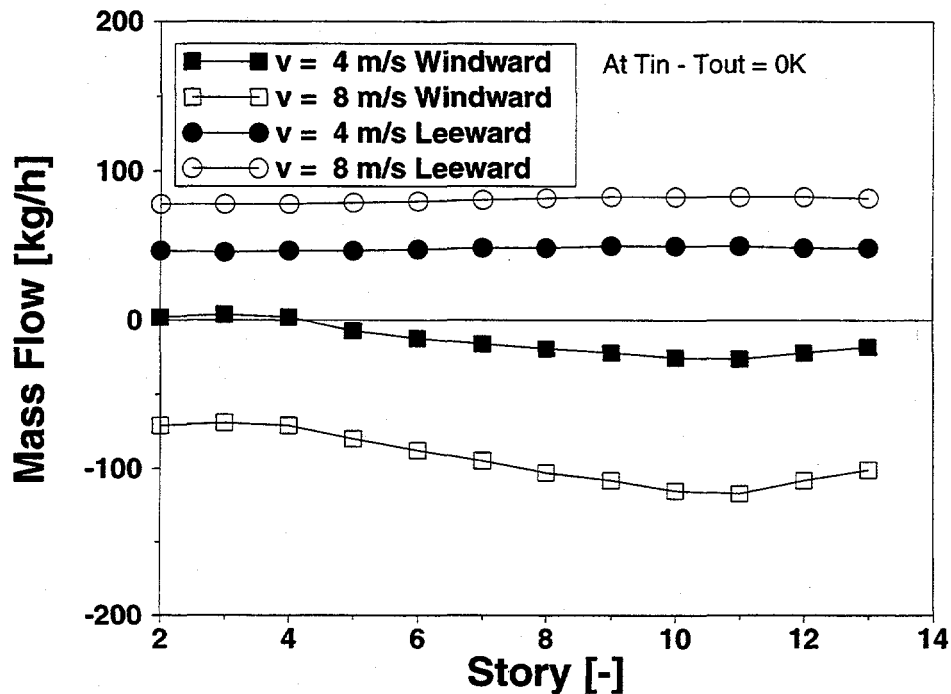


Figure 17. Mass air flow between the apartments and the corridor at different wind speeds and no inside/outside temperature difference, for all apartments and with the mechanical ventilation system on.

With larger temperature differences between inside and outside present (winter case), the infiltration flows for the lower windward side apartments increase significantly. As a consequence, flows from windward side apartments to the corridor will increase for the lower storeys (see Figure 18). Due to the stack effect, even leeward side apartments on floors 2 and 3 contribute to the excess flow of the corridors. Higher up in the building, leeward side apartments receive air from the corridor while windward side apartments exhaust air into the corridor. With increasing temperature difference, the stack effect is amplified.

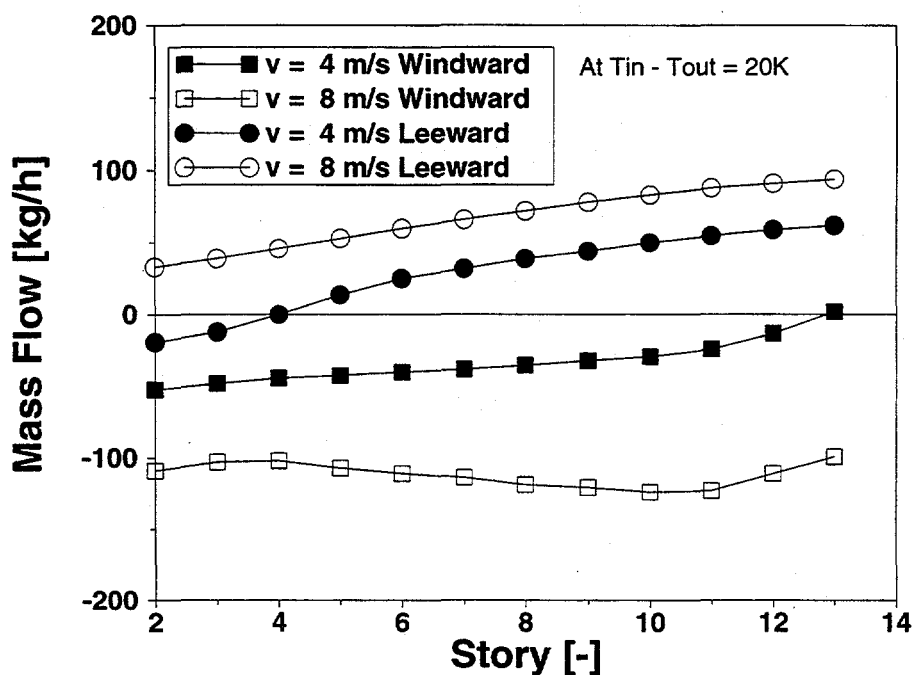


Figure 18. Mass air flow between the apartments and the corridor at different wind speeds and an inside/outside temperature difference of 20 K, for all apartments and with the mechanical ventilation system on.

With the mechanical system operating, the apartments on the leeward side have significantly higher ventilation rates than the apartments on the windward side, particularly in the case of high wind speeds. When the wind is parallel to the building, the mechanical ventilation system is needed in order to ensure proper ventilation to the apartments.

4.0 Conclusions

In any study of a building as complex as a highrise apartment it is important to validate the findings using as many techniques as possible. In the case of the Margolis Apartments we have been fortunate to have different data sources: leakage measurements, pressure tests and air infiltration measurements which have all been used to validate the model. Because comparisons between the model and measurement data agree well in several areas, such as similar directions and

magnitude of pressure differences across apartment doors and stairwell doors, we have a high degree of confidence in the simulation results.

Based on our analysis of the air flow simulations we see that the ventilation to the individual units varies considerably. With the mechanical ventilation system disabled (pre-retrofit case), units at the lower level of the building had adequate ventilation only on days with high temperature differences, while units on higher floors had no ventilation at all. Units facing the windward side were over-ventilated when the building experienced wind directions between west and north. At the same time, leeward side upper apartments would not experience any fresh air--air flows would enter the apartments from the corridor and exit through the exhaust shafts and the cracks in the facade. Even with the mechanical ventilation system operating, we found wide variation in the air flows to the individual apartments.

A fundamental issue here is the design question of how to best supply ventilation to individual apartments in a highrise building. Using the corridor as the supply route has several challenges, including the control of the temperature of the supply air, the temperature of the corridor, the opening from the corridor to the apartment, tenant comfort and the balance between supply and apartment exhaust.

A major conclusion from our measurements and simulations is that each apartment has to be supplied with ventilation air directly. Pressure drops of the system have to be high enough to overcome natural forces to be able to ensure an even distribution of ventilation air. If ventilation air is supplied directly to the individual apartments, the apartments should be uncoupled from the rest of the building by tight apartment doors. This condition not only decreases the impact of natural forces on the distribution of ventilation air, but also reduces the disturbance to tenants of odors or noise from other apartments. In winter, supply air has to be preheated to avoid unpleasant cold drafts. Supply air provided by vents in the envelope should either be preheated by heating elements in the vent itself, or be supplied adjacent to heating sources. Ducted supply air should be preheated in the central unit.

On the exhaust side, studies have shown that when apartment occupants have local control over bathroom and kitchen exhaust, they use them less than one hour per day, if at all (Shapiro-Baruch, 1993), which makes it difficult to size the supply ventilation system. Continuous exhaust ventilation, however, presents the possibility of over ventilation and unnecessary use of energy.

