RESEARCH REPORT

Field Investigation Survey of Airtightness, Air Movement & IAQ In High Rise Apartment Buildings Summary Report

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FIELD INVESTIGATION SURVEY OF AIRTIGHTNESS, AIR MOVEMENT AND INDOOR AIR QUALITY IN HIGH RISE APARTMENT BUILDINGS SUMMARY REPORT

Submitted to:

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July, 1993

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This publication is one of the many items of information published by CMHC with the assistance of federal funds.

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This study was conducted by Wardrop Engineering Inc. for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretation and recommendations are those of the consultants and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

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Field Investigation Survey Summary Report of Air Tightness, Air Movement, and Indoor Air Quality in High-Rise Apartment Buildings in Five Canadian Regions

JULY 1993

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Field Investigation Survey Summary Report of Air Tightness, Air Movement, and Indoor Air Quality in High-Rise Apartment Buildings in Five Canadian Regions

ABSTRACT

Field Investigation Survey Summary Report of Airtightness, Air Movement, and Indoor Air Quality In High-rise Apartment Buildings In Five Canadian Regions, by B.W. Gulay, C.D. Stewart, and G.J. Foley, of Wardrop Engineering Inc.

This report is a summary of five independent field investigation surveys conducted across Canada for Canada Mortgage and Housing Corporation. The intent of the investigations was to determine air exfiltration rates through the building envelope, inter-suite and inter-floor air leakage rates, and indoor air quality in a representative number of residential high-rise apartment buildings. Air exfiltration, inter-suite, and inter-floor air leakage rates were determined by conducting suite, floor, and whole building fan depressurization tests. Indoor air quality was established by means of a survey of the tenants of the buildings, and by testing and monitoring for specific pollutants.

ACKNOWLEDGEMENTS

This summary report was prepared for Mr. Jacques Rousseau, Project Manager, Project Implementation Division of Canada Mortgage and Housing Corporation. The report was prepared by B.W. Gulay, P.Eng., C.D. Stewart, P.Eng., and G.J. Foley, P.Eng., of Wardrop Engineering Inc.

The original field investigation surveys summarized in this report were prepared by the following firms:

Atlantic Region	-	BFL Consultants Limited, in conjunction with Heat Seal Limited and Newfoundland Envirotech.
Quebec Region	-	CMA Chalifour, Marcotte & Assoc. Inc., in conjunction with Air-Ins Inc. and the University of Montreal.
Ontario Region	-	Scanada Consultants Limited, in conjunction with Canam Building Envelope Specialists Inc.
Prairie Region	-	Wardrop Engineering Inc., in conjunction with Unies Ltd. and National Testing Laboratories Ltd.
B.C. Region	-	Avalon Mechanical Consultants Ltd., in conjunction with Scott Technical Services, Island Energy Inc.

EXECUTIVE SUMMARY

Five independent regional field investigation surveys were conducted across Canada for Canada Mortgage and Housing Corporation. This report is a summary of these surveys. The intent of the investigations was to study airtightness, air movement, and indoor air quality in a representative number of Canadian residential high-rise apartment buildings. Air exfiltration, inter-suite, and inter-floor air leakage rates for 11 high-rise residential apartment buildings were determined by conducting suite, floor, and whole building fan depressurization tests. An alternate method of determining whole building air leakage rates was also evaluated. This alternate method is a simplified air infiltration estimation procedure, based on visually estimated equivalent air leakage areas and local net pressure distribution. Indoor air quality was established by means of a survey of the tenants of the buildings, and by testing and monitoring for specific pollutants. Air movement within the buildings was evaluated by the point source tracer gas technique, and by studying the floor-to-floor and suite-to-suite air leakage rates. The major findings are as follows.

Air leakage rates for the high-rise residential buildings investigated in the five regions are in excess of NRC's proposed air leakage guidelines of 0.05 to 0.15 L/sec.m^2 at 75 Pa.

The overall air leakage rates per unit of exterior wall found during suite fan depressurization testings was in the range of 2.10 to 3.15 L/sec.m^2, at a pressure differential of 50 Pa across the exterior wall. When testing was conducted such that leakage through the corridor wall could not be isolated from leakage through the exterior wall, the range of air leakage rates increased to 4.56 to 8.33 L/sec.m^2.

The overall air leakage rates per unit of exterior wall found during floor fan depressurization testing was in the range of 0.68 to 10.9 L/sec.m^2, at a pressure differential of 50 Pa across the exterior wall.

The overall air leakage rate per unit area of exterior wall found during the whole building fan depressurization testing of the Donald Street building before conducting air sealing repairs, was 2.33 L/sec.m^2, at a pressure differential of 50 Pa across the exterior wall. After air sealing the building, this rate was reduced to 1.76 L/sec.m^2.

Air movement within a building with a high exterior wall leakage rate is predominately influenced by stack effect, combined with exterior wind direction and speed.

Air movement within a building with a low exterior wall leakage rate is predominately influenced by stack effect and internal building activities, such as elevators moving, doors opening, and people moving through the building.

While ventilation supply air rates are generally adequate to make up for the air intentionally exhausted, they do not appear to be adequate to satisfy occupant requirements.

Air quality testing for pollutants were generally less than the recommended maximum guidelines set by Health and Welfare Canada.

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1.0 INTRODUCTION

This report is a summary of five independent field investigation surveys conducted across Canada for Canada Mortgage and Housing Corporation (CMHC).

The overall objective of the investigations, taken from the original Request for Proposal, is as follows:

"Little is known about actual air change rates, pollutant levels, or the incidence of air leakage through exterior walls. A survey of high-rise buildings is required to assess air leakage, air movement, and the indoor air quality of high-rise buildings in order to confirm or disclaim suspicions of problems."

The airtightness, air movement, and indoor air quality of high-rise buildings is poorly characterized relative to low-rise detached buildings. The most well understood aspect of high-rise building performance is that building envelope, moisture, energy, comfort, and air quality problems do exist. This summary reports on the extent of the problems found within the buildings investigated.

The specific objectives of the investigations were as follows:

- Quantify building envelope airtightness of a representative group of Canadian high-rise apartment buildings.
- Quantify interior air movement patterns within high-rise apartment buildings.
- Survey building residents to establish the general environmental conditions.
- Monitor temperature, relative humidity, and identify specific pollutants and their concentrations.

The individual field investigations were conducted separately and independently from each other to encourage research and innovative development of test protocols. As a result of this independent approach, not all results presented in the individual reports are directly comparable with each other.

2.0 OVERVIEW OF REPORTS

2.1 ATLANTIC REGION

This report presents the findings of a field investigation and assessment of airtightness, air movement, and indoor air quality in two residential high-rise apartment buildings located in St. John's, Newfoundland.

The investigation was performed in three phases. Phase I involved the identification and selection of two suitable buildings. Phase II involved an initial assessment of the buildings and identification of any problem areas, including identification of potential sources of pollution. Phase III was the physical testing of the buildings for airtightness, air movement, and indoor air quality.

Airtightness testing of exterior walls and between floors for both buildings was assessed using a fan depressurization technique. A total of twelve individual floors in the two buildings were tested using this method. In addition, exterior wall airtightness testing was done on four adjacent apartments in Building I by using a suite fan depressurization technique.

Air movement and air flow patterns within the buildings was studied by conducting point source release tracer gas tests.

Indoor air quality and occupant satisfaction was assessed by means of a detailed survey of the tenants to identify any concerns and potential problem areas. Using the results of the questionnaire, testing for six specific pollutants was conducted. As well, temperature and relative humidity levels were recorded.

2.2 QUEBEC REGION

This report presents the findings of a field investigation and assessment of airtightness, air movement, and indoor air quality in two residential high-rise apartment buildings located in Montreal, Quebec.

The investigation was performed in three stages; airtightness testing of the exterior wall, a preliminary assessment of the building and survey of the tenants, and testing for specific pollutants and their concentrations.

Airtightness testing of the buildings was conducted using a suite fan depressurization technique. One complete set of air leakage tests was conducted in each building.

Air movement and air flow patterns within the buildings was studied by analyzing the suite-to-suite and floor-to-floor air leakage rates established during the airtightness testing.

Indoor air quality was initially assessed by means of a detailed survey of the tenants and building owners to identify any concerns and potential problem areas. Using the results of the questionnaire, testing for twelve specific pollutants was conducted. As temperature and relative humidity levels were not identified as areas of concern, they were not tested for.

2.3 ONTARIO REGION

This report presents the development and field evaluation of a simplified method to calculate whole building air leakage rates, and to estimate the potential for air leakage control and the resulting energy savings. The procedure is applicable to residential high-rise buildings eight storeys or greater in height. It is based primarily on calculating equivalent air leakage areas and local net pressure distribution.

Two high-rise apartment buildings, one located in Toronto and the other located in Ottawa, were selected for field evaluation of the air infiltration estimation procedure. They were also used to demonstrate potential energy savings resulting from air leakage control. The accuracy of the estimated whole building air leakage rates was verified against the results of whole building and floor fan depressurization tests. The energy savings realized by reduction in air leakage rates was demonstrated by monitoring energy and power consumption before and after air sealing of the buildings.

Indoor air quality tests were conducted in both buildings to verify that no air quality problems were created by the air sealing measures implemented. Eight apartments were tested prior to air sealing of the building to establish concentration levels of carbon dioxide, formaldehyde, and radon. Temperature and relative humidity were also recorded. After air sealing, these same apartments were retested.

The development of the estimation procedure and resulting guidelines for reducing electrical demand by air leakage control was conducted for Ontario Hydro. The fan depressurization airtightness testing was conducted for the Canada Mortgage and Housing Corporation.

2.4 PRAIRIE REGION

This report presents the findings of a field investigation and assessment of airtightness, air movement, and indoor air quality in two residential high-rise apartment buildings located in Winnipeg, Manitoba.

The investigation was performed in three stages; airtightness testing of individual apartments, a preliminary assessment of the building and survey of the tenants to identify potential sources of indoor air pollutants, and testing for specific pollutants and their concentrations.

Airtightness testing of the buildings was conducted using a suite fan depressurization technique. Three complete sets of air leakage tests were conducted in each building to determine air leakage rates through the exterior wall, between floors, and between adjacent suites.

Air movement and air flow patterns within the buildings was studied by analyzing the suite-to-suite and floor-to-floor air leakage rates established during the airtightness testing.

Hallway fresh air supply and bathroom exhaust flow rates were also measured as an indicator of air movement and air flow patterns.

Indoor air quality was initially assessed by means of a detailed survey of the tenants to identify any concerns and potential problem areas. Using the results of the questionnaire, testing for five specific pollutants was conducted. As well, temperature and relative humidity levels were recorded.

2.5 BRITISH COLUMBIA REGION

This report presents the findings of a field investigation and assessment of airtightness, air movement, and indoor air quality in five residential high-rise apartment buildings located in Victoria, British Columbia.

The investigation was performed in three stages; airtightness testing of individual floors, a preliminary assessment of the building and survey of the tenants to identify potential sources of indoor air pollutants, and testing for specific pollutants and their concentrations.

Airtightness testing of the buildings was conducted using a floor fan depressurization technique. A total of six sets of air leakage tests were conducted in Buildings A, B and C to determine air leakage rates through the exterior wall and between floors.

Air movement and air flow patterns within the buildings were studied by analyzing the floor-to-floor air leakage rates established during the airtightness testing. The contribution of stair shafts, fireplaces, and garbage chutes to air movement within the buildings was also evaluated during the airtightness testing of the floors.

Indoor air quality in Buildings A, D and E was assessed by means of a detailed survey of the tenants and building owners to identify any concerns and potential problem areas. Specific spot testing for carbon dioxide and carbon monoxide was conducted in Buildings D and E.

3.0 BUILDING DESCRIPTIONS

3.1 ATLANTIC REGION

Building I is a seven-storey condominium with an underground parking garage. It was constructed in 1982. Building II is a six-storey low cost housing unit constructed in 1983. The exterior walls of both buildings are of brick veneer and steel stud construction. The buildings are heated by electric baseboard heaters located under the windows. Mechanical cooling of the suites is provided by tenant installed window air conditioning units. The apartments in each building are equipped with bathroom and kitchen exhaust fans that are ducted directly to the exterior, with their operation being controlled by the tenant. Make-up supply air is provided to the hallway corridor on each floor and to the common areas on the main floors. There is a separate exhaust fan system for the underground parking garage of Building I that is controlled by a CO probe.

3.2 QUEBEC REGION

Building 1 is a fifteen-storey condominium building constructed in 1991. The exterior wall is of brick veneer steel stud construction. Heating is provided by electric baseboard heater, and mechanical cooling is provided by individual central air conditioning units located in each suite. The individual suites are provided with central bathroom, kitchen, and dryer exhaust vents. The hallways, stairwells, and common areas on the first floor are provided with make-up supply air. There are separate air handling systems for both the swimming pool area and the underground parking garage.

Building 2 is a four-storey apartment building constructed in 1960. The exterior wall is of double wythe brick construction. Heating is provided by hot water radiant heating cabinets fed by two low pressure boilers. Mechanical cooling of the suites is provided by tenant installed window air conditioning units. The individual suites are equipped with bathroom and kitchen exhaust fans that are ducted directly to the exterior, with their operation being controlled by the tenant. Heated ventilation make-up air is provided for the corridors on each floor. The ventilation for the underground parking garage is provided by a separate system controlled by a carbon dioxide probe.

3.3 ONTARIO REGION

The Donald Street building, located in Ottawa, is a 21-storey senior citizen's apartment complex. The Bridleview building, located in Toronto, is a 10-storey condominium building. The exterior walls of both buildings are of brick veneer steel stud construction. Heating is provided by electric baseboard heaters. The individual suites are equipped with bathroom and kitchen exhaust fans ducted directly to the exterior and are controlled by the tenant. Heated ventilation make-up air is provided for the corridors on each floor and to the common areas of the building.

3.4 PRAIRIE REGION

Buildings A and B are both 13-storey senior citizen's apartment complexes of very similar design. Building A was constructed in 1973 and Building B was constructed in 1970. The exterior walls of both buildings are double wythe brick and wood stud construction. The major difference between the two buildings is that in 1986, a thermal fusible membrane was applied to the exterior of Building A. New windows were installed and the building was then insulated with an additional 125 mm of semi-rigid fibreglass insulation and sheathed with aluminum siding. Building B remains essentially as originally constructed in 1970.

Both buildings are heated by means of low pressure hot water boilers utilizing radiant heating cabinets located around the perimeter of the buildings. The individual apartments are provided with central bathroom exhaust ducts only. Heated ventilation make-up air is provided to the corridors on each floor and to the common areas of the two buildings.

3.5 BRITISH COLUMBIA REGION

Building A is an 11-storey apartment building constructed in 1984. The exterior wall is constructed of precast concrete and steel stud construction.

Building B is an 8-storey apartment building constructed in 1991. The exterior wall is of steel stud construction with an acrylic stucco exterior finish.

Building C is a 10-storey apartment building constructed in 1991. The exterior wall is of steel stud construction with an acrylic stucco exterior finish.

Building D is a 7-storey apartment building constructed in 1982. The exterior wall is of grouted concrete block construction with interior steel studs and drywall.

Building E is a 10-storey apartment building constructed in 1976. The exterior wall is of steel stud construction with a stucco exterior finish.

All five buildings are heated with electric baseboard heaters and typically the apartment suites are provided with bathroom and kitchen exhaust fans. Mechanical make-up air is typically unheated and provided to corridor hallways on each floor, and to the common areas of the buildings.

4.0 AIRTIGHTNESS TEST PROCEDURES AND RESULTS

4.1 METHODOLOGY

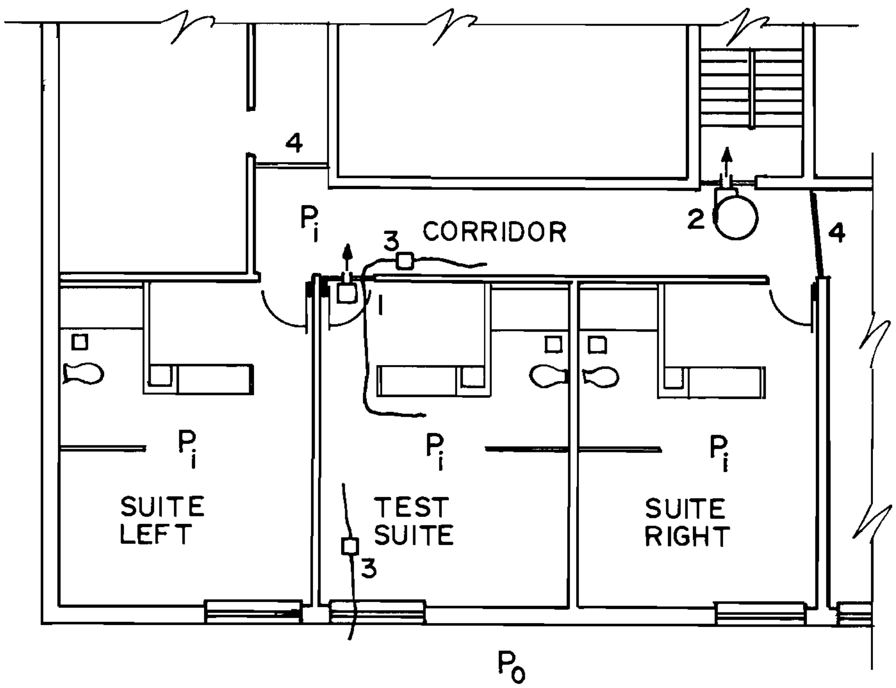
The air leakage test protocols utilized by the firms involved in the project were based on the Canadian General Standards Board CAN/CGSB-149.10-M86, Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method, and on Canada Mortgage and Housing Corporation Report No. CR5855.1, Establishing the Protocols for Measuring Air Leakage and Air Flow Patterns in High-rise Apartment Buildings.

The determination of the airtightness of building envelopes can be accomplished by testing individual suites in a building, by testing individual floors, or by testing the whole building. The decision as to which test to conduct is influenced by a number of parameters. These include the availability and capacity of the depressurization fans, the layout of the building and suites, accessibility of the building, and the overall intent of the testing.

If the intent is to study the overall air leakage rate of a building then the testing should be done using the whole building fan depressurization technique. This method is very valuable if studying energy efficiency or consumption parameters. By itself, it does not yield specific information on actual air exfiltration/moisture transportation rates through the exterior walls or roof. Included in the leakage rate that is established using this method, is the leakage that occurs at all intentional openings, such as entrances, vertical shafts, exhaust ducts, and the air that is exhausted through penthouses. Table 1 (opposite page) is a partial list of intentional openings typically found in a building's envelope, and identifies their preparation prior to conducting any of the three fan depressurization air leakage tests.

