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FIELD INVESTIGATION SURVEY OF

AIR TIGHTNESS, AIR MOVEMENT

AND INDOOR AIR QUALITY IN

HIGH-RISE APARTMENT BUILDINGS

ATLANTIC REGION

STRACT

ietailed air tightness, air movement, and
on two residential high-rise apartment
The general findings of the tests are
·eport while the details of the testing
in a series of appendices.

›oration

Date: 1991 04 30

Canada Mortgage and Housing Corporation, the Federal Government's housing agency is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part IX of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statuary responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

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

DISCLAIMER

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SUMMARY

This report presents the findings of a field investigation and assessment into air tightness, air movement and indoor air quality conducted on two (2) residential high-rise apartment buildings located in St. John's, Newfoundland.

The investigations were performed in three phases. The first phase involved a building assessment in which the likely candidates for the study were screened to meet selected criteria. The second phase involved a pollution source identification process in which a building survey was conducted with the occupants to identify possible pollutants within the building. The third phase involved physical testing of the selected buildings during the months of February and March 1991 to establish air tightness, air movement and air quality.

Two buildings were selected during Phase 1, Building 1 a seven (7) storey building with 51 apartments, Building 2 a six (6) storey building with 65 apartments. Phase II survey of the occupants in Building 1 revealed only minor problems on the first level while most complaints related to the air infiltration problems in the structure. In Building 2, similar results related to air quality and air tightness were recorded.

Phase III testing was conducted in both buildings. The air tightness of exterior walls and between storey slabs was assessed using a storey by storey fan depressurization technique. Certain portions of the building were depressurized while flow rates at designated external pressure differentials were measured on the test storey. Contaminant airflow patterns within the buildings were studied using a tracer gas technique. A specified volume of tracer gas was instantaneously released at a specified location within the building. Following this release, air samples were taken at specified locations through the building at pre-determined time intervals. Air quality was assessed by monitoring the levels of various pollutants, which had previously been identified during a building assessment, at various locations through the building.

From the Phase III testing, it was concluded that in both Building 1 and Building 2 air infiltration rates exist which are higher than NRC and international standards for air infiltration. Building 1 is substantially leakier than Building 2. Outside weather conditions dominate air movement in the buildings by promoting travel up through the building through garbage chutes, stairwells and elevator shafts by stack effect in Building 1. Occupant movement promotes air movement in Building 2 as opposed to weather conditions due to the lower infiltration in this building.

During testing for indoor air quality, it was observed in Building 1, CO_2, Radon and relative humidities to be lower than Building 2 due to the relative tightness of Building 1 being less than Building 2. However, all contaminant levels, except Total Suspended Particulates (TSP) in smoker's apartment, were within

government recommended guidelines. No testing of the effectiveness of ventilation systems was performed during this project.

Air change rates were observed to be 6.5 times greater than the normal value of 1.5 air changes per hour used for design purposes (wind speed = 48 km/h and 75 Pa pressure difference for St. John's).

Possible causes include inadequately sealing backdraft dampers, or other mechanical system components. The testing procedures did not include the complete sealing of all air diffusion equipment which can contribute significantly to high air infiltration rates. In Building 1 extreme care was exercised to meticulously seal all openings for these systems and still higher air infiltration was observed.

RÉSUMÉ

Ce rapport expose les résultats d'une enquête sur le terrain et d'une évaluation de l'étanchéité à l'air, du mouvement de l'air ainsi que de la qualité de l'air intérieur menées dans deux tours d'habitation situées à Saint John's (Terre-Neuve).

Les enquêtes se sont déroulées en trois phases. La première visait à examiner des bâtiments en vue de sélectionner ceux qui répondaient le mieux aux critères établis. La deuxième a servi à déterminer les sources possibles de polluants au moyen d'un sondage auquel ont répondu les occupants. A la troisième phase, les évaluateurs ont étudié les bâtiments choisis durant les mois de février et de mars 1991 afin de déterminer l'étanchéité à l'air, le mouvement de l'air ainsi que sa qualité.

Deux bâtiments ont été sélectionnés lors de la phase 1, à savoir le bâtiment 1, une tour de sept étages abritant 51 appartements, et le bâtiment 2, un immeuble de six étages comptant 65 appartements. Le sondage destiné aux occupants, constituant la phase 2 de l'enquête, n'a mis en évidence que de légers problèmes touchant le rez-de-chaussée. La plupart des plaintes avaient trait aux problèmes d'infiltration d'air à travers l'ossature. Dans le cas du bâtiment 2, des résultats similaires ont été obtenus au sujet de la qualité de l'air et de l'étanchéité à l'air.

Les essais de la phase III ont été menés dans les deux immeubles. En dépressurisant chaque étage, on a pu évaluer l'étanchéité à l'air des murs extérieurs et des dalles séparant les étages. Certaines parties des immeubles ont été dépressurisées tandis qu'on mesurait le débit, à l'étage soumis à l'essai, selon des différences de pression externes déterminées. La direction des mouvements d'air contaminant à l'intérieur des bâtiments a été observée au moyen d'un gaz traceur. Un volume précis de ce gaz a été libéré d'un seul coup à un endroit précis dans l'immeuble. Par la suite, des échantillons d'air ont été recueillis à intervalles de temps déterminés au préalable dans des zones bien définies du bâtiment. On a évalué la qualité de l'air en contrôlant les niveaux de divers polluants, lesquels avaient déjà été cernés à l'occasion d'une évaluation préliminaire, à divers endroits de l'immeuble.

Les évaluations de la phase III permettent de conclure que, dans les deux bâtiments, les taux d'infiltration d'air sont supérieurs aux normes internationales et à celles du CNR à ce sujet. Le bâtiment 1 est beaucoup moins étanche que le bâtiment 2. Les conditions climatiques influent grandement sur les mouvements d'air à l'intérieur des immeubles. Dans le bâtiment 1, elles contribuent, par effet de tirage, à l'ascension de l'air par le vide-ordures, les cages d'escalier et les gaines d'ascenseur. Dans le bâtiment 2, les mouvements d'air sont davantage favorisés par les déplacements des occupants que par les conditions climatiques, car le taux d'infiltration d'air y est inférieur.

A l'évaluation de la qualité de l'air intérieur du bâtiment 1, on a relevé des taux de CO_2, de radon et d'humidité relative inférieurs à ceux du bâtiment 2 compte tenu de l'étanchéité relativement supérieure de ce dernier. Cependant, tous les niveaux de contaminant, sauf le total des particules en suspension dans les appartements de fumeurs, respectaient les directives gouvernementales à ce sujet. Aucun contrôle de l'efficacité des installations de ventilation n'a été effectué au cours de cette étude.

Les taux de renouvellement d'air se sont avérés 6,5 fois supérieurs à la valeur normale de 1,5 renouvellement d'air par heure servant à la conception des habitations (à Saint John's, la vitesse du vent est de 48 km/h et la différence de pression est de 75 Pa).

On soupçonne que cette différence est due à la présence de registres anti-refoulement, ou autres composants mécaniques, mal scellés. Les méthodes d'évaluation ne comprenaient pas le scellement de tout l'équipement de distribution d'air, ce qui a pu contribuer considérablement aux taux élevés d'infiltration d'air. Dans le bâtiment 1, on a mis une attention particulière à sceller toutes les ouvertures des installations et le taux d'infiltration d'air a quand même été supérieur.

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1.0 INTRODUCTION

Based on the findings of previous CMHC investigations in low-rise housing and in high rise office buildings, there is reason to suspect that high-rise apartment buildings may have ventilation, air quality, and moisture problems due to air leakage.

High-rise apartments rely heavily on air leakage for fresh air, and as a result are much leakier and less energy efficient than detached housing. Most apartment buildings only provide ventilation air to corridors and common areas. Comfort related complaints regarding temperature fluctuations and smells are common, and suggest potential problems with air quality and uncontrolled air movement within the buildings.

In a recently completed nation wide survey of eight high-rise residential buildings constructed with brick veneer and steel stud construction, moisture problems were observed. Corrosion of metal framing elements, brick ties, wet brick, and wet sheathing to the point of supporting extensive mold growth were found in many of the buildings. Warm moist air entering into walls through cracks condenses on cold exterior surfaces within the walls. It is suspected that the problems observed can be attributed to this condensation.

Unplanned air leakage through exterior walls, between units, and to and from service chases is suspected to be widespread in apartment buildings across the country. Little is known about actual air change rates, pollution levels, or the incidence of air leakage through exterior walls. A survey of high-rise apartment buildings is therefore required to assess the air tightness, the air movement, and the indoor air quality of high rise buildings in order to confirm or disclaim suspicions of these problems.

BFL Consultants Limited, in conjunction with Heat Seal Limited and Newfoundland EnviroTech, has been selected by CMHC to conduct this survey in the Atlantic Region. Testing was conducted on buildings located in St. John's, Newfoundland.

The testing procedure itself took place in three (3) phases.

PHASE I - BUILDING ASSESSMENT:

Phase I involved building selection and assessment. A basic building criteria was established with the intent of providing guidelines on which to base building selection. Once the criteria was established, those buildings which met the criteria were identified and the building owners were determined. Once a building was selected, careful analyses was performed on such building features as:

- Exterior Wall Construction
- Window Type
- Quality of Construction,
- Building Age and Overall Condition
- Building Occupancy
- Mechanical Ventilation Systems
- Similarity with Other Building Stock

This analyses was directed towards determining the suitability of the building for further testing.

PHASE II - POLLUTANT SOURCE IDENTIFICATION:

Phase II consisted of collecting information which could be helpful in identifying possible pollutants, locating their sources, assessing the effectiveness of the ventilation systems, and defining the severity of any problems experienced. This information was obtained from building plans, complaint records, inspecting different areas of the building, and interviews with occupants, managers, and others.

Once completed, the buildings were assessed to determine the required testing to be performed. The information gathered at this stage will also assist in determining appropriate locations for later testing.

The preliminary assessment provided the greatest single opportunity to find the true cause of any indoor air quality problems. Information gathering techniques employed at this stage included three steps: Occupant response sampling, Pollutant source identification, and general mechanical systems observation.

PHASE III - PHYSICAL TESTING:

Physical testing was conducted in February and March in order to help assure that the maximum number of windows and doors controlled by the building occupants were closed during the tests. Tests were grouped into three categories.

(a) Air Tightness

One of the primary objectives for the testing was to determine the air tightness values associated with the buildings. It was required to determine the air tightness values for each individual floor of the building. This was achieved by the use of portable, variable speed fans to pressurize and depressurize certain areas of the building. By depressurizing adjacent areas and by the calibrated depressurization of the test area, the infiltration rate verses test pressure for the test area was determined.

(b) Air Movement

Air flow patterns for the building were studied by conducting point source release tracer gas tests. A specified volume of tracer gas was instantaneously released at a specified release site and air samples were subsequently taken periodically at different locations throughout the building over a three hour duration. These samples were then analyzed for changing concentrations of tracer gas.

(c) Air Quality

Testing was performed for the various pollutants identified by the questionnaire analysis in the building. Specific concerns such as Carbon Monoxide, Carbon Dioxide, Humidity, Formaldehyde, Particulates, Volatile Organic Compounds, Radon, Biological Contamination, Ozone, and Asbestos were assessed as indicated by the occupant questionnaire.

2.0 PHASE I - BUILDING ASSESSMENT

The first task in this field investigation was to identify and assess buildings on which the study could be conducted. In order to do this, a basic building criteria had to be determined.

2.1 Building Selection

In "Establishing a Protocol for Measuring Air Leakage and Air Flow Patterns in High Rise Apartment Buildings", the test building was identified as a five story masonry building consisting of a basement, a ground floor, and four typical stories. This test building was therefore used to set the basic criteria for qualifying a "high-rise" building to be used in this study.

For the purposes of this report a high-rise apartment building was therefore defined as a multi-level residential complex consisting of no fewer than five floors.

A listing of all residential apartment buildings was obtained from the City of St. John's Planning Department. Using this list as a guide, all apartment buildings which fit into the basic criteria were identified.

It was found that the majority of residential apartment buildings in the St. John's area would be classified as low-rise apartments. Typical building construction has three stories up and one story down from the ground level. This typical building falls outside of the basic building definition required by the project. Only eight residential buildings were identified within the St. John's area which fell into the basic building criteria.
Using information obtained from the City of St. John's tax assessment rolls, the owner or managing company for each building was determined. Formal requests were sent out to the owners or managing companies of each of the buildings.

In an effort to identify the availability of building drawings, the City of St. John's building department was contacted. A search through the city's various resources indicated that no drawings were available for any of the buildings of interest. Any drawings obtained for this project were therefore obtained from the building owner or from the building's original design agent.

Permission to include their buildings in the study was obtained from four building owners. Two of these buildings were locally owned and managed while the other two were owned by individuals or companies outside the province. Budgetary constraints limited the testing to two buildings therefore the two locally owned and managed buildings were selected since building drawings and the owner's co-operation could be obtained more easily.

2.2 Building Descriptions

The first building selected, Building I, is a 7 storey building of simple rectangular shape, built in 1982, containing a total of 51 apartments with 8 on a typical floor. Level 1 has 5 and Level 7 (known as the Penthouse) has 6, somewhat larger than the rest, but within the same perimeter. There are two elevators, centrally located, and a garbage chute serving each floor. A central corridor at each level gives access to an exit stair at each end. A single level parking garage is adjacent to the northern face of the building. Although built as an apartment block the units are currently owned separately as condominiums. In the St. John's area they are representative of "above average" in cost and quality, at least by reputation.

The second building selected, Building II, is a 6 storey building with a basement under about 60% of it. It was constructed in 1983. Its plan is a simple rectangle, essentially the same on all 6 levels, with 11 apartments per floor except for Level 1 which has 10. The apartments are virtually identical, having a living room and two bedrooms, except for one single-bedroom apartment on level 1. There is only one elevator, centrally located, and a garbage chute serving each floor. A central corridor at each level gives access to an exit stair near each end. The image of the building around town is that it is "low-cost housing", with all that term implies.

The buildings selected have similar, designs, structures, and mechanical systems.

Mechanical exhaust is provided to common spaces, kitchens areas and bathrooms, which are planned typically along the corridor spines. The living spaces are dependent on opening windows for ventilation, as is customary in the city, although each apartment on the south side of Building I has a through wall air conditioner below the Living Room window. Heating is by electricity, employing baseboard-type units.

The general building designs of are quite similar and are extremely simple. A rectangular block of construction is surmounted by an off-centre cube containing elevator machinery. The roofs are "flat", though there are slight slopes to roof-drains. The main entrances are central, on the first level, and are defined by a flat canopies. The exteriors are primarily clad in brown brick.

Both buildings' structures are unusual in Newfoundland, being comprised of a "lift-slab" system, in which steel columns are first erected and flat reinforced concrete floor slabs, cast on top of each other at ground level, are then jacked up the columns one by one to be anchored in position by the welding of embedded plates.

Detailed Architectural reviews of the buildings appear in Appendix I and Appendix II.

3.0 PHASE II - POLLUTANT SOURCE IDENTIFICATION

Phase II of the study consisted of collecting information which was helpful in identifying possible pollutants, locating their sources, assessing the effectiveness of the ventilation system, and defining the severity of any problems encountered. This information was obtained from building plans, on site inspections, occupant interviews, and building and mechanical systems questionnaires.

On site inspections of individual apartment units were conducted concurrently with the occupant questionnaires in those cases where the occupants were contacted in person. An independent inspection of the main mechanical systems was also conducted.

3.1 Ventilation Systems

The mechanical ventilation system designed for Building I does not provide adequate ventilation to the apartments. The ventilation required is intended to be introduced into apartments by way of openable windows. Each storey is provided with 135 L/s of supply air from the penthouse unit which is sufficient to makeup some of the air exhausted from each apartment.

In Building II, a great amount of moisture accumulation was noted on windows and water closets. The actual ventilation of the various apartments cannot be handled by the present ventilation systems. Even though there would be minimal air movement with the apartment exhaust fans active, during the winter months with the windows closed, very little air exchange would be present. Air infiltration would offset, to some degree, the inadequacies associated with this lack of air movement provided infiltration, not exfiltration is occurring in the respective apartments. However, without mechanical means, no net positive supply of ventilation air can be provided for the apartments in this building. 112 L/s of supply air from the penthouse unit is provided to each level to makeup some of the exhausted air. This, however, is not sufficient to satisfy occupant ventilation requirements.

3.2 Occupant Questionnaires

The objective of conducting the air quality questionnaire was to help identify any air quality problems which the building occupants may have noticed occurring either in the building in general or in their apartments.

It was decided that in order to maximize the quality and quantity of occupant response, the surveys would be conducted in person. Attempts were made to contact by telephone, those people who were not contacted in person. Those persons not contacted in person or by telephone were sent personalised letters requesting that they fill out the survey and return it to a designated drop off spot.

The assessment questionnaire was designed so that a yes answer to a question implied that a problem was possible. With the subsidiary questions, the more yes answers encountered, the more likely that a problem existed. A copy of the questionnaire appears in Appendix IX.

The occupant profile portion of the survey was designed to generate a profile of a typical occupant of the building so that this information could be taken into consideration if any air quality or moisture problems were identified.

The occupant complaints section and the apartment observation section were assessed on an individual apartment bases in an attempt to identify if and where any air quality problems existed. The complaints and observations were recorded on a floor plan of the building so that the information and the trends could be noted and correlated.

The compiled information was then used to help identify what air quality contaminants should be tested for and where the tests should be conducted.

3.2a Building I

Building I is generally considered to be one of the higher rental buildings in St. John's. Each apartment is individually owned by individuals, groups, or businesses. Only four of the units are owner occupied, the rest are jointly managed by a management company which handles the rental of the units.

Nineteen of the units are considered to be furnished apartments. These units are managed somewhat like hotel suites where individual apartments can be rented for periods of several days to several months. These units are generally let to business professionals who are in the city for a week or two and to families who are relocating to the area. The remaining twenty seven units are rented by long term tenants. Occupancy in these units range from one to two days a week to full time residency.

At the time the survey was conducted, three long term rental units were vacant. This left twenty eight possible long term residential units in the building.

Of the twenty eight possible units, a survey response was obtained from twenty six. (93% response rate). In addition several short term residents were interviewed and the three vacant apartment were inspected.

From the responses received from the long term apartments, thirty two occupants were reported. Fifty percent of these occupants were females over the age of sixty five. Sixty eight percent of the respondents indicated that they were retired. Fifty percent of the respondents also indicated that their apartments were occupied an average of twenty to twenty four hours a day. In addition, all residents indicated that their units were occupied at least twelve hours a day. Fifty percent of respondents indicated that there were no smokers in the unit.

When questioned about opening windows, all respondents indicated that the windows were opened regularly in good weather in order to get fresh air into the apartment.

All respondents indicated that exhaust fans were available in the bathrooms and kitchen although twenty percent indicated that the fans were not used either because they were too drafty or because they were too noisy. No particular trends were noticed in kitchen or bathroom usage.

All apartment had their own laundry facility but no particular trends were noted as to when and how often, laundry was done.

The complaints most commonly encountered did not pertain to air quality but were associated with air tightness. The most common complaint was extreme drafts through windows, exhaust fans, dryer vents, and kitchen cabinets. Many occupants had tape and plastic secured around their windows and had the kitchen exhaust fan blocked off. Many windows leaked water as well as air. Many occupants complained of cold feet while sitting in a warm room.

Detailed analyses of the survey results did not identify any specific building air quality problems however a few problem areas were noted:

The building superintendent indicated that mildew is observed on the inside of the external walls when the face brick is removed.

In Apt 104 the occupant experiences tiredness, dry eyes, blurred vision, stuffy nose, and dry throat. In the apartment above (Apt 207) the occupant experiences runny nose, stuffy nose, and dry throat. Apt 104 is the only apartment surveyed which is located adjacent to the parking garage. The health symptoms noted may indicate that some sort of air quality testing may be required. The occupant also noted a blackness around the walls of the apartment. This was especially prevalent near the heaters.

In Apt 605, located beside the garbage chute, the smell of garbage has sometimes been noted. In addition there appears to be a small amount of mould growth along the base boards of the section of wall shared with the garbage chute.

Another noticeable observation occurs in the apartments located across from the elevator. The occupants in the apartments on the 4th and 5th floors have complained about the smell of the cleaning solution used in the elevators.

It should also be noted that several apartment occupants complained about a white dust which always seemed to be covering everything.

These locations were subsequently identified for air quality testing.

General responses to some question areas can be summarized as follows:

When asked about temperature 66% of respondents stated it was okay or sometimes too hot. Only 10 % stated it was too cold.

When asked to describe the air 40% respondents stated it was dry, stale or stuffy. Ten indicated it was okay and 5 stated it was drafty.

When asked about odour only 4 occasionally and 1 rarely smell an odour. Cooking and garbage odours were noted by respondents.

Five respondents indicated they had allergies - 4 respiratory and 1 skin allergy. Two of the 5 stated their allergy was worse in the building.

Six respondents suffer various symptoms, such as tiredness, dry itching watery eyes, and think the building is the cause. Elevator maintenance was noted as a specific cause by one respondent.

Thirteen responded with complaints of moisture accumulation around windows. Included were complaints of mould on walls and carpet dampness. Eight noted visible dust accumulations on flat surfaces.

3.2b Building II

Building II consists of sixty five government subsidized units. At the time the survey was conducted there was one hundred percent occupancy. Of the sixty five units, responses were obtained from fifty one (78.5% response rate)

From the responses received, ninety two residents were reported. There was a much greater distribution of people between the age groups and the sexes than was noted in Building I. The largest component of the residents consisted of females over the age of sixty five. This component only accounted for twenty two percent of the reported residents however. Only a very small proportion of the residents were under the age of twenty five. The rest of the residents were pretty well evenly distributed among the age groups and sexes.

Of those reporting occupation, forty two percent indicated that they were retired, twenty percent indicated that they were professionals, fourteen percent indicated that they were labourers, and eleven percent indicated that they were unemployed

Fifty three percent of respondents indicated that there were no smokers in the household.

Fifty seven percent of the respondents also indicated that their apartments were occupied an average of twenty to twenty four hours a day. In addition, ninety seven percent of residents indicated that their units were occupied at least twelve hours a day.

When questioned about opening windows, all respondents indicated that the windows were opened regularly in good weather in order to get fresh air into the apartment.

All respondents indicated that exhaust fans were available in the bathrooms and kitchen. The bathroom fan was always used because it was connected by a single switch system to the light.

No apartments had their own laundry facility but a common facility is available in the basement. No particular trends were noted as to when and how often laundry was done. However it became apparent that the laundry room is in operation at least twelve hours each day.

The complaints most commonly encountered did not pertain to air quality but were associated with air tightness. The most common complaint was extreme drafts and leaks through windows. In addition, condensation was reported and observed on many of the windows and bathroom fixtures.

Detailed analyses of the survey results did not identify any specific building air quality problems however a few problem areas were noted:

The occupant of apartment 211 indicated that the air was dry and that there always seemed to be a mouldy or musty smell. The occupant complained of headaches, dry eyes, sneezing, and stuffy nose. Mold and moisture stains were observed around the windows.

Many occupant complaints included:

- mould around windows
- dry air
- cooking smells in apartment
- condensation around toilets causing dampness in washrooms
- draft windows
- heavy condensation on the windows
- smells around the garbage chute.

In addition, the occupants from the north west side of the fourth floor complained of bad odours coming from the corridor.

When asked about temperature (86 %) responded that it was okay. The remaining (24 %) thought that it was neither hot or too cold.

When asked to describe the air, 58% were satisfied, 31% felt it was too dry, and the remainder felt it was stagnant, stale or drafty.

When questioned about odour, 26% responded positively. However, only 6% were frequently bothered by odours. Cooking and garbage odours were noted.

Five respondents indicated a history of allergies - 4 respiratory and one skin allergy. Allergies were no worse while in the building.

Seven respondents suffer various symptoms, such as tiredness, sore and dry throat which they feel are due to the building.

Twenty nine respondents noted condensation and/or mold around windows. In 7 cases, there was also condensation reported around toilets.

3.3 Discussion

Examination of the ventilation systems in both buildings indicated that they were insufficient to meet the ventilation requirements of the apartment units. Both buildings depended on air infiltration and ventilation through openable windows to meet fresh air requirements.