Efforts to improve the energy efficiency of high-rise apartment buildings have been frustrated because of the lack of knowledge on air flows for individual apartments. Ventilation rates for individual apartments vary greatly due to height, orientation, and wind speed and outdoor temperature. Any recommendations for reducing air leakage will have to take these variables into account, so that efforts to tighten the shell for energy efficiency do not create health and comfort problems for the residents.

5.0 Acknowledgments

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APPENDIX:

Margolis Apartments Input File for the *COMIS* Simulation Program

&-CIF

1

COMIS Input File

help.cif

&-PR-IDENTification

2

1. Problemname

Boston/Chelsea Housing for the Elderly

All Input in kg/h; Dimensions in *SET-File must be in kg/s!
 Kitchen- and Bathroom-Shaft were combined. No Fans at the
 Floor-Level present; only on the Roof. Resistance for the
 Duct is distributed between Dampers in the Flats and Dampers
 adjacent to the Fans. Only Corner-Apartments are modelled;
 middle Apartments are combined (East- and West-Apartments
 are treated separately).
 LINK heights are adjusted!

2. Versionname

June 18, 1992

&-PR-OUTPut options

3

Output Option Keywords: One keyword per line only
 Keywords may be preceded by NO

VENT:ilation POL:utant HEAT:flow
 CONC:entrations

INPUT echo
 DEFAULT echo
 SET echo

SCHED:time<time>

START:time<time>[CONT|REUSE] STOP:time<time>[KEEP]

Graphical Output Options: Define data to be Stored:

PZ-S {Zones} = Pressure	FL-S {Links} = Flow
TZ-S {Zones} = Temperature	TL-S {Links} = Temperature
MZ-S {Zones} = Moisture	SL-S {Links} = Status
FZ-S {Zones} = Flow	HU-G = Humidity
VE-G = Velocity	TE-G = Air Temp.
Cn-S {Zones} = Concentr.	Pn-S {Zones} = Poll. Str.
Sn-S {Zones} = Poll. Sink	WP-S {Points} = Windpr.
for Gas n (1<= n <=5)	

To define graphs: replace -S with -T (Table entry)

VENTILATION

PZ-S 1

STARTtime 1992jan01_0:00

STOPTIME 1992jan01_10:00

&-PR-CONTROL parameters 4

--- OPTIONAL DATASE CTION ---

1.	Under Relaxation Factor [-]	T o l e r a n c e s			Start Number of Iterations [-]	Link Flow Pressure Laminar Flow DifLim [Pa]
		absolute EpsFA [kg/s]	Relative EpsFR [-]	CORR*JAC(i,i) EpsCJ [kg/s]		
1.		1.E-06	1.E-05	0.	1	1.E-12

2.	use old Pressures 0=Zero Pressures 1=use Previous UseOPz [-]	No Pressure Initialization 0=Lin.initial. 1=No initial. NoInit [-]	Solver Selector 0=optimum relax COMIS 1=Newton (with given Relax) 2=Newton Steffensen 3=Walton Steffensen 4=One avg. Steffensen 5=Walton 2 fixed relax.fact SlvSel [-]	Max Number of Iterations allowed Miter [-]
1		0	5	50

&-NET-AIR flow components

Allowed prefixes are: *CR *FA *DS *DF *F1 *F2 *F3 *F4 *WI *TD
crack duct flow-controllers testdata points
fan duct-fitting window(openable)
keep the KEYWORDS &-CR,...,&-TD in this part &-NET-AIR

&-CR CRACK

1.	Cs (kg/s@1Pa)	Exp n (-)	Lenght [m]	Wall Properties	
				Thickness [m]	U-Value [W/m2 K]

2.	Filter 1 (-)	Filter 2 [-]	Filter 3 [-]	Filter 4 [-]	Filter 5 [-]
----	-----------------	-----------------	-----------------	-----------------	-----------------

*CRw1 Windows (individual)
10. 0.67
0

*CRw2 Two Windows (units 001 & 013 for floors 2-5)
20 0.67
0

*CRwse Sum of windows east facade
50. 0.67
0

*CRwsW Sum of windows west facade
40. 0.67
0

*CRd1 Entry door to individual flat
10. 0.67
0

*CRdse Sum of entry doors east facade

50. 0.67

0

*CRdsw Sum of entry doors west facade

40. 0.67

0

*CRb1 Balcony doors (individual)

40. 0.67

0

*CRbse Sum of balcony doors east facade

200. 0.67

0

*CRbsw Sum of balcony doors west facade

160. 0.67

0

*CRsd Staircase door

35. 0.67

0

*CRed Elevator and lobby door

100. 0.67

0

*CRfd Fire door in corridor

0. 0.67

0

*CRev Elevator vent (Penthouse)

2000. 0.67

0

*CRda Dampers for kitchen or bathroom exhaust

12.00 0.5

#4.17 0.50

0

*CRdsae two times Sum of dampers for kitchen or bathroom east facade

120. 0.5

#42.0 0.50

0

*CRdsaw two times Sum of dampers for kitchen or bathrooms west facade

106. 0.5

#33.6 0.50

0

*CRdr1 Exhaust damper for kitchen or bathroom on the roof

365. 0.5

#100. 0.50

0

*CRdre Sum of exhaust dampers on the roof east facade

1852. 0.50

#500. 0.50

0

*CRdrw Sum of exhaust dampers on the roof west facade

1460. 0.50

#400. 0.50

0

*CRdsr Supply air damper in central system
1806. 0.50

0

*CRdsc Supply air damper in corridor
150. 0.5

0

*CRho leakage horizontal
0. 0.67

0

*CRve leakage vertical
0. 0.67

0

*CRsvw vertical leakage west
0. 0.67

0

*CRsve vertical leakage east
0. 0.67

0

*CRfan 0.5
100. 0.5

0

&-FA FAN

line1= flag.... #line2=Pminimum.... #line3=C0.....

line4 - line7=datapairs,last line is always the filter line

1.	# Flag: 1=use Polynomial C0,..C5 2=use Data pairs to calculate C0,..Cni
----	--

Flag (-)	Exp Polynom. (-)	RhoI (kg/m3)	NfI [rpm]	Cm [kg/s@1Pa]	Exp n [-]
-------------	---------------------	-----------------	--------------	------------------	--------------

2.	Pmin (Pa)	Pmax (Pa)	Slope (m3/s/Pa)	Intercept (m3/s)
----	--------------	--------------	--------------------	---------------------

3.	C0 (m3/s)	C1 [m3/s/Pa]	C2 [.../Pa2]	C3 [.../Pa3]	C4 [.../Pa4]	C5 [.../Pa5]
----	--------------	-----------------	------------------	------------------	------------------	-----------------

4.	Fan Curve Pressure Rise vs FlowRate maximum 4 Lines				
	Data Pairs	minimum 3 Pairs,	maximum 12 Pairs		
(Pa)	(m3/s)	(Pa)	(m3/s)	(Pa)	(m3/s)

8.	Filter 1 (-)	Filter 2 [-]	Filter 3 [-]	Filter 4 [-]	Filter 5 [-]
----	-----------------	-----------------	-----------------	-----------------	-----------------