If the intent is to study detailed exterior wall air leakage rates, then the testing should be done on a suite-by-suite or floor-by-floor basis. Through the use of balancing fans, it is possible to eliminate air leakage between floors and through adjacent walls, by eliminating the pressure differential across these elements. Using a combination of these

PLAN



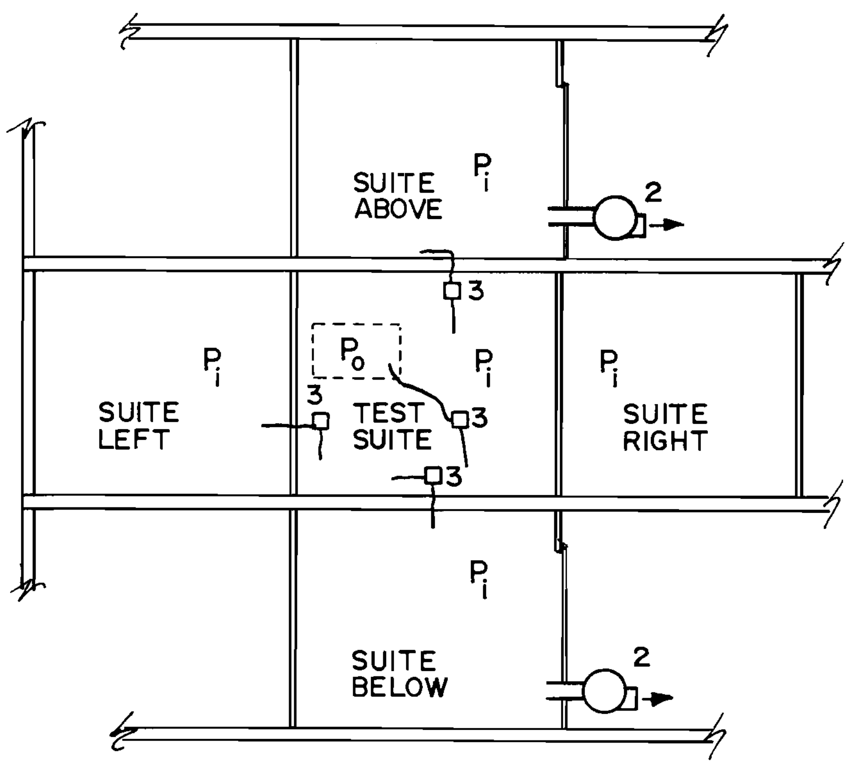
LEGEND

1. FAN WITH CALIBRATED NOZZLE.
2. PRESSURE BALANCING (MASKING) FAN.
3. PRESSURE MEASURING DEVICE.
4. CORRIDOR BARRIER MASK.

P_i INTERIOR PRESSURE

P_o EXTERIOR PRESSURE

ELEVATION



CLIENT: CANADA MORTGAGE AND HOUSING CORPORATION		
DWG DESCRIPTION: SUITE AIR LEAKAGE TEST EQUIPMENT LAYOUT WITH CORRIDOR BARRIER MASKS		
DESIGNED BY	DRAWN BY KBB	DRAWING NO
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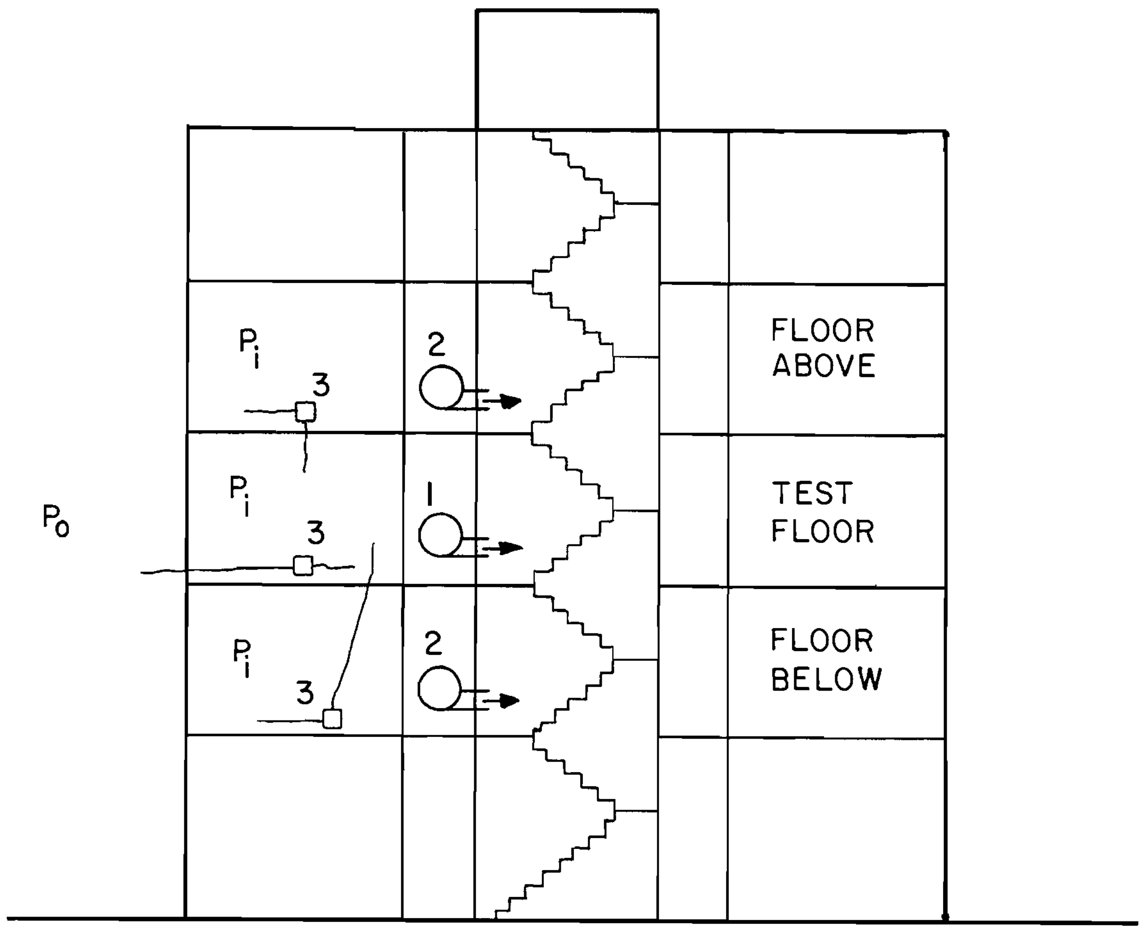
tests, it is possible to determine air leakage rates through exterior walls, between adjacent suites, and between floors.

4.2 SUITE AIR LEAKAGE TESTING

Suite-to-suite air leakage testing was conducted by the teams in the Atlantic Region, the Quebec Region, and the Prairie Region. A total of twelve individual apartment suites were tested in the three regions to determine air leakage rates through the exterior wall, between floors and between adjacent apartments.

Conducting a complete set of air leakage tests on one individual apartment suite actually requires access to five suites. These being the test suite and the four suites directly above, directly below, and to the left and right of the test suite. These suites are required for the installation of balancing or masking depressurization fans. The masking fans are required to maintain the pressure differentials between the test suite and the adjacent suites at zero. This zero pressure differential theoretically eliminates the air leakage between suites. By sequentially eliminating the operation of one of the fans, if four balancing fans are being utilized, it is possible to directly calculate air leakage rates for the ceiling, floor, left and right partition walls, and the combined exterior wall and corridor wall leakage rate. If only one balancing fan is being used, it can be operated sequentially in the four balancing positions to achieve the same results. To isolate the actual air leakage rate of the exterior wall from the corridor requires the elimination of the pressure differential between the test suite and the corridor. This can be accomplished by the construction of two temporary walls, or barrier masks, in the hallway corridor and maintaining the pressure differential between the corridor, left, and right suites, and the test suite at zero. See Figure 1 (opposite page) for a typical equipment layout necessary to conduct a suite air leakage test utilizing corridor barrier masks. An alternative approach to the corridor barrier masks, used by the Quebec Region, is to seal the leaks through the corridor wall and doorway.

The advantage of the sequential pressure-masking technique over the simultaneous pressure masking procedure is the significantly reduced equipment and manpower



BUILDING SECTION

LEGEND

1. FAN WITH CALIBRATED NOZZLE.
2. PRESSURE BALANCING (MASKING) FAN.
3. PRESSURE MEASURING DEVICE.

P_i INTERIOR PRESSURE.

P_o EXTERIOR PRESSURE

CLIENT	CANADA MORTGAGE AND HOUSING CORPORATION
DWG DESCRIPTION	FLOOR AIR LEAKAGE TEST EQUIPMENT LAYOUT

WARDROP ENGINEERING INC.
WINNIPEG TORONTO THUNDER BAY EDMONTON

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requirements, fewer accessibility problems, and easier establishment of stabilized conditions, since one instead of four pressure differentials have to be maintained.

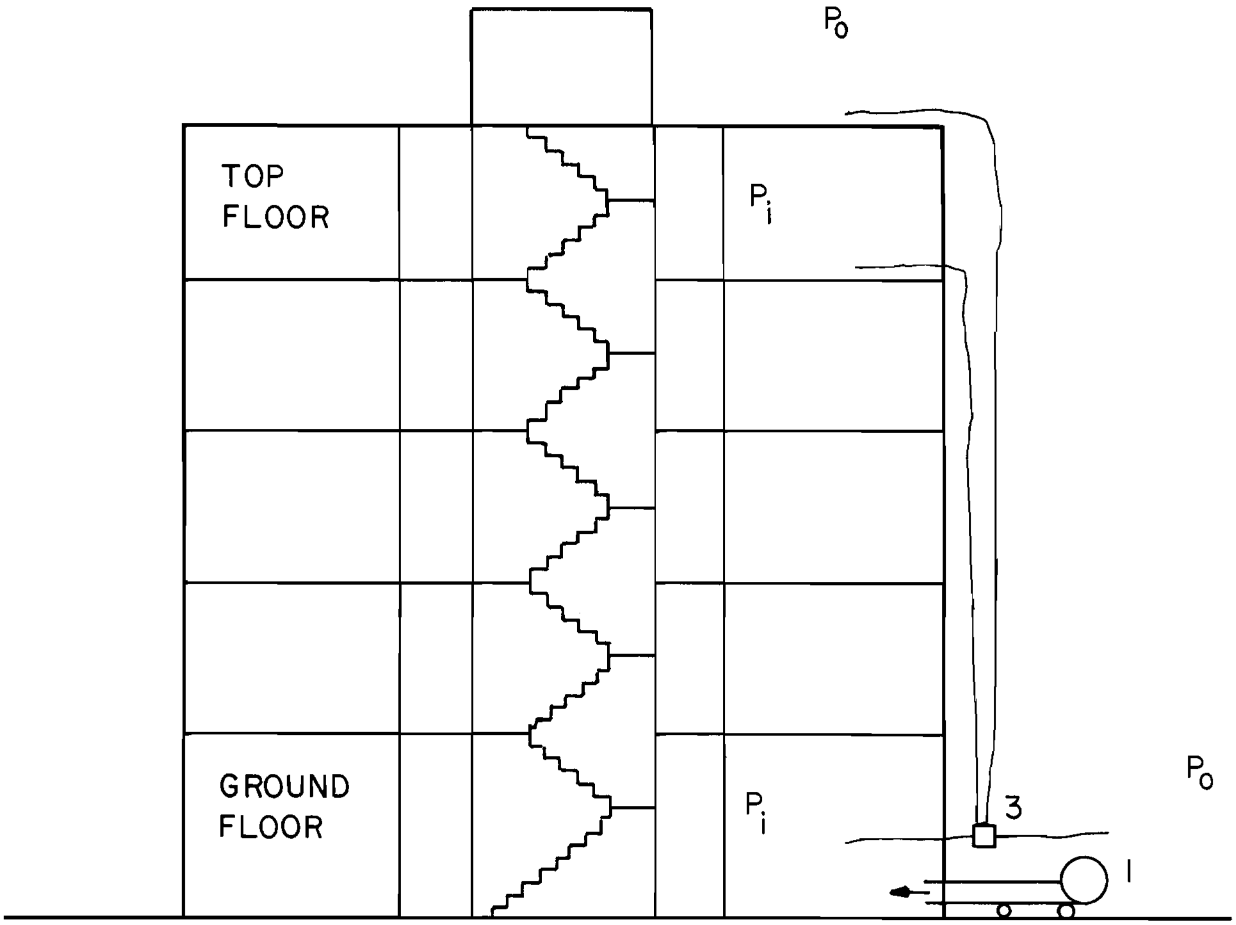
The disadvantage of the sequential pressure-masking technique is that it may not as effectively neutralize the effects of network leakage (i.e., leakage which occurs through a complex path involving more than one adjacent suite), since all adjacent suites are not depressurized at the same time.

4.3 Floor Air Leakage Testing

Floor-to-floor air leakage testing was conducted by the teams in the Atlantic Region, the Ontario Region, and the British Columbia Region. A total of 21 individual floors were tested to determine air leakage rates through the exterior walls and between floors.

Conducting a complete set of air leakage tests on an individual floor requires access to the test floor and to the floors directly above and below (see Figure 2 on opposite page). The additional floors are required for the installation of balancing or masking depressurization fans. The masking fans are required to maintain the pressure differential between the test floor and the adjacent floors at zero. This zero pressure differential theoretically eliminates the air leakage between floors. By sequentially eliminating the operation of one of the fans, if two balancing fans are utilized, it is possible to directly calculate air leakage rate for the floor, ceiling, and exterior wall.

If only one balancing fan is being used, it can be operated sequentially to achieve the same results. However, the same advantages and disadvantages of utilizing a single depressurization balancing fan noted for the suite air leakage procedure is also applicable to the floor air leakage procedure. Regardless if one or two balancing fans are being utilized, particular attention must be made to account for network air leakage through vertical shafts, such as stairways and elevators. The volume of air that can pass through these shafts can easily distort the test results if not properly accounted for.



BUILDING SECTION

LEGEND

1. FAN WITH CALIBRATED NOZZLE.
3. PRESSURE MEASURING DEVICE.

P_i INTERIOR PRESSURE

P_o EXTERIOR PRESSURE

CLIENT: CANADA MORTGAGE AND HOUSING CORPORATION		
DWG DESCRIPTION: WHOLE BUILDING AIR LEAKAGE TEST EQUIPMENT LAYOUT		
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The results obtained by the Ontario Region from conducting four such tests on the Bridleview building were extrapolated to determine the whole building air leakage rate.

4.4 WHOLE BUILDING AIR LEAKAGE TESTING

Whole building air leakage testing was conducted by the Ontario Region team on the Donald Street building in Ottawa. This method directly provides the total air leakage rate for the entire building. The tests were conducted before and after air sealing of the Donald Street building, to refine and validate the assessment procedure used to visually estimate the air leakage rate.

Conducting a complete whole building air leakage test requires access to every suite and room located around the perimeter of the building. Of the four air leakage test procedures, this method requires the most cooperation from tenants and owners. It also requires access to equipment owned and operated by the Nation Research Council (NRC). At present, NRC is the only available source of test equipment capable of performing a whole building fan depressurization test. The alternative is to use the building's own mechanical system to conduct the test. However, except in rare instances, the mechanical systems in high-rise residential buildings are rarely adequate to maintain pressure differentials across the building envelope necessary to obtained meaningful results.

As shown in Figure 3 (opposite page), NRC's large vane-axial fan of 24 m^3/sec. capacity is used to depressurize the entire building. The fan inlet is connected by 12 m of 0.9 m diameter ducting to a plywood panel replacing either an entry door or window on the ground floor of the building. All interior doors to the stair shafts are kept open and the intentional openings through the building envelope are prepared in accordance with Table 1 (see opposite page 10). The pressure differences across the building envelope are measured and recorded at both the ground and top floors before, after, and during the testing. The average of the ground and top floor readings is taken as the mean pressure differential across the building envelope. The average of the values obtained before and after the test is used to establish a baseline pressure differential across the

Figure 4. Procedure For Air Leakage Assessment and Control In Buildings

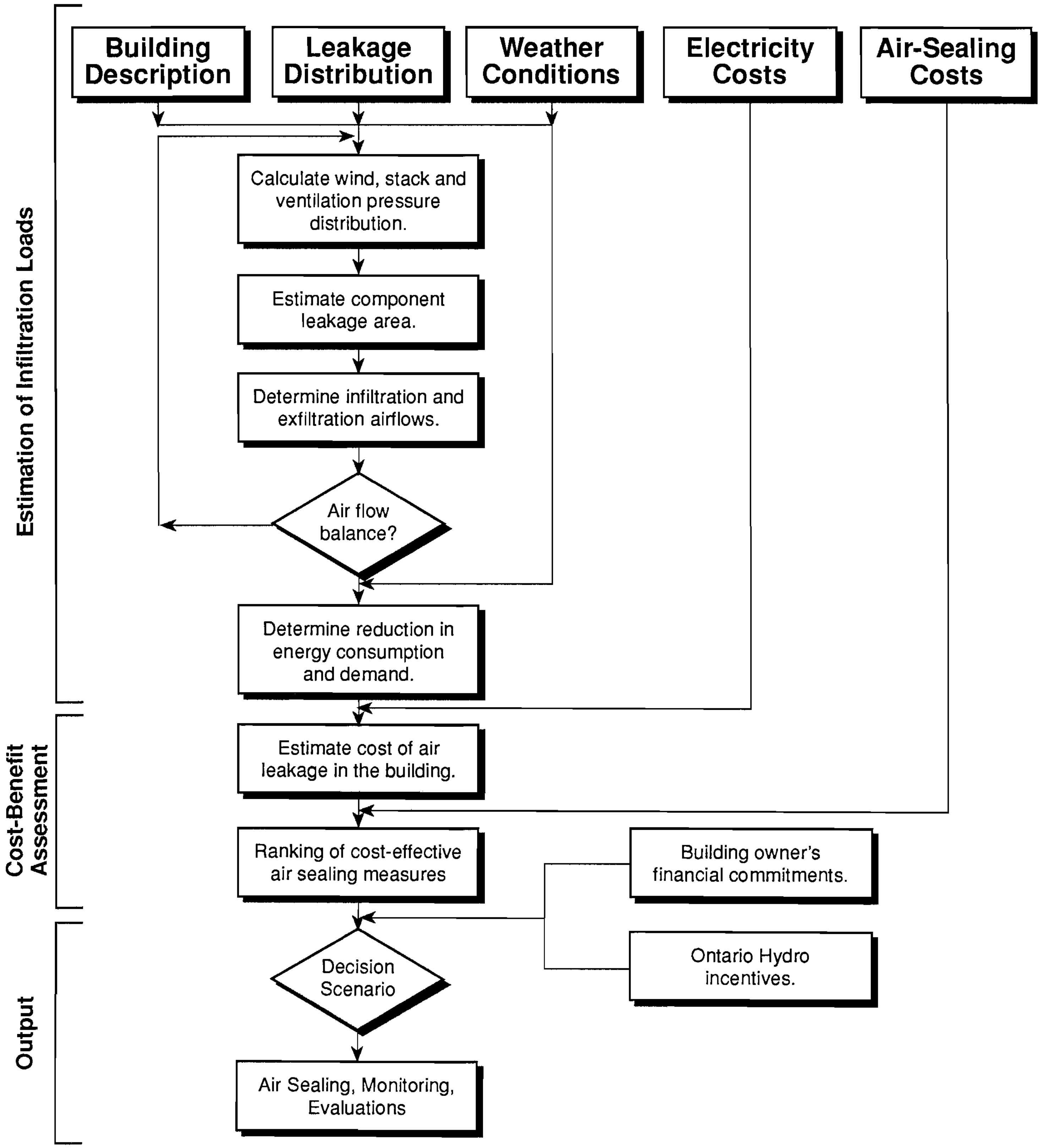


Figure 4
Reproduced From The Ontario Region Final Report Entitled "Development of Design Procedures and Guidelines For Reducing Electric Demand By Air Leakage Control In High-Rise Residential Buildings

building envelope. This baseline pressure is then subtracted from the test pressures to minimize the effects of weather.