Common occupant complaints dealt more with infiltration problems, especially around windows, than air quality problems. The occupants complaints regarding drafts were therefore taken into consideration when air tightness and air movement testing was conducted.

Based on the information obtained from the surveys, it was determined that it was not necessary to test for Volatile Organic Compounds, Ozone, or Asbestos. No particular air quality problems were identified therefore, as a matter of standard procedure, a series of tests were conducted to monitor Carbon Dioxide, Carbon Monoxide, Relative Humidity, Temperature, Radon, Bioaerosols, Formaldehyde, and Total Suspended Particulate levels.

4.0 PHYSICAL TESTING

Physical testing was conducted in order to monitor air tightness, air movement, and indoor air quality in the test buildings. Testing was conducted in February and march of 1991 in order to help assure that the maximum number of windows and doors controlled by the building occupants were closed.

Air tightness testing was conducted using the fan depressurization method; air movement testing was conducted using point source release of tracer gas to measure contaminant migration; and air quality was measured by monitoring various contaminant levels.

4.1 Air Tightness Testing

Air tightness testing was conducted in late February and early March of 1991. The objective of the testing was to determine the component air leakage through the walls and slabs of each storey of the test buildings. Testing and calculation procedures were conducted in accordance to National Standard Of Canada #CAN/CGSB-149.10-M86 - " Determination of the Air Tightness of Building Envelopes by the Fan Depressurization Method" - and in accordance to the procedures outlined in the CMHC publication "Establishing The Protocol for Measuring Air Leakage and Air Flow Patterns in High-Rise Apartment Buildings".

A testing procedure was established with the objective of minimizing the testing which was required while maximizing the results obtained. Thirteen physical air leakage tests were to be conducted on each building and as a result data for twenty one tests would be obtained. The test set ups are listed in Table 1 of Appendix V.

The data from the physical tests was used to conduct "paper tests" in which further data was generated. These "paper tests" consisted of combining measured flows from previous tests to estimate flows through different building components under similar conditions.

Based on the procedures outlined in CAN/CGSB-149.10-M86, the actual measurement data was corrected for differences in air density between the reference and calibration conditions and between the indoor and outdoor air temperature. The resultant flows were those which would occur under the reference conditions where atmospheric pressure would be 101.325 kPa and the inside and outside temperatures would both equal 20 °C.

The corrected flows were then used to determine the flow coefficient (C) and the flow exponent (n) which are used to generate a representative equation of the form $Q=C\Delta P^n$ relating pressure to the flow through the unbalanced building components.

A detailed explanation of the testing and calculation procedures appears in Appendix III.

4.1a Building I

Building I was the first building tested. The desired pressure differentials, which were expected to be generated, were not obtained during the testing. As a result, a great deal of time was lost attempting to determine why the desired pressures were not being achieved. Due to the problems which were encountered, the planned testing sequence was not followed. Appendix IV outlines the problems encountered during the testing and presents detailed analyses of the data which was obtained.

Although the planned testing sequence was not followed, several tests were successfully completed. Exterior wall leakage tests were performed on the first five storeys of the building and on four adjacent apartments on the fifth storey. The slabs were successfully balanced during the storey by storey testing. However, it was not possible to balance the slabs during the individual apartment testing since access to the apartments above and below the test unit was not available.

The tests for determining slab leakage rates were not performed. For the purposes of analyzing the data, the slab leakage rate was therefore assumed to be 5% of the total leakage determined for the floor. This estimate was based on information obtained from the CMHC protocol mentioned previously.

The external wall leakage rates for each floor and for each apartment were then determined and normalized. The normalized leakage rates determined for each floor were then compared to each other and the normalized leakage rates determined for each apartment were compared to each other. In addition, the average normalized leakage rate determined for the apartments was compared to the normalized leakage rate determined for the fifth floor. The comparison of this data illustrated several points.

The wall leakage rates determined for some stories were quite close to the wall leakage rate determined for other floors. This was particularly evident in the comparison of the first, fourth and fifth floors. The wall leakage determined for other floors, however, varied considerably from the others. This is evident when the data for the second and third stories is studied. The wall leakage rates determined for the individual apartments compared quite well to each other. As with the story by story analyses, however, a great variance was noted between one unit and the others. Table 1 lists the air change rates at 50 Pa associated with the exterior wall component of the zones listed.

TABLE 1: BUILDING I - LEAKAGE THROUGH WALLS

ZONE	AIR CHANGES PER HOUR @ 50 Pa
Apt 501	7.2
Apt 503	6.1
Apt 505	7.7
Apt 507	7.9
5th Floor	5.5
4th Floor	5.2
3rd Floor	7.4
2nd Floor	4.2
1st Floor	5.4

These air change rates were based on the leakage rates through the exterior wall of the zone under an external pressure differential of 50 Pa. The air changes are in terms of the air changes of the particular zone. For example, the leakage through the external wall of apartment 501 will cause the air in that apartment to change itself 7.2 times.

The average of the normalized leakage rates determined for the apartments was compared to the normalized leakage rate determined for the fifth floor. The two corresponded quite well. This indicates that, in this particular case, the estimate that the slab would account for 5% of the total flow for the floor is reasonable.

The overall results, however, demonstrate that although the assumptions taken about the slabs seem to be relatively valid in this case, there is a great amount of variance which can exist within an individual building component. This is evident when the variance of some of the wall leakage rates are considered.

4.1b Building II

Based on the experience gained from testing Building I, it was decided to conduct the planned testing sequence on Building II regardless as to whether or not the desired maximum pressure differential was obtained. During this testing, a higher success rate was achieved in obtaining pressure differentials of over 30 Pa. Appendix V presents a detailed analyses of the data obtained from testing Building II.

Each of the physical tests met the CAN/CGSB standard. When the "paper tests" were performed, however, it was found that several of the results failed to meet the standard.

From subsequent examination of the data, it was determined that the integrity of the measured flows associated with the third floor became questionable. The measured combined flow through the external walls and the lower slab was only marginally greater than the measured flow through the external wall by itself. The difference between the two ranged from 0.4% to 4.3%. A similar situation occurred between the measured combined flow through the external walls and the upper slab and the measured flow through the external wall by itself. In this case the difference between the two ranged from 1.6% to 9.9%.

The accepted margin of error for this type of testing is ± 5%. When the calculated differences between the measured values are taken as a percent of the measured values, these are, for the most part, found to be smaller than a reasonable error estimation for either of the measurements. This problem reduces the reliability of the calculated flows through the upper and lower slabs which in turn effect the calculated flows for the floor above and the floor below.

For each floor, the percentage influence of each building component (lower slab, walls, upper slab) was determined. In studying and comparing the graphs which were generated, it becomes apparent that the component breakdown of air leakage for the basement, first, fifth and sixth floors, remained relatively constant from pressure to pressure while the second, third, and fourth floors' component breakdown tended to vary substantially from pressure to pressure. The variance noted for the second, third and fourth floors is directly related to the flows associated with the third floor's upper and lower slabs.

When studying the data for the other floors,it can be seen that the contribution of the slab is much greater than the .4 to 9.9% indicated by the third floor slabs. The basement, first floor, fifth floor and sixth floor all indicate that the influence of the slab is in the neighbourhood of 10 to 20% of the total flow. This again brings into question the integrity of the third floor data.

The air change rates attributed to each component of each floor was determined and are presented in Table 2.

TABLE 2: BUILDING II - AIR CHANGE RATES

FLOOR	AIR CHANGES PER HOUR (ACH) @ 50 Pa			
	OVERALL	LOWER SLAB	WALLS	UPPER SLAB
BASEMENT	7.7		5.9	1.84
1ST	4.6	1.37	2.5	0.80
2ND	9.8	0.79	4.3	0.18
3RD	5.5	0.18	5.4	0.03
4TH	3.9	0.03	3.6	0.48
5TH	5.8	0.48	3.8	1.43
6TH	6.0	1.55	4.5	

The influence of the slabs is relatively small when compared to the influence of the walls. Since the air tightness values of the slab separations were obtained indirectly by subtracting the exterior wall leakage from the combined leakage, the flows determined for the slabs are very sensitive to even the smallest error in the measurement of the combined flows.

Something as simple as turning an exhaust fan on during a test could therefore have serious consequences in the slab flow determination.

In order to provide a fair comparison between floors, plots of normalized leakage rates verses pressure differential were generated for each type of component. The results clearly indicated that the air tightness of the exterior walls varied from storey to storey. When the leakage rates for the slabs were compared, these too were found to vary from floor to floor. This comparison also demonstrated the problems which exist with the third floor data. The flow through the 3rd to 4th floor slab was actually found to decrease with increased pressure. This is a physical impossibility although the data all falls within the margin of error for the test.

These results again echo the problems which exist with the third floor data. The conclusion must be drawn that either the third floor slabs are very tight - and consequently the small measured flows are subject to great sensitivity - or that there was an unaccountable factor which influenced the measured readings.

4.1c Discussion

Taking all these factors into consideration, the most definite conclusion which may be drawn from these results indicate that the influence of a particular building component varies from floor to floor. For example, the individual slab components range in influence from as little as 4% of a floor's flow to almost 25% of a floor's flow. This would indicate very tight to very leaky slabs.

Subsequently, it can be concluded that it is not a legitimate practice to estimate the influence of a particular building component (ie a slab) based solely on the construction of the building. The effectiveness of the construction technique, no matter how sophisticated, is at the mercy of the quality of the workmanship which went into the building. A large database needs to be developed before any general conclusions can be dawn for each component construction type.

The 5% slab leakage assumption used for Building I proved valid in the case of the fifth floor. However, further verification is required to determine if this assumption is valid for the other floors.

The testing sequence was set up so as to minimize the physical testing required. As a result, the leakage through certain components of the building, specifically the exterior walls on some floors which could have been measured directly, were calculated from data obtained from other tests. Due to the great inaccuracies involved in determining the leakage through the slabs, this procedure proved to be insufficient as problems where amplified when one derived value was used to determine another derived value. This clearly becomes evident when the problems encountered on the third floor of Building II is considered. In short, anything that can be measured directly should be measured directly. This results in more data of higher integrity, and thus more reliable conclusions may be drawn.

As indicated earlier, since air tightness values of the slabs are obtained indirectly from measured values, and since the influence of the slabs is relatively small when compared to the influence of the walls, the flows determined for the slabs are sensitive to even the smallest errors in the measurement of the combined flows. This is a strong argument for minimizing the number of leakage rates determined indirectly. Consideration must also be given to other sources of errors which are present during pressurization testing.

Errors can be present in pressurization measurements due to the test conditions. This may include factors such as physical characteristics of the building leaks or the weather conditions, such as temperature and wind speed, which existed during the test.

Some building leaks may behave differently when the inside is at a higher pressure than the outside, as opposed to the inside pressure being lower. Testing the building at both positive and negative pressure differences would avoid serious errors due to extreme directional effects due to directional openings.

A significant inside-outside temperature difference will cause a pressure difference across the building envelope that varies with height. This may lead to results which may not correctly characterize the building's leakage.

Excessive wind speeds induce unsteady exterior pressures which inhibit the establishment of a constant inside-outside pressure difference during a test. On upwind building faces, the static pressures are higher due to the stagnation of the wind velocity. To reduce the errors due to wind effect, a mixing box was used to average the pressures on the four faces of the building. The pressure taps were located on each test floor at the positions indicated by Figure 1 and Figure 2. This technique improves the accuracy of the pressure measurement, however, it assumes that each building face represents one quarter of the leakage sites. This technique does not take into account the non-uniform distribution of leakage sites on the four faces of the building. In addition, the leakage through the floor or ceiling might not be properly represented by this averaged pressure either.

According to the National Building Code, the internal walls of a residential apartment unit should be smoke tight. Therefore the internal walls should actually be tighter than the external walls. Since apartment units have less external wall area than a residential home, the apartment units should actually be more airtight than residential homes. According to 1989 AIRTIGHTNESS SURVEY, co-sponsored by CMHC and CHBA, the national norm of leakage rates in conventionally built residential homes is 3 ACH at 50 Pa. R-2000 residential homes are usually less than 1.5 ACH at 50 Pa. Apartment units in high-rise buildings should have leakage rates in the neighbourhood of 1 to 3 ACH at 50 Pa.

Countries such as Sweden have already initiated programs that specify building tightness standards in new construction. [1] The maximum air leakage rate has been set at 1 ACH at 50 Pa for multi-

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1. Jackman, P.J., 1984. "Review of building airtightness and ventilation standards," The Implementation and Effectiveness of Air Infiltration Standards in Buildings - 5th AIC Conference

family buildings of three or more stories. The results of this study indicate leakage rates of 5 to 10 times this rate.

As can be seen from Table 1 and Table 2, Building I's external walls are extremely leaky compared to Building II. This could account for the inability of the test team to generate the desired pressure differentials at Building I.

Previous testing, conducted in 1985 by Heat Seal Limited, identified several leakage sources in the building. The current testing and interviews with tenants confirmed many of these locations as sources of continuing problems. The problem areas which have been identified are listed below:

- Through air conditioner heater unit
- Around the air conditioner heating units
- Electrical outlets on exterior walls
- Around window sills
- Around operable windows
- Window Mullions
- Exterior wall baseboard
- Plaster cracks around windows
- Around heaters
- All around kitchen cabinets
- Electrical, telephone, cable t.v. outlets interior walls
- Around plumbing pipes
- Around fans
- Around door frames
- Around dryer vents
- Around electrical panel
- Around light fixture and smoke detector
- Interior wall baseboards
- Floor drain in Laundry room
- Mechanical penetrations through concrete slab
- Through exterior block joist at concrete slab
- Through exterior block
- Around steel columns
- Joists in exterior gyplap sheeting

Some of these problem areas have been corrected in some of the units. However, it must be realized that simply sealing locations, such as electrical outlets, does not solve the overall problems. By simply sealing one leakage site, the leaking air will be redirected to another location. The issue of making the overall building envelope tighter has to be addressed if any significant gains are to be made.

The commercial building sector has fallen behind the residential home sector in research and development as it relates to air tightness. Further studies directed towards improving air tightness of individual apartment units is necessary.

Information regarding leakage through exterior walls and between storey slabs has been obtained in this study. However, further information pertaining to internal wall leakage rates needs to be assembled.

4.2 Air Movement Testing

Tracer gas testing was conducted with the objective of providing a mechanism by which indoor airflow patterns within a test building could be qualitatively be studied. Based on information received from the building and occupant questionnaires, specific release sites and sampling locations were identified for each test building. Testing was conducted in late February and early March of 1991.

Testing was conducted by instantaneously releasing a specified amount of tracer gas (SF_6) at the release site. At specified intervals during the test, air samples were taken at the release site and at designated sampling locations throughout the building. Due to budgetary constraints, only four sampling locations on four floors of each building were selected. Two tests were conducted on each building with different release sites being selected for each test.

The testing procedure followed was based on testing procedures presented in "ESTABLISHING THE PROTOCOL FOR MEASURING AIR LEAKAGE AND AIR FLOW PATTERNS IN HIGH RISE APARTMENT BUILDINGS" and on ASTM standard # E741-83 - STANDARD TEST METHOD FOR DETERMINING AIR LEAKAGE RATE BY TRACER DILUTION. A description of the testing procedure appears Appendix VI. Gas chromatography with electron capture was used to determine the tracer gas concentrations in the samples.

Tracer gas concentrations which were detected were found to be much lower than initially expected. Upon further examination it was determined that vacutainers punctured with a syringe needle appear to have tracer gas loss due to diffusion through the syringe needle hole in the septa. Analysis of known sample concentrations checked on successive days demonstrated this problem.

The data therefore does not provide quantitative information regarding tracer gas concentration dispersal. However, it does provide information on tracer gas flow patterns. Detailed analysis of the tracer gas tests appears in Appendix VII.

4.2a Building I

Analysis of the tracer gas data obtained for Building I indicated that there is a tendency for the tracer gas to rise to the upper floors and congregate on the leeward side of the building. This indicated that the wind and the stack effect were the most influential factors effecting air movement in the building. Such a finding would indicate that the building is not very air tight.

This finding is echoed by informal discussions with tenants regarding electrical bills. Although not formally addressed in the survey and therefore not analyzed scientifically, the responses from many tenants indicated that electrical bills tended to be lower in the upper and southern facing apartments. Some tenants even noted that on cold days with northerly winds they do not have to turn on their heat. A formal study into electrical consumption correlated with information regarding position within the building and outside weather conditions may be another avenue of approach in assessing the influence of wind and stack effects on air movement.

4.2b Building II

Analysis of the tracer gas data obtained for Building II did not reveal any discernable trends in the air flow patterns of the building. No correlation between wind direction and higher tracer gas concentrations could be determined.

Higher concentrations were noted on the upper floors indicating that the stack effect could be playing a roll. In the case where the gas was released on a middle floor, none of the gas was detected migrating downwards as no tracer gas concentrations were detected on the lower floors.

When variances in tracer gas concentrations were correlated to occupant activity, some trends were noted. This tends to indicate that the factor influencing tracer gas distribution within this building is internal building activity. Opening and closing doors, elevator activity, exhaust fans, and even people walking around all creates air movement which moves the tracer gas around.

4.2c Discussion

Generally, apartments in closer proximity to the garbage chute, stairwells or elevators experienced the greatest rise in tracer gas concentration. It was noted that in Building I the sampling location located furthest away from the corridor experienced the slowest initial increase in tracer gas concentration. In addition, it was noted that the upper floors of both buildings tended to reach peak concentrations at a later time than the other floors. All these factors suggest that stack effect caused the contaminant to disperse into the corridor on every floor from the garbage chute, stair and elevator shafts. The contaminant would then migrate into individual apartment units from the corridor.

The extent and rate of this migration would depend on wind speed and direction, stack action, and on the use of exhaust fans in the apartments. The influence of the wind was particularly strong in Building I which was apparently not as tight as Building II.

Concurrently, with the increase in quality of building construction and the subsequent increase in air tightness of the building, the influence of climatic parameters, such as wind, is reduced. Other parameters gain a greater influence on the air movement. In such cases, the influence of the building occupants becomes much more prevalent as indicated in the results for Building II.

With the influence of the building occupants on air movement becoming of greater importance, the source of error due to the movement of the sampling team inside the building, opening and closing corridor doors, becomes increasingly important.

Further testing is required in Building II if any clear air flow patterns are to be detected. More sampling locations would be required on more floors. In conducting further tests, however, the expenses involved in sample analyses need to be considered.

4.3 Air Quality Testing

Investigations into indoor air quality is often broken down into preliminary assessment, simple measurements, and complex measurements. The preliminary assessment was conducted in the form of site inspections and investigation of potential problems and complaints by use of occupant and building questionnaires. Examples of these questionnaires appear in Appendix IX. The results of the questionnaire have already been discussed. The simple measurements were conducted in those areas indicated by the preliminary assessment. These measurements are dealt with in this section. Complex measurements were not conducted. No definite air quality problems were identified although some areas where further investigation would be beneficial were noted.

Air quality testing was conducted during March and April of 1991. The tests which were conducted were selected as a result of studying the preliminary air quality assessment. The objective of the testing was to identify any air quality problems which might exist and to indicate areas where further testing would be required.

Respondents in both buildings indicated that odours seemed to be originating from the garbage chute. In Building I, an occupant adjacent to the garbage chute noticed mould growth along the wall shared with the garbage chute. In Building II, mould growth was detected around several windows. Based on these responses it was decided to conduct Bioaerosal sampling in both Buildings. In Building I the units adjacent to the garbage chute were identified as the sampling locations.

Complaints regarding the stuffiness and the staleness of the air occurred in both buildings. Such complaints are indicative of Carbon Dioxide (CO_2) and Relative Humidity (RH) problems. CO_2 and RH monitoring was therefore performed.

A few occupants in both buildings complained of eye or respiratory tract irritation. It was unclear whether such complaints were due to allergies or not. It was therefore decided to test for formaldehyde (CH_2O) which could be another cause of such symptoms.

Both buildings are constructed of concrete which is a potential source of Radon. Testing was therefore conducted to detect any possible concentrations of radon in the building.

Several occupants in both buildings complained of dust accumulation. Therefore TSP (Total Suspended Particulates) sampling was also conducted.

Three sampling locations per building were chosen to conduct CO_2, CO, CH_2O, Radon, RH, T, and TSP testing. In addition, a control location in the lobby of each building was selected for gathering further Radon and CH_2O samples. Two series at bioaerosol samples were taken in each building. Details of the testing techniques and the subsequent analyses is presented in Appendix VIII.

4.3a Building I

No quantifiable bioaerosol levels were detected in Building I. Both runs, incubated at different temperatures, produced no measurable results. Radon, CH_2O, CO_2, CO, RH, and T levels all remained within the Health and Welfare Canada guidelines. CO_2 levels did have a tendency to increase with increased occupancy. This result is expected.

The CO levels noted in apartment 104, adjacent to the parking garage, was noticeably transient with peaks occurring in the morning and evenings. The RH tended to fluctuate with outside weather conditions.

The TSP levels in apartment 104 were particularly high (200 ug/m^3 when accepted level is only 40 ug/m^3) . Again, this may be linked to the proximity of the apartment unit to the parking garage. As noted in the survey results, the occupant had reported soot around his heaters.

4-3b Building II

Radon, CH_2O, CO_2, CO, RH and T levels all remained within the guidelines set by Health and Welfare Canada. CO_2 levels did vary with occupancy and did approach and exceed the 1000 ppm level with two or more occupants. RH levels tended to fluctuate with outside weather conditions. TSP levels were excessive in apartments which contained smokers. Although 40 ug/m^3 is the recommended exposure guidelines, levels as high as 77 ug/m^3 were measured. Apart from one location which had a lot of plants, all Bioaerosol levels were within Agriculture Canada's recommended guidelines.

4.3c Discussion

Generally, air quality is acceptable for occupants of both buildings. This is reasonable, given the few complaints of poor air quality and symptoms associated with air quality which were received.

CO_2 levels does increase with occupancy and often exceeds 1000 ppm in apartments with two or more occupants. Studies of office air quality have indicated that complaints appear to increase when CO_2 levels are at or above 1000ppm. Apartments occupied by smokers will have higher TSP and CO levels.

Particularly high levels of CO and TSP were noted in apartment 104 of Building I. Trends were noted in CO levels which would tend to correspond to parking garage activity. Further study is required in order to better understand the relationship between the air quality of apartment 104 and the parking garage activity.

5.0 GENERAL DISCUSSION

This study was undertaken with the objective of assessing air tightness, air movement, and indoor air quality problems in high rise apartment buildings with particular attention being directed at linking such problems to comfort related complaints regarding temperature fluctuations and smells.

Occupant questionnaire responses did contain comments regarding temperature fluctuations and smells but the majority of complaints dealt with drafts and other leakage problems.

Air tightness testing conducted on both buildings indicated that both buildings were very leaky by international standards. In addition, Building I was found to be substantially more leaky than Building II. The air tightness of the buildings tended to have a dominant effect on the other building characteristics. This is particularly evident in Building I.

When the air movement testing was conducted on Building I, it was found that the outside weather conditions dominated the tracer gas migration. The stack effect carried the gas up the building through the garbage chute, stair wells, and elevator shafts and the wind moved the gas towards the leeward side of the building.

Apart from apartment 104, which was located adjacent to the southern side of the parking garage, air quality in Building I was very good. Of particular note is the fact that no bioaerosals could be located in the building. As indicated, apartment 104 did experience higher CO_2, CO, and TSP levels than would normally be expected. Further investigation is required to determine any connection between the parking garage and these high contaminant levels.

Building II was found to be substantially tighter than Building I. As a result the influence of the outside weather conditions on internal air movement was markedly declined. The stack effect still played a role, however occupant activity seemed to have the greatest influence on air movement. More testing utilizing a greater number of sampling locations is required if any discernable air flow patterns are to be noted in the building.

CO_2, Radon, and RH levels were all higher in Building II than in Building I. This could be linked to the fact that Building II is tighter than Building I. Bioaerosols were also detected. All contaminant levels, except TSP in smokers' apartments, remained within government recommended guideline.