*FAsup

Supply Fan

```

2      4      1.2      1      0.1      0.5
0.00000E+00 0.17474E+03 -0.91624E+02 0.16011E+05
0.16011E+05 -0.69381E+01 -0.15266E+00 0.32635E-02 -0.29547E-04 0.00000E+00
0. 16000      30      15800      50      15400

```

```

80      15000      125      11900      160      5000
0

```

*FAr1

Rooftop Exhaust Fan (Double Value)

```

2      4      1.2      1      0.1      0.5
0.00000E+00 0.17476E+03 -0.18844E+02 0.32932E+04
0.32932E+04 -0.14421E+01 -0.30499E-01 0.66098E-03 -0.60439E-05 0.00000E+00
0      3291      30      3250      50      3168
80      3086      125      2448      160      1029
0

```

*FArw

Sum of Fans for the West

```

2      4      1.2      1      0.1      0.5
0.00000E+00 0.17475E+03 -0.74908E+02 0.13090E+05
0.13090E+05 -0.56936E+01 -0.12458E+00 0.26680E-02 -0.24159E-04 0.00000E+00
0      13081      30      12917      50      12590
80      12263      125      9729      160      4088
0

```

*FAre

Sum of Fans for the East

```

2      4      1.2      1      0.1      0.5
0.00000E+00 0.17475E+03 -0.94240E+02 0.16468E+05
0.16468E+05 -0.71717E+01 -0.15569E+00 0.33435E-02 -0.30351E-04 0.00000E+00
0      16457      30      16251      50      15840
80      15429      125      12240      160      5143
0

```

&-NET-ZONes

18

Zone No (-)	Name [-]	Temp [oC]	Ref. Height [m]	Vol [m3]	Abs. Hum [gr/kg]	Schedule Name [T./H..]
1	0202	20.	3.			
2	0201	20.	3.			
3	0212	20.	3.			
4	0213	20.	3.			
5	0204	20.	3.			
6	0207	20.	3.			
7	0214	20.	3.			
8	0302	20.	6.			
9	0301	20.	6.			
10	0312	20.	6.			
11	0313	20.	6.			
12	0304	20.	6.			
13	0307	20.	6.			
14	0314	20.	6.			
15	0402	20.	9.			
16	0401	20.	9.			
17	0412	20.	9.			
18	0413	20.	9.			
19	0404	20.	9.			
20	0407	20.	9.			
21	0414	20.	9.			
22	0502	20.	12.			
23	0501	20.	12.			
24	0512	20.	12.			

25	0513	20.	12.
26	0504	20.	12.
27	0507	20.	12.
28	0514	20.	12.
29	0602	20.	15.
30	0601	20.	15.
31	0612	20.	15.
32	0613	20.	15.
33	0604	20.	15.
34	0607	20.	15.
35	0614	20.	15.
36	0702	20.	18.
37	0701	20.	18.
38	0712	20.	18.
39	0713	20.	18.
40	0704	20.	18.
41	0707	20.	18.
42	0714	20.	18.
43	0802	20.	21.
44	0801	20.	21.
45	0812	20.	21.
46	0813	20.	21.
47	0804	20.	21.
48	0807	20.	21.
49	0814	20.	21.
50	0902	20.	24.
51	0901	20.	24.
52	0912	20.	24.
53	0913	20.	24.
54	0904	20.	24.
55	0907	20.	24.
56	0914	20.	24.
57	1002	20.	27.
58	1001	20.	27.
59	1012	20.	27.
60	1013	20.	27.
61	1004	20.	27.
62	1007	20.	27.
63	1014	20.	27.
64	1102	20.	30.
65	1101	20.	30.
66	1112	20.	30.
67	1113	20.	30.
68	1104	20.	30.
69	1107	20.	30.
70	1114	20.	30.
71	1202	20.	33.
72	1201	20.	33.
73	1212	20.	33.
74	1213	20.	33.
75	1204	20.	33.
76	1207	20.	33.
77	1214	20.	33.
78	1302	20.	36.
79	1301	20.	36.
80	1312	20.	36.
81	1313	20.	36.
82	1304	20.	36.
83	1307	20.	36.
84	1314	20.	36.
85	staircase	20.	0.
86	staircase	20.	0.
87	elevator	20.	0.
88	shaft02	20.	0.

89	shaft01	20.	0.
90	shaft12	20.	0.
91	shaft13	20.	0.
92	shaft04	20.	0.
93	shaft07	20.	0.
94	shaftsupp	20.	0.
95	lobby	20.	0.
96	damper02	20.	41.
97	damper01	20.	41.
98	damper12	20.	41.
99	damper13	20.	41.
100	damper04	20.	41.
101	damper07	20.	41.
102	dapersup	20.	41.

&-NET-EXtErnal node data

21

--- OPTIONAL DATASECTION ---

External Node No (-)	Facade Elem No (-)	Outside Conc Factor [-]
1	1	0.
2	2	0.
3	3	0.
4	4	0.
5	5	0.
6	6	0.
7	7	0.
8	8	0.
9	9	0.
10	10	0.
11	11	0.
12	12	0.
13	13	0.
14	14	0.
15	15	0.
16	16	0.
17	17	0.
18	18	0.
19	19	0.
20	20	0.
21	21	0.
22	22	0.
23	23	0.
24	24	0.
25	25	0.
26	26	0.
27	27	0.
28	28	0.
29	29	0.
30	30	0.
31	31	0.
32	32	0.
33	33	0.
34	34	0.
35	35	0.
36	36	0.
37	37	0.
38	38	0.
39	39	0.
40	40	0.
41	41	0.
42	42	0.
43	43	0.

44	44	0.
45	45	0.
46	46	0.
47	47	0.
48	48	0.
49	49	0.
50	50	0.
51	51	0.
52	52	0.
53	53	0.
54	54	0.
55	55	0.
56	56	0.
57	57	0.
58	58	0.
59	59	0.
60	60	0.
61	61	0.
62	62	0.
63	63	0.
64	64	0.
65	65	0.
66	66	0.
67	67	0.
68	68	0.
69	69	0.
70	70	0.
71	71	0.
72	72	0.
73	73	0.
74	74	0.
75	75	0.
76	76	0.
77	77	0.
78	78	0.
79	79	0.
80	80	0.
81	81	0.
82	82	0.
83	83	0.
84	84	0.
85	85	0.
86	86	0.
87	87	0.
88	88	0.
89	89	0.
90	90	0.
91	91	0.
92	92	0.
93	93	0.
94	94	0.
95	95	0.
96	96	0.
97	97	0.
98	98	0.
99	99	0.
100	100	0.
101	101	0.
102	102	0.
103	103	0.
104	104	0.
105	105	0.
106	106	0.
107	107	0.

108	108	0.
109	109	0.
110	110	0.
111	111	0.
112	112	0.
113	113	0.
114	114	0.
115	115	0.
116	116	0.
117	117	0.
118	118	0.
119	119	0.
120	120	0.
121	121	0.
122	122	0.
123	123	0.
124	124	0.
125	125	0.
126	126	0.
127	127	0.
128	128	0.
129	129	0.
130	130	0.
131	131	0.
132	132	0.
133	133	0.
134	134	0.
135	135	0.
136	136	0.
137	137	0.
138	138	0.