4.5 SIMPLIFIED AIR INFILTRATION PROCEDURE

The simplified air infiltration procedure (see Figure 4, opposite page) was used by the Ontario Region team on both the Bridleview and Donald Street buildings. The procedure is based primarily on equivalent air leakage areas and local net pressure distribution. Air leakage rates through a building envelope are dependant on the net driving force, or pressure differential across the envelope, and the characteristics of the openings in the envelope. Using a simplified calculation method, based on the net pressure differential across the exterior wall and the estimated equivalent leakage areas, infiltration and exfiltration rates are determined for each floor of the building. By balancing the infiltration of air with the exfiltration, it is possible to determine the neutral pressure plane.

The calculation of infiltration and exfiltration rates are done on a floor-by-floor basis, by determining the leakage paths and leakage areas of each floor. This is accomplished by visually examining the air leakage paths through the exterior wall, by determining the size of these leakage paths, and finally, by assessing if the leakage paths should be classified as tight, loose, or average. The algebraic sum of all leakage areas found for a given floor are used to determine an equivalent leakage area through the building envelope for each floor.

By establishing the stack effect and wind pressure distribution, it is possible to determine the net pressure differential across the exterior wall for each floor. Using the net pressure differential and net equivalent leakage areas, it is possible to calculate infiltration and exfiltration air flow rates for each floor. The height of the neutral pressure plane, originally assumed to be mid-height of the building, is adjusted floor-by-floor until net infiltration equals net exfiltration. The net inflow or outflow of air is then used to estimate the infiltration heating load.

TABLE 2 SUITE AIR LEAKAGE TEST RESULTS			
Region and Building	Air Leakage Rate Through Exterior Wall (L/s m²)		Year Constructed
	ΔP Across Exterior Wall		
	25 Pa	50 Pa	
Atlantic:			
Building No. 1			1982
• Apartment 501	3.9[1]	6.3[1]	
• Apartment 503	5.1[1]	7.8[1]	
• Apartment 505	5.1[1]	7.8[1]	
• Apartment 507	4.9[1]	7.4[1]	
Quebec:			
Building No. 1	1.34	2.20	1991
Building No. 2	2.79[2]	4.58[2]	1960
Prairies:			
Building A			
• Apartment 405	1.81	2.50	1973
• Apartment 409	4.12[3]	7.03[3]	(1986)[4]
• Apartment 909	6.03[3]	8.33[3]	
Building B			
• Apartment 509	2.17	3.15	1970
• Apartment 609	1.97	3.11	
• Apartment 1009	1.43	2.10	

[1] Air leakage rates shown were reduced by 10% to account for leakage through floor slabs. Rates shown are combined leakage through the corridor and exterior walls.

[2] Rates shown are combined leakage through the concrete roof slab and exterior wall.

[3] Rates shown are combined leakage through the corridor and exterior wall.

[4] Construction year exterior wall retrofit was completed.

This assessment method was able to predict the potential savings in energy consumption within 5 to 10% of the actual savings. This investigation also found that commercial air sealing can be effective in reducing air leakage rates by 35%.

4.6 AIR LEAKAGE TEST RESULTS

A summary of the air leakage rates established for the exterior wall based on the suite, floor, whole building, and estimated whole building test procedures are presented in Table 2 on the opposite page, and in Tables 3 through 6 on the pages following.

The overall air leakage rates per unit area of exterior wall found during suite fan depressurization testing was in the range of 2.10 to 3.15 L/sec.m^2 at a pressure differential of 50 Pa. When the testing was conducted such that the leakage through the corridor wall could not be isolated from the leakage through the exterior wall, the range of air leakage rates increased to 4.58 to 8.33 L/sec.m^2.

The overall air leakage rates per unit area of exterior wall found during the floor fan depressurization testing was in the range of 0.68 to 10.9 L/sec.m^2 at a pressure differential of 50 Pa.

The overall air leakage rate per unit area of exterior wall found during the whole building fan depressurization test of the Donald Street building, before conducting the air sealing repairs, was 2.33 L/sec.m^2 at a pressure differential of 50 Pa. After air sealing the building, this rate was reduced to 1.76 L/sec.m^2.

The results of this testing confirms that the air leakage rates for the high-rise residential buildings investigated in the five regions are far in excess of NRC's proposed guidelines of 0.05 to 0.15 L/sec.m^2 at 75 Pa. The results also seem to suggest that the newer the construction, the tighter the exterior wall is constructed. This is strongly evidenced by the results obtained by the Quebec and British Columbia Regions.

TABLE 3

FLOOR AIR LEAKAGE TEST RESULTS

Region and Building	Air Leakage Rate Through Exterior Wall (L/s m²)		Year Constructed
	ΔP Across Exterior Wall		
	25 Pa	50 Pa	
Atlantic:			
Building 1			
• 1st Floor	5.0	6.4	1982
• 2nd Floor	3.7	5.5	
• 3rd Floor	6.2	10.9	
• 4th Floor	5.2	7.7	
• 5th Floor	5.2	8.3	
Building 2			
• Basement	2.2	3.1	1983
• 1st Floor	1.2	1.8	
• 2nd Floor	3.9	5.5	
• 3rd Floor	4.7	6.9	
• 4th Floor	2.8	4.5	
• 5th Floor	3.4	5.1	
• 6th Floor	1.4	1.9	
Ontario			
Bridleview			
• Ground Floor	n/a	1.36 0.89[1]	n/a
• Middle Floors	n/a	1.82 1.16[1]	
• Top Floor	n/a	2.69 1.53[1]	
British Columbia:			
Building A			
• 3rd Floor	1.25	1.90	1984
Building B			
• 4th Floor	0.50	0.68	1991
• 5th Floor	0.49	0.69	
Building C			
• 5th Floor	1.24	1.74	1991
• 6th Floor	0.50	0.76	
• 7th Floor	0.49	0.69	

[1]After air sealing building.

TABLE 4

WHOLE BUILDING AIR LEAKAGE TEST RESULTS

Region and Building	Whole Building Air Leakage Rates ($L/s\ m^2$) — ΔP Across Exterior Wall: 25 Pa	50 Pa
Ontario:		
Donald Street Building		
• Before Sealing	1.23	2.15
• After Sealing	0.96	1.76

TABLE 5

WHOLE BUILDING AIR LEAKAGE TEST RESULTS

Region and Building	Total Air Leakage Rates				ΔP Across Exterior Wall (Pa)
	Estimated (L/s)	Actual Before Sealing (L/s)	Actual After Sealing (L/s)	% Reduction	
Ontario:					
Donald Street	5,933 (0.79 $L/s\ m^2$)	4,740 (0.63 $L/s\ m^2$)	0.43 3,225 (0.43 $L/s\ m^2$)	32	10
Bridleview	1,880 (0.29 $L/s\ m^2$)	1,885[1] (0.29 $L/s\ m^2$)	1,165[1] (0.18 $L/s\ m^2$)	38	7

[1]Total air leakage rate approximated from floor air leakage testing.

TABLE 6

PERCENT DISTRIBUTION OF WHOLE BUILDING AIR LEAKAGE BY BUILDING COMPONENT

Windows	Doors	Building Envelope	Vertical Shafts	Miscellaneous
42%	26%	6%	14%	12%

TABLE 7

DISTRIBUTION OF SIX-SIDED AIR LEAKAGE
SUITE AIR LEAKAGE TESTING @ 50 PA

	Prairie Region				Quebec Region			
	Building A		Building B		Building 1		Building 2	
	L/s	%	L/s	%	L/s	%	L/s	%
Entry Door	121	42	--	--	--	--	--	--
Left, Right and Corridor Walls	72	25	48	27	39	14	37	20
Floor	6	2	29	16	54	18	33	18
Ceiling	17	6	25	14	85	29	--	--
Exterior Wall	71	25	78	43	115	39	115[1]	62

[1]Includes air leakage through concrete roof slab

TABLE 8

PERCENT INCREASE IN TOTAL FLOOR AIR LEAKAGE DUE TO UNSEALING
FLOOR AIR LEAKAGE TESTING @ 50 PA

	British Columbia Region				
	Building B		Building C		
	Floor		Floor		
	4	5	5	6	7
Elevator	80%	78%	128%	264%	323%
Garbage Chute	13%	23%	n/a	n/a	n/a
Stairs	128%	93%	42%	96%	75%
Fireplaces	n/a	n/a	2%	n/a	n/a
Floor	n/a	n/a	80%	173%	n/a
Ceiling	n/a	n/a	n/a	253%	n/a

The percentage increase in air leakage is calculated as (increased air flow) ÷ (all sealed air flow) at the same pressure difference

5.0 AIR MOVEMENT TEST PROCEDURES AND RESULTS

Air movement testing was conducted as part of the suite and floor fan depressurization testing and separately by the point source tracer gas technique. The air leakage test protocols utilized by the firms involved in the project were based on the Canadian General Standards Board CAN/CGSB-149.10-M86, Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method, and on Canada Mortgage and Housing Corporation Report No. CR5855.1, Establishing the Protocols for Measuring Air Leakage and Air Flow Patterns in High-rise Apartment Buildings. The point source tracer gas technique utilized by the Atlantic Region was based on ASTM standard No. E741-83, Standard Test Method For Determining Air Leakage Rates By Tracer Dilution.

As part of the fan depressurization testing, it was possible to determine air leakage rates for not only the exterior wall, but between floors and between adjacent apartments. It was also possible to determine what effect vertical shafts in the building, such as stairs, elevators and garbage chutes have on air movement within a building. These results are presented in Tables 7 and 8 (opposite page).

The objective of the tracer gas testing was to quantitatively determine air flow patterns within the two buildings tested under normal operating conditions. The results of the testing suggest that the internal movement of air within a building, with a high exterior wall leakage rate, is predominately influenced by stack effect, combined with exterior wind direction and speed. It also suggests that air movement within a building with a tighter exterior wall, is more influenced by stack effect and internal building activities such as elevators moving, doors opening, and people moving through the building than it is by wind direction and speed.

TABLE 9 SUITABLE CONTROL LOCATIONS FOR MEASURING POLLUTANTS	
Pollutant	Suitable Control Location
Carbon Dioxide	• air intakes (if not contaminated) • outdoors - street level or roof • indoors - unoccupied area
Carbon Monoxide	• air intakes (if not contaminated) • outdoors - roof or upper floor • indoors - above second floor
Formaldehyde	• air intakes (if not contaminated) • outdoors - roof or upper floors on the building side of particulate filters • indoors - unoccupied area
Particulates	• air intakes (if not contaminated) • outdoors - roof or upper floor on the building side of particulate filters • indoors - unoccupied area
Radon	• outdoors - sheltered area (no wind or rain) • indoors - above second floor
VOC	• air intakes (if not contaminated) • outdoors - street level or roof • indoors - away from identical pollutant sources
Biological Contamination	• air intakes (if not contaminated) • outdoors - roof • indoors - area with no mould, water or plants
Reproduced from CMHC publication entitled "Indoor Air Quality Test Protocol for High-rise Residential Buildings"	

6.0 INDOOR AIR QUALITY

6.1 METHODOLOGY

The indoor air quality test protocol utilized by the firms involved in the project are based on Canada Mortgage and Housing Corporation's report entitled Indoor Air Quality Test Protocol For High-rise Residential Buildings. The investigation of indoor air quality in buildings follows three basic stages; a preliminary assessment of the building including a survey of the tenants, simple measurements of pollutant levels, and the final stage, if required, being complex measurement of pollutant levels.

The preliminary assessment is essentially the collection of information to determine if, where, and when an indoor air quality problem exists. It generally involves a detailed survey of the tenants, managers, maintenance staff, and building owners as the first step in the assessment. This is then typically followed by a walk-through inspection of the building and a basic review of the mechanical systems and their operation.

The intent of the preliminary assessment is to collect sufficient information to determine if air quality problems exist. This information is also helpful in identifying possible pollutants to test for, and where and when to test for them.

The second stage of the investigation is the simple measurement of pollutant levels. Table 9 on the opposite page and Table 10 on the following page, list possible pollutants to test for, and suggests when and where the measurements should be taken. As defined by the CMHC test protocol, simple measurement of pollutants are those measurements which a reasonably knowledgeable, but not specially trained, technologist could undertake with the appropriate instruments and samplers. These simple measurements are usually sufficient to identify the majority of indoor air quality problems.

The final stage of the investigation is the complex measurements of pollutant levels. These measurements typically require the services of a specially trained technologist.

TABLE 10

TEST LOCATIONS AND IDEAL TIMES FOR MEASURING POLLUTANTS AND OTHER PARAMETERS

Pollutant or Parameter	Test Locations	Time to Measure
Carbon Dioxide	• pollutant sources	• when heavily occupied • when fresh air rate low • when combustion products could be produced
Carbon Monoxide	• pollutant sources • complaint areas • stairwells linked to sources • elevators linked to sources • exhausts	• when fresh air rate low • when combustion products could be produced
Formaldehyde	• pollutant sources (building) • complaint areas	• when fresh air rate low
Particulates	• pollutant sources • complaint areas • exhausts	• when source is suspected
Radon	• pollutant sources	• when fresh air rate low
VOC	• pollutant sources (building) • complaint areas • exhausts	• when fresh air rate low
VOC	• pollutant sources (activity) • complaint areas • exhausts	• late morning • late afternoon • when fresh air rate low • after cleaning/maintenance
Biological Contamination	• pollutant sources (building) • complaint areas	• when fresh air rate low • summer
Humidity	• supply air • complaint areas	• mid-winter • mid-summer
Air Movement	• near diffusers	• while the ventilation system is operating

Reproduced from CMHC publication entitled "Indoor Air Quality Test Protocol for High-rise Residential Buildings"

This stage is required only when the first two stages have failed to identify both the causes and likely sources of the pollutant detected.

6.2 TENANT SURVEY RESPONSES

As part of the initial stage of the indoor air quality investigations conducted in the five regions, a detailed survey of the tenants was conducted. The general results of these surveys are summarized as follows:

Atlantic Region:

Building I

Most tenant complaints did not pertain to concerns with indoor air quality, but were associated with air leakage, mainly drafts through windows, exhaust fans, and dryer vents. There were no specific air quality problems identified. When asked about temperature, 66% of the tenants indicated the temperature was either acceptable or too hot; 40% indicated that the air was dry, stale, or stuffy; 20% indicated their apartments were drafty; and 23% of the tenants reported various symptoms such as tiredness and dry itching eyes, and believe the building is the cause.

The building manager also reported that mildew was observed on the inside of the exterior wall when the face brick was removed.

Building II

Most complaints did not pertain to concerns with indoor air quality, but were associated with air leakage, mainly drafts through windows. Again, there were no specific air quality problems identified. When asked about temperature, 86% of the tenants indicated the temperature was acceptable; 42% indicated that the air was dry, stale, or stagnant;

and 14% of the tenants reported various symptoms such as tiredness and sore or dry throats, and believe the building is the cause.

Prairie Region:

Building A

There were numerous complaints from the tenants about the indoor air quality of the building. When asked about the temperature, 55% of the tenants indicated it was too hot, 90% indicated it was too dry; 83% of the tenants reported insufficient air movement in their suites; 65% indicated the air was stuffy; and 47% of the people indicated the presence of dusty, musty, or stale odours in their apartments. There were also a number of health related complaints uncovered by the survey, 75% of the tenants complained of dry skin, 66% experienced fatigue, and 64% experienced nasal irritation. Of the tenants reporting these health related problems, 43% indicated they experience some relief while away from the building.

Building B

There were numerous complaints from the tenants about the indoor air quality of the building. When asked about the temperature, 76% of the tenants indicated it was too hot and dry; 69% of the tenants reported insufficient air movement in their suites; 74% indicated the air was stuffy; and 51% of the people indicated the presence of dusty, musty, or stale odours in their apartments. There were also a number of health related complaints uncovered by the survey, 66% of the tenants complained of dry skin, 71% experienced fatigue, and 46% experienced nasal irritation. Of the tenants reporting these health related problems, 48% indicated they experience some relief while away from the building.

British Columbia Region:

Building A

This building had the highest level of tenant satisfaction of the three British Columbia region buildings investigated. The most common problem, reported by 39% of the tenants, was drafts in the suites related to faulty backdraft dampers and window construction. There were no specific air quality problems identified. When asked about temperature, 94% of the tenants indicated the temperature was acceptable; 29% of the tenants indicated persistent odours; 19% reported dust was a problem; 13% indicated the air was stale; and 10% of the tenants reported water leakage and damp spots in their suites.

Building D

This building, while having less occupant satisfaction than Building A, also had very few complaints. The most frequent concerns raised during the tenant survey dealt with the operation of the mechanical systems and with water penetration. The hallway pressurization and garage exhaust fans are not continuously operated due to complaints of noise. The intermittent operation of the hallway pressurization fan tends to increase the migration of odours between suites. Stack effect, combined with the hallway pressurization and garage fans being shut down, tends to allow automobile exhaust fumes (CO) to enter into the building. Also, the fresh air intake for the hallway pressurization fan is surrounded by fireplace chimneys. If the pressurization fan is operating at the same time as one of these fireplaces is burning, it is possible to draw combustion gases into the building through the fresh air intake. Seventy-five percent of the tenants reported water leakage into their suites and 42% reported damp spots. When asked about the temperature, all tenants indicated the temperature was acceptable, however, 16% indicated dust was a problem, and 8% reported drafts, persistent odours, and stale air.

TABLE 11

MECHANICAL SYSTEMS REVIEW
SUPPLY AND EXHAUST AIR FLOW RATES

Region and Building	Supply Air Hallways (L/s)	Bathroom Exhaust (L/s)	Kitchen Exhaust (L/s)
Atlantic:			
Building 1 (elev. room)	135 (8)[2]	55[1]	100[1]
Building 2	112 (11)[2]	55[1]	100[1]
Quebec:			
Building 1	Central	Central	Central
Building 2	Central	25-50[1]	75-125[1]
Ontario:			
Donald Street	283 (12)[2]	25-50[1]	75-125[1]
Bridleview	330 (10)[2]	n/a	n/a
Prairies:			
Building A	268 (10)[2]	6.8	--
Building B	390 (10)[2]	8.1	--
British Columbia:			
(Typical Rates)	25/suite	25-50[1]	75-125[1]

[1]Operation of fan controlled by occupant
[2]Typical number of suites per floor

Building E

This building has the lowest occupant satisfaction of the three buildings investigated. It is also the oldest and largest. Air infiltration and drafts from the windows were reported by 38% of the tenants during windy conditions, 13% reported water penetration into their suites, and 25% reported musty odours that are believed to be associated with water penetration. When asked about temperature, all tenants indicated the temperature was acceptable but 33% of the tenants reported persistent odours in their suites; 19% indicated dust was a problem; and 13% reported poor ventilation, air movement and stale air in their suites.

6.3 Mechanical Systems Reviews

As part of the initial stage of the indoor air quality investigations, the mechanical ventilation systems of the 11 buildings involved were reviewed. The systems found were generally simple, with fresh air typically being supplied to the corridor hallway on each floor, and exhausted from the individual apartments. This design is intended to promote the containment of odours and pollutants generated within the suites from spreading to the corridors.

It was generally found that the quantity of fresh air being supplied to the corridors was sufficient to make up for the air exhausted. However, it appears that the typical supply air flow rates found are inadequate to satisfy occupant ventilation requirements. In the two buildings investigated in the Manitoba Region, where adequate fresh air was being provided to satisfy occupant requirements, it was found that this air was not making it into the apartments. The majority of the air was being unintentionally exhausted through elevator and stair shafts before it had a chance to enter the individual apartment suites.