This increase in contaminant levels is indicative of situations which will occur if adequate mechanical ventilation is not provided in buildings to substitute for natural infiltration as buildings are built tighter.

No testing was conducted to measure the effectiveness of the mechanical ventilation systems to deliver fresh air throughout the buildings. This also could be an area of further study.

Normal air change rates used in the design calculations to determine heater sizing range up to a maximum of 1.5 ACH. The present infiltration standards of NRC indicate a required infiltration rate of 0.1 l/s/m. The results for both buildings which were tested indicate air change rates up to 6.5 times this value. The apartments would require 237 W/m^2 to sustain normal heating capacity of 54 W/m^2. The 1.5 ACT rate was based on an average wind speed of 48 km/h which generates 75 Pa pressure differentials on exterior wall faces. While no conclusive evidence is available and no conclusions are readily apparent to contradict the validity of the calculated air change rate, the values determined are significantly higher than the norm. Apartments examined do not experience extreme cold as would be the case implied by the air change rate determined in the tests. Possible contributing factors could be fan back draft dampers not sealing or other items in the mechanical system which can provide a significant area for air leakage if improper closure occurs. The protocol documents do not require sealing of all mechanical system air diffusion devices which can contribute significantly to air change rates in the experimental procedures outlined in these documents. However, at Building I all devices, openings and other air leakage sources were meticulously sealed and still high air changes were observed.

International standards are directing leakage rates for apartment units to be in the neighbourhood of one air change per hour at 50 Pa. In order to achieve this, further studies need to be directed towards determining leakage rates from individual apartments with particular attention being given to individual apartment components such as windows, mechanical systems and internal "smoke tight" walls.

As buildings become tighter, equal effort will need to be directed at maintaining adequate mechanical ventilation to the apartment units. Only by doing this will air quality and air movement standards be maintained. Ventilation systems are basic in both the buildings examined in this study with ventilation requirements handled by the openable windows. First cost considerations are the prime concern of the developer and not items which pay over the life of the project. Improvements in energy efficiency through the reduction of air infiltration and the subsequent need for mechanical ventilation to replace the need for openable windows will not be the norm in building construction in the near future unless developers are forced by regulatory means to meet energy consumption targets.

From an energy efficiency standpoint the buildings examined in this study demonstrate that significant energy wastage is occurring. Air infiltration contributes to as much as 40 percent of the total energy consumed in building construction and the buildings examined under this study are exceeding this value. While the scope of this project involves the air infiltration through exterior walls and not overall energy efficiency, it is prudent, in light of present trends to improve energy efficiency, to state that the buildings examined are wasting energy and contributing to the environmental problems such as global warming.

While no evidence was apparent in the testing of each building regarding moisture damage internally, the high air infiltration rates should contribute to the potential of water damage in the exterior walls. The rain screen effect of curtain wall construction is handicapped by the number of leakage sites in the wall cavity. Judging by the air infiltration values recorded the potential exists to have moisture penetration into the buildings.

Testing methodology used for this project requires refinement to become more practical. The air infiltration methods as described in the documentation forwarded by CMHC to be used for this project neglects to emphasize the importance of sealing any and all potential sites for air infiltration into the test area. Common items include air diffusers and grilles for the mechanical ventilation systems, dryer vents, washroom exhaust vents and range hoods. Any one grille left uncovered during the test can contribute an area for air infiltration significantly greater than the area in the wall structure and of much lower resistance to airflow as to the invalidate the results obtained. Quality control of this effect is extremely cumbersome and plays havoc with the budgeted time for the field analysis, but it is a vital part of the success of the study. Future test documentation must explain and emphasize this exercise to insure proper results are achieved.

Air movement testing proved to be extremely time consuming and difficult in both buildings examined. Difficulties encountered revolved around the test sampling frequency and the manpower required to perform the testing. Also, analysis facilities cannot measure the extremely low levels of sulphur dioxide content captured during the test sampling easily and errors can result from the handling and processing of the samples obtained.

6.0 RECOMMENDATIONS

Based on the problems encountered during the testing, and the findings resulting form the analysis, this investigation into air tightness, air movement, and indoor air quality presents the following recommendations.

1) Conduct Further Air Tightness Testing On Both Buildings.
2) Create A Large Building Data Base.
3) Assess Influence of Parking Garage.
4) Include Margin of Error Analysis Techniques.
5) Implement A Greater Amount of Direct Testing.
6) Implement Test Repetition.
7) Use More Sampling Locations.
8) Prepare Control Sample of Known Tracer Gas Concentrations.
9) Establish More Meticulous Air Tightness Testing Procedures.

1) Conduct Further Air Tightness Testing On Both Buildings.

Both buildings were very leaky when compared to international standards. Further testing is required in both buildings in order to determine the air tightness of between-apartment internal walls and in order to identify primary leakage areas. In Building I, further testing is also required in order to verify the validity of the assumption regarding the slab leakage rate (ie. slab leakage was assumed to be 5% of the total leakage determined for the storey).

2) Create A Large Building Data Base

A larger data base is required if general assumptions about buildings in Atlantic Canada are to be drawn from this study. Comparison of building components of like construction has demonstrated the greater variability of leakage rates which can result within a particular component type. In addition, the two buildings compared here, although very similar to each other, are not typical of the construction style in the St. John's area. More studies of different types need to be conducted before general assumptions can be made.

3) Assess Influence of Parking Garage

The high TSP levels and the transient CO levels noted in apartment 104 of Building I, located adjacent to the parking garage, has indicated a link between parking garage activity and indoor air quality. Further air quality testing of the units adjacent to the parking garage is required in order to assess the impact of the parking garage on air quality.

4) Include Margin of Error Analysis Techniques

The air tightness testing and the air movement testing procedures both have a large margin of error associated with the measurement techniques. Effort should be directed at reducing the margin of error and including such error in the techniques used to analyze the data. In this way the validity of the data and the associated calculations may be readily assessed.

5) Implement a Greater Amount of Direct Testing

Flow values derived from measured values are very susceptible to errors in the measured values. This is especially relevant to cases where the derived valve is small in comparison to the measured value. Such problems are amplified when one derived value is used to determine another derived value. In order to minimize this problem, any component leakage which can be measured directly should be measured directly.

6) Implement Test Repetition

The accepted margin of error for air tightness measurements is $\pm 5\%$. Something as simple as a single exhaust fan can effect the measured air flow values substantially. For that reason, individual tests should be repeated at least twice in order to assess the integrity of the measured values obtained. Although testing costs will increase, so too will the data integrity and the reliability of the results.

7) Use More Sampling Locations

The most important constraint placed on tracer gas testing is the analysis costs involved. Budgetary constraints limits the number of samples which may be used during the testing. This limits the ability of the test to detect discernable air flow patterns in tighter buildings, such as Building II, where outside climatic factors do not have such a great influence.

8) Prepare Control Sample of Known Tracer Gas Concentrations

Vacutainers previously punctured with a syringe needle appear to have SF_6 loss due to diffusion through the syringe needle hole in the septa. In order to compensate for this, either the sampling procedure used in tracer gas testing must be changed to eliminate the need to puncture the septa, or control samples containing known tracer gas concentrations should be prepared in the same manner and at the same time as the tracer gas samples are taken. These control samples would provide a method by which the sample diffusion rate could be quantified.

9) Establish More Meticulous Air Tightness Testing Procedures.

In order to clearly isolate the air leakage due to individual building components it is required to conduct more rigorous testing which isolates the particular component being tested. For example; all mechanical systems should be sealed when testing external walls. Tests should also be conducted to determine the flow rates associated with the individual building components such as windows and mechanical systems.

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APPENDIX I

BUILDING I

ARCHITECTURAL AND MECHANICAL SYSTEM REVIEW

APPENDIX I

BUILDING I

ST. JOHN'S, NEWFOUNDLAND

ARCHITECTURAL AND MECHANICAL SYSTEM REVIEW

<u>**INDEX**</u>

Building I

St. John's, Newfoundland

Architectural and Mechanical System Review

1.0 INTRODUCTION

This is a 7 storey building of simple rectangular shape, built in 1982, containing a total of 51 apartments with 8 on a typical floor. Level 1 has 5 and Level 7 (known as the Penthouse) has 6, somewhat larger than the rest, but within the same perimeter.

Although built as an apartment block the units are currently owned separately as condominiums.

This review is based on the original construction drawings and on-site inspections. It is assumed that construction proceeded in accordance with the drawings, except where any obvious differences have become evident.

2.0 ARCHITECTURAL REVIEW

2.1 GENERAL DESIGN

The general building design is extremely simple. The rectangular block of construction is surmounted by an off-centre cube containing elevator machinery. The roofs are "flat", though there are slight slopes to roof-drains. There is a low parapet all round, averaging 600 mm in height. The main entrance is central, on Level 1, and is defined by a flat canopy. The exterior is clad in brown brick throughout except where windows occur.

The design uses windows to overcome the inevitable blandness of the building's form and cladding. There are ten types of windows, if one counts each size as a type. Windows on the Level 1 entrance facade are much larger than one would normally find in apartments. On each level there are bay windows in the Living Rooms, those on the Penthouse level having sloped glass "roof" sections, while those on lower levels are oversailed by floor extensions.

There are some common spaces on Level 1, but these are minimal - storage cubicles, a "Common Room" and a small parking garage.

There are two elevators, centrally located, and a garbage chute serving each floor. A central corridor at each level gives access to an exit stair at each end.

Some mechanical ventilation is provided to common spaces and kitchens and bathrooms, which are planned typically along the corridor spine, have the necessary exhaust systems. Most living spaces are dependent on opening windows for ventilation as is customary in the city, though on the south side each apartment has a through wall air conditioner below the Living Room window. Heating is by electricity, employing baseboard-type units.

2.2 STRUCTURE

The building's structure, except for the steel roof, is unusual in this province, being comprised of a "lift-slab" system, in which steel columns are first erected and flat reinforced concrete floor slabs, cast on top of each other at ground level, are then jacked up the columns one by one to be anchored in position by the welding of embedded plates. The system may have economic advantages, but has no implications for the success of the building in use as far as this study is concerned.

2.3 ENVELOPE

2.3.1 Roof

The roof, which seems to be in reasonably good shape, is comprised of conventional built-up roofing on 75 mm of rigid insulation on 38 mm galvanized steel fluted deck, supported by open web steel joists. A vapour barrier is assumed, though not confirmed by the construction drawings.

2.3.2 Walls

The same wall system is used throughout except on the roof-top enclosure and part of the East wall on Level 1. Generally it consists of a 100 mm brick veneer backed by a 45 mm air space, 12 mm exterior grade gypsum board, 150 mm steel studs and 12 mm interior gypsum board with 150 mm fibreglass batt insulation between the studs. Again, a vapour barrier is assumed, though none is shown on the drawings. The cavity between the brick veneer and concrete slab edges is filled with Styrofoam board. Soffits below bay windows have Glasweld panels glued to 75 mm Styrofoam secured to the underside of the concrete floor slabs.

The Elevator Machine Room walls are comprised of a field-assembled insulated metal wall system having 50 mm blanket insulation incorporated.

Part of the Level 1 East wall has the brick veneer backed up with a 45 mm air space, 150 mm concrete block and 75 mm styrofoam beneath 12 mm gypsum board on the interior.

Walls below ground are generally of mass concrete without any perimeter insulation. (No insulation under Level 1 slab-on-grade either.)

2.3.3 Windows

The windows are of aluminum extrusions, factory-finished in dark brown. It is not clear from the drawings or site inspection whether or not the sections are thermally broken. Most of the windows are of fixed lites, gasket-glazed with hermetically-sealed clear glazing units, but each major room has a sideways-sliding opening lite, screened with mesh. The sliding sashes are removable, and are weatherstripped with pile strips.

Superficially the windows are in good condition, but most gaskets have shrunk, leaving gaps at corner joints and some are displaced. The pile stripping appears to be ineffective. There is clear evidence of leakage at many windows, while the building management complains of drafts and water entering below windows during rainstorms. The drawings give no clear details of the window installation. No flashings below sills are indicated, though cavity flashings at window heads are shown. From the drawings it appears that the top-most bay windows rely on only a pre-painted steel flashing to protect the junction of the sloped glazing with the brick wall.

2.3.4 Doors

The front entrance has standard glazed aluminum doors as do the rear apartments on Level 1. Exit doors are hollow metal. Taken together the doors are a very minor element in the envelope's performance.

3.0 MECHANICAL SYSTEMS

3.1 GENERAL

Mechanical systems present include residential grade plumbing fixtures and related water supply and drainage system, a wet pipe sprinkler system serving the basement apartment storage area and garbage chute, fire hose standpipe system, general ventilation providing make up air for the apartment exhaust fans, and miscellaneous exhaust for the garbage room, elevator equipment room, janitor's room, and storage rooms. Each apartment on the south has a single through the wall air conditioning unit and the office area has a ceiling mounted water cooled air conditioning unit.

3.2 DESIGN PHILOSOPHY

The mechanical systems installed in this building are minimal and satisfy code and jurisdictional authority requirements for apartment buildings in this area.

Each apartment has the required plumbing fixtures for a single (or double) bathroom, a kitchen sink and a single domestic hot water tank. Provision is made for individual laundry use.

Fire protection meets the code and local authority requirements for the building at the time of construction. Protection consists of a wet pipe sprinkler system located in the basement for the tenant storage area and also the garbage chute. Fire hose cabinets at each level provide the necessary occupant protection along with individual apartment multipurpose dry chemical fire extinguishers. A fire pump is also used to ensure required water flow and pressure for the sprinkler and stand pipe system.

Ventilation provided to this building is minimal and basically satisfies makeup air requirements only for the various apartment exhaust systems and also the miscellaneous exhausts on the first level. It was assumed by the designer that occupant ventilation would be obtained by the openable windows in each apartment and not by mechanical ventilation systems. Air conditioning units are installed in this building for the occupants on the south side of the building and in the office area.

3.3 DETAILED SYSTEMS DESCRIPTIONS

3.3.1 PLUMBING

Individual apartment plumbing systems consist of a single washroom which has a residential grade water closet, bathtub and lavatory. The kitchen has a single stainless steel kitchen sink.

Domestic hot water is provided by individual electric domestic hot water tanks located in each apartment. Each tank has a storage capacity of 136 litres and is heated by a single 3 kW electric heating element.

Provision is also made for the connection of the laundry washer for the individual apartments.

A sump pump is provided for the elevator pit which complies with code requirements.

3.3.2 FIRE PROTECTION

As stated previously, a wet pipe sprinkler system is provided in the basement to provide protection of the apartment tenant storage spaces. Also, sprinklers are provided at the top of the garbage chute and also in the garbage room, and at alternating floor levels in the garbage chute.

Fire hose cabinets are provided at each level. Each cabinet has a 4.5 Kg ABC rated extinguisher, a 38 mm fire hose and nozzle (normally referred to as a small hose system), a 65 mm fireman's hose valve, and a trinal spanner.

Individual apartments have a 1.13 Kg wall mounted multipurpose fire extinguisher.

3.3.3 MECHANICAL VENTILATION

Each apartment has a single kitchen exhaust hood, a single washroom exhaust fan, and a single laundry exhaust fan. Each of these fans exhausts directly to the outside through individual ducts. These fans are controlled solely by the occupants and are rated as follows:

.1 Washrooms - 55 L/s
.2 Range Hood - 100 L/s

Makeup air for the apartments is provided by a fresh air supply unit located in a penthouse on the roof. The unit consists of a single 42 kW electric resistance heating element, a supply fan with a capacity of 1144 L/s at 505 Pa, and a throw away filter arrangement. The unit is time clock controlled. Ductwork distributes air to discharge grilles located in the corridor for each floor.

Miscellaneous exhaust fans and the related airflow rates are as follows: -

.1 Storage Room Exhaust - 90 L/s
.2 Garbage Room Exhaust - 90 L/s
.3 First Level Public Washroom Exhaust - 90 L/s
.4 Elevator Machine Room Exhaust - 705 L/s

The fans have individual controls and run independent of the time clock controlled supply air unit. The elevator machine room fan operates through a cooling thermostat which operates the fan only during temperatures above the thermostat setpoint. A separate fresh air duct feeds the garbage room independent of the supply air unit. This air is unheated for the garbage room.

From the available drawings, each of the seven levels is provided with 135 L/s of supply air from the penthouse unit. While this amount of air is used to makeup some of the exhausted air from each level, it is apparent that no intention existed to provide mechanical ventilation to each apartment of sufficient quantity to satisfy occupant ventilation requirements.

3.3.4 DISCUSSION

The ventilation system for this building was not designed to provide mechanical ventilation of the apartment for the tenants. The ventilation required is intended to be introduced into the apartments by way of openable windows. In this building, no moisture accumulation was evident and this could be attributed to the leaky nature of the building construction. However, should the building be sealed tighter, there would be more pronounced evidence of ventilation problems due to insufficient ventilation air movement to the apartments in this building.

APPENDIX II

BUILDING II

ST. JOHN'S, NEWFOUNDLAND

ARCHITECTURAL AND MECHANICAL SYSTEM REVIEW

INDEX

APPENDIX II

BUILDING II

ARCHITECTURAL AND MECHANICAL SYSTEM REVIEW

Building II

St. John's, Newfoundland

Architectural and Mechanical System Review

1.0 INTRODUCTION

This is a 6 storey building with a basement under about 60% of it. It was constructed in 1983. Its plan is a simple rectangle, essentially the same on all 6 levels, with 11 apartments per floor except for Level 1 which has 10. The apartments are virtually identical, having a living room and two bedrooms, except for one single-bedroom apartment for the Building Superintendent on Level 1.

The image of the building around town is that it is "low-cost housing", with all that term implies.

This review is based on the original construction drawings and on-site inspections. It is assumed that construction proceeded in accordance with the drawings except where any obvious differences have become evident.

2.0 ARCHITECTURAL REVIEW

2.1 GENERAL DESIGN

The general building design is extremely simple. The rectangular block of construction is surmounted by an off-centre cube containing elevator machinery. The roofs are "flat", though there are slight slopes to roof-drains. There is a low parapet all round, averaging 300 mm in height. The main entrance is central, on Level 1, and is defined by a flat canopy. The exterior is clad in brown jumbo brick throughout except where pre-painted metal siding is used at parapets and under bay windows.

There are five types of windows, if one counts each size as a type. There are bay windows in each living room.

There are some common spaces on Level 1, but these are minimal - storage cubicles, a "Recreation Room" and a laundry.

There is only one elevator, centrally located, and a garbage chute serving each floor. A central corridor at each level gives access to an exit stair near each end.

Mechanical exhaust is provided to common spaces, kitchens areas and bathrooms, which are planned typically along the corridor spine. The living spaces are dependent on opening windows for ventilation as is customary in the city. Heating is by electricity, employing baseboard-type units.

2.2 STRUCTURE

The building's structure is unusual in this province, being comprised of a "lift-slab" system, in which steel columns are first erected and flat reinforced concrete floor slabs, cast on top of each other at ground level, are then jacked up the columns one by one to be anchored in position by the welding of embedded plates. The system may have economic advantages, but has no implications for the success of the building in use as far as this study is concerned.

2.3 ENVELOPE

2.3.1 Roof

The main roof, which seems to be in reasonably good shape, is comprised of conventional built-up roofing on R.S.I. 3.5 rigid insulation on a sloped concrete slab. A vapour barrier is incorporated below the insulation. The machine room roof is of a patented metal roofing system with R.S. I. 2.1 blanket insulation and integral vapour barrier.

2.3.2 Walls

The same wall system is used throughout except on the roof-top enclosure. Generally it consists of a 100 mm brick veneer backed by a 25 mm air space, 12 mm exterior grade gypsum board, 150 mm steel studs and 12 mm interior gypsum board with R.S.I. 3.5 fibreglass batt insulation between the studs. A vapour barrier is incorporated between the insulation and interior gypsum board. The cavity between the brick veneer and concrete slab edges is filled with fire stopping. Cavity flashings with weepholes occur where the firestopping fills the cavity and also above windows and doors. Soffits below bay windows on Level 1 have plywood panels over R.S.I. 2.6. Styrofoam secured to the underside of the concrete floor slabs through wood strapping. There are no other soffits.

The Elevator Machine Room walls are comprised of a field-assembled insulated metal wall system having R.S.I. 1.75 rigid insulation and vapour barrier over 12 mm exterior grade gypsum board on 150 mm steel studs.

Basement walls are of mass concrete with full height perimeter insulation, R.S.I. 1.75, below 12 mm gypsum board finish, with vapour barrier.

2.3.3 Windows

All of the windows, which are of minium size, are fabricated of painted wood. All are double hung, except for a fixed lite central in each bay window. All are glazed with hermetically-sealed clear double glazing units. The opening lights are screened, springbalanced and operate on vinyl extrusions working together with vinyl weather stripping. Their glass units are held in place with snap-on vinyl stops which in a few cases are damaged or missing possibly due to vandalism. Sealants around the windows appear to be in good condition and indeed the windows generally are so.

In addition there are flashings below each window while each has a vapour seal to achieve continuity with the vapour barrier of the wall.

A few leaks and drafts are reported where vinyl components have been broken.

2.3.4 Doors

All exterior doors are insulated hollow metal, glazed or half-glazed with clear hermetically sealed double glazing units. Taken together the doors are a very minor element in the envelope's performance.

2.4 DISCUSSION

The building appears to have been carefully designed to achieve good envelope performance within the available budget. The occupants seem to be generally satisfied with their environment and have few complaints. Energy bills are said to be low. Some maintenance is required, particularly to damaged windows, but by and large the building is performing well.

3.0 MECHANICAL SYSTEMS

3.1 GENERAL

Mechanical systems present include residential grade plumbing fixtures and related water supply and drainage system, a wet pipe sprinkler system serving the basement apartment storage area and garbage chute, fire hose standpipe system, general ventilation providing make up air for the apartment exhaust fans, and miscellaneous exhaust for the garbage room, elevator equipment room, janitor's room, laundry room and storage rooms.

3.2 DESIGN PHILOSOPHY

The mechanical systems installed in this building are minimal and satisfy code and jurisdictional authority requirements for apartment buildings in this area.

Each apartment has the required plumbing fixtures for a single bathroom, a kitchen sink and a single domestic hot water tank. No provision is made for individual laundry use. Instead, a common laundry facility is provided in the basement.

Fire protection meets the code and local authority requirements for the building at the time of construction. Protection consists of a wet pipe sprinkler system located in the basement for the tenant storage area and also the garbage chute. Fire hose cabinets at each level provide the necessary occupant protection along with individual apartment multipurpose dry chemical fire extinguishers.

Ventilation provided to this building is minimal and basically satisfies makeup air requirements only for the various apartment exhaust systems and also the miscellaneous exhausts in the basement. It was assumed by the designer that occupant ventilation would be obtained by the openable windows in each apartment and not by mechanical ventilation systems. No air conditioning units are installed in this building for the occupants.

3.3 DETAILED SYSTEMS DESCRIPTIONS

3.3.1 PLUMBING

Individual apartment plumbing systems consist of a single washroom which has a residential grade water closet, bathtub and lavatory. The kitchen has a single stainless steel kitchen sink.

Domestic hot water is provided by individual electric domestic hot water tanks located in each apartment. Each tank has a storage capacity of 136 litres and is heated by a single 3 kW electric heating element.

In the basement, there is a laundry room provided for the tenants. Four (4) washing machines and a laundry sink are located in the laundry room. In addition, a janitor's sink, a service sink, and a single washroom with water closet and lavatory are located in adjacent rooms. Domestic hot water in the basement area is provided by two (2) 454 litre electrically heated domestic hot water tanks each with 2 - 10 kW heating elements. A sump pump is provided for the elevator pit in this building.

3.3.2 FIRE PROTECTION

As stated previously, a wet pipe sprinkler system is provided in the basement to provide protection of the apartment tenant storage spaces. Also, sprinklers are provided at the top of the garbage chute and also in the garbage room, and at alternating floor levels in the garbage chute. Sprinkler heads are also located at each elevator lobby on each level.

Fire hose cabinets are provided at each level. Each cabinet has a 4.5 kg ABC rated extinguisher, a 38 mm fire hose and nozzle (normally referred to as a small hose system), a 65 mm fireman's hose valve, and a trinal spanner.