&-NET-LINKs

22

Link	Type	Zone No		Height		Own	Act.	3Dflow or	Schedule Name(5char.)	
No	Name	From	To	From	To	Height	Val.	Press	T-Junct.	Ref.Link
(-)	(-)	(-)	(-)	[m]	[m]	[m]	[-]	[Pa]	No [-]	Angle [deg]
#	stair-case 1 (south-west)									
1	CRsd	-11	85	1.	1.					
2	CRsd	-15	85	1.	1.					
3	CRw1	-22	85	3.	3.					
4	CRw1	-32	85	6.	6.					
5	CRw1	-42	85	9.	9.					
6	CRw1	-52	85	12.	12.					
7	CRw1	-62	85	15.	15.					
8	CRw1	-72	85	18.	18.					
9	CRw1	-82	85	21.	21.					
10	CRw1	-92	85	24.	24.					
11	CRw1	-102	85	27.	27.					
12	CRw1	-112	85	30.	30.					
13	CRw1	-122	85	33.	33.					
14	CRw1	-132	85	36.	36.					
15	CRsd	-135	85	41.	41.					
#	stair-case 2 (north-east)									
21	CRsd	-11	86	1.	1.					
22	CRsd	-15	86	1.	1.					
23	CRw1	-24	86	3.	3.					
24	CRw1	-34	86	6.	6.					
25	CRw1	-44	86	9.	9.					
26	CRw1	-54	86	12.	12.					

27	CRw1	-64	86	15.	15.
28	CRw1	-74	86	18.	18.
29	CRw1	-84	86	21.	21.
30	CRw1	-94	86	24.	24.
31	CRw1	-104	86	27.	27.
32	CRw1	-114	86	30.	30.
33	CRw1	-124	86	33.	33.
34	CRw1	-134	86	36.	36.
35	CRsd	-131	86	41.	41.
#	stair-case 1 and 2 to floors				
50	CRsd	85	7	4.	1.
51	CRsd	86	7	4.	1.
52	CRsd	85	14	7.	1.
53	CRsd	86	14	7.	1.
54	CRsd	85	21	10.	1.
55	CRsd	86	21	10.	1.
56	CRsd	85	28	13.	1.
57	CRsd	86	28	13.	1.
58	CRsd	85	35	16.	1.
59	CRsd	86	35	16.	1.
60	CRsd	85	42	19.	1.
61	CRsd	86	42	19.	1.
62	CRsd	85	49	22.	1.
63	CRsd	86	49	22.	1.
64	CRsd	85	56	25.	1.
65	CRsd	86	56	25.	1.
66	CRsd	85	63	28.	1.
67	CRsd	86	63	28.	1.
68	CRsd	85	70	31.	1.
69	CRsd	86	70	31.	1.
70	CRsd	85	77	34.	1.
71	CRsd	86	77	34.	1.
72	CRsd	85	84	37.	1.
73	CRsd	86	84	37.	1.
#	lobby (ground-floor)				
81	CRsd	-11	95	1.	1.
82	CRsd	-15	95	1.	1.
83	CRsd	-17	95	1.	1.
84	CRsd	-17	95	1.	1.
#	elevator				
111	CRed	87	95	1.	1.
112	CRed	87	7	4.	1.
113	CRed	87	14	7.	1.
114	CRed	87	21	10.	1.
115	CRed	87	28	13.	1.
116	CRed	87	35	16.	1.
117	CRed	87	42	19.	1.
118	CRed	87	49	22.	1.
119	CRed	87	56	25.	1.
120	CRed	87	63	28.	1.
121	CRed	87	70	31.	1.
122	CRed	87	77	34.	1.
123	CRed	87	84	37.	1.
124	CRsd	87	-131	41.	41.
125	CRev	87	-135	43.	43.
#	supply air shaft				
150	CRdsc	94	7	6.	3.
152	CRdsc	94	14	9.	3.
154	CRdsc	94	21	12.	3.
156	CRdsc	94	28	15.	3.
158	CRdsc	94	35	18.	3.
160	CRdsc	94	42	21.	3.
162	CRdsc	94	49	24.	3.
164	CRdsc	94	56	27.	3.

166	CRdsc	94	63	30.	3.
168	CRdsc	94	70	33.	3.
170	CRdsc	94	77	36.	3.
172	CRdsc	94	84	39.	3.
174	CRdsr	94	102	41.	0.
176	FAsup	-5	102	41.	0. 0. 1.0
#176	CRfan	-5	102	41.	0.
#	second floor apartments (202 201 212 213 sum/west sum/east)				
200	CRw1	-22	1	4.	1.
201	CRb1	-22	1	4.	1.
202	CRd1	7	1	1.	1.
203	CRho	5	1	1.5	1.5
204	CRve	8	1	0.	3.
205	CRda	88	1	6.	3.
206	CRda	88	1	4.5	1.5
210	CRw2	-21	2	4.	1.
212	CRw1	-28	2	4.	1.
213	CRw1	-28	2	4.	1.
214	CRb1	-28	2	4.	1.
215	CRd1	7	2	1.	1.
216	CRho	6	2	1.5	1.5
217	CRve	9	2	0.	3.
218	CRda	89	2	6.	3.
219	CRda	89	2	4.5	1.5
240	CRw1	-24	3	4.	1.
241	CRb1	-24	3	4.	1.
242	CRd1	7	3	1.	1.
243	CRho	5	3	1.5	1.5
244	CRve	10	3	0.	3.
245	CRda	90	3	6.	3.
246	CRda	90	3	4.5	1.5
250	CRw2	-25	4	4.	1.
252	CRw1	-26	4	4.	1.
253	CRw1	-26	4	4.	1.
254	CRb1	-26	4	4.	1.
255	CRd1	7	4	1.	1.
256	CRho	6	4	1.5	1.5
257	CRve	11	4	0.	3.
258	CRda	91	4	6.	3.
259	CRda	91	4	4.5	1.5
270	CRwsw	-23	5	4.	1.
271	CRbsw	-23	5	4.	1.
272	CRdsw	7	5	1.	1.
273	CRsvw	12	5	0.	3.
274	CRdsaw	92	5	6.	3.
280	CRwse	-27	6	4.	1.
281	CRbse	-27	6	4.	1.
282	CRdse	7	6	1.	1.
283	CRsve	13	6	0.	3.
284	CRdsae	93	6	6.	3.
300	CRw1	-32	8	7.	1.
301	CRb1	-32	8	7.	1.
302	CRd1	14	8	1.	1.
303	CRho	12	8	1.5	1.5
304	CRve	15	8	0.	3.
305	CRda	88	8	9.	3.
306	CRda	88	8	7.5	1.5
310	CRw2	-31	9	7.	1.
312	CRw1	-38	9	7.	1.
313	CRw1	-38	9	7.	1.
314	CRb1	-38	9	7.	1.
315	CRd1	14	9	1.	1.
316	CRho	13	9	1.5	1.5
317	CRve	16	9	0.	3.