A summary of the hallway supply air flow rates and exhaust flow rates found during the investigations are shown in Table 11 (opposite page). The exhaust flow rates shown for the Atlantic, Quebec, Ontario, and British Columbia buildings are typical capacities of separate kitchen and bathroom exhaust fans. These rates are not measured values and are included only to illustrate the imbalance found between some supply and exhaust flow rates.

6.4 MEASURED POLLUTANT LEVELS

The measurement of pollutant levels in the five regions was a combination of simple and complex measurements. The specific pollutants tested for were dictated by the results obtained during the preliminary assessment of the buildings, and as such, vary from region to region. In general, there were no measured pollutant levels in excess of recommended provincial of Federal guidelines.

The exceptions to this were elevated levels of carbon dioxide (CO_2) found in Building II in the Atlantic Region, and Building B in the Prairie Region. These buildings, while having measured CO_2 levels below Health and Welfare Canada's permissible exposure limits of 3,500 ppm, were at or above the 1,000 ppm level that studies suggest are indicative of inadequate fresh air supply. The other exception was high levels of total suspended particulates found in the Atlantic and Prairie Region buildings. Health and Welfare Canada suggests particulate levels should be less than 40 $\mu g/m^3$, Manitoba Workplace Safety and Health guidelines are 10,000 $\mu g/m^3$. The levels found in the Atlantic region at 200 $\mu g/m^3$ are not high enough to warrant undo concern. The levels recorded in Building B were extremely high, 32,500 $\mu g/m^3$, and demanded remedial actions to lower the recorded levels.

The owners of the Manitoba building were contacted and cleaning of the entire ventilation system was arranged. Follow-up testing confirmed that the cleaning of the ducts has reduced the particulates levels to below Manitoba provincial guidelines.

A summary of the specific pollutants, and their measured concentrations, found in the various regions is presented in Tables 12, 13 and 14 following.

TABLE 12

INDOOR AIR QUALITY
MEASURED POLLUTANT LEVELS

Region and Building	Carbon Dioxide CO_2 (ppm)	Carbon Monoxide CO (ppm)	Formaldehyde CH_2O (ppm)	Bioaerosol (CFU/m^3)
Atlantic:				
Building I	354-648	0-4	0.02-0.04	0
Building II	413-1896	0-2	0.02-0.04	6-53
Quebec:				
Building 1	380-400	<1	<0.05	7-237
Building 2	380	<1	<0.05	201
Ontario:				
Donald Street	862	--	0.024	--
	787[1]	--	0.025[1]	--
Bridleview	450 - 500	--	<0.05	--
	500 - 700[1]	--	<0.05[1]	--
Prairies:				
Building A	220-660	0-1	<0.006	1-20
Building B	540-960	0-7	<0.006	1-45
	745-1380[2]			
British Columbia:				
Building A	--	--	--	--
Building D	480-700	3-11	--	--
Building E	490	2-3	--	--
Recommended Limits:	1,000	1 hr <36 8 hr <9	<0.1	<300

[1]After sealing
[2]Follow-up testing

TABLE 13

INDOOR AIR QUALITY
MEASURED POLLUTANT LEVELS

Region and Building	Radon (Bq/m^3)	Total Suspended Particulates ($\mu g/m^3$)	Temperature (°C)	Relative Humidity (%)
Atlantic:				
Building I	3.7 - 18.3	45 - 200	21-24	24-38
Building II	7.8 - 18.4	1 - 77	21-26	27-50
Ontario:				
Donald Street	8.8 - 20.1	--	slight increase	29
	9.0 - 22.0[1]	--	after sealing	31[1]
Bridleview	6.0 - 9.5	--	21 - 25	24-43
	7.5 - 9.5[1]	--	20 - 33[1]	27-36[1]
Prairies:				
Building A	--	34 - 456	25-31	9-33
Building B	--	833 - 32,500	22-29	14-36
		459 - 7,950[2]		
Recommended Limits:	<800	<40	20-25	30-50

[1]After sealing
[2]Follow-up testing

TABLE 14

INDOOR AIR QUALITY
MEASURED POLLUTANT LEVELS

Region and Building	Ozone O_3 (ppm)	Nitrogen Dioxide NO_2 (ppm)	Nitric Oxide NO (ppm)	Toluene $C_6H_5CH_3$ (ppm)	Xylene $C_6H_4(CH_3)_2$ (ppm)	Gasoline C_nC_m (ppm)
Quebec:						
Building 1	<0.01	<0.1	<1.0	<1.0	<1.0	<1.0
Building 2	<0.01	<0.1	<1.0	<1.0	<1.0	<1.0
Recommended Limits:	<0.12	<3.0	<25.0	<100.0	<100.0	<300

7.0 RECOMMENDATIONS

The review and summary of the five regional reports has highlighted some areas in the testing and reporting procedures that can be improved upon. The following is a list of recommendations intended to improve the accuracy and usefulness of future investigation surveys:

1. Test procedures and the method of reporting air leakage test results should be standardized to permit easier comparison of results.

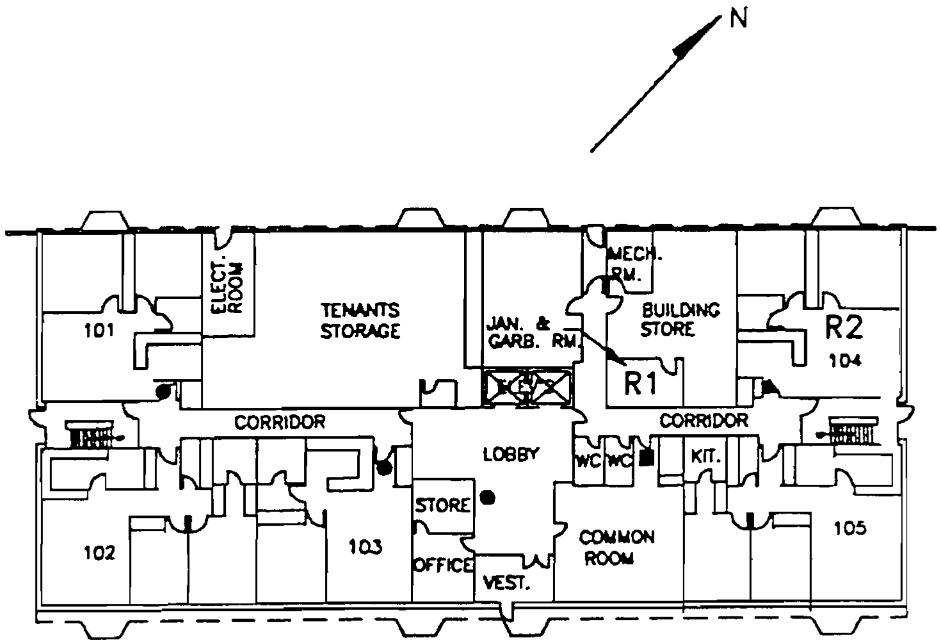
2. The test procedure for suite airtightness testing should be modified to include a requirement for separating corridor wall leakage from the exterior wall leakage. Combined corridor and exterior wall leakage rates do not provide accurate information about actual infiltration/exfiltration rates through the exterior wall.

3. The test procedure for floor airtightness testing should be modified to ensure air flow through vertical shafts such as elevator and stair shafts is accounted for. The volume of air that can pass through these shafts can easily distort the test results if not properly accounted for.

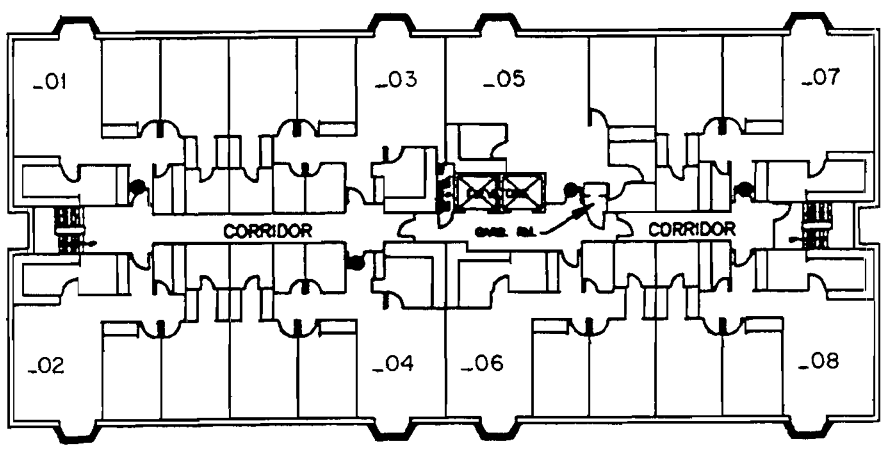
4. The method for conducting occupant surveys should be standardized to include a fixed set of common questions with provisions to modify the form to include additional local or regional concerns or questions.

5. The method for monitoring and testing of indoor air quality should include a standardized minimum list of pollutants that should be tested for with provision to test for any additional pollutants that may become apparent during the investigation. Temperature and relative humidity should also be consistently measured.

APPENDIX A

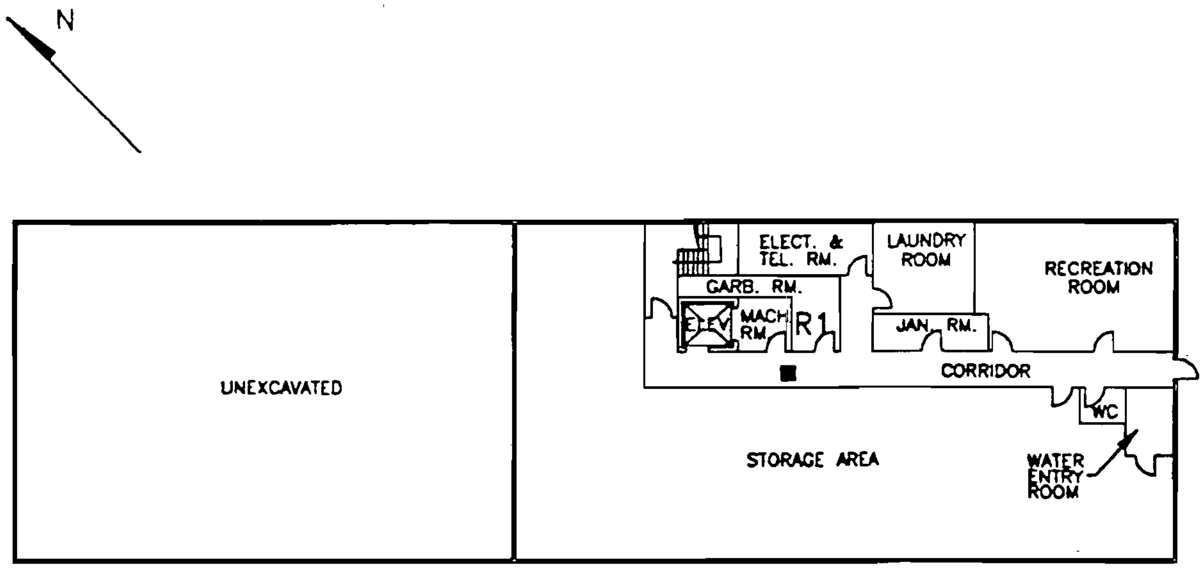


FIRST FLOOR PLAN

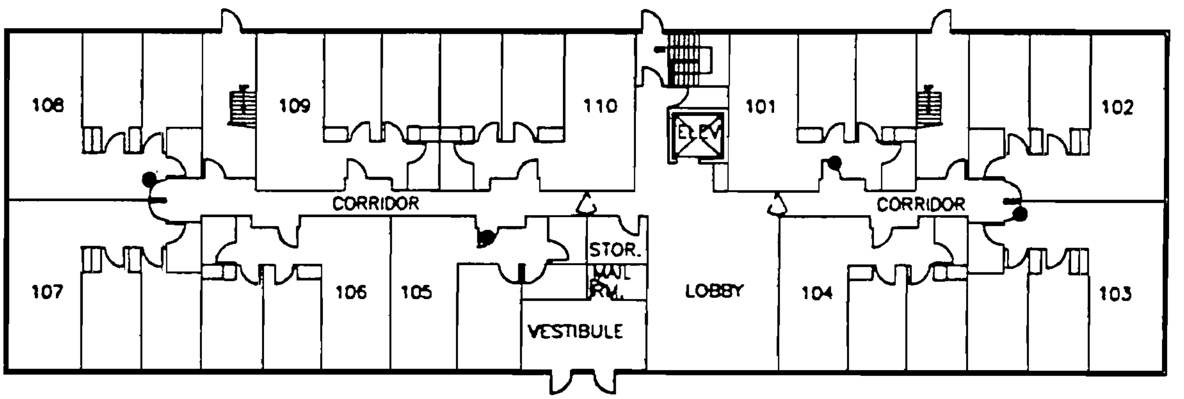


TYPICAL FLOOR PLAN

ATLANTIC REGION
BUILDING No. 1



BASEMENT FLOOR PLAN



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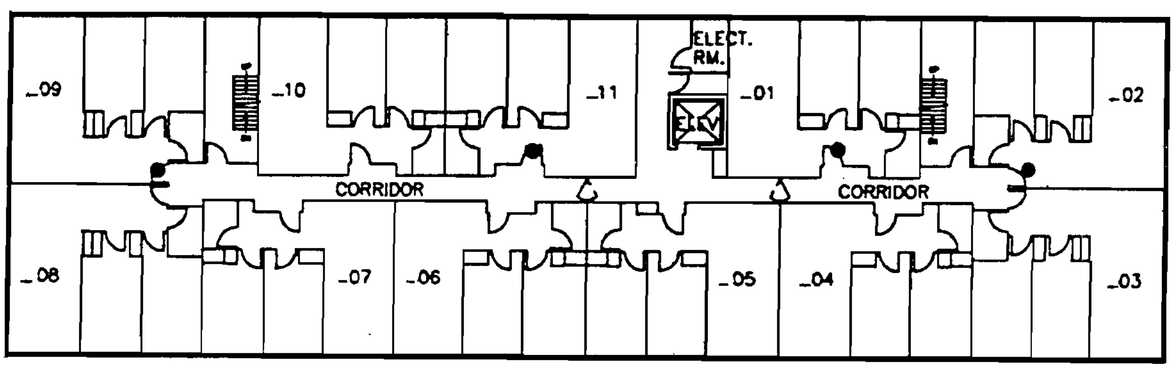
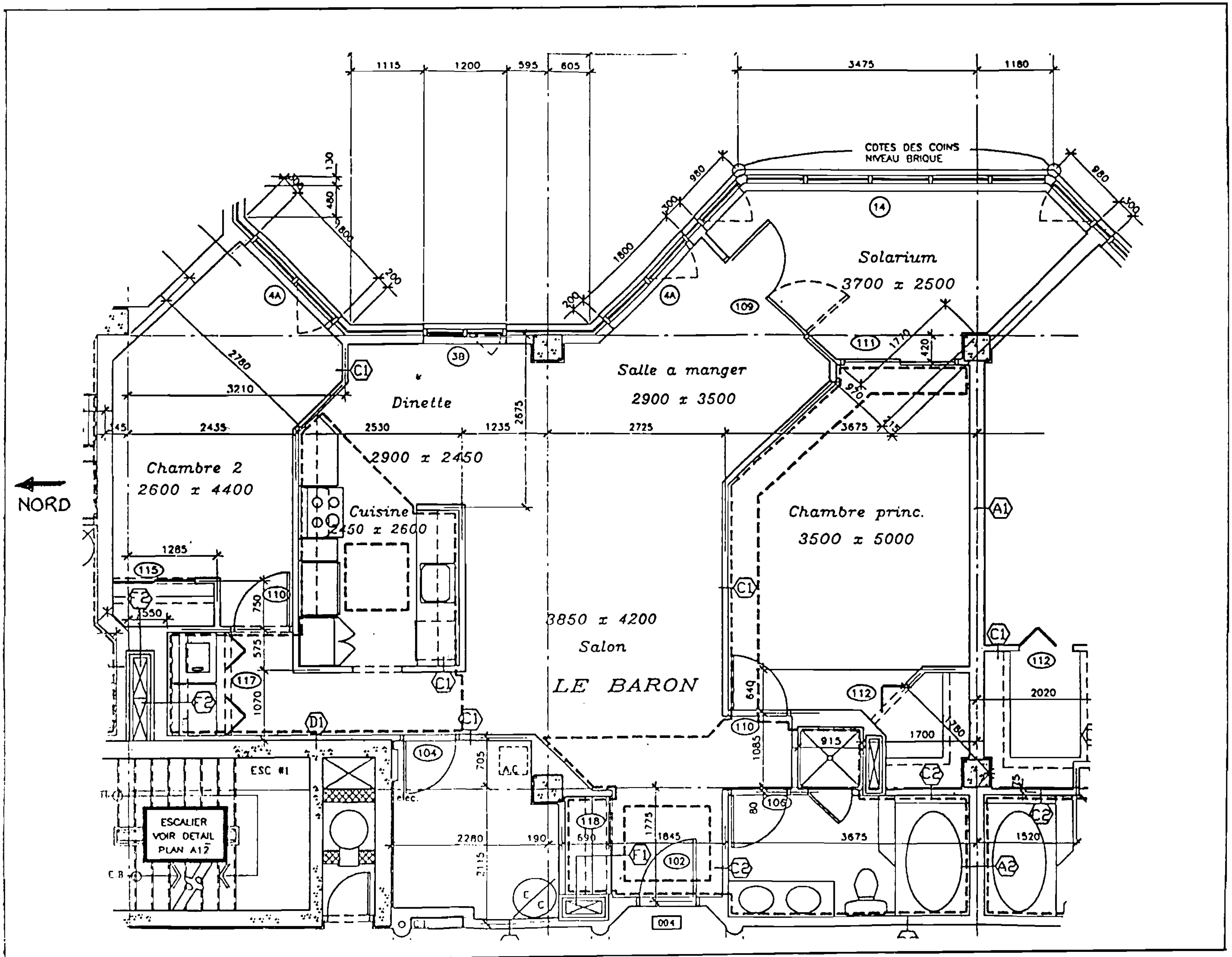
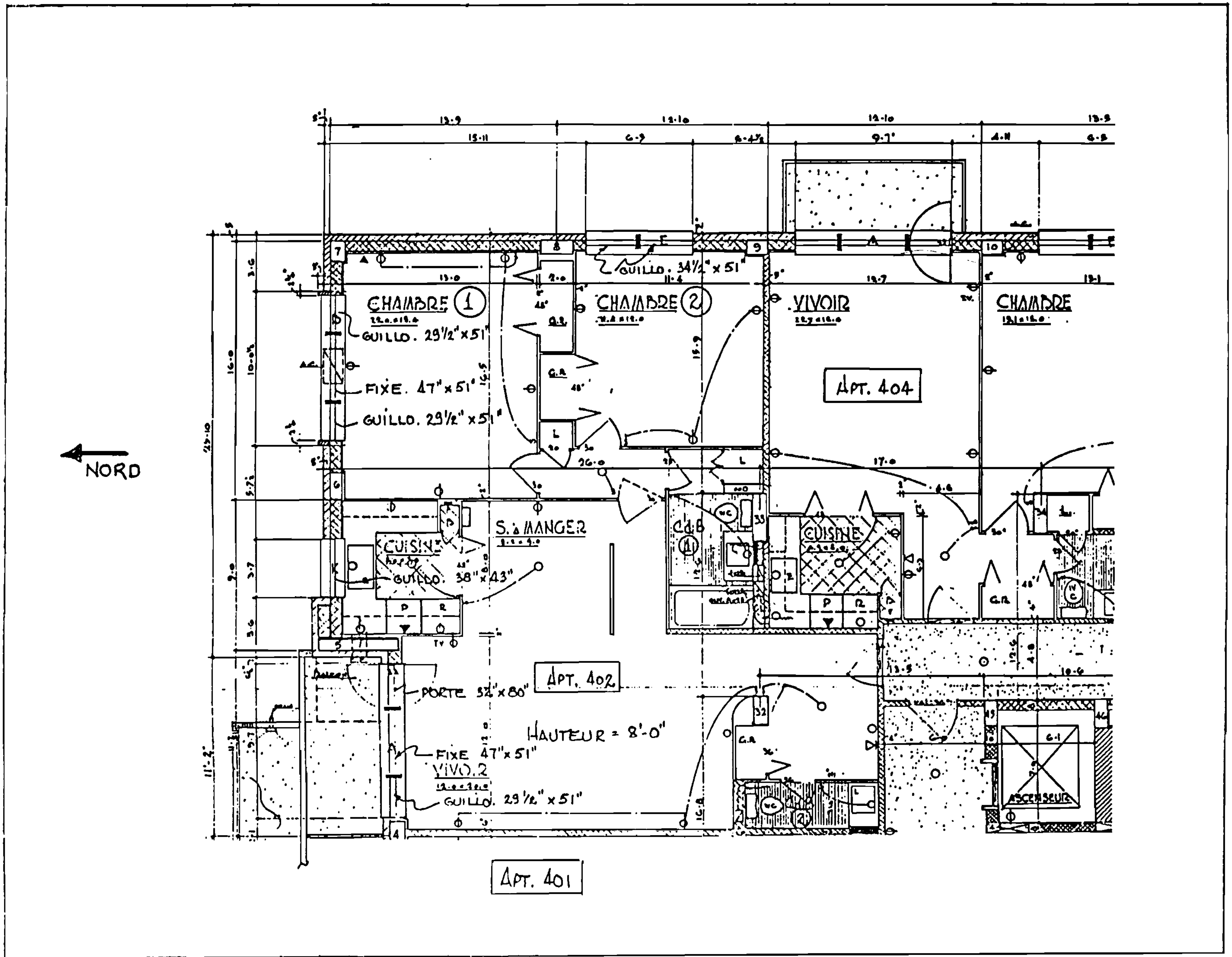