Individual apartments have a 1.13 kg wall mounted multipurpose fire extinguisher.

3.3.3 MECHANICAL VENTILATION

Each apartment has a single kitchen exhaust hood and a single washroom exhaust fan. Each of these fans exhausts directly to the outside through individual ducts. These fans are controlled solely by the occupants.

Makeup air for the apartments is provided by a fresh air supply unit located in a penthouse on the roof. The unit consists of a single 50 kW electric resistance heating element, a supply fan with a capacity of 1144 L/s at 186.4 Pa, and a throw away filter arrangement. The unit is time clock controlled. Ductwork distributes air to a single discharge grille located in the center of the building in the corridor for each floor. In addition, this unit provides air to makeup exhausted air in the basement for the miscellaneous exhaust fans and the laundry dryers.

In the basement, miscellaneous exhaust fans and the related airflow rates are as follows: -

.1	Storage Room Exhaust	- 177 L/s @ 93 Pa
.2	Garbage Room Exhaust	- 94.4 L/s @ 93 Pa
.3	Janitor Room and Washroom Exhaust	- 70.8 L/s @ 93 Pa
.4	Laundry Room Exhaust	- 177 L/s @ 93 Pa
.5	Elevator Machine Room Exhaust	- 267 L/s @ 150 Pa

The fans have individual controls and run independent of the time clock controlled supply air unit. The elevator machine room fan operates through a cooling thermostat which operates the fan only during temperatures above the thermostat setpoint. A separate fresh air duct feeds the garbage room independent of the supply air unit. This air is unheated for the garbage room.

From the available drawings, each of the six levels is provided with 112 L/s of supply air from the penthouse unit. While this amount of air is used to makeup some of the exhausted air from each level, it is apparent that no intention existed to provide mechanical ventilation to each apartment of sufficient quantity to satisfy occupant ventilation requirements.

3.3.4 DISCUSSION

From the evidence of moisture accumulation on windows and water closets, it is readily apparent that the actual ventilation of the various apartments cannot be handled by the present ventilation systems. Even though there would be minimal air movement with the apartment exhaust fans active, during the winter months with the windows closed, very little air exchange would be present. Air infiltration would offset to some degree the inadequacies associated with this lack of air movement provided infiltration, not exfiltration is occurring in the respective apartments. However, without mechanical means no net positive supply of ventilation air can be provided for the apartments in this building.

APPENDIX III

DETERMINING AIR LEAKAGE RATE THROUGH EXTERIOR WALLS AND FLOOR/CEILING SEPARATIONS OF INDIVIDUAL STORIES BY FAN DEPRESSURIZATION

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DETERMINING AIR LEAKAGE RATE THROUGH EXTERIOR WALLS AND FLOOR/CEILING SEPARATIONS OF INDIVIDUAL STORIES BY FAN DEPRESSURIZATION

The following testing procedure is based on the testing procedures presented in "ESTABLISHING THE PROTOCOLS FOR MEASURING AIR LEAKAGE AND AIR FLOW PATTERNS IN HIGH-RISE APARTMENT BUILDINGS and on NATIONAL STANDARD OF CANADA #CAN/CGSB-149.10-M86 - Determination of The Airtightness of Building Envelopes by the Fan Depressurization Method.

1.0 BUILDING DETAILS:

Conduct an initial site inspection and note the following:

- age
- construction type
- number of storeys
- perimeter (m)
- height (m)
- typical floor plan
- apartment details:
    - kitchen exhaust
    - bathroom exhaust
    - window air conditioners
- heating and ventilation systems:
    - location of:
        - exhaust fans and controls
        - supply fans and controls
        - fresh air intakes
        - exhaust air ducts
        - supply air ducts and grilles
        - return air ducts and grilles
- location of roof access(es)
- location of all vertical shafts (elevator, garbage, etc)
- space (cm) below doors to apartments from corridor
- space (cm) below internal doors connecting to building periphery
- presence of walls, ceilings, or floors common with adjacent rooms which are not to be included in the test
- underground garage access locations

2.0 ***SUITABILITY FOR TESTING:***

- door size suitable for fan connection
- area adjacent to door suitable for fan installation (including ducting and generator if necessary)
- distribution of traffic flow during testing
- openness of building
- clear route for discharge air to outside
- access to outside for pressure tap installation
- cooperation of tenants and requirement for notification prior to testing
- availability of building superintendent to assist with test preparation and management.
- space for equipment storage between tests.

3.0 ***APPARATUS SPECIFICATIONS AND CALIBRATION:***

All apparatus specifications and calibration shall be in conformance to CAN/CGSB-149.10-M86.Any references to appendices are appendices in this standard.

3.1 *APPARATUS SPECIFICATIONS:*

- The fan or fans must have a total flow capacity capable of producing a pressure difference of at least 50 Pa between the inside and outside of the building envelope.

- The fan shall have a variable speed control or a control damper in series with the fan

- The fan shall be calibrated in air flow units or be connected to an air flow metering system

- The accuracy of air flow measurement shall be ±5% of the measured flow rate.

- The Pressure Measuring Apparatus shall be capable of measuring pressure differences from 0 to at least 50 Pa. It shall have an accuracy of ±2 Pa and shall only be operated within its calibration range.

- Thermometers shall be used to measure temperature in degrees Celsius and it shall have an accuracy of ±1 °C

- A sealing apparatus shall be used to seal the fan into a window or a door

- Pressure Averaging and Damping equipment... a pressure averaging container shall be suitable for connection of not less than four tubes from exterior pressure taps and shall be constructed as described in Appendix A.

- A pressure averaging container shall not be required if capillary tubing, of dimensions corresponding to those in Table A-1 of Appendix A is added to the outside ends of the tubes from the pressure taps on the exterior walls of the building. The tubes from the outside pressure taps shall be manifolded together before connecting to the pressure measuring device.

3.2 CALIBRATION OF APPARATUS:

- All equipment must be calibrated originally. Re-calibrate all measuring devices when any major component is replaced.

- Calibrate the air flow measuring device in accordance with the manufacturer's instructions, or alternately calibrate it in accordance with Appendix B-1 and record this fact.

- When the fan is calibrated, calibrate it in accordance with Appendix B-2

- Calibrate the pressure measuring device in accordance with the manufacturer's instructions or alternately, calibrate it in accordance with Appendix B-3

- If paragraph 7.1.3 of CAN/CGSB-149.10-M86 is to be used to calculate corrected volumetric air flow rates at ambient test conditions, record ambient atmospheric pressure in kPa. A report of the atmospheric pressure from the local weather station <u>if not</u> corrected to sea level should normally be sufficient.

4.0 <u>TEST SETUP:</u>

- Tightly shut all windows and exterior doors and turn off all kitchen and bathroom exhaust fans on test floor and floors above and below (the balancing floors).

- Remove and seal all window air conditioners on test and balancing floors.

- Turn off all fans and air conditioners.

- Close and lock all apartment exterior doors and windows.

- Remove and seal all window air conditioners.

- Close dampers and seal, if possible, all exhaust grilles in the building envelope.

- Open all interior doors to stairwell(s).

- Include in the test all rooms which are heated to more than 10oC except rooms with separate ventilation (e.g boiler room, enclosed furnace rooms, and garages).

- Open all interior doors except to those rooms which are not included in the test.

- For all rooms to be included in the test: inspect opening below doors connecting the rooms to the corridor, remove any obstructions.

- If space under door is less than 2 cm, open doors slightly (2 cm is required for unrestricted air flow from apartment into the corridor).

- Install the test apparatus such that air will be exhausted from the building. To eliminate the possibility of disturbance of the flow entering the nozzle when using a bell-mouthed nozzle apparatus, ensure that no obstructions are placed within one throat diameter away from the center of the nozzle entrance. When using a blower door apparatus, ensure that no obstructions are placed within the width of the door and closer than three quarters of the fan diameter in front of the fan.

- Install fan and flow measuring apparatus following instructions recommended in ASHRAE Fundamentals or CGSB Standard CAN/CGSB - 149.10-M86 (depending on capacity, more than one fan may have to be installed). Ensure that the installation and operation of the fan(s) is/are consistent with calibration.

- Install pressure taps (48mm ID tubing; flattened copper tubing under doors/windows where necessary) at mid-points of four principle exterior walls at least 2m above grade if possible. All the square cut ends must point upwards or downwards.

- Install pressure taps to exterior surfaces of windows at midpoints of four principal exterior walls on test floor and manifold the taps (taps must point upwards or downwards).

- Install pressure taps at center of corridor on test and balancing floors. This may be accomplished by feeding tap through garbage chute.

- Seal garbage chutes.

- In case of top floor testing install pressure tap near center of the roof.

- Protect all interior and exterior pressure taps from the influence of the fan.

- Install pressure monitoring equipment to measure pressure differences between the center of the test floor and:

  (i) Manifolded exterior wall taps of the test floor (reads ΔP_{ew})
  (ii) The center of the floor above the test floor (or the roof) (reads ΔP_a)
  (iii) The center of the floor below the test floor (reads ΔP_b)

- Install plywood panels in a stairwell door on the test floor and on each balancing floor.

- Install fans and flow controllers in each plywood panel (flow direction from corridor to stairwell).

- Locate pressure measuring devices immediately adjacent to corresponding flow controllers.

- Install flow measuring equipment for fan on test floor.

- Seal door panel and all fan connections.

- Seal elevator doors on test floor and on balancing floors.

- If the test area has doors common with adjacent rooms, buildings or tunnels which are not included in the test, then close the doors and seal the openings with tapes or plastic sheets.

- If possible, position two members of test team at the balancing fans located on the floors above and below the test floor. During the test, communicate balancing instructions and data reporting with these members via two-way radios.

5.0 INSPECTION OF INSTALLED TEST EQUIPMENT:

- Visually inspect for any physical defects.

- Visually inspect for proper installation according to manufacturers's specifications.

- Inspect door panel and fan seals.
- Level any devices where required.
- Set all indicators to zero position.

6.0 SUITABILITY OF WEATHER CONDITIONS (On-Site or Nearest Weather Station:

Ideal climatic conditions are:

- temperature differential: $(t_{in} - t_{out}) < 10°K$
- wind speed < 20 km/h

These conditions are hard to obtain under St. John's winter testing conditions therefore the best judgement of the testing team is required to determine if the test may be performed.

7.0 TEST PROCEDURE:

- Turn off ventilation system for building and close fresh air intake dampers.
- Record test date and start time.
- Measure and record:
  - outdoor air temperature, $t_{out,I}$ (°C)
  - indoor air temperature, $t_{in,I}$ (°C)
  - wind speed, $V_{w,I}$ (km/h)
  - wind direction, $V_{d,I}$
  - initial ambient atmospheric pressure, $P_{a,I}$ (kPa)
- Inspect building exterior: make sure all windows and exterior doors are tightly closed.
- Open door to outside from stairwell to which fans have been connected.
- Zero pressure instruments. NOTE: Whenever a pressure reading is taken, it should be taken for a long enough time to be within ±1 Pa of its stable value.
- With all fans turned off, seal the pressurization fan opening(s) and record the pressure differences across the envelope between the test floor and exterior wall, floor above and floor below. $\Delta P_{ew,I}$, $\Delta P_{a,I}$ and $\Delta P_{b,I}$, respectively.

- Remove fan seal(s) and switch fan(s) on.

- Adjust air flow to produce a pressure difference across the exterior wall, ΔP_{ew}, of approximately 50 Pa.

- When the building to be tested has walls, ceilings or floors common with rooms that are not included in the test but which are heated to more than 10oC, make provision to reduce the pressure in the adjacent rooms to match the pressure in the rooms under test at each test point. In other words adjust the pressure in any adjacent rooms to achieve a zero pressure difference across common partitions.

- Adjust balancing fans to give 0 ±1 Pa pressure difference across floor separations (Note: continuous adjustments may be required to maintain ΔP_{ew} at desired level while balancing is in progress).

- Allow pressures and flows to stabilize.

- Measure and record:
  - all pressure differences (ΔP_{ew}, ΔP_a, ΔP_b)
  - air flow rate, Q_m (L/s) at fan
  - air temperature at fan intake, t_{fan} (°C)

- Adjust pressure difference across exterior wall to approximate 40 Pa. Re-balance and repeat measurements.

- Repeat for ΔP_{ew} of approximately 30, 20, 15 and/or 10 Pa (in that order).

- For each test the measured value of the pressure difference must be within ±2.5 Pa of the above specified pressure difference.

- Switch fan(s) off, seal the fan(s) and record the final pressure differences ($\Delta P_{ew,F}$, $\Delta P_{a,F}$, $\Delta P_{b,F}$).

- Note time of test completion.

- Measure and record:
  - outdoor air temperature, $t_{out,F}$ (°C)
  - indoor air temperature, $t_{in,F}$ (°C)
  - wind speed, $V_{w,F}$ (km/h)
  - wind direction, $V_{d,F}$
  - ambient atmospheric pressure, $P_{a,F}$ (kPa)

- Re-inspect building exterior: make sure all windows and exterior doors are still tightly closed (note any exceptions: repeat test if necessary; ideally, windows and doors should be continuously monitored while the test is in progress).

- Repeat test with one balancing fan on floor above turned off and sealed.
- Proceed as above balancing the other floor.
- Record the pressure differences generated across the two floors (ΔP_x).
- Record the flow measured at the test floor fan Q_{ax} where x= a,b depending on which component was unbalanced. (Q_{ax} is the combined leakage of the test floor exterior wall and the unbalanced floor).
- Repeat for fan on floor below.
- This procedure is repeated for each floor of the building to be tested.

8.0 CALCULATIONS:

8.1 TEST ENVELOPE AREA:

When determining the area of the test envelope, the interior dimensions of the test space were used. All ceilings (flat or sloping), floors and walls (including door and windows) that were correspondingly below, above and adjacent to the test envelope were included. This included:

- ceilings below unheated attics and roofs.
- basement floors and floors above unheated basements, cellars, crawl spaces, cold storage rooms, garages and floors exposed to the ambient environment.
- exterior above grade and below grade walls and walls adjacent to unheated areas.

The area of the test envelope is considered to be the total area of all eligible ceilings, floors and walls.

In cases where a middle floor is being tested with both balancing floor fans in operation, the area in question is considered to be the area of the exterior walls. In a case where a middle floor is being tested with one balancing fan turned off, the area in question is considered to be the area of the exterior walls of the storey plus the area of the unbalanced partition (ceiling or floor).

8.2 *TEST ENVELOPE VOLUME:*

Include in the test envelope interior volume is the total volume of all rooms which are heated to more than 10°C except rooms with separate ventilation. (eg boiler room, enclosed furnace rooms and garages.)

8.3 *DATA TO BE RECORDED:*

Prior to testing, with the fans turned off and sealed, the following were measured and recorded:

- Outdoor Air Temperature $t_{out,I}$ [oC]
- Indoor Air Temperature $t_{in,I}$ [oC]
- Wind Speed $V_{w,I}$ [km/h]
- Wind Direction $V_{d,I}$
- Ambient Atmospheric Pressure $P_{a,I}$ [kPa]

- Pressure Differences Between test floor and:
  - Exterior wall $\Delta P_{ew,I}$
  - Floor above $\Delta P_{a,I}$
  - Floor below $\Delta P_{b,I}$

For pressure differences of 50, 40, 30, 20 and 10 Pa measured across the manifolded exterior wall taps of the test floor (ΔP_{ew}) the following were measured and recorded: $\Delta P_{ew,i}$, $\Delta P_{a,i}$, $\Delta P_{b,i}$, $Q_{m,i}$, $t_{fan,i}$, where

- ΔP's are the pressure differences (kPa)
- $Q_{m,i}$ is the air flow rate at fan (L/s)
- $t_{fan,i}$ is the air temperature at fan (°C)

After testing with the fans turned off and sealed $t_{out,F}$, $t_{in,F}$, $V_{W,F}$, $V_{D,F}$, $P_{a,F}$, $\Delta P_{ew,F}$, $\Delta P_{a,F}$, $\Delta P_{b,F}$ were measured and recorded.

8.4 DATA CORRECTION:

Verify that data recorded meets CAN/CGSB-149.10-M86.

In this testing procedure, three cases existed:

- CASE I - All three fans turned on
- CASE II - Upper balancing fan turned off
- CASE III - Lower balancing fan turned off

8.41 CASE I - All three fans turned on:

In this case ΔP_a and ΔP_b should be 0 $\pm$ 1 Pa according to the testing standard. As such their influence is considered to be insignificant. $Q_{ew,i}$, the flow rate through the exterior wall, is measured at the fan on the test floor. ΔP_{ew} is the measured pressure difference across the exterior wall. Both $Q_{ew,i}$ and $\Delta P_{ew,i}$ are corrected to reference conditions in accordance to CAN/CGSB-149.10-M86. In order to correct pressure difference readings the base exterior wall pressure difference is first determined by:

$$\Delta P_{ew,b} = (\Delta P_{ew,I} + \Delta P_{ew,F}) \; / \; 2$$

This base value is a constant which is used to correct each individual pressure difference reading as follows:

$$\Delta P'_{ew,i} = \Delta P_{ew,i} - \Delta P_{ew,b}$$

Each air flow reading needs to be corrected for differences in the indoor, outdoor, and calibrated air temperatures in accordance to procedures presented in CAN/CGSB-149.10-M86. The measured air flow rates (Q_m) needs to be corrected for the differences in air density between:

(a) The reference and calibration conditions, and

(b) The indoor air moving out through the measuring device and the outdoor air moving in through the leaks in the building envelope. (the air flow of interest)

Assuming that indoor and outdoor atmospheric pressures are essentially the same, the measured air flow rate for each reading can be corrected for the differences in air density by using the following equation.

$$Q'_{ew,i}=Q_{ew,i}\frac{(t_o+273.15)}{(t_i+273.15)}\sqrt{\frac{P_c(t_i+273.15)}{P_a(t_c+273.15)}}$$

Where $Q'_{ew,i}$ is the corrected outside volumetric air flow rate into the building through the exterior wall at outdoor test conditions [L/s]. This may be corrected to reference conditions (t_i = t_o = 20 oC ; P = 101.325 kPa) by applying the following formulae.

$$(Q_{ew,r})_i=Q'_{ew,i}\sqrt{\frac{P_a(20+273.15)}{101.325(t_o+273.15)}}$$

$$\Rightarrow (Q_{ew,r})_i=Q_{ew,i}\sqrt{\frac{(t_o+273.15)P_c(20+273.15)}{(t_i+273.15)101.325(t_c+273.15)}}$$

Where:

$(Q_{ew,r})_i$ - is the corrected outside air flow rate into the building through the exterior wall under reference conditions. (L/s)

t_0 - is the outside air temperature (°C)

t_i - is the indoor air temperature (°C)

t_c - is the calibration air temperature (°C)

P_c - is the calibration atmospheric pressure (kPa)

P_a - is the ambient atmospheric pressure (kPa)

$Q_{ew,i}$ - the flow rate through the exterior wall as measured at the fan on the test floor. (L/s)

Using the ΔP and Q values <u>corrected to reference conditions</u> the procedure outlined in Can/CGSB - 149.10-M86 was used to calculate the following:

i) Regression Coefficients (C and n) and the correlation coefficient (r) of the fit of the data.

ii) The percent difference between the estimated air flow $(\hat{Q}_{ew,r})_i$ and the measured airflow $(Q_{ew,r})_i$ at each measured pressure difference.

iii) The relative standard error of $(\hat{Q}_{ew,r})_i$

iv) The standard error for the regression coefficient.

If the data has been collected at N corrected pressure differentials ΔP_1, ΔP_2.. ΔP_n giving corrected air flow rates Q_1, Q_2,..Q_n respectively, the following procedures should be used to fit the equation of the form $Q=C\Delta P^n$ to the data and to determine the correlation coefficient (r) and the various other measures of goodness of fit. To do this the following procedure was followed:

The following quantities were determined:

$$S_{xx}=(\sum_{i=1}^{N}Q_i^2)(\sum_{i=1}^{N}Q_i^2(\ln\Delta P_i)^2)-(\sum_{i=1}^{N}Q_i^2\ln\Delta P_i)^2$$

$$S_{yy}=(\sum_{i=1}^{N}Q_i^2)(\sum_{i=1}^{N}Q_i^2(\ln Q_i)^2)-(\sum_{i=1}^{N}Q_i^2\ln Q_i)^2$$

$$S_{xy}=(\sum_{i=1}^{N}Q_i^2)(\sum_{i-1}^{N}Q_i^2(\ln\Delta P_i)(\ln Q_i))-(\sum_{i=1}^{N}Q_i^2\ln\Delta P_i)(\sum_{i=1}^{N}Q_i^2\ln Q_i)$$

The best fit estimates of the regression (n and C) are calculated by:

$$C=\exp\left[\frac{\sum_{i=1}^{N}Q_i^2\ln Q_i}{\sum_{i=1}^{N}Q_i^2}-n\frac{\sum_{i=1}^{N}Q_i^2\ln\Delta P_i}{\sum_{i=1}^{N}Q_i^2}\right]$$

$$n=\frac{S_{xy}}{S_{xx}}$$

From the flow coefficient C and the flow exponent (n), the infiltration rate can be estimated by $Q=C\Delta P_{ew}^{n}$. The correlation coefficient (r) is calculated by:

$$r=\sqrt{\frac{(S_{xy})^2}{(S_{xx}S_{yy})}}$$

The percent difference between the estimated air flow $(\hat{Q}_{ew,r})_i$ and the measured airflow $(Q_{ew,r})_i$ at each measured pressure difference can then be determined. The estimated air flow $(\hat{Q}_{ew,r})_i$ can be calculated from the regression line for each corrected pressure difference $(\Delta P'_{ew,i})$ as defined by:

$$(\hat{Q}_{ew,r})_i = C(\Delta P'_{ew,i})^n$$

The relative error of each estimate can be calculated by:

$$\frac{abs[(\hat{Q}_{ew,r})_i - (Q_{ew,r})_i]}{(Q_{ew,r})_i}$$

The standard error of estimate of $(Q_{ew,r})_i$ on $\Delta P_{ew,i}$ is:

$$S_{y/x} = \sqrt{\frac{S_{yy} - nS_{xy}}{(\sum_{I=1}^{N} Q^2_{ew,i})(N-2)}}$$

Thus the relative standard error of $(\hat{Q}_{ew,r})_i$ at ΔP = 10 Pa is:

$$\frac{S_{y/x}}{\sqrt{\sum_{i=1}^{N} Q_{ew,i}{}^2}} \sqrt{1 + \frac{[(\sum_{i=1}^{N} Q^2_{ew,i}) \ln 10 - \sum_{i=1}^{N} Q^2_{ew,i} \ln \Delta P_{ew,i}]^2}{S_{xx}}}$$

The standard error for the regression coefficient can be calculated as follows:

$$S_o=S_{y/x}\sqrt{\frac{\sum_{i=1}^{N}Q^2{}_{ew,i}(\ln\Delta P_{ew,i})^2}{S_{xx}}}$$

Whence the standard error range for C is between $\exp(\ln C+S_0)$ and $\exp(\ln C-S_0)$

$$S_i=\frac{S_{y/x}}{\sqrt{\frac{S_{xx}}{\sum_{i=1}^{N}Q^2{}_{ew,i}}}}$$

Whence the standard error range for n is $n \pm S_1$;

If any of the following conditions are <u>not</u> met, the test must be repeated.

a) $0.5 \leq n \leq 1.00$

b) $r > 0.990$

c) for all i

$$\frac{abs[(\hat{Q}_{ew,r})_i-(Q_{ew,r})_i]}{(Q_{ew,r})_i}<0.06$$

d) relative standard error of $(\hat{}Q_{ew,r})_{10}$ is less than 0.07

8.42 CASE II - Upper balancing fan turned off:

During this test the fan on the balancing floor above is turned off while the fan on the balancing floor below remains running. In this way the pressure of the test floor and the floor below are balanced (ie $\Delta P_b = 0 \pm 1$ Pa). Except for this difference, the test in CASE II is carried out in the same manner as the test for CASE I.

The pressure difference across the partitions - $(\Delta P_{ew,i})_a$, $(\Delta P_{a,i})_a$, $(\Delta P_{b,i})_a$ - are measure. The subscript 'a' indicates that the fan above is turned off.