318	CRda	89	9	9.	3.
319	CRda	89	9	7.5	1.5
340	CRw1	-34	10	7.	1.
341	CRb1	-34	10	7.	1.
342	CRd1	14	10	1.	1.
343	CRho	12	10	1.5	1.5
344	CRve	17	10	0.	3.
345	CRda	90	10	9.	3.
346	CRda	90	10	7.5	1.5
350	CRw2	-35	11	7.	1.
352	CRw1	-36	11	7.	1.
353	CRw1	-36	11	7.	1.
354	CRb1	-36	11	7.	1.
355	CRd1	14	11	1.	1.
356	CRho	13	11	1.5	1.5
357	CRve	18	11	0.	3.
358	CRda	91	11	9.	3.
359	CRda	91	11	7.5	1.5
370	CRsw	-33	12	7.	1.
371	CRbsw	-33	12	7.	1.
372	CRdsw	14	12	1.	1.
373	CRsvw	19	12	0.	3.
374	CRdsaw	92	12	9.	3.
380	CRwse	-37	13	7.	1.
381	CRbse	-37	13	7.	1.
382	CRdse	14	13	1.	1.
383	CRsve	20	13	0.	3.
384	CRdsae	93	13	9.	3.
400	CRw1	-42	15	10.	1.
401	CRb1	-42	15	10.	1.
402	CRd1	21	15	1.	1.
403	CRho	19	15	1.5	1.5
404	CRve	22	15	0.	3.
405	CRda	88	15	12.	3.
406	CRda	88	15	10.5	1.5
410	CRw2	-41	16	10.	1.
412	CRw1	-48	16	10.	1.
413	CRw1	-48	16	10.	1.
414	CRb1	-48	16	10.	1.
415	CRd1	21	16	1.	1.
416	CRho	20	16	1.5	1.5
417	CRve	23	16	0.	3.
418	CRda	89	16	12.	3.
419	CRda	89	16	10.5	1.5
440	CRw1	-44	17	10.	1.
441	CRb1	-44	17	10.	1.
442	CRd1	21	17	1.	1.
443	CRho	19	17	1.5	1.5
444	CRve	24	17	0.	3.
445	CRda	90	17	12.	3.
446	CRda	90	17	10.5	1.5
450	CRw2	-45	18	10.	1.
452	CRw1	-46	18	10.	1.
453	CRw1	-46	18	10.	1.
454	CRb1	-46	18	10.	1.
455	CRd1	21	18	1.	1.
456	CRho	20	18	1.5	1.5
457	CRve	25	18	0.	3.
458	CRda	91	18	12.	3.
459	CRda	91	18	10.5	1.5
470	CRsw	-43	19	10.	1.
471	CRbsw	-43	19	10.	1.
472	CRdsw	21	19	1.	1.
473	CRsvw	26	19	0.	3.

474	CRdsaw	92	19	12.	3.
480	CRwse	-47	20	10.	1.
481	CRbse	-47	20	10.	1.
482	CRdse	21	20	1.	1.
483	CRsve	27	20	0.	3.
484	CRdsae	93	20	12.	3.
500	CRw1	-52	22	13.	1.
501	CRb1	-52	22	13.	1.
502	CRd1	28	22	1.	1.
503	CRho	26	22	1.5	1.5
504	CRve	29	22	0.	3.
505	CRda	88	22	15.	3.
506	CRda	88	22	13.5	1.5
510	CRw2	-51	23	13.	1.
512	CRw1	-58	23	13.	1.
513	CRw1	-58	23	13.	1.
514	CRb1	-58	23	13.	1.
515	CRd1	28	23	1.	1.
516	CRho	27	23	1.5	1.5
517	CRve	30	23	0.	3.
518	CRda	89	23	15.	3.
519	CRda	89	23	13.5	1.5
540	CRw1	-54	24	13.	1.
541	CRb1	-54	24	13.	1.
542	CRd1	28	24	1.	1.
543	CRho	26	24	1.5	1.5
544	CRve	31	24	0.	3.
545	CRda	90	24	15.	3.
546	CRda	90	24	13.5	1.5
550	CRw2	-55	25	13.	1.
552	CRw1	-56	25	13.	1.
553	CRw1	-56	25	13.	1.
554	CRb1	-56	25	13.	1.
555	CRd1	28	25	1.	1.
556	CRho	27	25	1.5	1.5
557	CRve	32	25	0.	3.
558	CRda	91	25	15.	3.
559	CRda	91	25	13.5	1.5
570	CRwsw	-53	26	13.	1.
571	CRbsw	-53	26	13.	1.
572	CRdsw	28	26	1.	1.
573	CRsvw	33	26	0.	3.
574	CRdsaw	92	26	15.	3.
580	CRwse	-57	27	13.	1.
581	CRbse	-57	27	13.	1.
582	CRdse	28	27	1.	1.
583	CRsve	34	27	0.	3.
584	CRdsae	93	27	15.	3.
600	CRw1	-62	29	16.	1.
601	CRb1	-62	29	16.	1.
602	CRd1	35	29	1.	1.
603	CRho	33	29	1.5	1.5
604	CRve	36	29	0.	3.
605	CRda	88	29	18.	3.
606	CRda	88	29	16.5	1.5
613	CRw1	-68	30	16.	1.
614	CRb1	-68	30	16.	1.
615	CRd1	35	30	1.	1.
616	CRho	34	30	1.5	1.5
617	CRve	37	30	0.	3.
618	CRda	89	30	18.	3.
619	CRda	89	30	16.5	1.5
640	CRw1	-64	31	16.	1.
641	CRb1	-64	31	16.	1.

642	CRd1	35	31	1.	1.
643	CRho	33	31	1.5	1.5
644	CRve	38	31	0.	3.
645	CRda	90	31	18.	3.
646	CRda	90	31	16.5	1.5
653	CRw1	-66	32	16.	1.
654	CRb1	-66	32	16.	1.
655	CRd1	35	32	1.	1.
656	CRho	34	32	1.5	1.5
657	CRve	39	32	0.	3.
658	CRda	91	32	18.	3.
659	CRda	91	32	16.5	1.5
670	CRsw	-63	33	16.	1.
671	CRbsw	-63	33	16.	1.
672	CRdsw	35	33	1.	1.
673	CRsvw	40	33	0.	3.
674	CRdsaw	92	33	18.	3.
680	CRwse	-67	34	16.	1.
681	CRbse	-67	34	16.	1.
682	CRdse	35	34	1.	1.
683	CRsve	41	34	0.	3.
684	CRdsae	93	34	18.	3.
700	CRw1	-72	36	19.	1.
701	CRb1	-72	36	19.	1.
702	CRd1	42	36	1.	1.
703	CRho	40	36	1.5	1.5
704	CRve	43	36	0.	3.
705	CRda	88	36	21.	3.
706	CRda	88	36	19.5	1.5
713	CRw1	-78	37	19.	1.
714	CRb1	-78	37	19.	1.
715	CRd1	42	37	1.	1.
716	CRho	41	37	1.5	1.5
717	CRve	44	37	0.	3.
718	CRda	89	37	21.	3.
719	CRda	89	37	19.5	1.5
740	CRw1	-74	38	19.	1.
741	CRb1	-74	38	19.	1.
742	CRd1	42	38	1.	1.
743	CRho	40	38	1.5	1.5
744	CRve	45	38	0.	3.
745	CRda	90	38	21.	3.
746	CRda	90	38	19.5	1.5
753	CRw1	-76	39	19.	1.
754	CRb1	-76	39	19.	1.
755	CRd1	42	39	1.	1.
756	CRho	41	39	1.5	1.5
757	CRve	46	39	0.	3.
758	CRda	91	39	21.	3.
759	CRda	91	39	19.5	1.5
770	CRsw	-73	40	19.	1.
771	CRbsw	-73	40	19.	1.
772	CRdsw	42	40	1.	1.
773	CRsvw	47	40	0.	3.
774	CRdsaw	92	40	21.	3.
780	CRwse	-77	41	19.	1.
781	CRbse	-77	41	19.	1.
782	CRdse	42	41	1.	1.
783	CRsve	48	41	0.	3.
784	CRdsae	93	41	21.	3.
800	CRw1	-82	43	22.	1.
801	CRb1	-82	43	22.	1.
802	CRd1	49	43	1.	1.
803	CRho	47	43	1.5	1.5