TYPICAL FLOOR PLAN

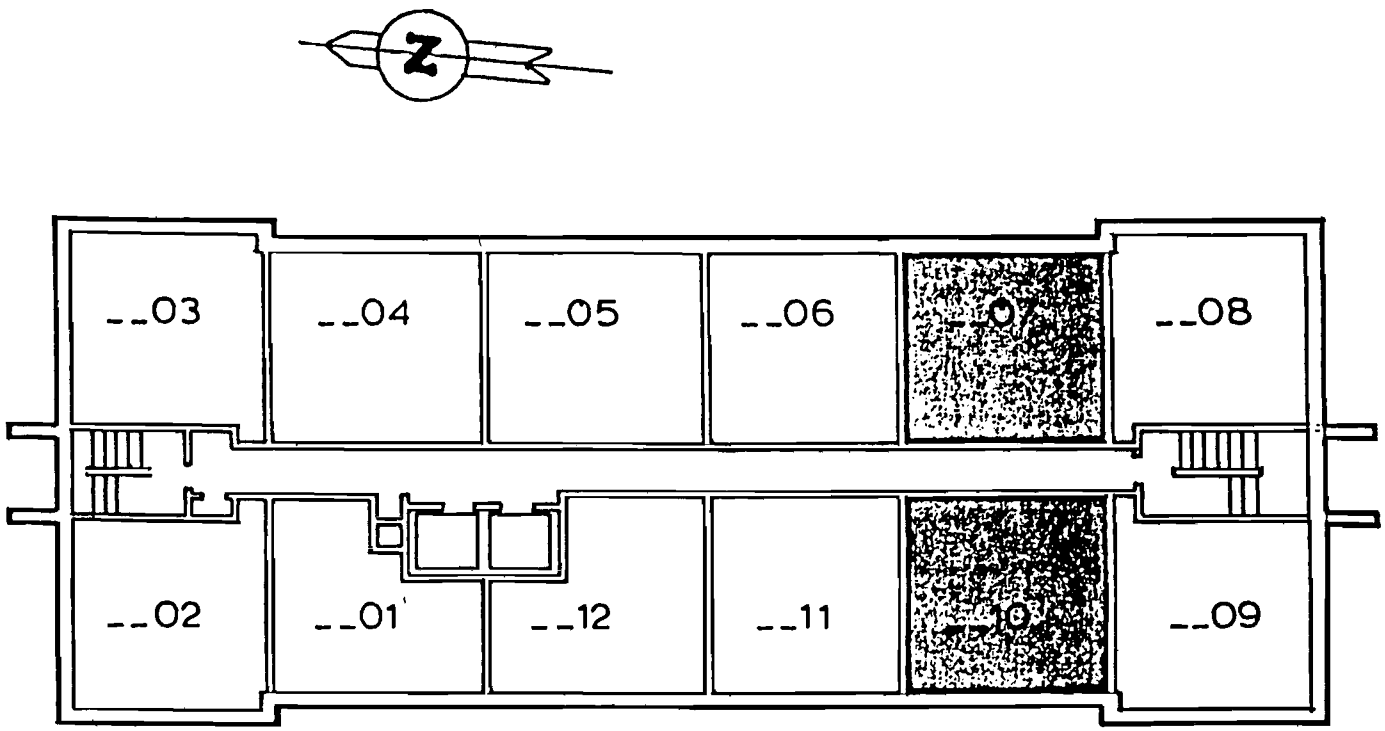
ATLANTIC REGION
BUILDING No. 2



QUEBEC REGION
BUILDING No. 1

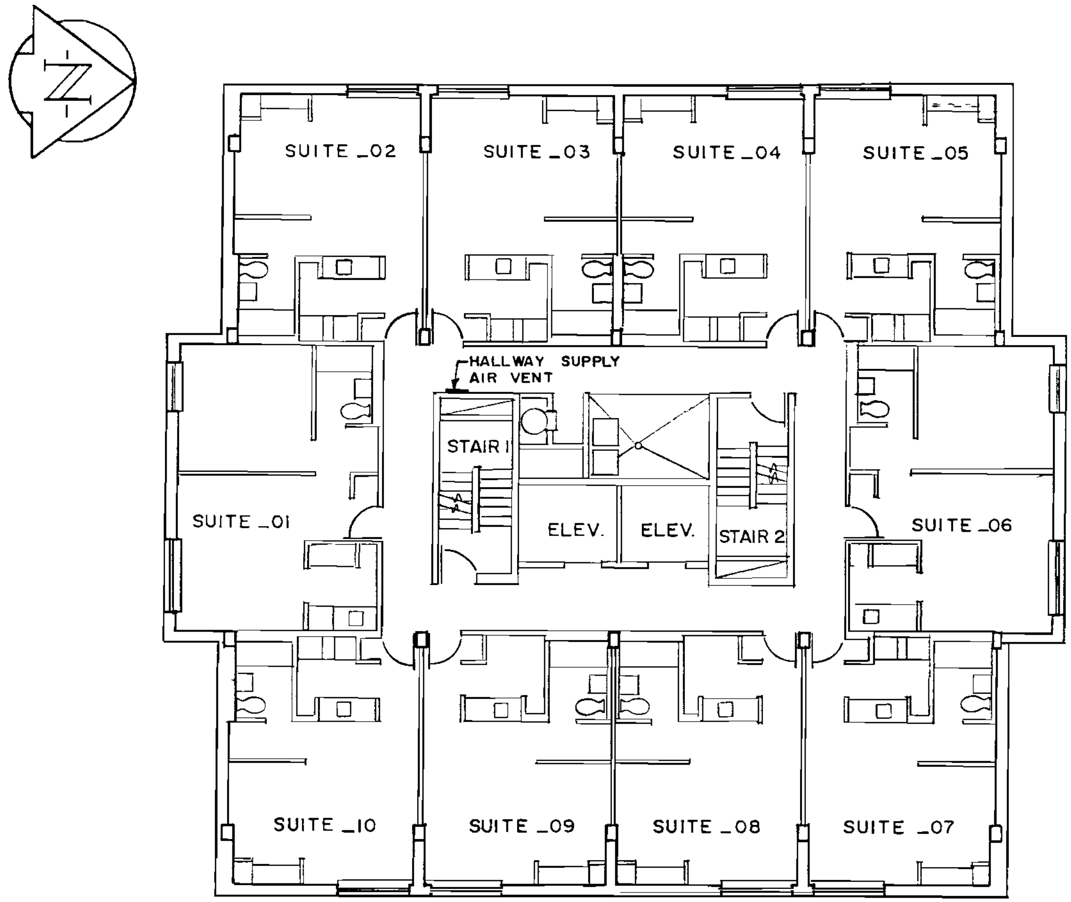


QUEBEC REGION
BUILDING No. 2

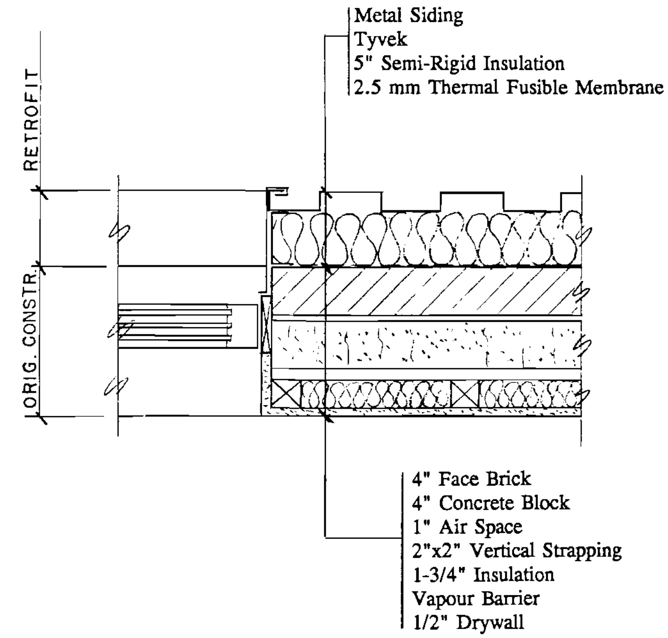


TYPICAL FLOOR

ONTARIO REGION
DONALD STREET BUILDING



TYPICAL FLOOR PLAN (3 TO 14 INCLUSIVE)



TYPICAL WALL CONSTRUCTION

NO.	DESCRIPTION	DATE	BY

REVISIONS/ISSUE

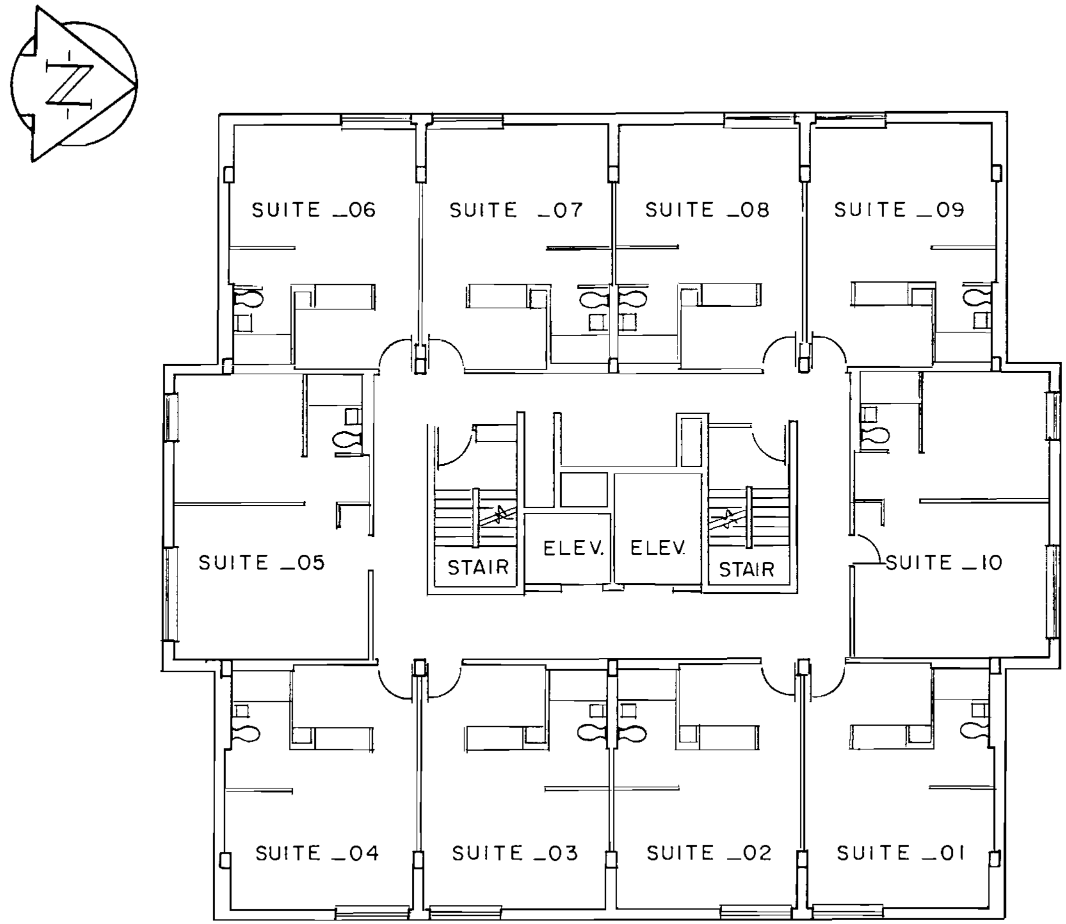
WARDROP ENGINEERING INC.

CLIENT
CANADA MORTGAGE AND HOUSING CORPORATION

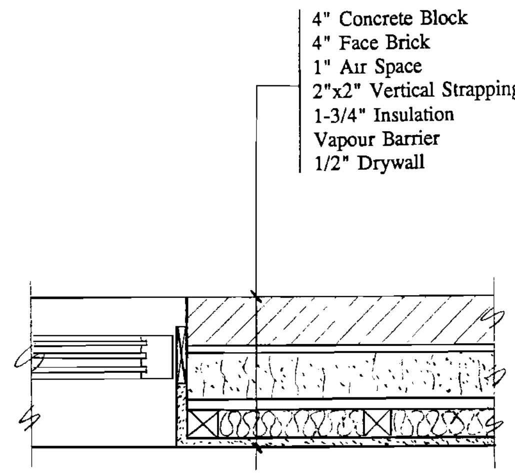
DWG. DESCRIPTION
MANITOBA REGION - BUILDING A
AIR LEAKAGE MONITORING

DESIGNED BY:	DRAWN BY: T.O.	DWG NO. 910839-01-00-SK2
CHECKED BY:	DATE: MARCH '91	

W5024-(09/87)



TYPICAL FLOOR PLAN (2 TO 12 INCLUSIVE)



TYPICAL WALL CONSTRUCTION

NO.	DESCRIPTION	DATE	BY

REVISIONS/ISSUE

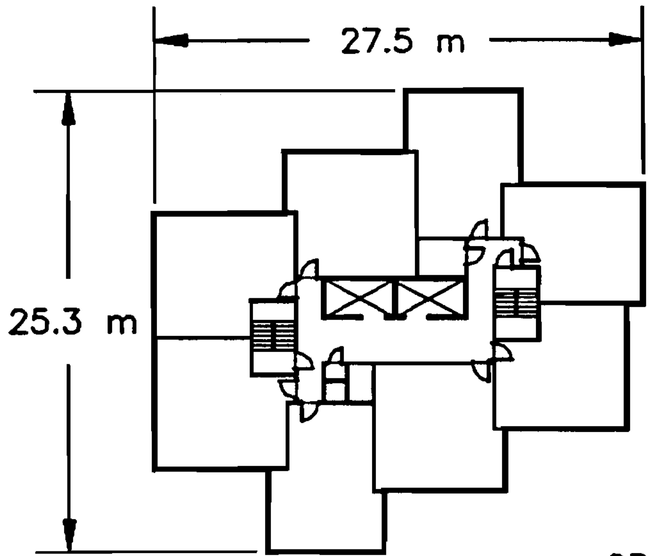
WARDROP ENGINEERING INC.

CLIENT: CANADA MORTGAGE AND HOUSING CORPORATION

DWG. DESCRIPTION: MANITOBA REGION - BUILDING B AIR LEAKAGE MONITORING

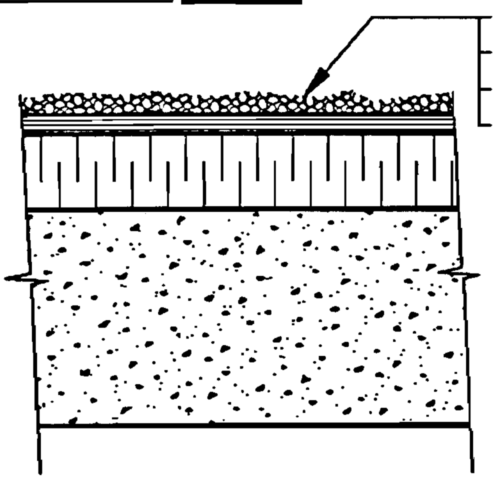
DESIGNED BY:	DRAWN BY: T. O	DWG NO.
CHECKED BY:	DATE: APRIL 91	910839-01-00-SK3

W5024-(09/87)