The fan flow on the test floor - $(Q_{m,i})_a$ - is recorded. This is the combined leakage of the test apartment exterior wall and the unbalanced partition (ceiling).

Using the same procedures stipulated in CASE I, $(\Delta P_{ew,i})_a$ can be corrected to get $(\Delta P'_{ew,i})_a$. This represents the corrected pressure difference across the exterior wall of the test floor while $(Q_{m,i})_a$ was measured.

To determine the leakage through the ceiling the uncorrected flow rate Q_{ew} from CASE I is plotted against the corrected pressure difference across the exterior wall $\Delta P'_{ew}$ in CASE I. On the same graph, the uncorrected flow rate $(Q_{m,i})_a$ from this case is plotted against the corrected pressure difference across the exterior wall while $(Q_{m,i})_a$ was being measured.

Q_{ew} vs $\Delta P'_{ew}$ from the previous test (wall only)

Q_{mX} vs $(\Delta P'_{ew})_{mX}$ from the current test (wall and ceiling)

This in effect plots uncorrected leakage against corrected pressures. Measured leakage values are regularly corrected for differences in the air densities between:

(a) the reference and calibration conditions
(b) indoor air moving out through the measuring device, outdoor air moving in through the leaks

Q_{ew} measures only the outdoor air moving in through the external wall. It must be corrected for both these factors.

Q_{mx} measures the combined air flow into the space through the exterior walls and through the unbalanced partition (ceiling). The flow through the exterior wall would need to be corrected for both factors but the flow through the ceiling would only need to be corrected for the first factor.

By plotting the uncorrected Q values, it is possible to do a straight subtraction (Q_{mx} - Q_{ew}) to get the uncorrected flow associated with the unbalanced partition (ceiling).

This may be achieved by plotting a best fit curve through each set of points and then subtracting the Q values at the appropriate ΔP values. The best fit curve can be estimated by assuming that the uncorrected flow rates are related to the corrected pressure differentials in the same manner as the corrected flow rates. (ie. Q would be related to ΔP by the following equation: $Q = (C)\Delta P^n$). In this way the flow at any pressure difference could be determined numerically instead of by graphical approximation.

To determine the best fit equation the uncorrected leakage values and the corrected pressure differences could be used to determine the regression coefficients, "n" and "C", according to the same procedures used in CASE I. Two curves would result: (assume $_{w}$ = wall and $_{wc}$ = wall and ceiling)

$$Q_w = C_w \Delta P_w^{n(w)}$$
$$Q_{wc} = C_{wc} \Delta P_{wc}^{n(wc)}$$

The ΔPs can be considered to be the independent variable and are considered to be the same. Thus the equations can be combined. To determine the uncorrected flow rate for the ceiling only...

$$Q_C = Q_{WC} - Q_W = C_{WC}\Delta P_{WC}^{n(WC)} - C_W\Delta P_W^{n(W)}$$
$$\Longrightarrow Q_C = C_{WC}\Delta P_{WC}^{n(WC)} - C_W\Delta P_W^{n(W)}$$

This equation can then be used to determine the uncorrected leakage value through the ceiling at specific values of ΔP.

In this manner, the combined leakage of the test floor exterior wall and the unbalanced ceiling can be compared directly to the leakage rate for the exterior wall which was determined in CASE I. The difference between the two at any particular corrected external wall pressure difference can be attributed to the leakage through the unbalanced partition (ceiling) $(Q_{a,i})_a$ at that pressure difference.

It must be remembered, however, that at the same time the pressure difference across the external wall was being measured, the pressure difference between the test floor and the floors above and below were also being measured. The uncorrected flow rate determined for the ceiling at a particular corrected external wall pressure difference is therefore the same flow rate which occurs for the corresponding uncorrected pressure difference between the two floors. In this manner, uncorrected Q an ΔP values are obtained for the ceiling.

The flow rate and pressure differences across the unbalanced partition is corrected for pressure, temperature, and air density differences so that the regression and the correlation coefficients for the characteristic leakage through the unbalanced partition (ceiling) can be determined using methods similar to those presented in CASE I.

Pressure is corrected by determining the base pressure correction.

$(\Delta P_{a,b})_a = ((\Delta P_{a,I})_a + (\Delta P_{a,F})_a) / 2$

and then correcting each reading for the base...

$(\Delta P'_{a,i})_a = (\Delta P_{a,i})_a - (\Delta P_{a,b})_a$

Assuming the density of the air is the same between floors, Q only needs to be corrected for the differences in air density between the reference condition and the calibration condition, the following correction method is therefore followed:

The true air flow through the measuring device is :

$$Q_i = Q_m \sqrt{\frac{\rho_c}{\rho_i}}$$

Where: Q_m is the measured flowrate
ρ_c is calibration air density
ρ_i is indoor air density

but,

$$\rho = \frac{P}{R(t+273.15)}$$

$$\Rightarrow Q_i = Q_m \sqrt{\frac{P_c}{R(T_c+273.15)} \frac{R(t_i+273.15)}{P_i}}$$

$$\Rightarrow Q_i = Q_m \sqrt{\frac{P_c(t_i+273.15)}{P_i(t_c+273.15)}}$$

Q_i is the corrected inside volumetric air flow rate into the space at inside test conditions.

To correct to reference conditions:

$$Q_r = Q_{1i}\sqrt{\frac{P_a(20+273.15)}{(101.325)(t_i+273.15)}}$$

$$Q_r = Q_m\sqrt{\frac{P_c(t_i+273.15)P_a(20+273.15)}{P_i(t_c+273.15)101.325(t_i+273.15)}}$$

$$Q_r = Q_m\sqrt{\frac{P_c(20+273.15)}{101.325(t_c+273.15)}}$$

These corrected P and Q values for infiltration through the unbalanced partition would then be used to determine the regression and correlation coefficients for the best fit curve. The same checks used in CASE I are used to determine if the data from the test run falls within the standards stipulated by CAN/CGSB-149.10-M86. If any of the conditions are not met, the test must be repeated.

8.43 <u>CASE III - The fan on the balancing floor below is turned off:</u>

During this test the fan on the balancing floor below the test floor is turned off while the fan on the balancing floor above remains on. The analyses for this case is exactly the same as the analyses applied to CASE II.

In the case where a top floor or a ground floor with no basement is tested (ie. no upper or no lower balancing fan) analyses is performed as in CASE I. Care must be taken, however, in determining the area of the test envelope.

Once all the runs have been completed and the data has been verified, data analyses can begin.

8.5 *EQUIVALENT AND NORMALIZED LEAKAGE AREA:*

EQUIVALENT LEAKAGE AREA (ELA) is a calculated value used for comparison. It is based on the assumption that the leakage openings in the building envelope can be combined and represented by a singe sharp-edged orifice. ELA can be calculated as follows:

where:

$$ELA = .001157\sqrt{\rho_r} * C * 10^{n-0.5}$$

- ELA is in units of m^2
- ρ_r is the air density at reference conditions
  $\rho_r = 1.204097$
- C and n as determined previously

To compare ELA of different areas or of different buildings, it is more informative to normalize the leakage area. Normalized Leakage Area (NLA) can is calculated by:

$$NLA = \frac{ELA}{Test.Envelope.Area} \times 10000$$

where:

- NLA is in units of cm^2/m^2
- ELA is in units of m^2
- Area of the test envelope is in units of m^2

APPENDIX IV

CALCULATIONS AND ANALYSIS

BUILDING I - AIR TIGHTNESS TESTING

APPENDIX IV
CALCULATIONS AND ANALYSES
BUILDING I - AIR TIGHTNESS TESTING

The objective of the testing was to determine the component air leakage of the lower slabs, the upper slabs, and the exterior walls of the test building on a per storey bases. A testing setup procedure was established with the objective of minimizing the testing which was required while maximizing the results obtained. Thirteen physical air leakage tests were to be conducted and as a result data for twenty one tests would be obtained.

Given that six Blower Door (fans) were available for use, a fan setup system was needed. Based on drawing reviews, building visits, calculated building volumes, and information obtained from the CMHC document entitled " Establishing The Protocol For Measuring Air Leakage And Airflow Patterns In High-Rise Apartment Buildings", a fan setup plan was established to maximize the efficient use of the units. Although TEST 1g (page 6) AIR TIGHTNESS VALUES OF EXTERIOR WALLS AND FLOOR/CEILING SEPARATION OF INDIVIDUAL STOREYS, outlined in the CMHC protocol, only utilized a variable speed fan with a capacity of 0-1300 L/s on the test story, the established fan setup plan had a variable speed capacity of 0-3000 L/s available on the test story.

When testing was originally proposed, it was expected that an upper limit of a minimum of 30 Pa could be achieved. With an increase in fan capacity of 130% it was felt that each level could be tested to a minimum upper limit of 50 Pa. The objective therefore was set to generate a pressure differential of 50 Pa across the exterior walls as indicated by testing standard CAN/CGSB-149.10-M86 - Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method.

When the test was actually performed, however, it was found that it was not possible to generate sufficiently high pressure differentials to meet this objective. Subsequently the testing sequence was not followed. The maximum pressures which were generated ranged from 20 to 30 Pa. Between each test, the test team met to analyze the results and to attempt to determine why the desired pressures were not generated. In each case it was determined that the fan capacity being utilized was sufficient (130% or greater) and the setup was sufficient.

It was verified that the elevators were sealed; the garbage chute was sealed at the base and at each opening; the stairwell doors were sealed; all corridor ventilation louvres were sealed; the elevator exhaust fan was turned off and sealed; and the fresh air supply fan was turned off and sealed. Upon re-examination of the mechanical system some errors were found and corrected but this did not solve the problem. Throughout the day other reasonable, or what was thought to be reasonable, solutions to the problems of low pressures were attempted. Unfortunately nothing proved effective.

Before starting the second day of testing, the project team met and concluded that the problem must be with the mechanical system. Each story had the following ventilation system elements: 4 supply grills from the central system and 40 exhaust fans. It was felt that the dampers were inoperable and were causing problems with air leakage.

Before starting the re-testing, all 44 supply and exhaust grills were sealed. The results of the testing were the same. Two levels were tested and the cause of the low pressures was still not identified.

At this point, in an effort to obtain at least some usable data, four adjacent apartment units on the fifth level, which happened to be vacant, were tested individually. Balancing pressures in adjacent apartments were maintained. Since access to the apartments above and below was not available, the upper and lower slabs were not balanced.

The data which was obtained was then analyzed. Due to the limited amount of data available, it was only possible to direct the data analyses towards establishing the air leakage for the exterior walls of the building.

During the story by story testing, although the desired pressures were not obtained, the testing procedure was followed as far as maintaining a zero pressure differential between the test story and the levels above and below. Consequently, it was assumed that there was zero air flow through the slabs in the story by story data. Each one of the tests conducted met the standard.

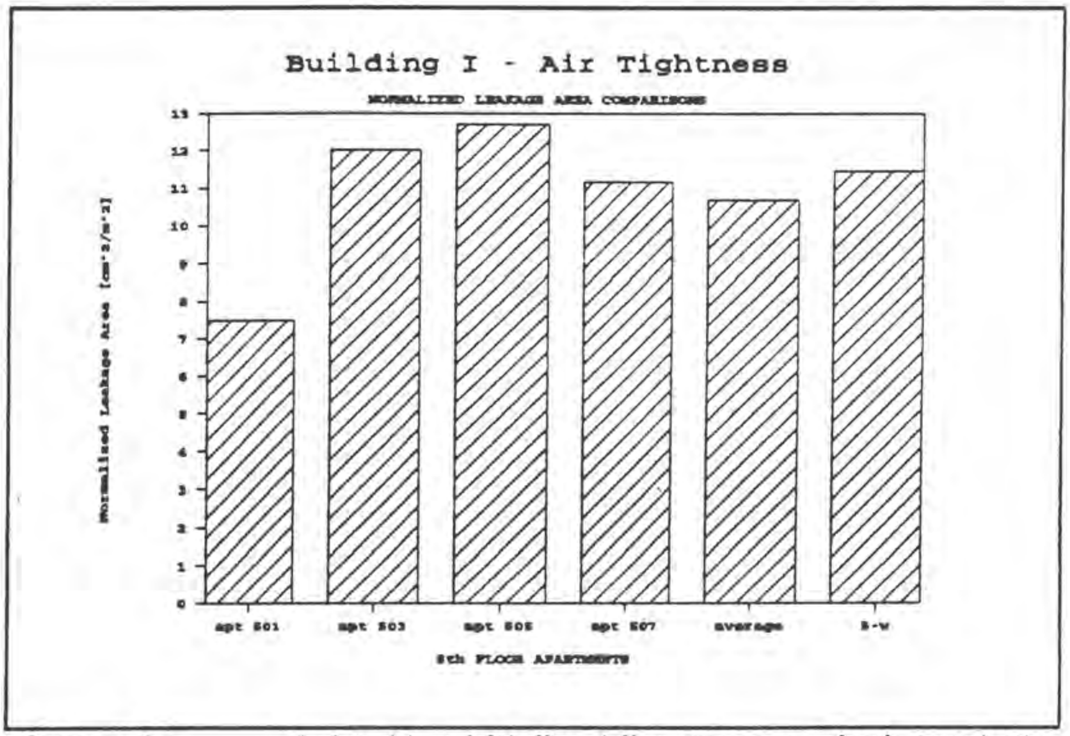

Figure 1: The 1st, 4th, and 5th floors' flows compare very closely to each other but are quite different from the 2nd and 3rd floors' flows.

The flows on each story at an exterior pressure differential of 10 Pa were then normalized by dividing each by the associated exterior wall area. These normalized flow rates were then graphed and appear in Figure 1.

In studying Figure 1, it becomes evident that the leakage rates vary from story to story. At first glance, the normalized flow rate for the first level is very low when compared to the others. This is due to the fact that the first level also had the influence of the lower slab, which is much tighter, included. In such a case, the additional flow was far outweighed by the additional area, and so the normalized flow decreased. In order to provide better comparison between stories, the influence of the slab had to be removed.

The building's structure is comprised of a "lift slab" system. The between storey separations therefore consist of solid concrete slabs. Since the between storey separations were slabs, it was assumed that the between storey leakage would be minimal.

Since no data was available on which to base an estimate for slab leakage, it was assumed that the leakage through the slab would correspond to the same values indicated in the CMHC protocol. For that reason it was assumed that the slab leakage rate would be comprised of 5% of the total leakage for an individual storey.

Therefore, based on this assumption, 90% of the actual flows measured for each apartment and 95% of the flow measured on the first level was assumed to be associated with flow through the exterior walls.

When the effect of the slab was eliminated from the first level's data, as indicated by the bar labelled "1st Floor*", it was found that the first, fourth, and fifth levels all had very similar normalized leakage rates. It also became evident, however, that the normalized leakage rates for the second and third levels varied considerably from the normalized leakage rate of the other stories.

An alternative method used to compare air tightness of the exterior walls was to calculate the normalized leakage area of each level's exterior walls. These results are illustrated in Figure 2. Again the comparison of the results indicates that the air tightness of the first, fourth, and fifth levels are very similar. These results also indicated that the air tightness for the second and third levels varied considerably from the air tightness of the other stories.

Next the air tightness values of the exterior walls of the four apartments were compared.

The four apartments which were tested were all adjacent and on the fifth story. This represented half the apartments on the floor. As indicated previously, the floor and ceiling slabs were not balanced during the testing and so it was assumed that 5% of the measured flow would be attributed to each slab.

During the testing, it was not possible to balance the corridor walls. Since the apartment doors were sealed with the test fans, any leakage through the corridor walls could only occur through the walls themselves. Since there was no data available on which to base an estimate, the air flow leakage through

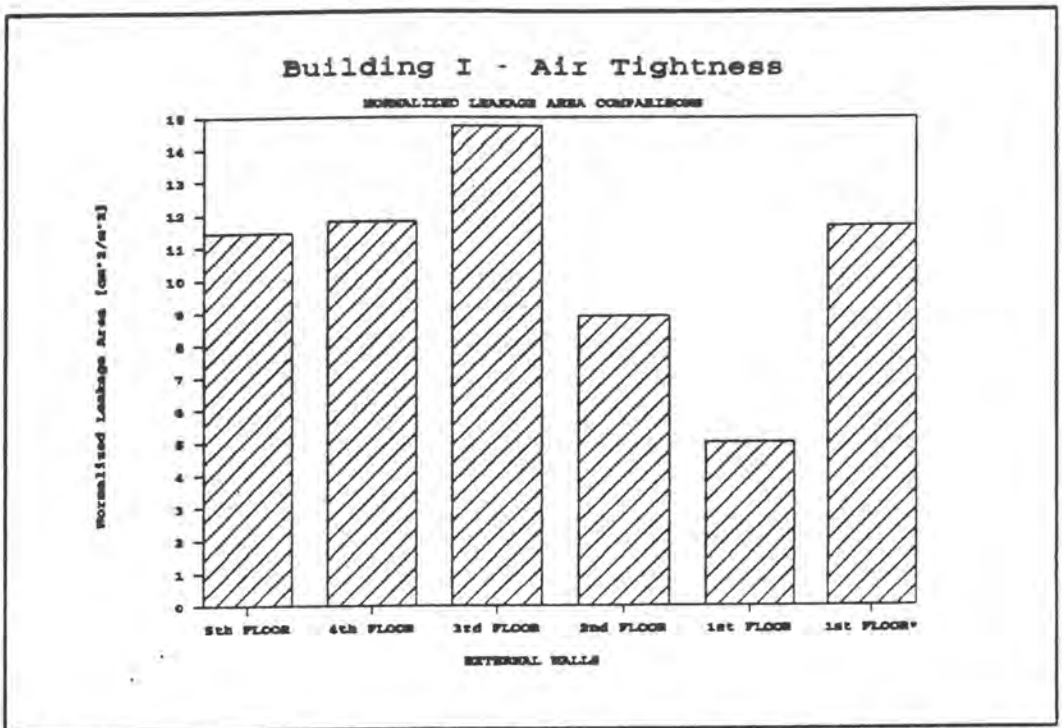

Figure 2: Comparison using normalized leakage areas echoes the results determined using normalized flow rates.

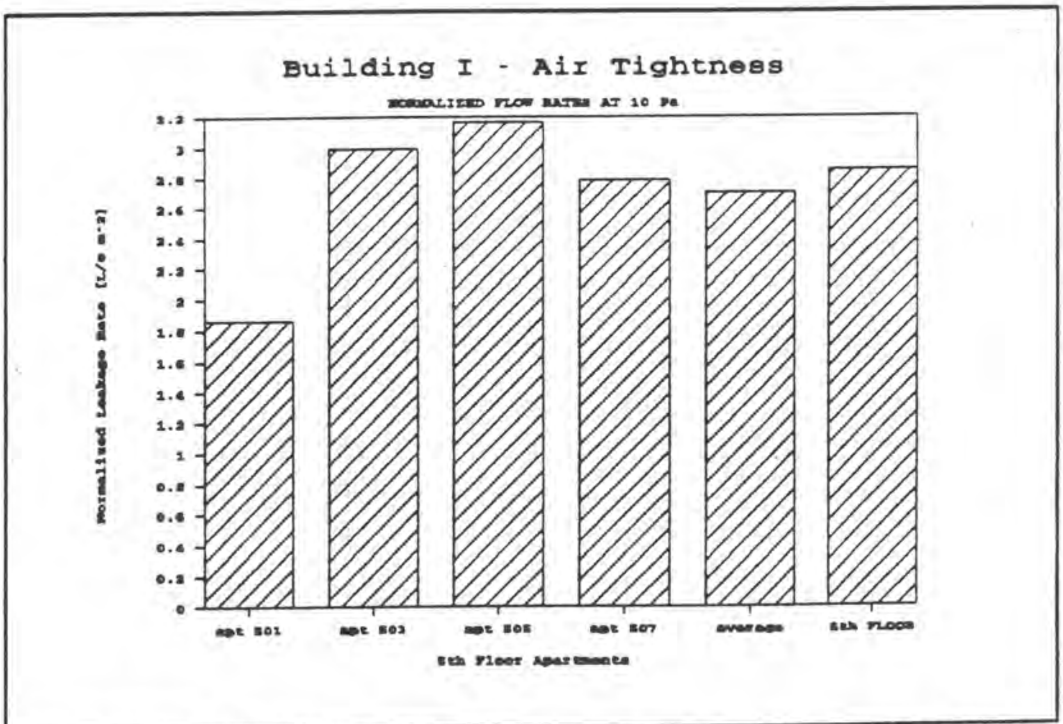

Figure 3: The average determined for the apartments compares well with the normalized flow already determined for the 5th floor.

these walls was not separated from the measured flows.

Adjacent walls to neighbouring apartments were balanced at a zero pressure differential and the flow through these walls was considered to be zero.

Given these factors, 90% of the flows measured for each apartment was considered to be through the exterior walls of the apartment.

The normalized flow rates at an exterior pressure differential of 10 Pa was determined for each apartment. These were averaged and compared to the normalized flow rate already determined for the fifth level. The results of this appear in Figure 3. It is evident that the average normalized flow determined from half the apartments on the story corresponds quite closely to the normalized flow determined for the story as a whole.

This indicates that the assumption of a 5% slab leakage is quite reasonable in this case. These results are echoed when normalized leakage areas were determined and compared in Figure 4.

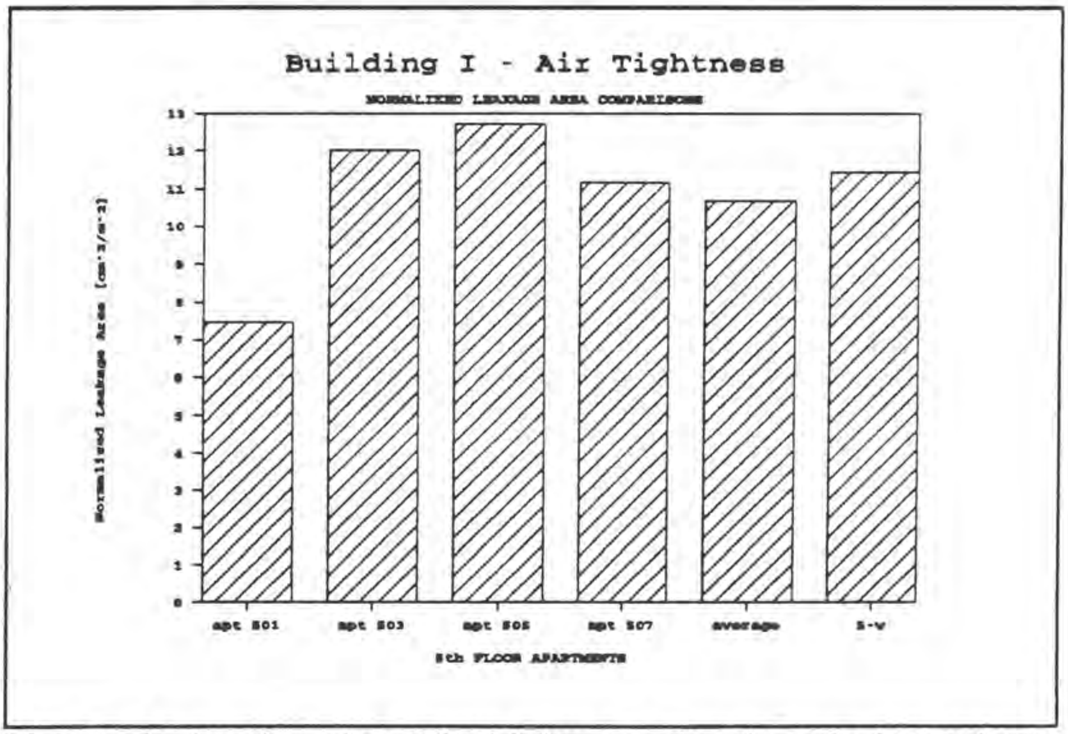

Figure 4: Comparison using normalized leakage area echoes the results determined using normalized flow rates.

As a final step in the analyses, the corrected flows associated with each story or apartment were used to determine the flow coefficient (C) and the flow exponent (n). These were used to generate a representative equation relating the exterior walls' pressure differential to the flow through the component. In each case, the standards set out by CAN/CGSB-149.10-M86 were met. Figures 5 and 6 present the logarithmic representation of these normalized equations.