804	CRve	50	43	0.	3.
805	CRda	88	43	24.	3.
806	CRda	88	43	22.5	1.5
813	CRw1	-88	44	22.	1.
814	CRb1	-88	44	22.	1.
815	CRd1	49	44	1.	1.
816	CRho	48	44	1.5	1.5
817	CRve	51	44	0.	3.
818	CRda	89	44	24.	3.
819	CRda	89	44	22.5	1.5
840	CRw1	-84	45	22.	1.
841	CRb1	-84	45	22.	1.
842	CRd1	49	45	1.	1.
843	CRho	47	45	1.5	1.5
844	CRve	52	45	0.	3.
845	CRda	90	45	24.	3.
846	CRda	90	45	22.5	1.5
853	CRw1	-86	46	22.	1.
854	CRb1	-86	46	22.	1.
855	CRd1	49	46	1.	1.
856	CRho	48	46	1.5	1.5
857	CRve	53	46	0.	3.
858	CRda	91	46	24.	3.
859	CRda	91	46	22.5	1.5
870	CRsw	-83	47	22.	1.
871	CRbsw	-83	47	22.	1.
872	CRdsw	49	47	1.	1.
873	CRsvw	54	47	0.	3.
874	CRdsaw	92	47	24.	3.
880	CRwse	-87	48	22.	1.
881	CRbse	-87	48	22.	1.
882	CRdse	49	48	1.	1.
883	CRsve	55	48	0.	3.
884	CRdsae	93	48	24.	3.
900	CRw1	-92	50	25.	1.
901	CRb1	-92	50	25.	1.
902	CRd1	56	50	1.	1.
903	CRho	54	50	1.5	1.5
904	CRve	57	50	0.	3.
905	CRda	88	50	27.	3.
906	CRda	88	50	25.5	1.5
913	CRw1	-98	51	25.	1.
914	CRb1	-98	51	25.	1.
915	CRd1	56	51	1.	1.
916	CRho	55	51	1.5	1.5
917	CRve	58	51	0.	3.
918	CRda	89	51	27.	3.
919	CRda	89	51	25.5	1.5
940	CRw1	-94	52	25.	1.
941	CRb1	-94	52	25.	1.
942	CRd1	56	52	1.	1.
943	CRho	54	52	1.5	1.5
944	CRve	59	52	0.	3.
945	CRda	90	52	27.	3.
946	CRda	90	52	25.5	1.5
953	CRw1	-96	53	25.	1.
954	CRb1	-96	53	25.	1.
955	CRd1	56	53	1.	1.
956	CRho	55	53	1.5	1.5
957	CRve	60	53	0.	3.
958	CRda	91	53	27.	3.
959	CRda	91	53	25.5	1.5
970	CRsw	-93	54	25.	1.
971	CRbsw	-93	54	25.	1.

972	CRdsw	56	54	1.	1.
973	CRsvw	61	54	0.	3.
974	CRdsaw	92	54	27.	3.
980	CRwse	-97	55	25.	1.
981	CRbse	-97	55	25.	1.
982	CRdse	56	55	1.	1.
983	CRsve	62	55	0.	3.
984	CRdsae	93	55	27.	3.
1000	CRw1	-102	57	28.	1.
1001	CRb1	-102	57	28.	1.
1002	CRd1	63	57	1.	1.
1003	CRho	61	57	1.5	1.5
1004	CRve	64	57	0.	3.
1005	CRda	88	57	30.	3.
1006	CRda	88	57	28.5	1.5
1013	CRw1	-108	58	28.	1.
1014	CRb1	-108	58	28.	1.
1015	CRd1	63	58	1.	1.
1016	CRho	62	58	1.5	1.5
1017	CRve	65	58	0.	3.
1018	CRda	89	58	30.	3.
1019	CRda	89	58	28.5	1.5
1040	CRw1	-104	59	28.	1.
1041	CRb1	-104	59	28.	1.
1042	CRd1	63	59	1.	1.
1043	CRho	61	59	1.5	1.5
1044	CRve	66	59	0.	3.
1045	CRda	90	59	30.	3.
1046	CRda	90	59	28.5	1.5
1053	CRw1	-106	60	28.	1.
1054	CRb1	-106	60	28.	1.
1055	CRd1	63	60	1.	1.
1056	CRho	62	60	1.5	1.5
1057	CRve	67	60	0.	3.
1058	CRda	91	60	30.	3.
1059	CRda	91	60	28.5	1.5
1070	CRwsw	-103	61	28.	1.
1071	CRbsw	-103	61	28.	1.
1072	CRdsw	63	61	1.	1.
1073	CRsvw	68	61	0.	3.
1074	CRdsaw	92	61	30.	3.
1080	CRwse	-107	62	28.	1.
1081	CRbse	-107	62	28.	1.
1082	CRdse	63	62	1.	1.
1083	CRsve	69	62	0.	3.
1084	CRdsae	93	62	30.	3.
1100	CRw1	-112	64	31.	1.
1101	CRb1	-112	64	31.	1.
1102	CRd1	70	64	1.	1.
1103	CRho	68	64	1.5	1.5
1104	CRve	71	64	0.	3.
1105	CRda	88	64	33.	3.
1106	CRda	88	64	31.5	1.5
1113	CRw1	-118	65	31.	1.
1114	CRb1	-118	65	31.	1.
1115	CRd1	70	65	1.	1.
1116	CRho	69	65	1.5	1.5
1117	CRve	72	65	0.	3.
1118	CRda	89	65	33.	3.
1119	CRda	89	65	31.5	1.5
1140	CRw1	-114	66	31.	1.
1141	CRb1	-114	66	31.	1.
1142	CRd1	70	66	1.	1.
1143	CRho	68	66	1.5	1.5