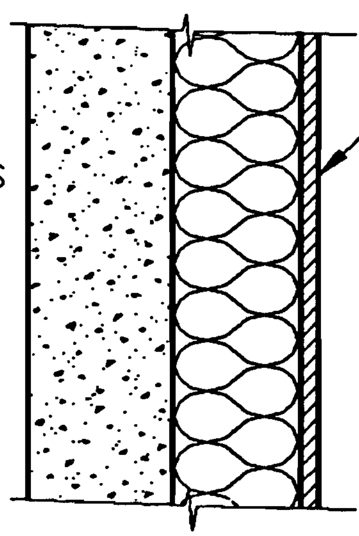


TYPICAL FLOOR PLAN

FLOOR AREA : 459 sq. m
WALL AREA : 273 sq. m
8 SUITES PER FLOOR



TYPICAL ROOF SECTION



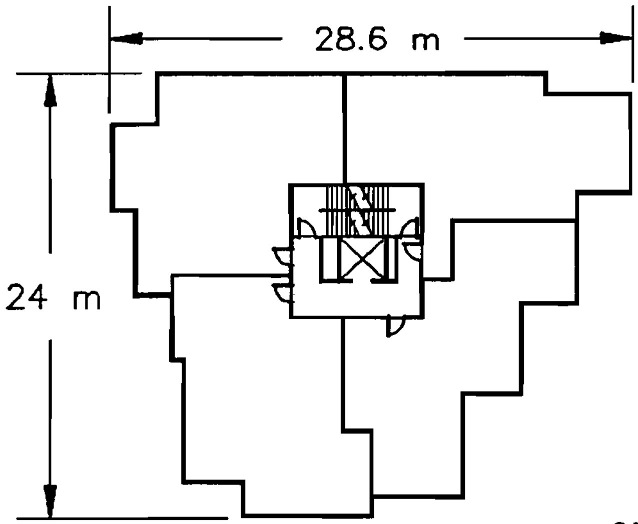
TYPICAL WALL SECTION

AVALON MECHANICAL CONSULTANTS

BRITISH COLUMBIA REGION

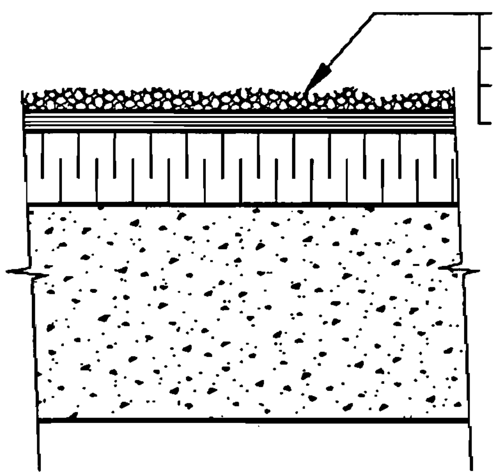
BUILDING A

FLOOR PLAN & SECTIONS

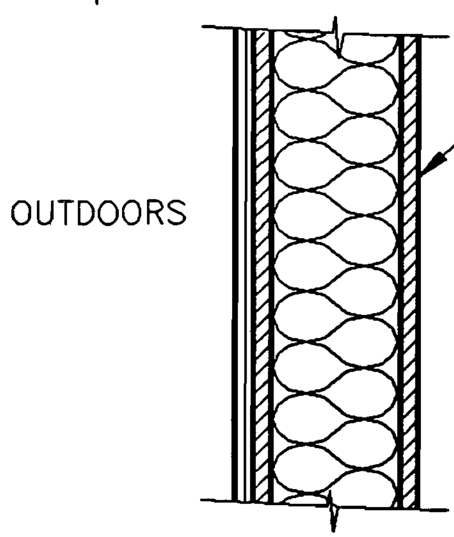


TYPICAL FLOOR PLAN

FLOOR AREA : 501 sq. m
WALL AREA : 305 sq. m
4 SUITES PER FLOOR



TYPICAL ROOF SECTION



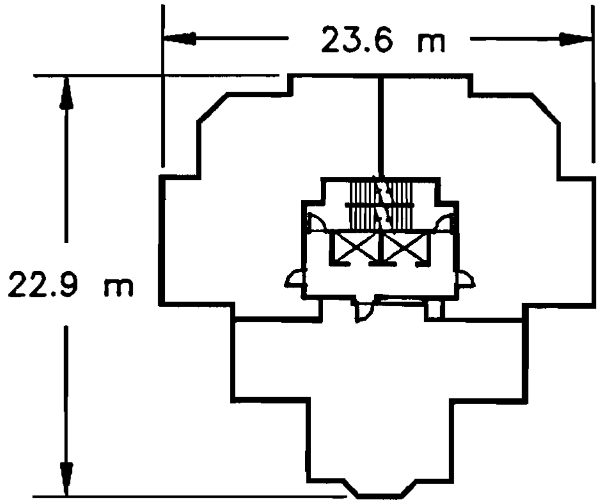
TYPICAL WALL SECTION

AVALON MECHANICAL CONSULTANTS

BRITISH COLUMBIA REGION

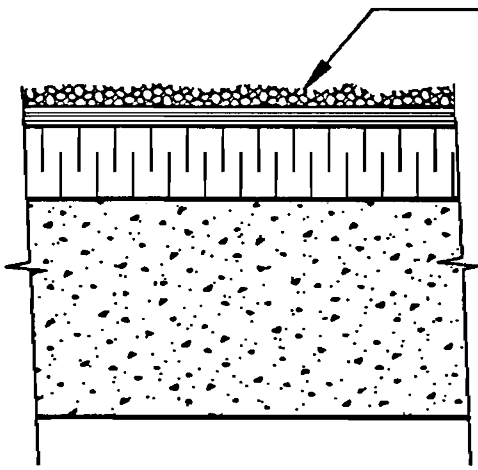
BUILDING B

FLOOR PLAN & SECTIONS

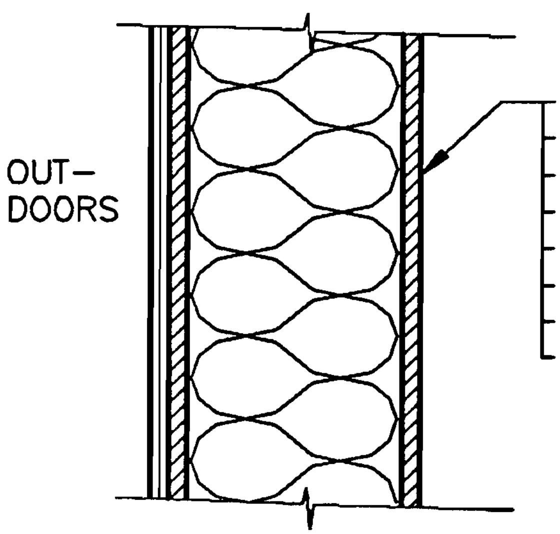


TYPICAL FLOOR PLAN

FLOOR AREA : 383 sq. m
WALL AREA : 242 sq. m
3 SUITES PER FLOOR



TYPICAL FLAT ROOF SECTION



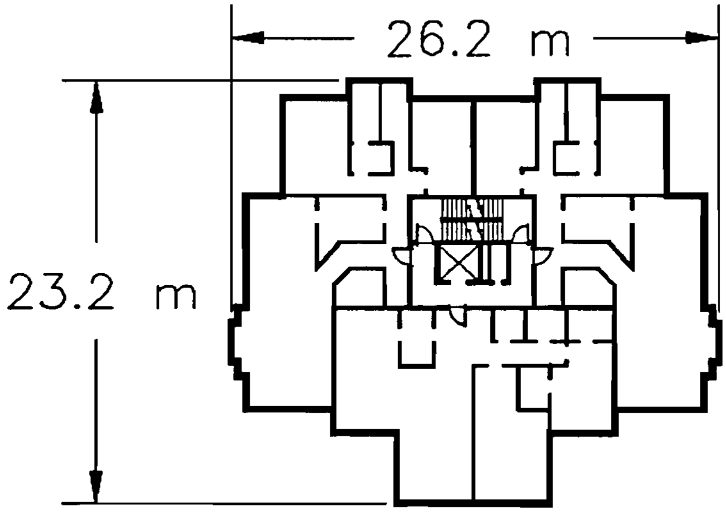
TYPICAL WALL SECTION

AVALON MECHANICAL CONSULTANTS

BRITISH COLUMBIA REGION

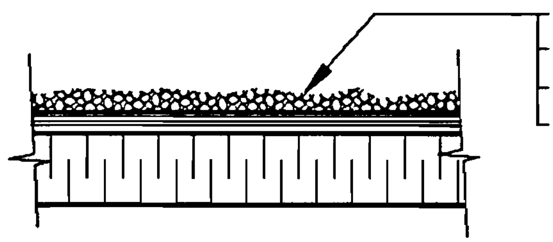
BUILDING C

FLOOR PLAN & SECTIONS

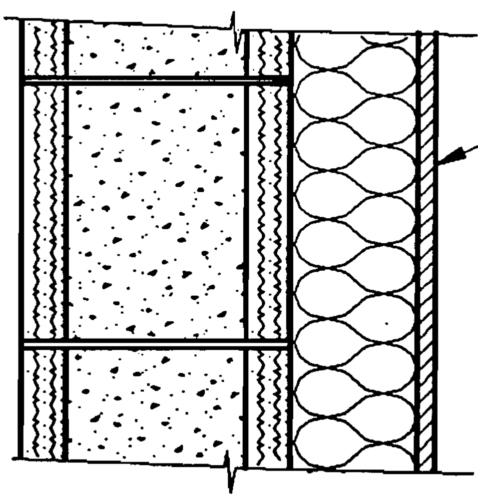


TYPICAL FLOOR PLAN

FLOOR AREA : 470.3 sq. m
WALL AREA : 295.8 sq. m
3 SUITES PER FLOOR



TYPICAL ROOF SECTION



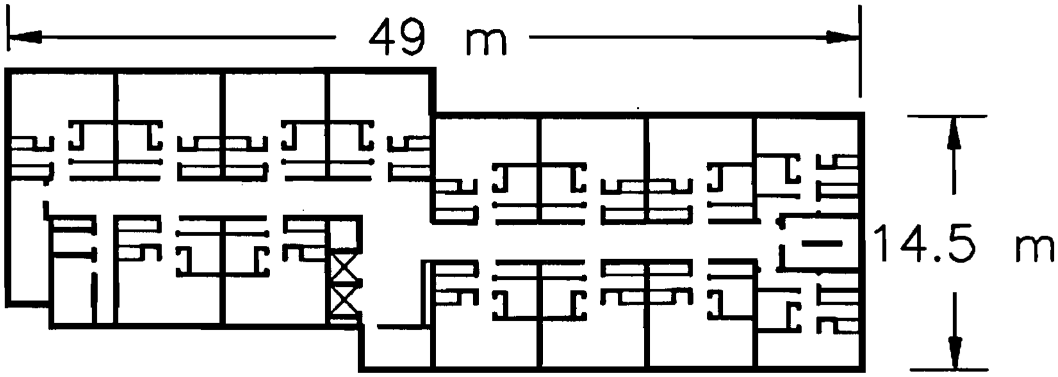
TYPICAL WALL SECTION

AVALON MECHANICAL CONSULTANTS

BRITISH COLUMBIA REGION

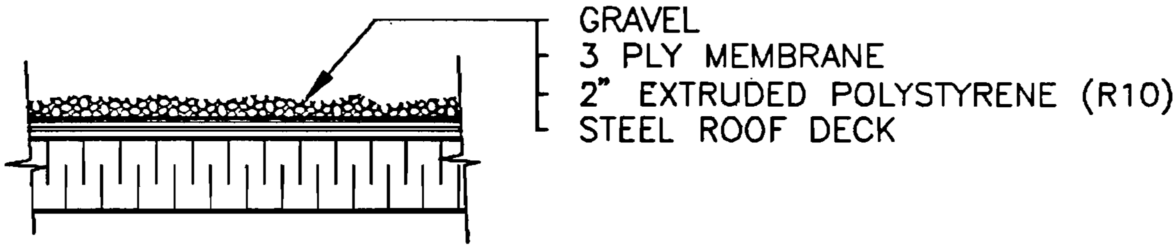
BUILDING D

FLOOR PLAN & SECTIONS

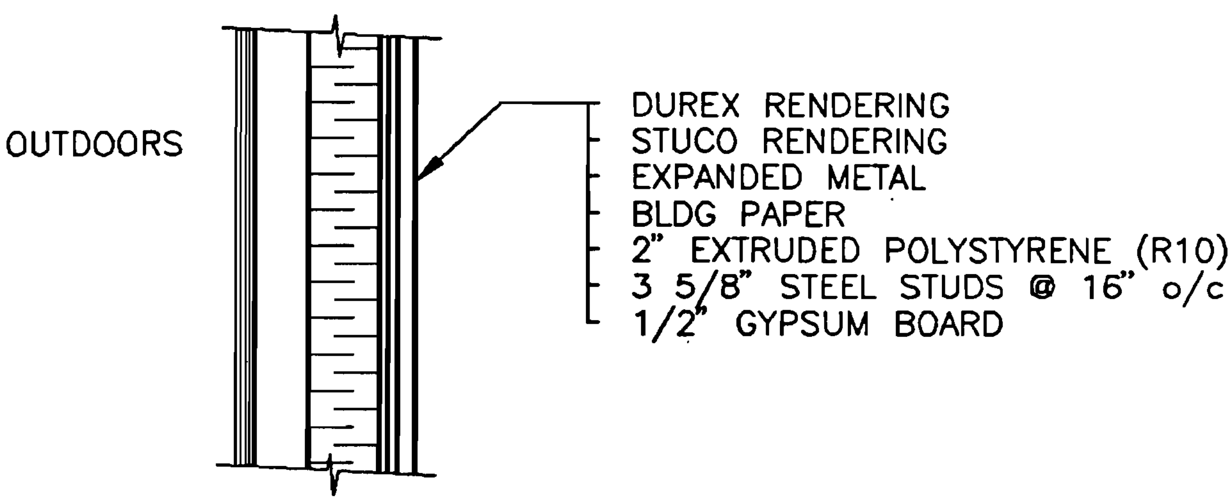


TYPICAL FLOOR PLAN

FLOOR AREA: 785 sq m
WALL AREA : 596 sq m
14 SUITES PER FLOOR



TYPICAL ROOF SECTION



TYPICAL WALL SECTION

AVALON MECHANICAL CONSULTANTS

BRITISH COLUMBIA REGION

BUILDING E

FLOOR PLAN & SECTIONS

APPENDIX B

DETAILED TEST PROCEDURE FOR
MEASURING AIR LEAKAGE AND AIR FLOW PATTERNS
IN HIGH-RISE APARTMENT BUILDINGS

TEST CONDITION A: **Blower Door Assembly Located in Entry Door to Subject Suite**

Test No. 1: **Total Six-Sided Air Leakage (No Pressure Masking)**

Test Set-Up

- Tightly close all windows.
- Open all interior doors.
- Seal off window air conditioners.
- Seal all supply air or exhaust vents.
- Open stair shaft doors on floor of suite being tested and on floors two levels above and below.
- Install pressure tap to the exterior, through the living room window (tap must point upwards or downwards).
- Install and seal blower in the centre of test suite as the reference pressure point.
- Connect the pressure tap from the exterior wall and one of the reference pressure taps to a digital manometer, connect the pressure tap from the calibrated nozzle, and the second reference pressure tap to a second digital manometer (keep the manometers out of all air drafts as they are sensitive to temperature changes).

Test Procedure

- Record test date and time.
- Measure and record:
  - outdoor air temperature
  - indoor air temperature
  - wind speed and direction
  - initial ambient atmospheric pressure
- Zero all manometers.
- With fan turned off and inlet nozzle sealed off, record initial base pressure differential across the exterior wall.
- Remove seal from inlet nozzle and turn fan off.
- Adjust flow rate of fan in subject suite until the pressure differential across the exterior wall is 50 Pa above the baseline pressure measured.
- Allow pressures and flows to stabilize.

- Record all pressures.
- Record air temperature at inlet nozzle of fan.
- Repeat the procedure varying indoor to outdoor pressure differentials from 50 15 Pa, in decreasing increments of approximately 3 Pa.
- Turn fan off and seal inlet nozzle, record final base pressure differential across the exterior wall (if substantial discrepancies exist between initial and final baseline pressure differentials, discard test results).

Test No. 2: **Exterior, Floor and Ceiling Leakage (Pressure Masks Built in Corridor)**

<u>Test Set-Up</u>

- Repeat set-up as per Test No. 1, in addition:

- Build pressure masks in corridor to encompass subject suite and suites immediately to the left and right of the subject suites.
- Open entry doors of left and right hand suites.
- Open all interior doors of left and right hand suites.
- Close windows of left and right hand suites.
- Install pressure tap in centre of corridor, located away from the influence of the pressurization fans.
- Install second blower door in stair shaft doorway (fan exhausting into stair shaft).
- Connect the pressure taps from the subject suite and the corridor to a digital manometer located in the hallway.

<u>Test Procedure</u>

- Record test date and time.
- Measure and record:
    - outdoor air temperature
    - indoor air temperature
    - wind speed and direction
    - initial ambient atmospheric pressure
- Zero all manometers.
- With all fans turned off and the subject suite fan inlet nozzle sealed off, record initial base pressure differential across the exterior wall.
- Remove seal from inlet nozzle and turn subject suite fan on.
- Adjust flow rate of fan in subject suite until the pressure differential across the exterior wall is 50 Pa above the baseline pressure measured.

- Allow pressures and flows to stabilize.
- Record all pressures.
- Record air temperature at inlet nozzle of fan.
- Repeat the procedure varying indoor to outdoor pressure differentials from 50 and 15 Pa, in decreasing increments of approximately 3 Pa.
- Turn all fans off and seal inlet nozzle, record final base pressure differential across the exterior wall (if substantial discrepancies exist between initial and final baseline pressure differentials, discard test results).

Test No. 3-6: Five-Sided Air Leakage (One Adjacent Suite Masked Off)

Test Set-Up

- Repeat set-up as per Test No. 1, in addition, perform the following on one of the adjacent suites:

- Install a pressure tap from the centre of the room into the hallway.
- Tightly close all windows.
- Install a blower door assembly in the entry door (fan assembly to exhaust into the corridor).
- Install a pressure tap from the centre of the subject suite to the doorway of the adjacent suite.
- Connect the pressure taps from the subject and adjacent suites to a manometer located in the hallway.

Test Procedure

- Repeat procedure from Test No. 2.
- Repeat this test with the second blower door located in the doorway of one of the suites immediately above, below, to the right, or left of the subject suite.

Note: This procedure can be used to mask out the suites above and below the subject suite only if the partition walls of these suites align with the partition walls of the subject suite.

TEST CONDITION B: Blower Door Assembly Located in Window of Subject Suite to Determine Leakage Through Entry Door

Test Set-Up and Procedure

- Repeat set-up and procedure as per Test No. 1, with the exception of the blower door location, in addition:

- Perform the test with the entry door closed normally, and a second time with the entry door closed and sealed.

TEST CONDITION C: Blower Door Assembly Located in Entry Door of Subject Suite to Determine Leakage Through the Exterior Window

Test Set-Up and Procedure

- Repeat set-up and procedure as per Test No. 1.
- Perform the test with the windows closed normally, and a second time with the windows closed and sealed off.

NOMENCLATURE

Pex = Indoor–to–outdoor pressure differential (Pa)
P b/d = Pressure differential across blower door (Pa)
Q6 = Six–sided leakage (l/s)
Qc = Ceiling leakage (l/s)
Qf = Floor leakage (l/s)
Ql,r,cor = Left and right partition and corridor leakage (l/s)
Qrem = Q6 – Qc – Qf – Ql,r,cor

WORKSHEET FOR CALCULATING THE REGRESSION EQN. OF A PARTITION USING THE DIFFERENCE BETWEEN TWO AIRTIGHTNESS TESTS.

BUILDING: A

TEST SUITE: 405

LEAKAGE CALCULATED: EXTERIOR WALL

EXTERIOR WALL AREA: 28.32 m2

ANALYSIS:

Q6 – NO PRESSURE MASKING

C = 19.9574

n = 0.5374

Airtightness test results for the Test Suite without simultaneous depressurization of adjacent suites.

*Suite orientations as viewed from corridor looking into suite.

TOP SUITE PRESSURE MASKED

C = 18.0237

n = 0.5359

Airtightness test results for the Test Suite with simultaneous depressurization.