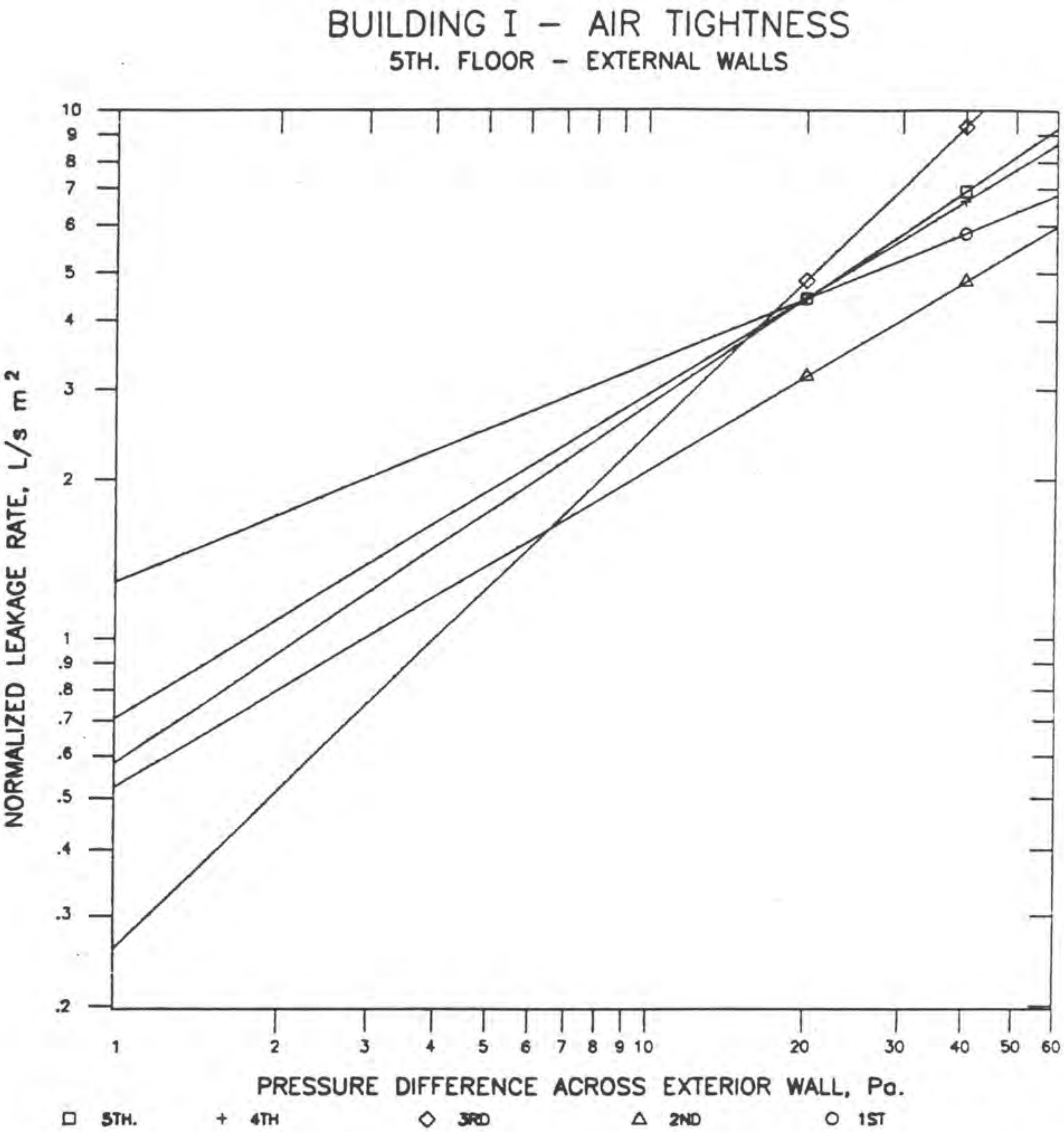

FIGURE 5: THIS CLEARLY SHOWS HOW SOME FLOOR'S LEAKAGE RATES ARE QUITE CLOSE TO EACH OTHER WHILE OTHER FLOOR'S LEAKAGE RATES VARY CONSIDERABLY.

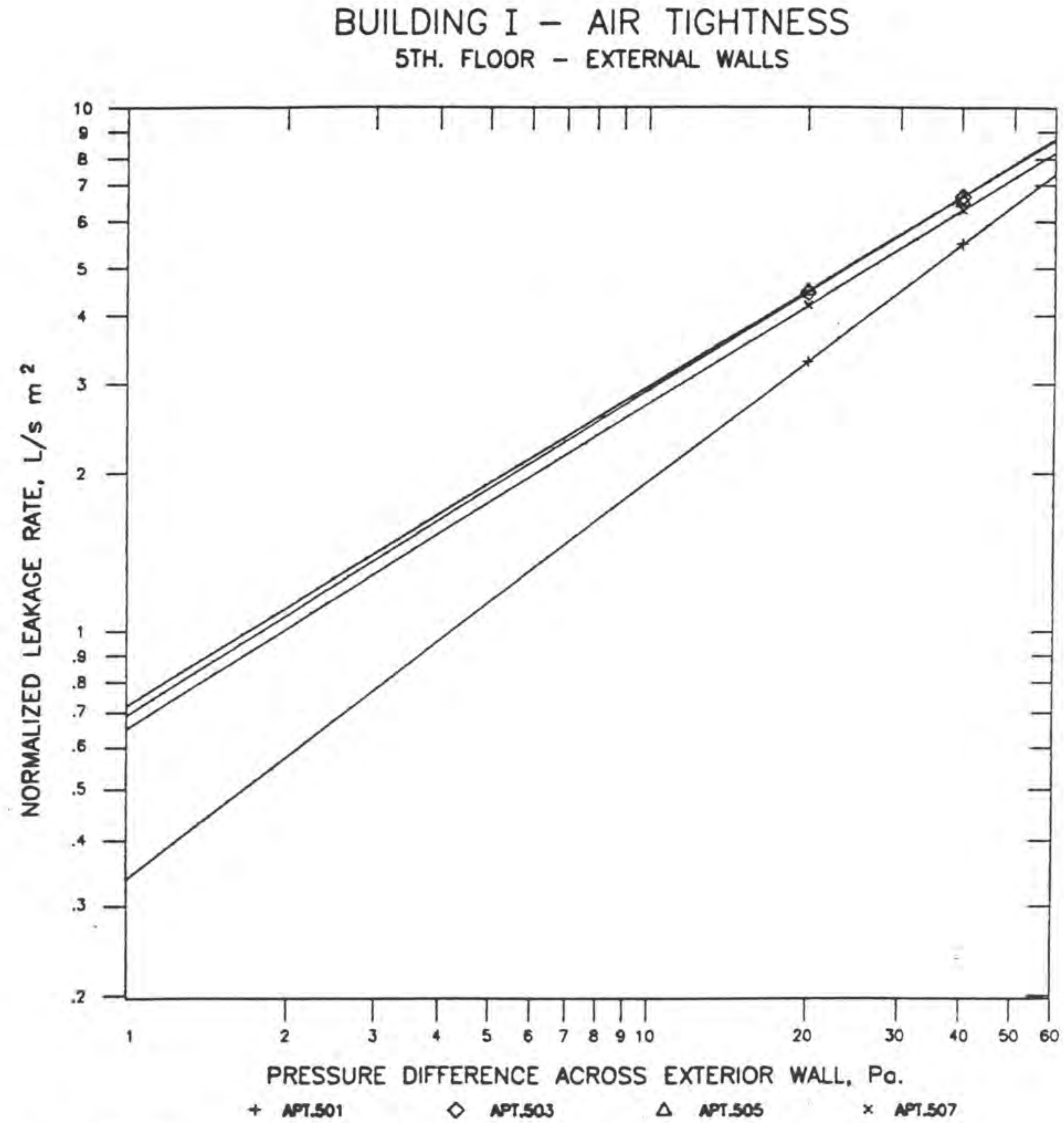

FIGURE 6: THIS INDICATES THAT EVEN ON THE SAME FLOOR, SOME GREAT VARIANCE MAY OCCUR WITHIN THE SAME BUILDING COMPONENT.

Figure 5 clearly shows how close the flows through the first, fourth, and fifth levels are to each other. Figure 5 also shows the great variability which exists between the flows associated with the second and third levels and the flows associated with the other levels.

Figure 6 shows how closely related the individual apartment flows are to the flow determined for the entire story. It also demonstrates the variability which can exist within a single building component. This is indicated by the great difference between the flows associated with apartment 501 and the flows associated with the other apartments.

These figures demonstrate that although the assumptions taken about the slabs seem to be relatively valid in these cases, there is a great amount of variability which can exist within an individual building component (in this case the exterior walls). This indicates that general assumptions may not always be valid when similar building components are compared.

DATA TABLES:

Table 1 summarizes the calculations involved in determining the flow coefficient (C) and the flow exponent (n) for various tests. A validity check is performed to verify if the standard is met. An explanation of the calculations involved appear in Appendix III.

TABLE 1: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING 1

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 1-w,ls

ALL FANS ON

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
28	0	0	22	3014.098	28	0	0	3621.439
24	0	0	22	3476.076	24	0	0	3300.492
18	0	0	21.5	2913.518	18	0	0	2768.696
14	0	0	21	2501.790	14	0	0	2379.453
10	0	0	21	2014.272	10	0	0	1915.775
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -6 WIND VELOCITY WNW 22 km/h
ATMOSPHERIC PRESSURE 97.8 kPa

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

envelope area: 1544.19 [m^2]

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C	
13114824	3.332204	43701278	1.5E+08	8.194626	1.1E+08	8.8E+08	3.6E+08	Sxx = 1.8E+14
10893240	3.178053	34619328	1.1E+08	8.101826	88255209	7.2E+08	2.8E+08	Syy = 6.8E+13
7665679.	2.890371	22156663	64040994	7.926131	60759186	4.8E+08	1.8E+08	Sxy = 1.1E+14
5661799.	2.639057	14941812	39432300	7.774626	44018372	3.4E+08	1.2E+08	Syx= 9.533065
3670195.	2.302585	8450936.	19459001	7.557877	27738887	2.1E+08	63871148	n = 0.614072
0	0	0	0	0	0	0	0	C = 468.6283
0	0	0	0	0	0	0	0	r = 0.999917
0	0	0	0	0	0	0	0	ELA= 0.773687 m^2
								NLA= 5.010310 cm^2/m^2
SUMS: 41005746		1.2E+08	3.8E+08		3.3E+08	2.6E+09	9.9E+08	

RELATIVE STANDARD ERROR (%):0.359096

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
3626.509	0.139993	--------	0
3298.971	0.046060		0
2764.758	0.142241		0
2369.378	0.423404		0
1927.086	0.590433	REL ERR	0
0	0		0
0	0		0
0	0	--------	0
		n	0
		r	0
		rel std err	0

			0

THIS TEST MEETS CAN/CGSB-149.10-M86

ALL FANS ON

CORRECTED PRESSURE DIFF	CORRECTED FLOW RATE	SLAB CORRECTION 95 % OF FLOW
28	3621.439	3440.367
24	3300.492	3135.467
18	2768.696	2630.261
14	2379.453	2260.480
10	1915.775	1819.986
0	0	0
0	0	0
0	0	0

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

envelope area: 0 [m^2]

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C	
11036129	3.332204	39440403	1.3E+08	8.143333	96385550	7.8E+08	3.2E+08	Sxx = 1.5E+14
9831156.	3.178053	31243944	99294936	8.050533	79146053	6.4E+08	2.5E+08	Syy = 5.5E+13
6918275.	2.890371	19996388	57796997	7.874838	54480304	4.3E+08	1.6E+08	Sxy = 9.0E+13
5109773.	2.639057	13484985	35587650	7.723332	39464485	3.0E+08	1.0E+08	Syx= 9.056412
3312351.	2.302585	7626970.	17561748	7.506584	24864444	1.9E+08	57252498	n = 0.614072
0	0	0	0	0	0	0	0	C = 445.1969
0	0	0	0	0	0	0	0	r = 0.999917
0	0	0	0	0	0	0	0	ELA= 0.735002 m^2
								NLA= 11.67467 cm^2/m^2
SUMS: 37007686		1.1E+08	3.4E+08		2.9E+08	2.3E+09	8.9E+08	

RELATIVE STANDARD ERROR (%):0.359096

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
3445.183	0.139993	--------	0
3134.023	0.046060		0
2626.520	0.142241		0
2250.909	0.423404		0
1830.732	0.590433	REL ERR	0
0	0		0
0	0		0
0	0	--------	0
		n	0
		r	0
		rel std err	0

			0

THIS TEST MEETS CAN/CGSB-149.10-M86

TABLE 1: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING I

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 2-W, ALL FANS ON

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
20	0	0	22	1892.340	20	0	0	1796.753
16	0	0	22	1657.408	16	0	0	1573.688
12	0	0	22	1404.320	12	0	0	1333.384
10	0	0	22	1270.536	10	0	0	1206.358
8	0	0	22	1147.134	8	0	0	1089.189
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

envelope area: 546.95 [m^2]

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	3228324.	2.995732	9671195.	28972312	7.493736	24192213	1.8E+08	72473394	Sxx = 1.0E+13	1788.190	0.476594	--------	0
	2476495.	2.772588	6866304.	19037438	7.361177	18229925	1.3E+08	50544087	Syy = 3.3E+12	1578.919	0.332378	!	0
	1777915.	2.484906	4417953.	10978201	7.195476	12792946	92051339	31789277	Sxy = 5.8E+12	1344.845	0.859493	!	0
	1455300.	2.302585	3350952.	7715653.	7.095361	10325881	73265059	23776220	Syx= 13.90719	1214.886	0.700297	!	0
	1186334.	2.079441	2466913.	5129802.	6.993189	8296262.	58017336	17251593	n = 0.557774	1072.637	1.519655	REL ERR	0
	0	0	0	0	0	0	0	0	C = 336.3046	0	0	!	0
	0	0	0	0	0	0	0	0	r = 0.999098	0	0	!	0
	0	0	0	0	0	0	0	0	ELA= 0.407720 m^2	0	0	--------	0
									NLA= 8.917097 cm^2/m^2			n	0
SUMS:	10124370		26773319	71833608		73837229	5.4E+08	2.0E+08				r	0
									RELATIVE STANDARD ERROR [%]:0.640176			rel std err	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C =============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -6 WIND VELOCITY NNW 22 km/h
ATMOSPHERIC PRESSURE 97.9 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TEST: 3-W, ALL FANS ON

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
22	0	0	22	3181.636	22	0	0	3020.924
18	0	0	22	2799.056	18	0	0	2657.669
14	0	0	22	2410.982	14	0	0	2289.197
10	0	0	22	1880.803	10	0	0	1780.820
8	0	0	22	1602.570	8	0	0	1521.620
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

envelope area: 486.55 [m^2]

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	9125985.	3.091042	28208808	87194625	8.013318	73129426	5.9E+08	2.3E+08	Sxx = 7.8E+13	3040.203	0.638172	--------	0
	7063207.	2.890371	20415295	59007792	7.885204	55694837	4.4E+08	1.6E+08	Syy = 3.6E+13	2655.445	0.083692	!	0
	5240426.	2.639057	13829786	36497599	7.735956	40539714	3.1E+08	1.1E+08	Sxy = 5.3E+13	2241.513	2.083017	!	0
	3120940.	2.302585	7186244.	16546939	7.478613	23334704	1.7E+08	53730200	Syx= 33.26983	1780.517	1.126321	!	0
	2315328.	2.079441	4814590.	10011660	7.327531	16965643	1.2E+08	35279064	n = 0.674299	1536.954	1.007749	REL ERR	0
	0	0	0	0	0	0	0	0	C = 370.1805	0	0	!	0
	0	0	0	0	0	0	0	0	r = 0.998751	0	0	!	0
	0	0	0	0	0	0	0	0	ELA= 0.717251 m^2	0	0	--------	0
									NLA= 14.74157 cm^2/m^2			n	0
SUMS:	26865894		74454725	2.1E+08		2.1E+08	1.6E+09	5.8E+08				r	0
									RELATIVE STANDARD ERROR [%]:1.115943			rel std err	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C =============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -6 WIND VELOCITY NNW 22 km/h
ATMOSPHERIC PRESSURE 97.9 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TABLE 1: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING I

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 4-V, ALL FANS ON

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
28	0	0	21	2799.056	28	0	0	2657.196
24	0	0	21	2531.332	24	0	0	2403.041
20	0	0	21	2271.208	20	0	0	2156.099
16	0	0	21	1984.495	16	0	0	1883.918
12	0	0	21	1648.395	12	0	0	1564.852
8	0	0	21	1350.195	8	0	0	1281.765
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

envelope area: 486.55 (m^2)

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
7060690.	3.332204	23527665	78398992	7.885026	55673734	4.4E+08	1.9E+08	Sxx = 8.0E+13	2641.331	0.597057	--------	0
5774607.	3.178053	18352012	58323682	7.784490	44952373	3.5E+08	1.4E+08	Syy = 2.9E+13	2409.187	0.255753		0
4640766.	2.995732	13926460	41719946	7.676056	35604194	2.7E+08	1.1E+08	Sxy = 4.0E+13	2160.011	0.210545		0
3549147.	2.772588	9840325.	27283175	7.541108	26764505	2.0E+08	74206966	Syx= 23.13408	1891.399	0.397125		0
2448763.	2.484906	6084948.	15120529	7.355546	18011994	1.3E+08	44758125	n = 0.596777	1593.025	1.800352	REL ERR	0
1642923.	2.079441	3416364.	7104129.	7.155994	11756753	84131259	24447482	C = 361.5696	1250.649	2.427655		0
0	0	0	0	0	0	0	0	r = 0.999057	0	0		0
0	0	0	0	0	0	0	0	ELA= 0.573631 m^2	0	0	--------	0
								NLA= 11.78978 cm^2/m^2			n	0
SUMS: 25124898		75147776	2.3E+08		1.9E+08	1.5E+09	5.8E+08				r	0

RELATIVE STANDARD ERROR (%):1.004520 rel std err 0

0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -7 WIND VELOCITY NNW 22 km/h
ATMOSPHERIC PRESSURE 98.1 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86

TEST: 5-V, ALL FANS ON

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
24	0	0	21	2612.267	24	0	0	2479.873
20	0	0	21	2224.805	20	0	0	2112.124
16	0	0	21	1954.261	16	0	0	1855.217
12	0	0	21	1639.333	12	0	0	1556.249
8	0	0	21	1293.798	8	0	0	1228.227
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

envelope area: 486.55 (m^2)

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
6149774.	3.178053	19544314	62112882	7.815962	48066409	3.8E+08	1.5E+08	Sxx = 3.6E+13	2433.670	1.863133	--------	0
4461071.	2.995732	13364176	40035493	7.655449	34151505	2.6E+08	1.0E+08	Syy = 1.5E+13	2164.475	2.478568		0
3441830.	2.772588	9542779.	26458203	7.525756	25902378	1.9E+08	71816641	Sxy = 2.3E+13	1875.188	1.076496		0
2421912.	2.484906	6018227.	14954733	7.350034	17801142	1.3E+08	44234176	Syx= 44.77380	1558.533	0.146781		0
1508541.	2.079441	3136924.	6523051.	7.113327	10730751	76331343	22313970	n = 0.642944	1200.879	2.226604	REL ERR	0
0	0	0	0	0	0	0	0	C = 315.4000	0	0		0
0	0	0	0	0	0	0	0	r = 0.996362	0	0		0
0	0	0	0	0	0	0	0	ELA= 0.556507 m^2	0	0	--------	0
								NLA= 11.43783 cm^2/m^2			n	0
SUMS: 17983130		51606422	1.5E+08		1.4E+08	1.0E+09	3.9E+08				r	0

RELATIVE STANDARD ERROR (%):2.087315 rel std err 0

0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -7 WIND VELOCITY NNW 19 km/h
ATMOSPHERIC PRESSURE 98.5 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86

TABLE I: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING I

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A'B^2))-(SUM(A'B))^2
Syy = (SUM A)(SUM(A'C^2))-(SUM(A'C))^2
Sxy = (SUM A)(SUM(A'C'B))-(SUM(A'C))(SUM(A'B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST:apt 501 ALL FANS ON

SLAB CORRECTION—USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE; envelope area: 318.19 [m^2]

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE	90% of flow rate	A	B	A'B	A'B^2	C	A'C	A'C^2	A'B'C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
50	0	0	16.5	692.5181	50	0	0	668.7015	601.8314	362201.0	3.912023	1416938.	5543097.	6.399977	2318078.	14835651	9068377.	Sxx = 1.6E+11	600.5567	0.211799	--------	0
45	0	0	16.5	629.1440	45	0	0	607.5069	546.7562	298942.3	3.806662	1137972.	4331878.	6.304003	1884533.	11880106	7173783.	Syy = 9.0E+10	552.4873	1.048201	:	0
~~40~~	~~0~~	~~0~~	~~16~~	~~594.9107~~	~~40~~	~~0~~	~~0~~	~~574.9551~~	~~517.4596~~	~~267764.3~~	~~3.688879~~	~~987751.0~~	~~3643694.~~	~~6.248931~~	~~1673242.~~	~~10455975~~	~~6172388.~~	~~Sxy = 1.2E+11~~	~~503.2904~~	~~2.730223~~	:	~~0~~
35	0	0	16	519.7174	35	0	0	502.2774	452.0496	204348.9	3.555348	726531.5	2583072.	6.113792	1249346.	7638246.	4441862.	Syx= 12.13483	452.7927	0.164382	:	0
30	0	0	16	438.4286	30	0	0	423.7163	381.3447	145423.8	3.401197	494615.0	1682283.	5.943703	864356.0	5137476.	2939845.	n = 0.791820	400.7648	5.092534	REL ERR	0
25	0	0	15.5	395.2845	25	0	0	382.3507	344.1156	118415.6	3.218875	381165.1	1226923.	5.840977	691662.9	4039987.	2226377.	C = 27.11905	346.8904	0.806334	:	0
~~20~~	~~0~~	~~0~~	~~15.6~~	~~346.7875~~	~~20~~	~~0~~	~~0~~	~~335.3025~~	~~301.8442~~	~~91109.95~~	~~2.995732~~	~~272941.0~~	~~817650.2~~	~~5.709911~~	~~520229.7~~	~~2970465.~~	~~1558460.~~	~~r = 0.994418~~	~~290.7079~~	~~3.609414~~	:	~~0~~
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ELA= 0.067415 m^2	0	0	--------	0
																		NLA= 2.118715 cm^2/m^2			n	0
								SUMS:		1488206.		5417915.	19820607		9201450.	56957909	33581103				r	0

RELATIVE STANDARD ERROR (%):5.124360 — rel std err 0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -2 WIND VELOCITY W 22 km/h
ATMOSPHERIC PRESSURE 99 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86 -------- 0

TEST: apt 503 ALL FANS ON

SLAB CORRECTION—USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE; envelope area: 299.73 [m^2]