1144	CRve	73	66	0.	3.
1145	CRda	90	66	33.	3.
1146	CRda	90	66	31.5	1.5
1153	CRw1	-116	67	31.	1.
1154	CRb1	-116	67	31.	1.
1155	CRd1	70	67	1.	1.
1156	CRho	69	67	1.5	1.5
1157	CRve	74	67	0.	3.
1158	CRda	91	67	33.	3.
1159	CRda	91	67	31.5	1.5
1170	CRsw	-113	68	31.	1.
1171	CRbsw	-113	68	31.	1.
1172	CRdsw	70	68	1.	1.
1173	CRsvw	75	68	0.	3.
1174	CRdsaw	92	68	33.	3.
1180	CRwse	-117	69	31.	1.
1181	CRbse	-117	69	31.	1.
1182	CRdse	70	69	1.	1.
1183	CRsve	76	69	0.	3.
1184	CRdsae	93	69	33.	3.
1200	CRw1	-122	71	34.	1.
1201	CRb1	-122	71	34.	1.
1202	CRd1	77	71	1.	1.
1203	CRho	75	71	1.5	1.5
1204	CRve	78	71	0.	3.
1205	CRda	88	71	36.	3.
1206	CRda	88	71	34.5	1.5
1213	CRw1	-128	72	34.	1.
1214	CRb1	-128	72	34.	1.
1215	CRd1	77	72	1.	1.
1216	CRho	76	72	1.5	1.5
1217	CRve	79	72	0.	3.
1218	CRda	89	72	36.	3.
1219	CRda	89	72	34.5	1.5
1240	CRw1	-124	73	34.	1.
1241	CRb1	-124	73	34.	1.
1242	CRd1	77	73	1.	1.
1243	CRho	75	73	1.5	1.5
1244	CRve	80	73	0.	3.
1245	CRda	90	73	36.	3.
1246	CRda	90	73	34.5	1.5
1253	CRw1	-126	74	34.	1.
1254	CRb1	-126	74	34.	1.
1255	CRd1	77	74	1.	1.
1256	CRho	76	74	1.5	1.5
1257	CRve	81	74	0.	3.
1258	CRda	91	74	36.	3.
1259	CRda	91	74	34.5	1.5
1270	CRsw	-123	75	34.	1.
1271	CRbsw	-123	75	34.	1.
1272	CRdsw	77	75	1.	1.
1273	CRsvw	82	75	0.	3.
1274	CRdsaw	92	75	36.	3.
1280	CRwse	-127	76	34.	1.
1281	CRbse	-127	76	34.	1.
1282	CRdse	77	76	1.	1.
1283	CRsve	83	76	0.	3.
1284	CRdsae	93	76	36.	3.
1300	CRw1	-132	78	37.	1.
1301	CRb1	-132	78	37.	1.
1302	CRd1	84	78	1.	1.
1303	CRho	82	78	1.5	1.5
1305	CRda	88	78	39.	3.
1306	CRda	88	78	37.5	1.5

1313	CRw1	-138	79	37.	1.	
1314	CRb1	-138	79	37.	1.	
1315	CRd1	84	79	1.	1.	
1316	CRho	83	79	1.5	1.5	
1318	CRda	89	79	39.	3.	
1319	CRda	89	79	37.5	1.5	
1340	CRw1	-134	80	37.	1.	
1341	CRb1	-134	80	37.	1.	
1342	CRd1	84	80	1.	1.	
1343	CRho	82	80	1.5	1.5	
1345	CRda	90	80	39.	3.	
1346	CRda	90	80	37.5	1.5	
1353	CRw1	-136	81	37.	1.	
1354	CRb1	-136	81	37.	1.	
1355	CRd1	84	81	1.	1.	
1356	CRho	83	81	1.5	1.5	
1358	CRda	91	81	39.	3.	
1359	CRda	91	81	37.5	1.5	
1370	CRsw	-133	82	37.	1.	
1371	CRbsw	-133	82	37.	1.	
1372	CRdsw	84	82	1.	1.	
1374	CRdsaw	92	82	39.	3.	
1380	CRwse	-137	83	37.	1.	
1381	CRbse	-137	83	37.	1.	
1382	CRdse	84	83	1.	1.	
1384	CRdsae	93	83	39.	3.	
1400	CRdr1	88	96	41.	0.	
1401	FAR1	96	-1	0.	41.	0. 1.10
#1401	CRfan	96	-1	0.	41.	
1402	CRdr1	89	97	41.	0.	
1403	FAR1	97	-1	0.	41.	0. 1.10
#1403	CRfan	97	-1	0.	41.	
1404	CRdr1	90	98	41.	0.	
1495	FAR1	98	-1	0.	41.	0. 1.10
#1495	CRfan	98	-1	0.	41.	
1406	CRdr1	91	99	41.	0.	
1407	FAR1	99	-1	0.	41.	0. 1.10
#1407	CRfan	99	-1	0.	41.	
1408	CRdrw	92	100	41.	0.	
1409	FARw	100	-1	0.	41.	0. 1.10
#1409	CRfan	100	-1	0.	41.	
1410	CRdre	93	101	41.	0.	
1411	FAre	101	-1	0.	41.	0. 1.10
#1411	CRfan	101	-1	0.	41.	

&-CP-BUILDing reference height for Cp data 32 - OPTIONAL DATASECTION ---

Height (m)

40

&-CP-VALUes

33

--- OPTIONAL DATASECTION ---

1. Dataset Name

non

2.	Facade	Winddirection				(first line)			
Elemno		Cp Values				(second and following lines)			
* (-)	(deg)	[deg]	[deg]	[deg]	[deg]	[deg]	[deg]	[deg]	[deg]
*	0.	45.	90.	135.	180.	225.	270.	315.	
1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	
2	0.	0.	0.	0.	0.	0.	0.	0.	
3	0.	0.	0.	0.	0.	0.	0.	0.	
4	0.	0.	0.	0.	0.	0.	0.	0.	
5	0.6	0.4	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	
6	0.	0.	0.	0.	0.	0.	0.	0.	
7	0.	0.	0.	0.	0.	0.	0.	0.	
8	0.	0.	0.	0.	0.	0.	0.	0.	
9	0.	0.	0.	0.	0.	0.	0.	0.	
10	0.	0.	0.	0.	0.	0.	0.	0.	
11	-0.5	-0.3	-0.5	-0.3	0.6	0.4	0.6	-0.3	
12	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.4	
13	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.4	
14	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.4	
15	0.6	0.4	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	
16	-0.5	-0.3	0.6	0.4	0.6	-0.3	-0.5	-0.3	
17	-0.5	-0.3	0.6	0.4	0.6	-0.3	-0.5	-0.3	
18	-0.5	-0.3	0.6	0.4	0.6	-0.3	-0.5	-0.3	
19	0.	0.	0.	0.	0.	0.	0.	0.	
20	0.	0.	0.	0.	0.	0.	0.	0.	
21	-0.5	-0.3	-0.5	-0.3	0.6	0.4	0.6	-0.3	
22	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.4	
23	0.3	-0.3	-0.5	-0.3	-0.5	-0.3	0.3	0.4	
24	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.4	
25	0.6	0.4	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	
26	-0.5	-0.3	0.6	0.4	0.	-0.3	-0.5	-0.3	
27	-0.5	-0.3	0.3	0.4	0.3	-0.3	-0.5	-0.3	
28	-0.5	-0.3	0.	0.4	0.6	-0.3	-0.5	-0.3	
29	0.	0.	0.	0.	0.	0.	0.	0.	
30	0.	0.	0.	0.	0.	0.	0.	0.	
31	-0.5	-0.3	-0.5	-0.3	0.6	0.38	0.6	-0.3	
32	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.38	
33	0.3	-0.3	-0.5	-0.3	-0.5	-0.3	0.3	0.38	
34	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.38	
35	0.6	0.38	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	
36	-0.5	-0.3	0.6	0.38	0.	-0.3	-0.5	-0.3	
37	-0.5	-0.3	0.3	0.38	0.3	-0.3	-0.5	-0.3	
38	-0.5	-0.3	0.	0.38	0.6	-0.3	-0.5	-0.3	
39	0.	0.	0.	0.	0.	0.	0.	0.	
40	0.	0.	0.	0.	0.	0.	0.	0.	
41	-0.5	-0.3	-0.5	-0.3	0.6	0.4	0.6	-0.3	
42	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.4	
43	0.3	-0.3	-0.5	-0.3	-0.5	-0.3	0.3	0.4	
44	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.4	
45	0.6	0.4	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	
46	-0.5	-0.3	0.6	0.4	0.	-0.3	-0.5	-0.3	
47	-0.5	-0.3	0.3	0.4	0.3	-0.3	-0.5	-0.3	
48	-0.5	-0.3	0.	0.4	0.6	-0.3	-0.5	-0.3	
49	0.	0.	0.	0.	0.	0.	0.	0.	
50	0.	0.	0.	0.	0.	0.	0.	0.	
51	-0.5	-0.3	-0.5	-0.3	0.6	0.47	0.6	-0.3	
52	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.47	
53	0.3	-0.3	-0.5	-0.3	-0.5	-0.3	0.3	0.47	
54	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.47	
55	0.6	0.47	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	