LEFT & RIGHT SUITES & CORRIDOR PRESSURE MASKED

C = 12.1659

n = 0.5163

BOTTOM SUITE PRESSURE MASKED

C = 21.0668

n = 0.5169

Pex	P b/d	Q6	Qc	Qf	Ql,r,cor	Qrem	ln(P ex)	ln(Qrem)
49	48	161.59	16.51	4.10	70.85	70.14	3.891820	4.250423
41	43	146.83	14.96	3.20	64.07	64.60	3.713572	4.168189
39	41	142.94	14.56	2.97	62.28	63.12	3.663561	4.145092
36	38	136.92	13.93	2.63	59.53	60.83	3.583518	4.108104
34	34	132.78	13.50	2.39	57.64	59.24	3.526360	4.081675
33	33	130.66	13.28	2.28	56.68	58.43	3.496507	4.067866
31	31	126.35	12.83	2.04	54.71	56.77	3.433987	4.038935
29	29	121.90	12.37	1.81	52.69	55.04	3.367295	4.008055
25	28	112.55	11.40	1.33	48.45	51.38	3.218875	3.939270
22	24	105.08	10.62	0.97	45.07	48.42	3.091042	3.879956
21	23	102.49	10.35	0.85	43.90	47.39	3.044522	3.858355
20	21	99.83	10.08	0.73	42.70	46.33	2.995732	3.835691
16	19	88.55	8.91	0.24	37.64	41.76	2.772588	3.731920
16	18	88.55	8.91	0.24	37.64	41.76	2.772588	3.731920

ln(P b/d)	ln(Qc)	ln(Qf)	ln(Ql,r,c)
3.871201	2.803732	1.410361	4.2605880
3.761200	2.705589	1.162923	4.1599599
3.713572	2.678052	1.088903	4.1317196
3.637586	2.633977	0.965366	4.0865135
3.526360	2.602503	0.872813	4.0542266

3.496507	2.586064	0.822856	4.0373620
3.433987	2.551636	0.714198	4.0020388
3.367295	2.514911	0.591427	3.9643533
3.332204	2.433175	0.285311	3.8804635
3.178053	2.362774	−0.03108	3.8081855
3.135494	2.337153	−0.16419	3.7818771
3.044522	2.310282	−0.31808	3.7542816
2.944438	2.187378	−1.41767	3.6280305
2.890371	2.187378	−1.41767	3.6280305

REGRESSION EQUATIONS:

EXTERIOR WALL

Regression equations to calculate the leakage characteristics of the exterior wall, ceiling, floor, and (combined) left and right partitions plus the corridor wall.

Regression Output:				
Constant		2.447331		
Std Err of Y Est		0.000234		
R Squared		0.999998	r =	0.9999990
No. of Observations		14		
Degrees of Freedom		12		
X Coefficient(s)	0.463429			
Std Err of Coef.	0.000185			

REGRESSION EQUATION DESCRIBING EXTERIOR WALL LEAKAGE:

C = 11.55746

n = 0.463429

CEILING

Regression Output:				
Constant		0.397435		
Std Err of Y Est		0.023416		
R Squared		0.986446	r =	0.9931999
No. of Observations		14		
Degrees of Freedom		12		
X Coefficient(s)	0.619665			
Std Err of Coef.	0.020968			

REGRESSION EQUATION DESCRIBING CEILING LEAKAGE:

C = 1.488004

n = 0.619665

FLOOR

Regression Output:				
Constant		−9.02564		
Std Err of Y Est		0.282485		
R Squared		0.908795	r =	0.9533078
No. of Observations		14		
Degrees of Freedom		12		
X Coefficient(s)	2.766041			
Std Err of Coef.	0.252954			

REGRESSION EQUATION DESCRIBING FLOOR LEAKAGE:

C = 0.000120

n = 2.766041

LEFT, RIGHT, PARTITION CORRIDORS

Regression Output:

Constant		1.791010		
Std Err of Y Est		0.024055		
R Squared		0.986420	r =	0.9931872
No. of Observations		14		
Degrees of Freedom		12		
X Coefficient(s)	0.635996			
Std Err of Coef.	0.021541			

REGRESSION EQUATION DESCRIBING LEFT, RIGHT, CORR. LEAKAGE:

C = 5.995508

n = 0.635996

RESULTS: AIR LEAKAGE RATES @ 50 Pa

CONDITION A: 6-SIDED LEAKAGE IGNORING DOOR

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
L & R PART. & CORR.	72.17	43.5 %
FLOOR	6.02	3.6 %
CEILING	16.80	10.1 %
EXTERIOR WALL	70.83	42.7 %
TOTAL	165.82 l/s	100.00 %

EXTERIOR WALL LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 2.50 l/s m2

CONDITION B: 6-SIDED LEAKAGE IGNORING WINDOW

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
DOOR	120.94	42.2 %
L & R PART. & CORR.	72.17	25.2 %
FLOOR	6.02	2.1 %
CEILING	16.80	5.9 %
EXTERIOR WALL	70.83	24.7 %
TOTAL	286.76 l/s	100.00 %

EXTERIOR WALL LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 2.50 l/s m2

WORKSHEET FOR CALCULATING THE REGRESSION EQN. OF A PARTITION USING THE DIFFERENCE BETWEEN TWO AIRTIGHTNESS TESTS.

BUILDING: A

TEST SUITE: 409

LEAKAGE CALCULATED: EXTERIOR WALL AND CORRIDOR

EXTERIOR WALL AREA: 12.17 m2

ANALYSIS:

Q6 – NO PRESSURE MASKING
C = 15.1435
n = 0.5740

Airtightness test results for the Test Suite without simultaneous depressurization of adjacent suites.

*Suite orientations as viewed from corridor looking into suite.

TOP SUITE PRESSURE MASKED
C = 10.7899
n = 0.6522

Airtightness test results for the Test Suite with simultaneous depressurization.

LEFT SUITE PRESSURE MASKED
C = 12.8594
n = 0.5226

RIGHT SUITE PRESSURE MASKED
C = 12.6294
n = 0.6109

BOTTOM SUITE PRESSURE MASKED
C = 12.7282
n = 0.6112

Pex	P b/d	Q6	Qc	Qr	Qf	Ql	Qrem	ln(P ex)	ln(Qrem)
57	54	154.20	3.48	4.91	3.56	47.83	94.43	4.043051	4.547876
55	52	151.08	3.82	5.00	3.68	46.67	91.91	4.007333	4.520769
52	49	146.29	4.32	5.14	3.86	44.90	88.07	3.951243	4.478158
48	46	139.72	4.97	5.30	4.09	42.48	82.87	3.871201	4.417255
48	44	139.72	4.97	5.30	4.09	42.48	82.87	3.871201	4.417255
39	38	124.02	6.34	5.62	4.56	36.78	70.72	3.663561	4.258734
36	33	118.45	6.76	5.70	4.70	34.79	66.51	3.583518	4.197414
30	29	106.68	7.51	5.81	4.92	30.62	57.82	3.401197	4.057284
26	25	98.27	7.93	5.84	5.03	27.69	51.77	3.258096	3.946838
24	23	93.86	8.12	5.84	5.07	26.17	48.66	3.178053	3.884879
18	17	79.57	8.50	5.74	5.10	21.33	38.90	2.890371	3.661064
15	14	71.66	8.56	5.62	5.05	18.72	33.73	2.708050	3.518262

ln(P b/d)	ln(Qc)	ln(Qr)	ln(Qf)	ln(Ql)
3.988984	1.245661	1.591173	1.269467	3.8676460
3.951243	1.339360	1.609943	1.303647	3.8430485
3.891820	1.463198	1.636368	1.351577	3.8043729
3.828641	1.603793	1.668352	1.409635	3.7490744
3.784189	1.603793	1.668352	1.409635	3.7490744
3.637586	1.846828	1.726016	1.517483	3.6050229
3.496507	1.910480	1.740371	1.546532	3.5492523

3.367295	2.016116	1.760276	1.593545	3.4216949
3.218875	2.071100	1.765569	1.615572	3.3210471
3.135494	2.093795	1.765206	1.623267	3.2645383
2.833213	2.139755	1.747688	1.629084	3.0601131
2.639057	2.147007	1.725742	1.618575	2.9294160

REGRESSION EQUATIONS:

EXTERIOR WALL AND CORRIDOR

Regression equations to calculate the leakage characteristics of the exterior wall, ceiling, floor, left and right partitions plus the corridor wall.

Regression Output:

Constant		1.435367	
Std Err of Y Est		0.001737	
R Squared		0.999977	0.999988
No. of Observations		12	
Degrees of Freedom		10	
X Coefficient(s)	0.770299		
Std Err of Coef.	0.001166		

REGRESSION EQUATION DESCRIBING EXTERIOR WALL & CORRIDOR LEAKAGE:

C = 4.201186

n = 0.770299

CEILING

Regression Output:

Constant		4.091846	
Std Err of Y Est		0.140377	
R Squared		0.830923	0.911550
No. of Observations		12	
Degrees of Freedom		10	
X Coefficient(s)	-0.66122		
Std Err of Coef.	0.094321		

REGRESSION EQUATION DESCRIBING CEILING LEAKAGE:

C = 59.85030

n = -0.66122

RIGHT PARTITION

Regression Output:

Constant		2.075727	
Std Err of Y Est		0.042053	
R Squared		0.592805	0.769938
No. of Observations		12	
Degrees of Freedom		10	
X Coefficient(s)	-0.10781		
Std Err of Coef.	0.028256		

REGRESSION EQUATION DESCRIBING RIGHT PARTITION LEAKAGE:

C = 7.970341

n = -0.10781

FLOOR

Regression Output:

Constant		2.422205
Std Err of Y Est		0.063950

R Squared		0.795018	0.891637
No. of Observations		12	
Degrees of Freedom		10	
X Coefficient(s)	-0.26760		
Std Err of Coef.	0.042969		

REGRESSION EQUATION DESCRIBING FLOOR LEAKAGE:

C = 11.27069

n = -0.26760

LEFT PARTITION

Regression Output:

Constant		1.069962	
Std Err of Y Est		0.013653	
R Squared		0.998295	0.999147
No. of Observations		12	
Degrees of Freedom		10	
X Coefficient(s)	0.702004		
Std Err of Coef.	0.009173		

REGRESSION EQUATION DESCRIBING LEFT PARTITION LEAKAGE:

C = 2.915269

n = 0.702004

RESULTS: AIR LEAKAGE RATES @ 50 Pa

CONDITION A: 6-SIDED LEAKAGE IGNORING DOOR

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
LEFT PARTITION	45.43	31.4 %
RIGHT PARTITION	5.23	3.6 %
FLOOR	3.96	2.7 %
CEILING	4.50	3.1 %
EXT. WALL & CORR.	85.52	59.1 %
TOTAL	144.64	100.00 %

EXTERIOR WALL AND CORRIDOR LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 7.03 l/s m2

CONDITION B: 6-SIDED LEAKAGE IGNORING WINDOW

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
DOOR	98.52	40.5 %
LEFT PARTITION	45.43	18.7 %
RIGHT PARTITION	5.23	2.1 %
FLOOR	3.96	1.6 %

CEILING	4.50	1.9	%
EXT. WALL & CORR.	85.52	35.2	%
TOTAL	243.16	100.00	%

EXTERIOR WALL AND CORRIDOR LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 7.03 l/s m2

WORKSHEET FOR CALCULATING THE REGRESSION EQN. OF A PARTITION USING THE DIFFERENCE BETWEEN TWO AIRTIGHTNESS TESTS.

BUILDING: A

TEST SUITE: 909

LEAKAGE CALCULATED: EXTERIOR WALL AND CORRIDOR

EXTERIOR WALL AREA: 12.17 m2

ANALYSIS:

Q6 – NO PRESSURE MASKING
C = 15.9189
n = 0.6218

Airtightness test results for the Test Suite without simultaneous depressurization of adjacent suites.

*Suite orientations as viewed from corridor looking into suite.

TOP SUITE PRESSURE MASKED
C = 15.6775
n = 0.5961

Airtightness test results for the Test Suite with simultaneous depressurization.

LEFT SUITE PRESSURE MASKED
C = 13.6276
n = 0.5953

RIGHT SUITE PRESSURE MASKED
C = 17.1164
n = 0.5881

BOTTOM SUITE PRESSURE MASKED
C = 16.8721
n = 0.5947

Pex	P b/d	Q6	Qc	Qr	Qf	Ql	Qrem.	ln(P ex)	ln(Qrem)
52	55	185.75	20.48	10.93	8.87	42.54	102.93	3.951243	4.634028
48	51	176.73	19.16	9.95	8.07	40.19	99.36	3.871201	4.598732
43	46	165.05	17.48	8.71	7.07	37.16	94.63	3.761200	4.549943
38	42	152.83	15.75	7.46	6.06	34.02	89.54	3.637586	4.494739
35	37	145.22	14.69	6.71	5.44	32.08	86.30	3.555348	4.457799
29	31	129.19	12.51	5.18	4.21	28.04	79.26	3.367295	4.372712
27	29	123.58	11.76	4.67	3.79	26.63	76.72	3.295836	4.340162
24	27	114.85	10.61	3.90	3.17	24.47	72.69	3.178053	4.286261
22	26	108.80	9.83	3.39	2.75	22.99	69.84	3.091042	4.246246
19	23	99.32	8.63	2.62	2.13	20.68	65.27	2.944438	4.178464
15	19	85.74	6.98	1.59	1.30	17.42	58.45	2.708050	4.068254

ln(P b/d)	ln(Qc)	ln(Qr)	ln(Qf)	ln(Ql)
4.007333	3.019488	2.391213	2.182549	3.7505287
3.931825	2.952961	2.297266	2.088504	3.6935851
3.828641	2.861009	2.164572	1.955704	3.6152188
3.737669	2.756915	2.009834	1.800889	3.5269992
3.610917	2.687194	1.903116	1.694151	3.4682153
3.433987	2.526265	1.645432	1.436548	3.3335083
3.367295	2.464533	1.541584	1.332790	3.2822129
3.295836	2.362041	1.361628	1.153080	3.1975321

3.258096	2.285704	1.220348	1.012081	3.1348665
3.135494	2.155810	0.961858	0.754347	3.0290693
2.944438	1.942686	0.464462	0.259531	2.8578931

REGRESSION EQUATIONS:

EXTERIOR WALL AND CORRIDOR

Regression Output:

Constant		2.840540		
Std Err of Y Est		0.001751		
R Squared		0.999915	r =	0.9999577
No. of Observations		11		
Degrees of Freedom		9		
X Coefficient(s)	0.454518			
Std Err of Coef.	0.001393			

REGRESSION EQUATION DESCRIBING EXTERIOR WALL & CORRIDOR LEAKAGE:

C = 17.12501

n = 0.454518

CEILING

Regression Output:

Constant		-0.93177		
Std Err of Y Est		0.036212		
R Squared		0.989983	r =	0.9949793
No. of Observations		11		
Degrees of Freedom		9		
X Coefficient(s)	0.992546			
Std Err of Coef.	0.033278			

REGRESSION EQUATION DESCRIBING CEILING LEAKAGE:

C = 0.393852

n = 0.992546

RIGHT PARTITION

Regression Output:

Constant		-4.36402		
Std Err of Y Est		0.113108		
R Squared		0.967855	r =	0.9837964
No. of Observations		11		
Degrees of Freedom		9		
X Coefficient(s)	1.711102			
Std Err of Coef.	0.103944			

REGRESSION EQUATION DESCRIBING RIGHT PARTITION LEAKAGE:

C = 0.012727

n = 1.711102

FLOOR

Regression Output:

Constant		-4.56399		
Std Err of Y Est		0.112252		
R Squared		0.968239	r =	0.9839916
No. of Observations		11		

Degrees of Freedom		9		
X Coefficient(s)	1.708728			
Std Err of Coef.	0.103158			

REGRESSION EQUATION DESCRIBING FLOOR LEAKAGE:

C = 0.010420

n = 1.708728

LEFT PARTITION

Regression Output:

Constant		0.460819		
Std Err of Y Est		0.027533		
R Squared		0.991613	r =	0.9957979
No. of Observations		11		
Degrees of Freedom		9		
X Coefficient(s)	0.825404			
Std Err of Coef.	0.025302			

REGRESSION EQUATION DESCRIBING LEFT PARTITION LEAKAGE:

C = 1.585372

n = 0.825404

RESULTS: AIR LEAKAGE RATES @ 50 Pa

CONDITION A: 6-SIDED LEAKAGE IGNORING DOOR

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
LEFT PARTITION	40.04	22.4 %
RIGHT PARTITION	10.28	5.7 %
FLOOR	8.34	4.7 %
CEILING	19.13	10.7 %
EXT. WALL & CORR.	101.35	56.6 %
TOTAL	179.13	100.00 %

EXTERIOR WALL AND CORRIDOR LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 8.33 l/s m2

CONDITION B: 6-SIDED LEAKAGE IGNORING WINDOW

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
DOOR	138.59	43.6 %
LEFT PARTITION	40.04	12.6 %
RIGHT PARTITION	10.28	3.2 %
FLOOR	8.34	2.6 %

CEILING	19.13	6.0	%
EXT. WALL & CORR.	101.35	31.9	%
TOTAL	317.72	100.00	%

EXTERIOR WALL AND CORRIDOR LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 8.33 l/s m2

WORKSHEET FOR CALCULATING THE REGRESSION EQN. OF A PARTITION USING THE DIFFERENCE BETWEEN TWO AIRTIGHTNESS TESTS.

BUILDING: B

TEST SUITE: 509

LEAKAGE CALCULATED: EXTERIOR WALL

EXTERIOR WALL AREA: 28.23 m2

ANALYSIS:

*Suite orientations as viewed from corridor looking into suite.

Q6 – NO PRESSURE MASKING
C = 22.0018
n = 0.5612

Airtightness test results for the Test Suite without simultaneous depressurization of adjacent suites.

TOP SUITE PRESSURE MASKED
C = 17.0784
n = 0.5714

Airtightness test results for the Test Suite with simultaneous depressurization.

LEFT & RIGHT SUITES & CORRIDOR PRESSURE MASKED
C = 17.9065
n = 0.5524

BOTTOM SUITE PRESSURE MASKED
C = 19.9903
n = 0.5458

Pex	P b/d	Q6	Qc	Qf	Ql,r,cor	Qrem	ln(P ex)	ln(Qrem)
54	56	206.38	39.53	30.04	44.21	92.60	3.988984	4.528329
51	53	199.87	38.38	28.94	42.73	89.82	3.931825	4.497758
47	49	190.91	36.79	27.44	40.71	85.98	3.850147	4.454074
45	47	186.31	35.97	26.67	39.67	84.00	3.806662	4.430817
41	43	176.83	34.27	25.10	37.54	79.92	3.713572	4.381030
40	39	174.40	33.83	24.69	36.99	78.87	3.688879	4.367824
36	35	164.38	32.03	23.05	34.75	74.55	3.583518	4.311476
33	33	156.55	30.62	21.77	33.00	71.16	3.496507	4.264941
31	31	151.15	29.64	20.89	31.80	68.82	3.433987	4.231505
28	29	142.76	28.11	19.54	29.93	65.17	3.332204	4.177072
27	28	139.87	27.59	19.08	29.29	63.92	3.295836	4.157623
26	27	136.94	27.05	18.61	28.64	62.64	3.258096	4.137440
23	24	127.84	25.38	17.16	26.63	58.67	3.135494	4.071874

ln(P b/d)	ln(Qc)	ln(Qf)	ln(Ql,r,c)
4.025351	3.677075	3.402566	3.7889358
3.970291	3.647455	3.365306	3.7550111
3.891820	3.605115	3.312007	3.7065261
3.850147	3.582568	3.283604	3.6807091
3.761200	3.534285	3.222738	3.6254332
3.663561	3.521474	3.206578	3.6107691

3.555348	3.466798	3.137557	3.5481896
3.496507	3.421626	3.080470	3.4964973
3.433987	3.389158	3.039401	3.4593483
3.367295	3.336282	2.972453	3.3988585
3.332204	3.317384	2.948504	3.3772416
3.295836	3.297769	2.923636	3.3548069
3.178053	3.234029	2.842741	3.2819120

REGRESSION EQUATIONS:

EXTERIOR WALL

Regression Output:

Constant		2.394977		
Std Err of Y Est		0.000002		
R Squared		0.999999	r =	0.9999999
No. of Observations		13		
Degrees of Freedom		11		
X Coefficient(s)	0.534809			
Std Err of Coef.	0.000002			

REGRESSION EQUATION DESCRIBING EXTERIOR WALL LEAKAGE:

C = 10.96795

n = 0.534809

CEILING

Regression Output:

Constant		1.618944		
Std Err of Y Est		0.014528		
R Squared		0.990599	r =	0.9952887
No. of Observations		13		
Degrees of Freedom		11		
X Coefficient(s)	0.512257			
Std Err of Coef.	0.015045			

REGRESSION EQUATION DESCRIBING CEILING LEAKAGE:

C = 5.047760

n = 0.512257

FLOOR

Regression Output:

Constant		0.802918		
Std Err of Y Est		0.018511		
R Squared		0.990438	r =	0.9952079
No. of Observations		13		
Degrees of Freedom		11		
X Coefficient(s)	0.647129			
Std Err of Coef.	0.019170			

REGRESSION EQUATION DESCRIBING FLOOR LEAKAGE:

C = 2.232046

n = 0.647129

WORKSHEET FOR CALCULATING THE REGRESSION EQN. OF A PARTITION USING THE DIFFERENCE BETWEEN TWO AIRTIGHTNESS TESTS.