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE	90% of flow rate	A	B	A'B	A'B^2	C	A'C	A'C^2	A'B'C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
50	0	0	18.5	588.2648	50	0	0	565.3514	508.8163	258894.0	3.912023	1012799.	3962094.	6.232087	1613450.	10055162	6311854.	Sxx = 1.9E+11	518.2920	1.862299	--------	0
45	0	0	18.5	563.8645	45	0	0	541.9015	487.7113	237862.4	3.806662	905461.9	3446787.	6.189723	1472302.	9113146.	5604559.	Syy = 6.6E+10	487.1929	0.106310	:	0
~~40~~	~~0~~	~~0~~	~~18.5~~	~~520.6731~~	~~40~~	~~0~~	~~0~~	~~500.3923~~	~~450.3533~~	~~202818.1~~	~~3.688879~~	~~748171.3~~	~~2759914.~~	~~6.110032~~	~~1239225.~~	~~7571706.~~	~~4571352.~~	~~Sxy = 1.1E+11~~	~~454.6308~~	~~0.949812~~	:	~~0~~
35	0	0	18	507.0018	35	0	0	487.6719	438.9047	192637.3	3.555348	684892.8	2435032.	6.084282	1172059.	7131143.	4167081.	Syx= 12.65805	420.3392	4.229942	:	0
30	0	0	18	458.5083	30	0	0	441.0273	396.9245	157549.1	3.401197	535855.6	1822550.	5.983746	942734.0	5641081.	3206424.	n = 0.587303	383.9563	3.267174	REL ERR	0
25	0	0	17.5	380.4170	25	0	0	366.2279	329.6051	108639.5	3.218875	349697.2	1125631.	5.797895	629880.7	3651982.	2027507.	C = 52.09101	344.9676	4.660896	:	0
~~20~~	~~0~~	~~0~~	~~17.5~~	~~338.1113~~	~~20~~	~~0~~	~~0~~	~~343.2003~~	~~321.2303~~	~~85815.00~~	~~2.995732~~	~~257093.4~~	~~770183.0~~	~~5.680003~~	~~487457.2~~	~~2768738.~~	~~1460291.~~	~~r = 0.990335~~	~~302.5957~~	~~3.292508~~	:	~~0~~
15	0	0	17.5	297.6756	15	0	0	286.5726	257.9154	66520.36	2.708050	180140.4	487829.5	5.552631	369363.1	2050937.	1000253.	ELA= 0.080859 m^2	255.5558	0.914872	--------	0
																		NLA= 2.697743 cm^2/m^2			n	0
								SUMS:		1310740.		4674112.	16810025		7926473.	47983919	28349324				r	0

RELATIVE STANDARD ERROR (%):4.904148 — rel std err 0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: b ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -2.7 WIND VELOCITY WSW 17 km/h
ATMOSPHERIC PRESSURE 99 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86 -------- 0

TEST: apt 505 ALL FANS ON

SLAB CORRECTION—USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE; envelope area: 281.49 [m^2]

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE	90% of flow rate	A	B	A'B	A'B^2	C	A'C	A'C^2	A'B'C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
50	0	0	22	675.0213	50	0	0	644.8708	580.3837	336845.2	3.912023	1317746.	5155054.	6.363689	2143570.	13641069	8305729.	Sxx = 2.0E+11	576.2923	0.704944	--------	0
45	0	0	21.5	624.3700	45	0	0	596.9878	537.2890	288679.5	3.806662	1098905.	4183162.	6.286536	1814794.	11408769	6908308.	Syy = 5.8E+10	544.4618	1.335000	:	0
~~40~~	~~0~~	~~0~~	~~21.5~~	~~604.0959~~	~~40~~	~~0~~	~~0~~	~~578.3677~~	~~520.5309~~	~~270952.4~~	~~3.688879~~	~~999511.0~~	~~3687075.~~	~~6.254849~~	~~1694766.~~	~~10600511~~	~~6251790.~~	~~Sxy = 1.1E+11~~	~~518.9550~~	~~1.039640~~	:	~~0~~
35	0	0	21	536.7237	35	0	0	513.6213	462.2591	213683.5	3.555348	759719.4	2701067.	6.136125	1311189.	8045621.	4661733.	Syx= 8.512252	475.4552	2.854696	:	0
30	0	0	21	513.9230	30	0	0	491.8020	442.6218	195914.0	3.401197	666342.5	2266362.	6.092715	1193648.	7272563.	4059835.	n = 0.539264	437.5297	1.150427	REL ERR	0
25	0	0	20.5	458.4744	25	0	0	439.1134	395.2021	156184.7	3.218875	502739.2	1618255.	5.979397	933890.5	5584102.	3006077.	C = 69.89532	396.5591	0.343374	:	0
~~20~~	~~0~~	~~0~~	~~20.5~~	~~410.1726~~	~~20~~	~~0~~	~~0~~	~~392.8514~~	~~353.5663~~	~~125009.1~~	~~2.995732~~	~~374493.0~~	~~1121883.~~	~~5.868071~~	~~733562.4~~	~~4304596.~~	~~2197556.~~	~~r = 0.995004~~	~~351.5991~~	~~0.556374~~	:	~~0~~
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ELA= 0.097135 m^2	0	0	--------	0
																		NLA= 3.450754 cm^2/m^2			n	0
								SUMS:		1507268.		5719458.	20732860		9825431.	60857235	35471033				r	0

RELATIVE STANDARD ERROR (%):3.219716 — rel std err 0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0

TABLE 1: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING 1

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: apt 507 ALL FANS ON

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
50	0	0	22	766.3061	50	0	0
45	0	0	21.5	709.3819	45	0	0
40	0	0	21.5	666.0997	40	0	0
35	0	0	21	638.5843	35	0	0
30	0	0	21	558.5906	30	0	0
25	0	0	20.5	515.9230	25	0	0
20	0	0	20.5	424.5368	20	0	0
0	0	0	0	0	0	0	0

SLAB CORRECTION — USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

envelope area: 310.19 (m^2)

ACTUAL CORRECTED FLOW RATE	90% of flow rate	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C	
732.0782	658.8704	434110.2	3.912023	1698249.	6643590.	6.490526	2817604.	18287736	11022532	Sxx = 3.0E+11
678.4626	610.6163	372852.7	3.806662	1419325.	5402863.	6.414460	2391649.	15341162	9104203.	Syy = 1.1E+11
636.8874	573.1987	328556.7	3.688879	1212006.	4470945.	6.351232	2086740.	13253373	7697733.	Sxy = 1.0E+11
611.0974	549.9877	302486.5	3.555348	1075444.	3823580.	6.309895	1908658.	12043435	6785944.	Syx= 11.72760
534.5469	481.0922	231449.7	3.401197	787206.3	2677444.	6.176059	1429447.	8828351.	4861832.	n = 0.603010
492.2205	442.9985	196247.0	3.218875	631696.2	2033353.	6.093566	1195840.	7286980.	3849287.	C = 62.33643
406.6090	365.9481	133918.0	2.995732	401182.5	1201835.	5.902491	790450.0	4665624.	2367976.	r = 0.993653
0	0	0	0	0	0	0	0	0	0	ELA= 0.100328 m^2
										NLA= 3.153098 cm^2/m^2
SUMS:		1999021.		7225109.	26253653		12620390	79706666	45689511	

RELATIVE STANDARD ERROR (%):4.086095

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
659.5557	0.104014	--------	0
618.9547	1.365574	¦	0
576.5102	0.579117	¦	0
531.9157	3.285089	¦	0
484.6996	0.749835	REL ERR	0
434.2351	1.978187	¦	0
379.5653	3.721070	¦	0
0	0	--------	0
		n	0
		rel std err	0

			0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: c ===========> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -2 WIND VELOCITY WSW 13 km/h
ATMOSPHERIC PRESSURE 99 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86

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APPENDIX V

CALCULATIONS AND ANALYSIS

BUILDING II - AIR TIGHTNESS TESTING

APPENDIX V
CALCULATIONS AND ANALYSES
BUILDING II - AIR TIGHTNESS TESTING

Air tightness testing was conducted on March 1 and March 6 1991. Testing and calculation procedures were conducted in accordance to National Standard Of Canada #CAN/CGSB-149.10-M86 - "Determination of the Air Tightness of Building Envelopes by the Fan Depressurization Method" - and in accordance to the procedures outlined in the CMHC publication "Establishing The Protocol for Measuring Air Leakage and Air Flow Patterns in High-Rise Apartment Buildings".

The test names and sequencing are presented in Table 1. The structure of the test name is directed towards identifying which component of the building is being tested for air leakage. The names are broken into two parts; the first portion identifies on which floor the measurements were taken; the second portion lists the building component through which the measured air flow is moving.
(ie. 1-W,PLS implies First Floor - Walls & Partial Lower Slab)

A fundamental precept of the testing procedure stipulated that if a pressure differential across a building component was maintained at zero, there would be no air flow across that component. The measured air flow during the test would then represent the flow through the building components which were not balanced.

Based on the procedures outlined in CAN/CGSB-149.10-M86, the actual measurement data was corrected for the differences in air density between the reference and calibration conditions and between the indoor and the outdoor air. The resultant flows were those which would occur under the reference conditions where atmospheric pressure would be 101.325 kPa and the inside and outside temperatures would both equal 20 •C. Since the elevation of the building was closer to sea level than to the elevation of the airport, the barometric pressure used for correcting the flow measurements were those taken at sea level.

The corrected flows were then used to determine the flow coefficient (C) and the flow exponent (n) which are used to generate a representative equation of the form $Q=C\Delta P^n$ relating pressure to the flow through the unbalanced building components. Except where indicated, these equations were used to represent the air flows associated with that particular test.

The following summarizes, in a floor by floor fashion, what testing was performed and illustrates how the resulting data was treated.

BASEMENT:

Three physical tests were performed in order to determine the flows through each component of the half-basement.

During the first test, B-W,LS, (ie. Basement - Wall & Lower Slab) the flows were measured in the basement while the basement-to-first-floor pressure differential

TABLE 1: **Building II - Testing Sequence**

BUILDING II - AIRTEST SETUP				
TEST NUMBER	TEST NAME	STATUS OF FAN BELOW	TEST FLOOR	STATUS OF FAN ABOVE
1	B-W,LS	N/A	B	ON
2	1-W,PLS	ON	1	ON
3	1-W,PLS,LS	OFF	1	ON
4	1-LS	PAPER TEST 4 = 3-2		
5	1-W,PLS,US	ON	1	OFF
6	1-US	PAPER TEST 6 = 5-2		
7	2-W,LS	OFF	2	ON
8	2-W	PAPER TEST 8 = 7-6		
9	3-W	ON	3	ON
10	3-W,LS	OFF	3	ON
11	3-LS	PAPER TEST 11 = 10-9		
12	3-W,US	ON	3	OFF
13	3-US	PAPER TEST 13 = 12-9		
14	4-W,LS	OFF	4	ON
15	4-W	PAPER TEST 15 = 14-13		
16	5-W	ON	5	ON
17	5-W,LS	OFF	5	ON
18	5-LS	PAPER TEST 18 = 17-16		
19	5-W,US	ON	5	OFF
20	5-US	PAPER TEST 20 = 19-16		
21	6-W,US,PENT	ON	6	N/A

LEGEND	
W - EXTERNAL WALLS	PLS - PARTIAL LOWER SLAB
LS - LOWER SLAB	PENT - PENTHOUSE
US - UPPER SLAB	

was maintained at zero. By doing this, it was assumed that the between-floor flow would be zero and the measured flow would represent the flow through the combined external walls and lower slab. These results are tabulated in Table 2 under the heading B-W,LS.

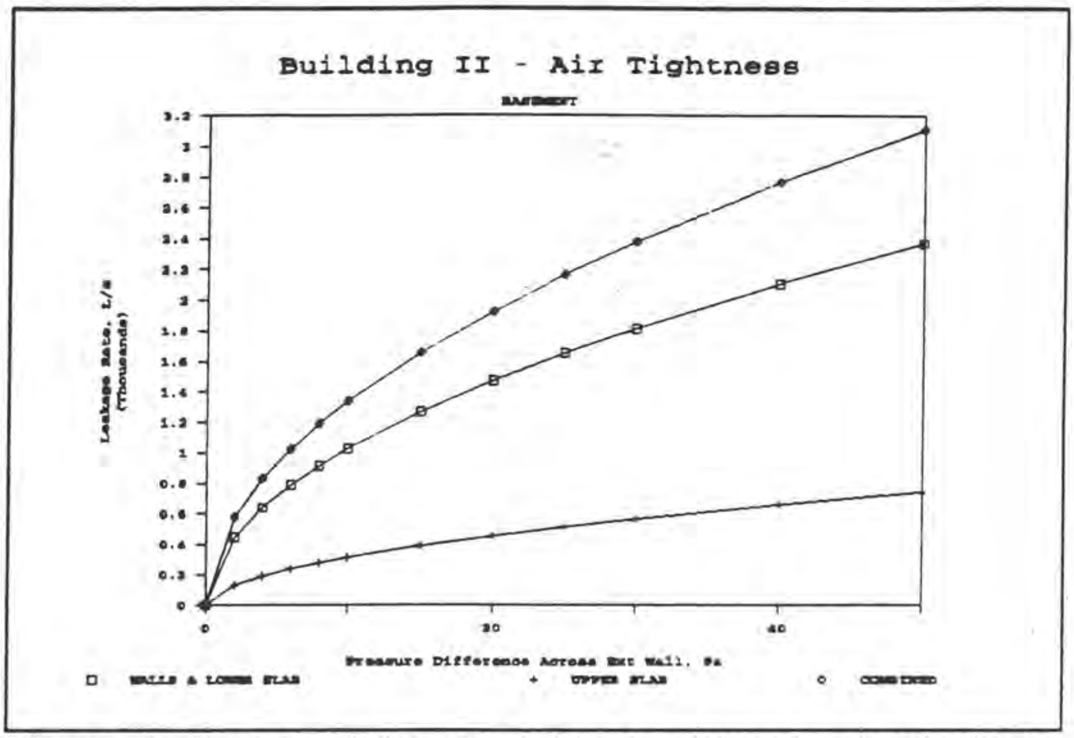

Figure 1: The component leakage rates which have been determined may be combined to get a total leakage rate for the floor.

During the second test, 1-W,PLS (ie. First Floor - Walls & Partial Lower Slab), the flows were measured on the first floor while the basement-to-first-floor and the first-to-second-floor pressure differentials were maintained at zero. The measured flow therefore represented the flow through the external walls of the first floor and that part of the first floors' lower slab which was not balanced by the basement. The results of this test are tabulated in Table 2 under the heading 1-W,PLS.

During the third test, 1-W,PLS,LS, the flows were again measured on the first floor and the first-to-second-floor pressure differential was maintained at zero. The basement-to-first-floor partition was not balanced and so the measured flow represented the flow through the first floor external walls and the entire first floor lower slab. These results are tabulated under 1-W,PLS,LS.

A paper test using the representative equations was then conducted whereby the flows from the second test (1-W,PLS) were subtracted from the flows from the third test (1-W,PLS,LS). By using the test data in this manner, the flow associated with the portion of the first floor's lower slab shared by the basement was isolated. These results are tabulated under 1-LS. Figure 2 illustrates graphically the resulting curves from these tests.

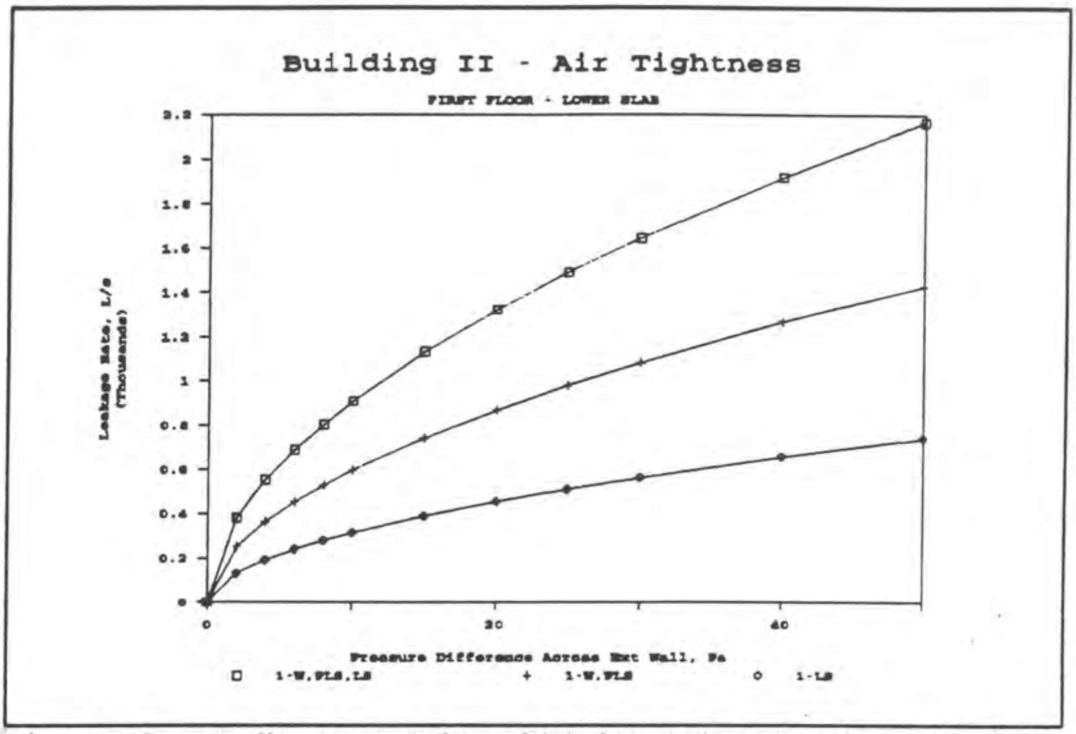

Figure 2: The flow through the lower slab is determined by subtracting the flow through walls and partial lower slab only from the combined flow with the lower slab included.

This flow through the common portion of the first floor lower slab is also the flow through the upper slab of the basement. By combining this with the flow measured from the first test (B-W,LS), the total flow for the basement was determined. This is illustrated in Figure 1 which was shown previously.

FIRST FLOOR:

Since Building II contains only a half basement, it was only possible to isolate the flow through that portion of the first floor lower slab which was shared by the excavated portion of the basement. This was determined by paper test 1-LS. The flow through that portion of the lower slab over the unexcavated area was included in the flow through the external walls. This combined flow was determined by test 1-W,PLS.

The next test involved maintaining the basement-to-first-floor pressure differential at zero. The subsequent flow, which was measured on the first floor, represented the combined flow through the first floor external walls, partial lower slab, and entire upper slab. These results are tabulated in 1-W,PLS,US.

A paper test using representative equations was then conducted whereby the flows from test 1-W,PLS were subtracted from the flows from 1-W,PLS,US. In this manner the flow associated with the upper slab shared by the first and the second floors could be isolated at each given external wall pressure differential. These results are tabulated under 1-US and are illustrated in Figure 3.

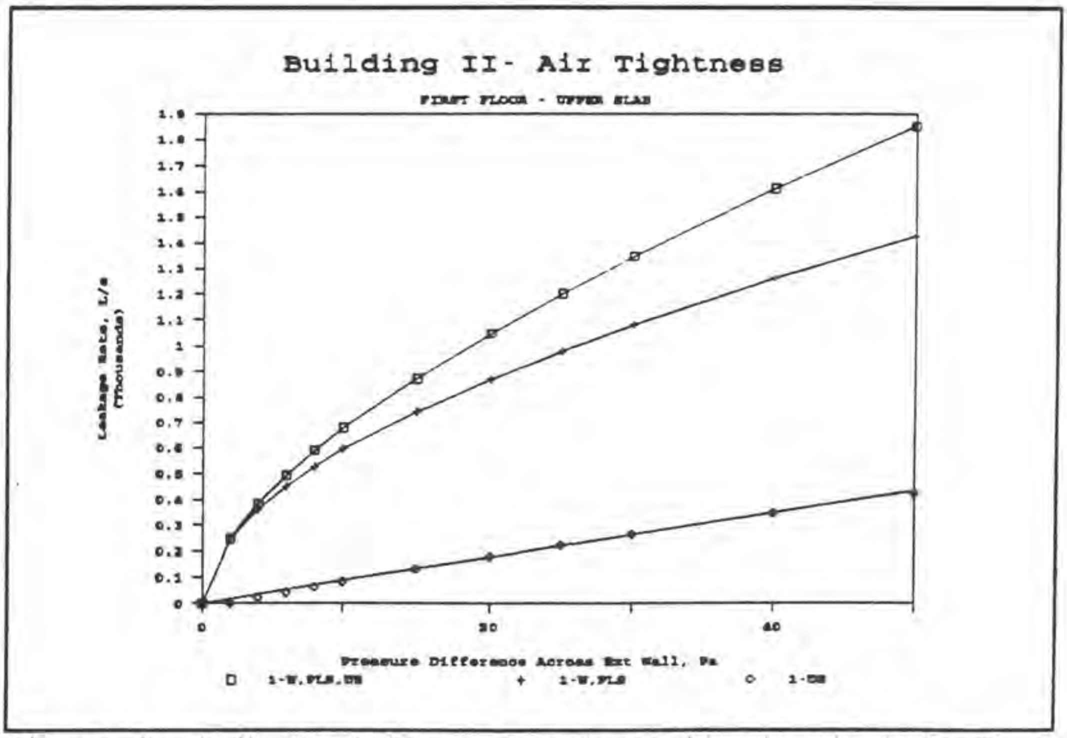

Figure 3: The flow through the upper slab is determined by subtracting the flow through the walls and partial lower slab only from the combined flow with the upper slab included.

In this manner the flow for each component of the first floor was determined. The total flow for the floor can be determined by combining these components. This is illustrated in Figure 4. When studying this figure it must be remembered that the walls component also includes that portion of the lower slab which could not be balanced. This does not imply, however, that the leakage rate through the unbalanced portion of the lower slab is the same as the leakage rate through the walls. One cannot be isolated from the other thus the combined flow is illustrated under the single heading of walls.

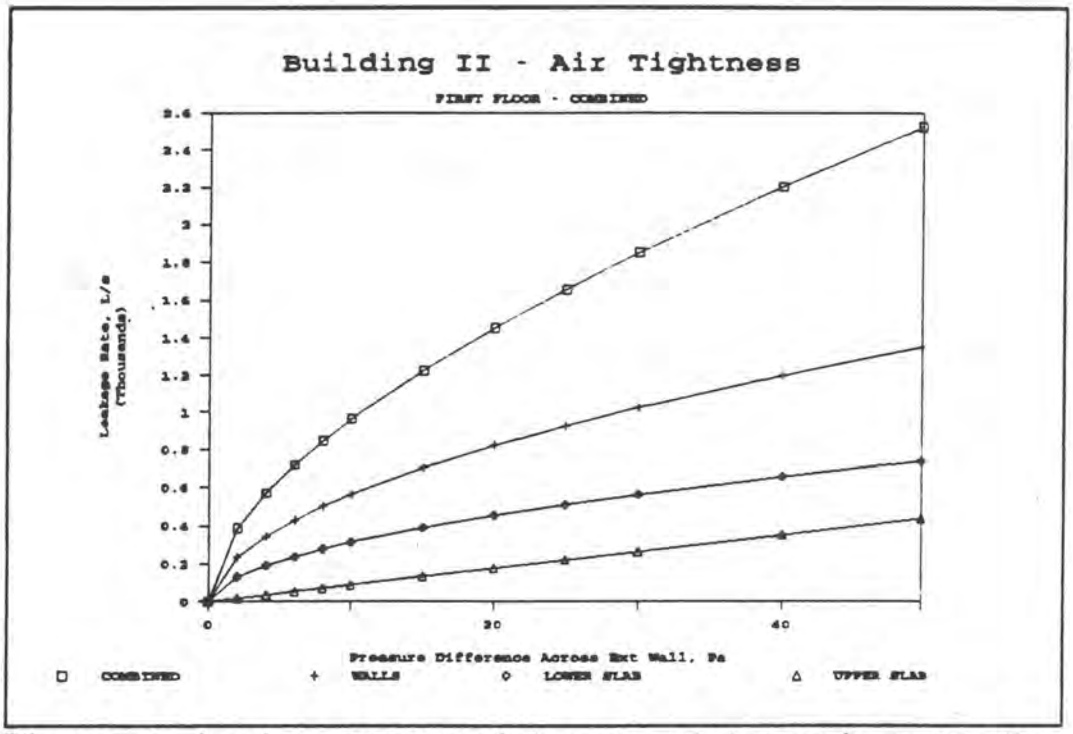

Figure 4: By combining the component leakage rates, a leakage rate for the entire floor may be determined.

SECOND FLOOR:

Only one test was conducted where flow measurements were taken on the second floor. During this test the pressure differential between the second floor and the third floor was maintained at zero while the flow at incremental external wall pressure differentials was measured. These flows represented the combined flow through the second floor external walls and the second floor lower slab. The results of this test are tabulated in 2-W,LS.

Since the first floor upper slab is the same as the second floor lower slab, the first floor upper slab flow, which was already established, was used to determine the second floor external wall flow. This was achieved by conducting a "paper test" whereby the first floor upper slab flow rates (1-US) were subtracted from the second floor combined walls and lower slab flow rates (2-W,LS) at specified external wall pressure differentials. These results are tabulated under 2-W and are illustrated by Figure 5.