56	-0.5	-0.3	0.6	0.47	0.	-0.3	-0.5	-0.3
57	-0.5	-0.3	0.3	0.47	0.3	-0.3	-0.5	-0.3
58	-0.5	-0.3	0.	0.47	0.6	-0.3	-0.5	-0.3
59	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.
61	-0.5	-0.3	-0.5	-0.3	0.6	0.54	0.6	-0.3
62	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.6	0.54
63	0.3	-0.3	-0.5	-0.3	-0.5	-0.3	0.3	0.54
64	0.6	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.54
65	0.6	0.54	0.6	-0.3	-0.5	-0.3	-0.5	-0.3
66	-0.5	-0.3	0.6	0.54	0.	-0.3	-0.5	-0.3
67	-0.5	-0.3	0.3	0.54	0.3	-0.3	-0.5	-0.3
68	-0.5	-0.3	0.	0.54	0.6	-0.3	-0.5	-0.3
69	0.	0.	0.	0.	0.	0.	0.	0.
70	0.	0.	0.	0.	0.	0.	0.	0.
71	-0.5	-0.3	-0.5	-0.3	0.7	0.6	0.7	-0.3
72	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.7	0.6
73	0.35	-0.3	-0.5	-0.3	-0.5	-0.3	0.35	0.6
74	0.7	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.6
75	0.7	0.6	0.7	-0.3	-0.5	-0.3	-0.5	-0.3
76	-0.5	-0.3	0.7	0.6	0.	-0.3	-0.5	-0.3
77	-0.5	-0.3	0.35	0.6	0.35	-0.3	-0.5	-0.3
78	-0.5	-0.3	0.	0.6	0.7	-0.3	-0.5	-0.3
79	0.	0.	0.	0.	0.	0.	0.	0.
80	0.	0.	0.	0.	0.	0.	0.	0.
81	-0.5	-0.3	-0.5	-0.3	0.7	0.67	0.7	-0.3
82	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.7	0.67
83	0.35	-0.3	-0.5	-0.3	-0.5	-0.3	0.35	0.67
84	0.7	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.67
85	0.7	0.67	0.7	-0.3	-0.5	-0.3	-0.5	-0.3
86	-0.5	-0.3	0.7	0.67	0.	-0.3	-0.5	-0.3
87	-0.5	-0.3	0.35	0.67	0.35	-0.3	-0.5	-0.3
88	-0.5	-0.3	0.	0.67	0.7	-0.3	-0.5	-0.3
89	0.	0.	0.	0.	0.	0.	0.	0.
90	0.	0.	0.	0.	0.	0.	0.	0.
91	-0.5	-0.3	-0.5	-0.3	0.8	0.72	0.8	-0.3
92	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.8	0.72
93	0.4	-0.3	-0.5	-0.3	-0.5	-0.3	0.4	0.72
94	0.8	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.72
95	0.8	0.72	0.8	-0.3	-0.5	-0.3	-0.5	-0.3
96	-0.5	-0.3	0.8	0.72	0.	-0.3	-0.5	-0.3
97	-0.5	-0.3	0.4	0.72	0.4	-0.3	-0.5	-0.3
98	-0.5	-0.3	0.	0.72	0.8	-0.3	-0.5	-0.3
99	0.	0.	0.	0.	0.	0.	0.	0.
100	0.	0.	0.	0.	0.	0.	0.	0.
101	-0.5	-0.3	-0.5	-0.3	0.8	0.78	0.8	-0.3
102	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.8	0.78
103	0.4	-0.3	-0.5	-0.3	-0.5	-0.3	0.4	0.78
104	0.8	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.78
105	0.8	0.78	0.8	-0.3	-0.5	-0.3	-0.5	-0.3
106	-0.5	-0.3	0.8	0.78	0.	-0.3	-0.5	-0.3
107	-0.5	-0.3	0.4	0.78	0.4	-0.3	-0.5	-0.3
108	-0.5	-0.3	0.	0.78	0.8	-0.3	-0.5	-0.3
109	0.	0.	0.	0.	0.	0.	0.	0.
110	0.	0.	0.	0.	0.	0.	0.	0.
111	-0.5	-0.3	-0.5	-0.3	0.9	0.8	0.9	-0.3
112								

120	0.	0.	0.	0.	0.	0.	0.	0.
121	-0.5	-0.3	-0.5	-0.3	0.8	0.72	0.8	-0.3
122	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.8	0.72
123	0.4	-0.3	-0.5	-0.3	-0.5	-0.3	0.4	0.72
124	0.8	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.72
125	0.8	0.72	0.8	-0.3	-0.5	-0.3	-0.5	-0.3
126	-0.5	-0.3	0.8	0.72	0.	-0.3	-0.5	-0.3
127	-0.5	-0.3	0.4	0.72	0.4	-0.3	-0.5	-0.3
128	-0.5	-0.3	0.	0.72	0.8	-0.3	-0.5	-0.3
129	0.	0.	0.	0.	0.	0.	0.	0.
130	0.	0.	0.	0.	0.	0.	0.	0.
131	-0.5	-0.3	-0.5	-0.3	0.75	0.65	0.75	-0.3
132	0.	-0.3	-0.5	-0.3	-0.5	-0.3	0.75	0.65
133	0.4	-0.3	-0.5	-0.3	-0.5	-0.3	0.4	0.65
134	0.75	-0.3	-0.5	-0.3	-0.5	-0.3	0.	0.65
135	0.75	0.65	0.75	-0.3	-0.5	-0.3	-0.5	-0.3
136	-0.5	-0.3	0.75	0.65	0.	-0.3	-0.5	-0.3
137	-0.5	-0.3	0.4	0.65	0.4	-0.3	-0.5	-0.3
138	-0.5	-0.3	0.	0.65	0.75	-0.3	-0.5	-0.3

&-SCH-METeo data

36

--- OPTIONAL DATASECTION ---

1.	Dataset Name

help

F:boston.bin DOE2

2.	Time	Wind		Temperature	Humidity	Barometer
		Speed	Direction			Pressure
(-)		(m/sec)	(deg)	(oC)	[g/kg]	Absolute
						[kPa]
1992jan01_0:00		0.0	315.	20.	0.	103.5
1992jan01_1:00		4.0	315.	20.	0.	103.5
1992jan01_2:00		8.0	315.	20.	0.	103.5
#1992jan01_3:00		12.	315.	20.	0.	103.5
1992jan01_4:00		0.0	315.	0.	0.	103.5
1992jan01_5:00		4.0	315.	0.	0.	103.5
1992jan01_6:00		8.0	315.	0.	0.	103.5
#1992jan01_7:00		12.	315.	0.	0.	103.5
1992jan01_8:00		0.0	315.	-20.	0.	103.5
1992jan01_9:00		4.0	315.	-20.	0.	103.5
1992jan01_10:00		8.0	315.	-20.	0.	103.5
#1992jan01_11:00		12.	315.	-20.	0.	103.5