BUILDING: B

TEST SUITE: 609

LEAKAGE CALCULATED: EXTERIOR WALL

EXTERIOR WALL AREA: 28.23 m2

ANALYSIS:

Q6 – NO PRESSURE MASKING
C = 20.0891
n = 0.5753

Airtightness test results for the Test Suite without simultaneous depressurization of adjacent suites.

*Suite orientations as viewed from corridor looking into suite.

TOP SUITE PRESSURE MASKED
C = 16.6172
n = 0.6006

Airtightness test results for the Test Suite with simultaneous depressuriztion.

LEFT & RIGHT SUITES & CORRIDOR PRESSURE MASKED
C = 13.2000
n = 0.5919

BOTTOM SUITE PRESSURE MASKED
C = 16.7835
n = 0.5787

Pex	P b/d	Q6	Qc	Qf	Ql,r,cor	Qrem	ln(P ex)	ln(Qrem)
62	60.5	215.84	17.65	32.97	63.96	101.26	4.127134	4.617667
58	55.5	207.71	17.31	31.77	61.71	96.92	4.060443	4.573917
52	50.5	195.06	16.75	29.89	58.20	90.22	3.951243	4.502234
49	46.5	188.51	16.44	28.92	56.38	86.76	3.891820	4.463201
46	44.5	181.78	16.12	27.92	54.50	83.24	3.828641	4.421682
40	41.5	167.74	15.42	25.83	50.56	75.93	3.688879	4.329764
40	42.5	167.74	15.42	25.83	50.56	75.93	3.688879	4.329764
37	39.5	160.38	15.03	24.73	48.49	72.13	3.610917	4.278448
36	37.5	157.87	14.89	24.36	47.78	70.84	3.583518	4.260406
34	36.5	152.76	14.61	23.60	46.34	68.22	3.526360	4.222754
32	32.5	147.53	14.31	22.81	44.85	65.55	3.465735	4.182801
31	30.5	144.86	14.16	22.41	44.09	64.19	3.433987	4.161870
30	30.5	142.15	14.00	22.01	43.32	62.82	3.401197	4.140247
28	29.5	136.62	13.67	21.18	41.74	60.02	3.332204	4.094731
26	26.5	130.92	13.32	20.32	40.11	57.16	3.258096	4.045812
24	23.5	125.02	12.95	19.44	38.42	54.21	3.178053	3.992943
20	20.5	112.58	12.12	17.56	34.83	48.06	2.995732	3.872383

ln(P b/d)	ln(Qc)	ln(Qf)	ln(Ql,r,c)
4.102643	2.870843	3.495506	4.1582465
4.016383	2.851226	3.458395	4.1225029

LEFT, RIGHT, PARTITION CORRIDORS

Regression Output:

Constant		1.433481		
Std Err of Y Est		0.016603		
R Squared		0.990626	r =	0.9953020
No. of Observations		13		
Degrees of Freedom		11		
X Coefficient(s)	0.586245			
Std Err of Coef.	0.017194			

REGRESSION EQUATION DESCRIBING LEFT, RIGHT, CORR. LEAKAGE:

C = 4.193273

n = 0.586245

RESULTS: AIR LEAKAGE RATES @ 50 Pa

CONDITION A: 6-SIDED LEAKAGE IGNORING DOOR

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
L & R PART. & CORR.	41.55	21.2 %
FLOOR	28.06	14.3 %
CEILING	37.45	19.1 %
EXTERIOR WALL	88.87	45.4 %
TOTAL	195.93 l/s	100.00 %

EXTERIOR WALL LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 3.15 l/s m2

3.921973	2.818301	3.397627	4.0639559
3.839452	2.799983	3.364556	4.0320852
3.795489	2.780210	3.329394	3.9981920
3.725693	2.735430	3.251603	3.9231844
3.749504	2.735430	3.251603	3.9231844
3.676300	2.709861	3.208207	3.8813259
3.624340	2.700779	3.192955	3.8666120
3.597312	2.681675	3.161136	3.8359116
3.481240	2.661187	3.127386	3.8033419
3.417726	2.650367	3.109711	3.7862824
3.417726	2.639128	3.091456	3.7686612
3.384390	2.615273	3.053044	3.7315774
3.277144	2.589344	3.011782	3.6917333
3.157000	2.560997	2.967213	3.6486859
3.020424	2.495168	2.865684	3.5505841

REGRESSION EQUATIONS:

EXTERIOR WALL

Regression Output:

Constant		1.900209		
Std Err of Y Est		0.000289		
R Squared		0.999998	r =	0.9999990
No. of Observations		17		
Degrees of Freedom		15		
X Coefficient(s)	0.658557			
Std Err of Coef.	0.000229			

REGRESSION EQUATION DESCRIBING EXTERIOR WALL LEAKAGE:

C = 6.687293

n = 0.658557

CEILING

Regression Output:

Constant		1.453365		
Std Err of Y Est		0.011658		
R Squared		0.988269	r =	0.9941173
No. of Observations		17		
Degrees of Freedom		15		
X Coefficient(s)	0.346182			
Std Err of Coef.	0.009738			

REGRESSION EQUATION DESCRIBING CEILING LEAKAGE:

C = 4.277488

n = 0.346182

FLOOR

Regression Output:

Constant		1.102738		
Std Err of Y Est		0.021957		
R Squared		0.985296	r =	0.9926212
No. of Observations		17		

Degrees of Freedom		15		
X Coefficient(s)	0.581502			
Std Err of Coef.	0.018341			

REGRESSION EQUATION DESCRIBING FLOOR LEAKAGE:

C = 3.012403

n = 0.581502

LEFT, RIGHT, PARTITION CORRIDORS

Regression Output:

Constant		1.849968		
Std Err of Y Est		0.021136		
R Squared		0.985362	r =	0.9926542
No. of Observations		17		
Degrees of Freedom		15		
X Coefficient(s)	0.561012			
Std Err of Coef.	0.017654			

REGRESSION EQUATION DESCRIBING LEFT, RIGHT, CORR. LEAKAGE:

C = 6.359616

n = 0.561012

RESULTS: AIR LEAKAGE @50 Pa

CONDITION A: 6-SIDED LEAKAGE IGNORING DOOR

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
L & R PART. & CORR.	57.09	29.9 %
FLOOR	29.30	15.3 %
CEILING	16.57	8.7 %
EXTERIOR WALL	87.93	46.1 %
TOTAL	190.89 l/s	100.00 %

EXTERIOR WALL LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 3.11 l/s m2

WORKSHEET FOR CALCULATING THE REGRESSION EQN. OF A PARTITION USING THE DIFFERENCE BETWEEN TWO AIRTIGHTNESS TESTS.

BUILDING: B

TEST SUITE: 1009

LEAKAGE CALCULATED: EXTERIOR WALL

EXTERIOR WALL AREA: 28.23 m2

ANALYSIS:

WINDOW SEALED
C = 12.9992
n = 0.621

Q6 – NO PRESSURE MASKING
C = 14.3858
n = 0.6132

Airtightness test results for the Test Suite without simultaneous depressurization of adjacent suites.

*Suite orientations as viewed from corridor looking into suite.

TOP SUITE PRESSURE MASKED
C = 13.5768
n = 0.5896

Airtightness test results for the Test Suite with simultaneous depressurization.

LEFT & RIGHT SUITES & CORRIDOR PRESSURE MASKED
C = 13.6809
n = 0.5363

BOTTOM SUITE PRESSURE MASKED
C = 9.3647
n = 0.6669

Pex	P b/d	Q6	Qc	Qf	Ql,r,cor	Qrem	ln(P ex)	ln(Qrem)
60	61	177.13	25.36	33.47	54.18	64.12	4.094344	4.160828
55	55	167.93	23.75	32.37	50.58	61.24	4.007333	4.114740
53	53	164.16	23.09	31.90	49.12	60.05	3.970291	4.095148
52	52	162.25	22.76	31.66	48.38	59.45	3.951243	4.085080
46	48	150.50	20.73	30.17	43.88	55.72	3.828641	4.020374
45	47	148.49	20.39	29.90	43.11	55.08	3.806662	4.008792
44	46	146.45	20.04	29.63	42.34	54.43	3.784189	3.996956
40	40	138.14	18.64	28.51	39.22	51.77	3.688879	3.946821
38	38	133.86	17.92	27.92	37.62	50.39	3.637586	3.919881
37	38	131.69	17.56	27.62	36.82	49.69	3.610917	3.905886
35	36	127.28	16.83	26.99	35.19	48.27	3.555348	3.876748
32	34	120.47	15.70	26.01	32.71	46.05	3.465735	3.829829
28	30	111.00	14.17	24.58	29.30	42.95	3.332204	3.760068
27	27	108.55	13.77	24.21	28.43	42.14	3.295836	3.741099
25	24	103.55	12.97	23.42	26.67	40.49	3.218875	3.701001

ln(P b/d)	ln(Qc)	ln(Qf)	ln(Ql,r,c)
4.110873	3.233110	3.510631	3.9922985
4.007333	3.167376	3.477087	3.9235903
3.970291	3.139338	3.462662	3.8942368
3.951243	3.124906	3.455211	3.8791174

3.871201	3.031806	3.406734	3.7813907
3.850147	3.015076	3.397951	3.7637940
3.828641	2.997958	3.388942	3.7457771
3.688879	2.925211	3.350422	3.6690795
3.637586	2.885961	3.329488	3.6276067
3.637586	2.865527	3.318550	3.6059886
3.583518	2.822884	3.295639	3.5608168
3.526360	2.753939	3.258365	3.4876064
3.401197	2.650776	3.202106	3.3776380
3.295836	2.622588	3.186640	3.3474979
3.178053	2.562804	3.153716	3.2834361

REGRESSION EQUATIONS:

EXTERIOR WALL

Regression Output:

Constant		2.009908		
Std Err of Y Est		0.000382		
R Squared		0.999993	r =	0.9999966
No. of Observations		15		
Degrees of Freedom		13		
X Coefficient(s)	0.525169			
Std Err of Coef.	0.000376			

REGRESSION EQUATION DESCRIBING EXTERIOR WALL LEAKAGE:

C = 7.462633

n = 0.525169

CEILING

Regression Output:

Constant		0.113756		
Std Err of Y Est		0.022677		
R Squared		0.988979	r =	0.9944743
No. of Observations		15		
Degrees of Freedom		13		
X Coefficient(s)	0.757901			
Std Err of Coef.	0.022189			

REGRESSION EQUATION DESCRIBING CEILING LEAKAGE:

C = 1.120478

n = 0.757901

FLOOR

Regression Output:

Constant		1.849727		
Std Err of Y Est		0.011633		
R Squared		0.989794	r =	0.9948844
No. of Observations		15		
Degrees of Freedom		13		
X Coefficient(s)	0.404190			
Std Err of Coef.	0.011382			

REGRESSION EQUATION DESCRIBING FLOOR LEAKAGE:

C = 6.358083

n = 0.404190

LEFT, RIGHT, PARTITION CORRIDORS

Regression Output:

Constant		0.694758		
Std Err of Y Est		0.023620		
R Squared		0.989307	r =	0.9946394
No. of Observations		15		
Degrees of Freedom		13		
X Coefficient(s)	0.801575			
Std Err of Coef.	0.023112			

REGRESSION EQUATION DESCRIBING LEFT, RIGHT, CORR. LEAKAGE:

C = 2.003224

n = 0.801575

WINDOW

Regression Output:

Constant		0.387627		
Std Err of Y Est		0.000402		
R Squared		0.999992	r =	0.9999960
No. of Observations		15		
Degrees of Freedom		13		
X Coefficient(s)	0.509941			
Std Err of Coef.	0.000395			

REGRESSION EQUATION DESCRIBING WINDOW LEAKAGE:

C = 1.473480

n = 0.509941

RESULTS: AIR LEAKAGE @ 50Pa

CONDITION A: 6-SIDED LEAKAGE IGNORING DOOR

	LEAKAGE l/s	PERCENTAGE DISTRIBUTION
L & R PART. & CORR.	46.09	29.4 %
FLOOR	30.91	19.7 %
CEILING	21.73	13.8 %
EXTERIOR WALL	58.23	37.1 %
TOTAL	156.95 l/s	100.00 %

EXTERIOR WALL LEAKAGE PER SQUARE METRE OF EXTERIOR WALL: 2.06 l/s m2

WINDOW LEAKAGE (EXCLUDING ROUGH-OPENING)

	LEAKAGE l/s
WINDOW	10.83 l/s

APPENDIX C

THE NATIONAL TESTING LABORATORIES LIMITED
Established in 1923
199 Henlow Bay
Winnipeg, Manitoba R3Y 1G4
Phone (204) 488-6999
Fax (204) 488-6947

INDOOR AIR QUALITY SURVEY

This survey is being used to determine the quality of the indoor environment of your apartment. Your assistance in completing the following questions as accurately as possible is very much appreciated. All information will be treated as confidential and anonymous and will be used for analyses only. Questions are answered using a √ mark.

NOTE: This survey is part of a larger national survey to obtain data on indoor air quality in apartment buildings. Your apartment building was randomly selected and there is no reason to believe that the indoor air quality is better of worse than the average of other apartment buildings.

APARTMENT ADDRESS: ______________________ DATE: ______________________

WILL THIS FORM BE COMPLETED BY: ________ 1 PERSON OR ________ GROUP OF OCCUPANTS

GENERAL INFORMATION

1. Age, Years
   - _____ 18 - 30
   - _____ 31 - 60
   - _____ Over 60

2. Sex
   - _____ Male
   - _____ Female

3. Number of Occupants
   - _____ 1
   - _____ 2
   - _____ 3
   - _____ More than 3

4. Are there smokers in the apartment?

Cigarettes _____ yes _____ no

Cigars _____ yes _____ no

Pipe _____ yes _____ no

5. On the average, how many hours a day are you in the apartment?

_____ 1 to 5

_____ 5 to 10

_____ over 10

APARTMENT INFORMATION

6. COMMENTS: ____

____

____

7. Are there operable windows in your apartment?

_____ yes

_____ no

COMMENTS: ____

____

____

8. Are you able to control the following (choose all that apply in your apartment)?

_____ temperature _____ lighting

_____ ventilation _____ humidity

9. In your apartment, how often do each of the following conditions occur?

	NEVER	RARELY	SOMETIMES	ALWAYS
(a) Too little air movement	_____	_____	_____	_____
(b) Too much air movement	_____	_____	_____	_____
(c) Just the right air movement	_____	_____	_____	_____
(d) Air too dry	_____	_____	_____	_____
(e) Air too moist	_____	_____	_____	_____
(f) Humidity just right	_____	_____	_____	_____
(g) Air too smokey	_____	_____	_____	_____
(h) Air too stuffy	_____	_____	_____	_____
(i) Unpleasant odours in the air	_____	_____	_____	_____
(j) Temperature too hot	_____	_____	_____	_____
(k) Temperature too cold	_____	_____	_____	_____
(l) Temperature just right	_____	_____	_____	_____
(m) Lighting too bright	_____	_____	_____	_____
(n) Lighting too dim	_____	_____	_____	_____
(o) Lighting just right	_____	_____	_____	_____
(p) Too noisy	_____	_____	_____	_____
(q) Too quiet	_____	_____	_____	_____
(r) Noise level just right	_____	_____	_____	_____

10. Do you have and use any of the following in your apartment:

_____ Portable heater

_____ Table top fan

_____ Portable air cleaner

_____ Portable humidifier

_____ Negative ion generator

_____ Radio/Piped music

11. How is your apartment lit? (choose all that apply)

_____ Fluorescent ceiling light

_____ Incandescent ceiling light

_____ Table lamps

_____ Natural window light

12. Which of the following cooking appliances are used in your apartment? (choose all that apply)

_____ Gas stove

_____ Electric stove

_____ Microwave oven

_____ Other

13. What types of heating systems are used in your apartment? (choose all that apply)

_____ Forced air

_____ Radiators

_____ Fireplace

_____ Portable heater

_____ Stove

14. Is your apartment air conditioned?

_____ Yes

_____ No

15. If yes, what type of air conditioning system?

_____ Central

_____ Window-Type

16. If there is a smell in your apartment, how would you describe the smell?

(a) The smell resembles:

glue	_____	propane	_____
vinegar	_____	gasoline	_____
alcohol	_____	perfume	_____
ammonia	_____	other (specify)	_______________________

(b) It smells:

smoky	_____	stale	_____
dusty	_____	other (specify)	_______________________
musty	_____		

SYMPTOMS

17. Have any of the following symptoms been experienced while in the apartment?

	NEVER	RARELY	SOMETIMES	ALWAYS
Headache	_____	_____	_____	_____
Fever	_____	_____	_____	_____
Dizziness	_____	_____	_____	_____
Fatigue	_____	_____	_____	_____
Sleepiness	_____	_____	_____	_____
Weakness	_____	_____	_____	_____
Nausea	_____	_____	_____	_____
Respiratory problems	_____	_____	_____	_____
Muscular aches	_____	_____	_____	_____
Chest pain or tightness	_____	_____	_____	_____
Backache	_____	_____	_____	_____
Neckache	_____	_____	_____	_____
Eye irritation	_____	_____	_____	_____
Trouble focusing eyes	_____	_____	_____	_____
Sore or irritated throat	_____	_____	_____	_____

	NEVER	RARELY	SOMETIMES	ALWAYS
17. Nose irritation (itching or running)	_____	_____	_____	_____
Cold/Flu symptoms	_____	_____	_____	_____
Depression	_____	_____	_____	_____
Difficulty concentrating	_____	_____	_____	_____
Tension or nervousness	_____	_____	_____	_____
Skin dryness, rash or itching	_____	_____	_____	_____
Cold extremities (feet, hands, etc.)	_____	_____	_____	_____
Hearing disturbances	_____	_____	_____	_____
Insomnia	_____	_____	_____	_____
Nose bleeds	_____	_____	_____	_____

18. Does anyone in the apartment suffer from any of the following?

Migraine	_____ yes	_____ no
Asthma	_____ yes	_____ no
Eczema	_____ yes	_____ no
Hayfever or other allergies	_____ yes	_____ no

19. Is there any relief from these symptoms when away from the apartment?

_____ yes

_____ no

Thank you for your assistance in this survey. It is very important that all survey forms are returned. We would ask that the forms be returned to the building manager upon completion.