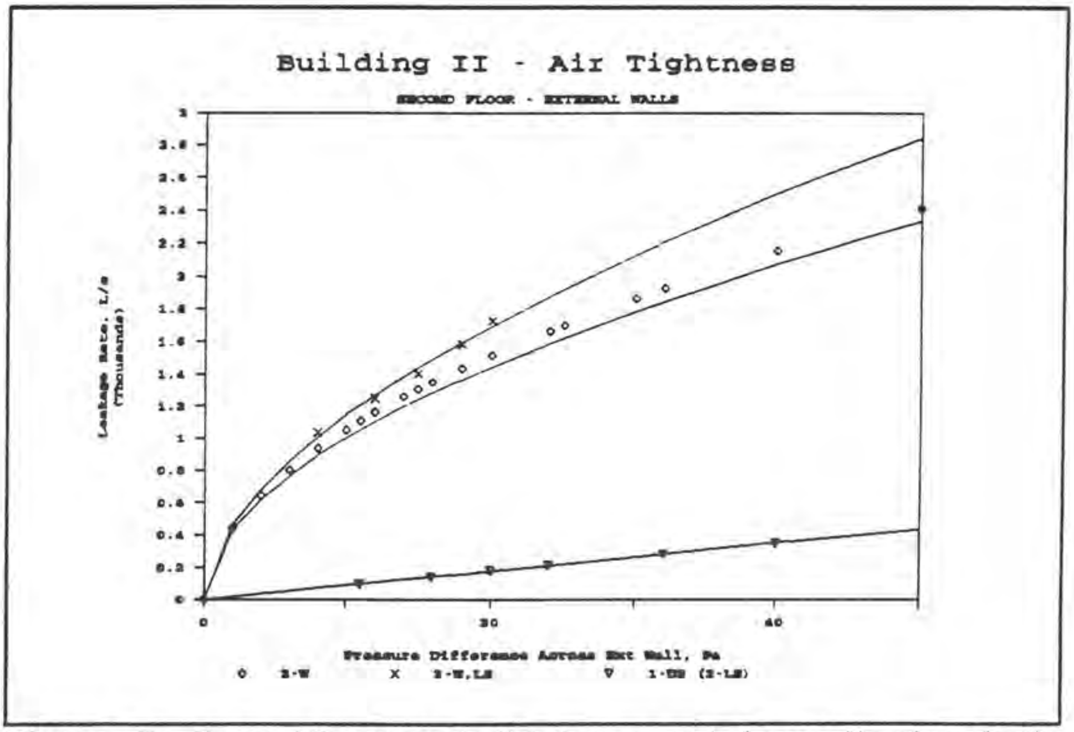

Figure 5: The second floor external wall leakage rate can be determined by subtracting the first floor upper slab (second floor lower slab) leakage rate from the combined second floor and lower slab leakage rate.

The flow through the second floor upper slab was determined from calculations from the third floor tests. The combined second floor results are illustrated in Figure 6 and Figure 6B.

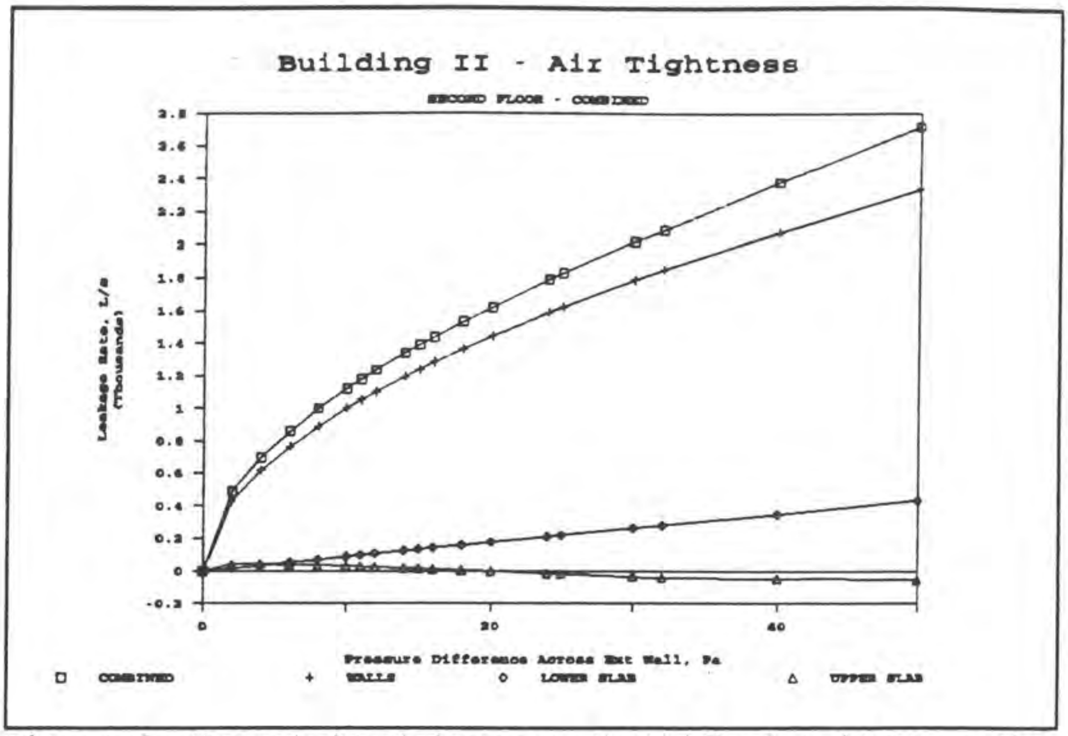

Figure 6: The equation determined to represent the third floor lower slab creates problems when it is used to calculate the second floor's overall flow.

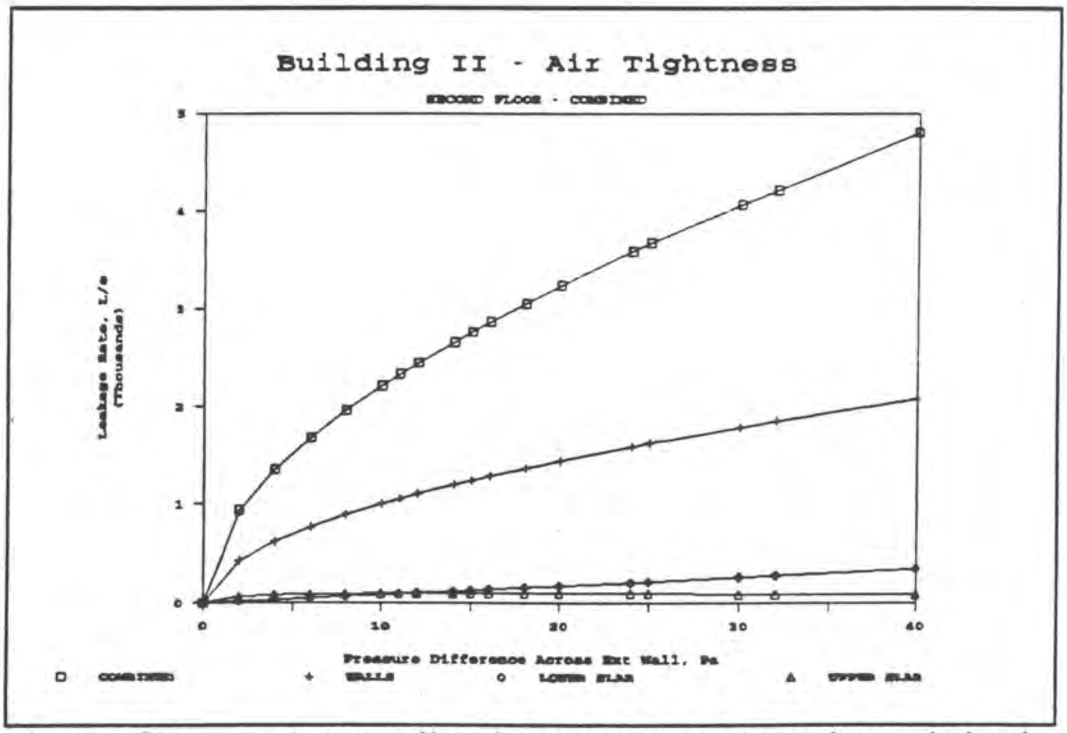

Figure 6B: Better overall results are achieved when the actual measured values for the third floor lower slab's flow are used to determine the second floor's overall flow.

THIRD FLOOR:

Testing on the third floor was conducted in the same manner as the testing which was conducted on the first floor. During the first test, the second-to-third-floor and the third-to-fourth-floor pressure differentials were maintained at zero so that the flow measured on the third floor represented the flow through the exterior walls only. This data is tabulated under 3-W.

During the next test the third-to-fourth-floor pressure differential was maintained at zero while the flow was measured on the third floor. In this case the measured flow represented the combined flow through the external walls and the third floor lower slab. These results are tabulated under 3-W,LS.

Both the above tests met CAN/CGSB-149.10-M86, however, when the paper test was conducted, whereby the representative equation for the flow through the walls was subtracted from the representative equation for the combined flows through the external walls and the lower slab, it was found that the test failed to meet the standard. These results are tabulated under 3-LS.

The accepted margin of error for this type of testing is ± 5%. When the calculated differences between the two representative equations were taken as a percentage, they were found to be smaller than reasonable error estimations for either of the measurements. The representative equation created using these calculated differences did not conform to the standard shape which is expected for a flow equation. This is illustrated in Figure 7.

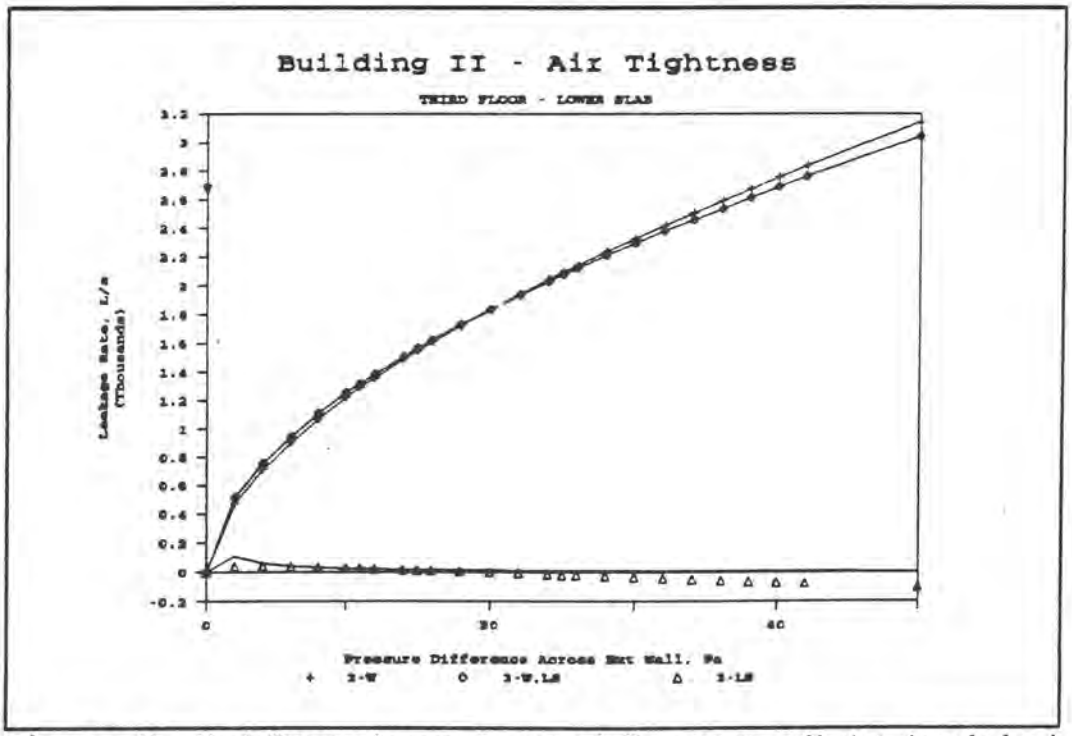

Figure 7: The differences between the measured flows are so small that the calculated equation for the third floor lower slab is not representative of the common flow equation.

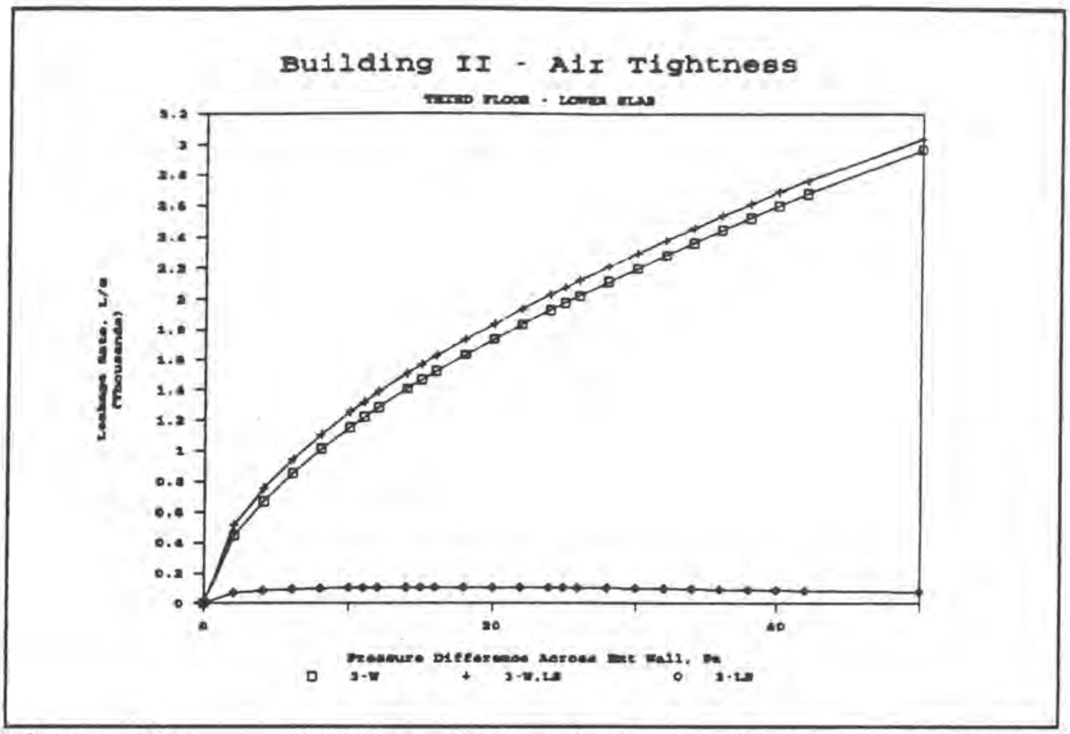

Figure 7B: When the actual subtracted values are plotted, a curve corresponding more closely to the common flow equation results.

In order to compensate for this, the actual flow differences at specified pressure differentials were used in the calculations. As can be seen from Figure 7B, this provided a much better representation of the flow through the third floor lower slab.

The problems encountered in determining the third floor lower slab flows have an effect on the calculations for the second floor since the third floor lower slab flow is also the second floor upper slab flow. Figures 6 and 6B illustrate the effect the third floor lower slab representation has on the second floor total flow calculations. In order to maintain a curve which conforms to the accepted shape of a flow curve, the actual flow differences between 3-W,LS and 3-W were used to represent the flows through the second-to-third-floor slab.

Another test was conducted on the third floor whereby the second-to-third-floor pressure differential was maintained at zero and the combined flow through the third floor external walls and third floor upper slab was measured. The results of this test are tabulated in 3-W,US. A similar problem to that which occurred with the lower slab paper test occurred with the upper slab paper test. The results of this are tabulated under 3-US. Again, the paper test failed the standard although the physical tests both met the standard. In this case, the calculated flows represented a higher percentage of the actual flows. However, these percentages were not great enough to overcome, with any degree of certainty, the inherent errors in the measurement techniques. Again, as illustrated by Figures 8 and 8B, these problems were minimized by using the actual subtracted values rather than a representative equation calculated by the techniques outlined in CAN/CGSB-149.10-M86.

The combined flows from the third floor are presented in Figures 9 and 9B.

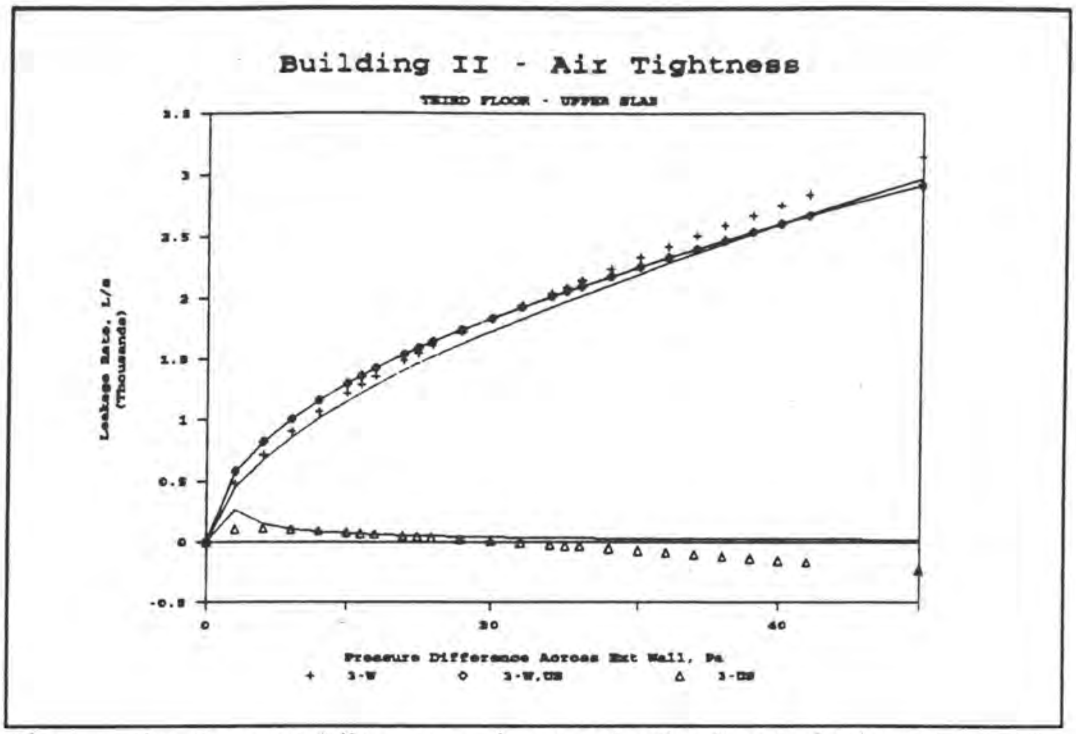

Figure 8: The measured flows are so close together that the calculated equation for the third floor upper slab is not representative of the common flow equation.

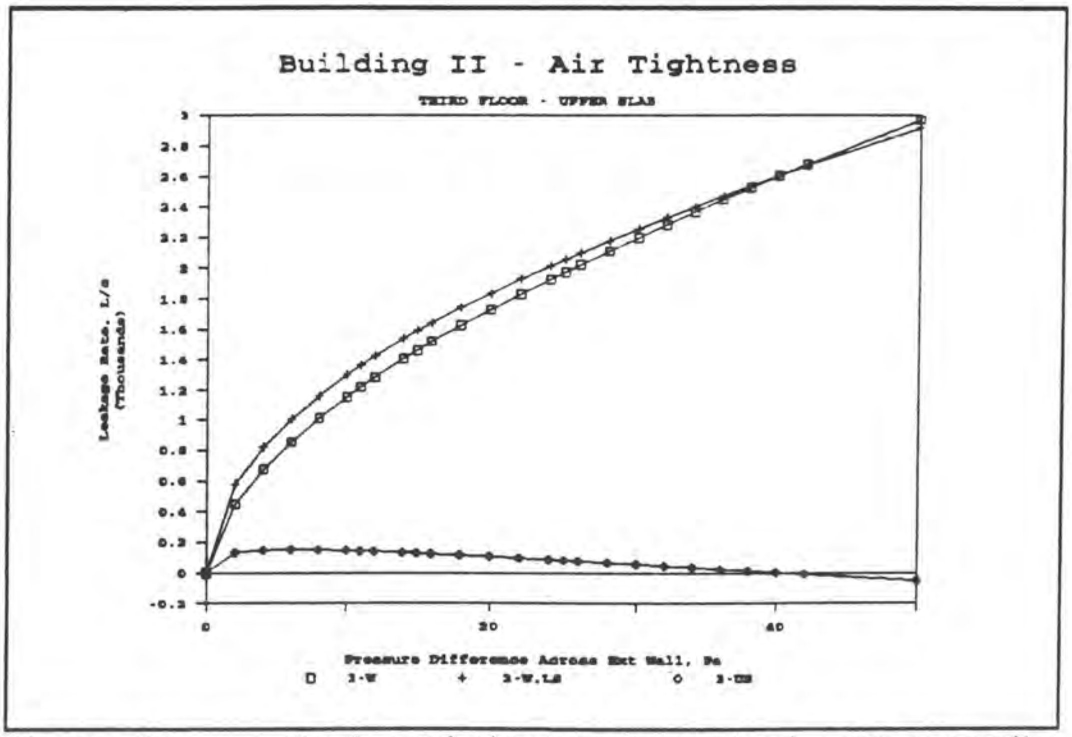

Figure 8B: When the actual subtracted values are plotted, a curve corresponding more closely to the common flow equation results.

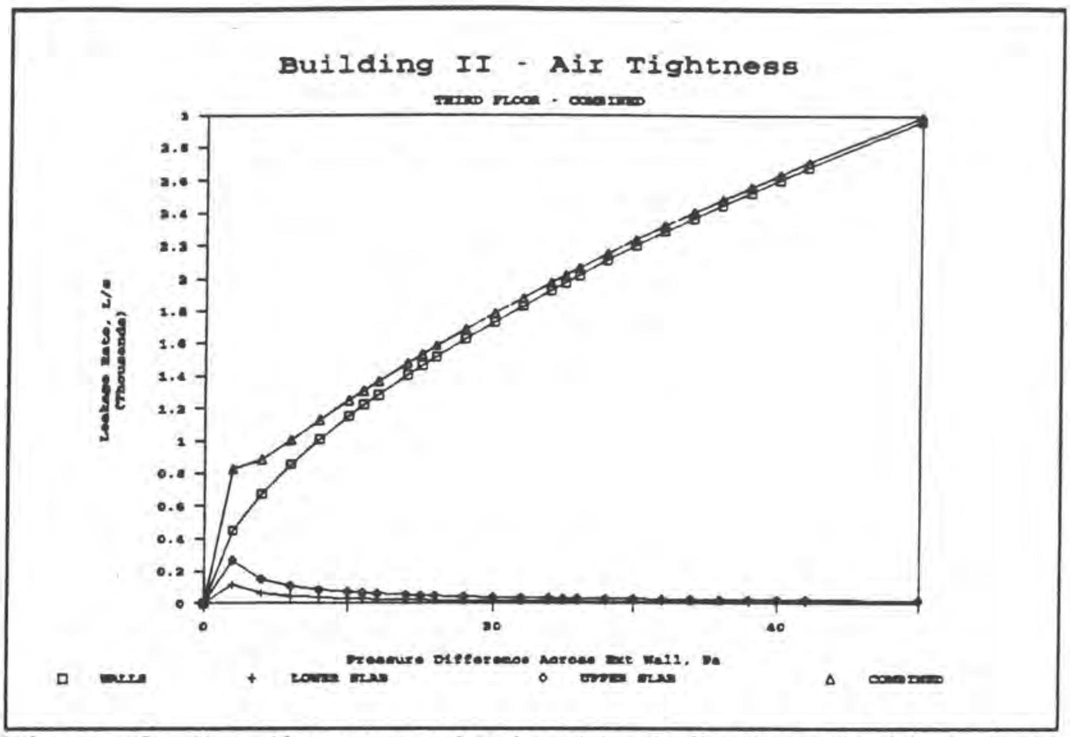

Figure 9: The problems encountered in determining the flow through the slabs is clearly echoed in the combined results.

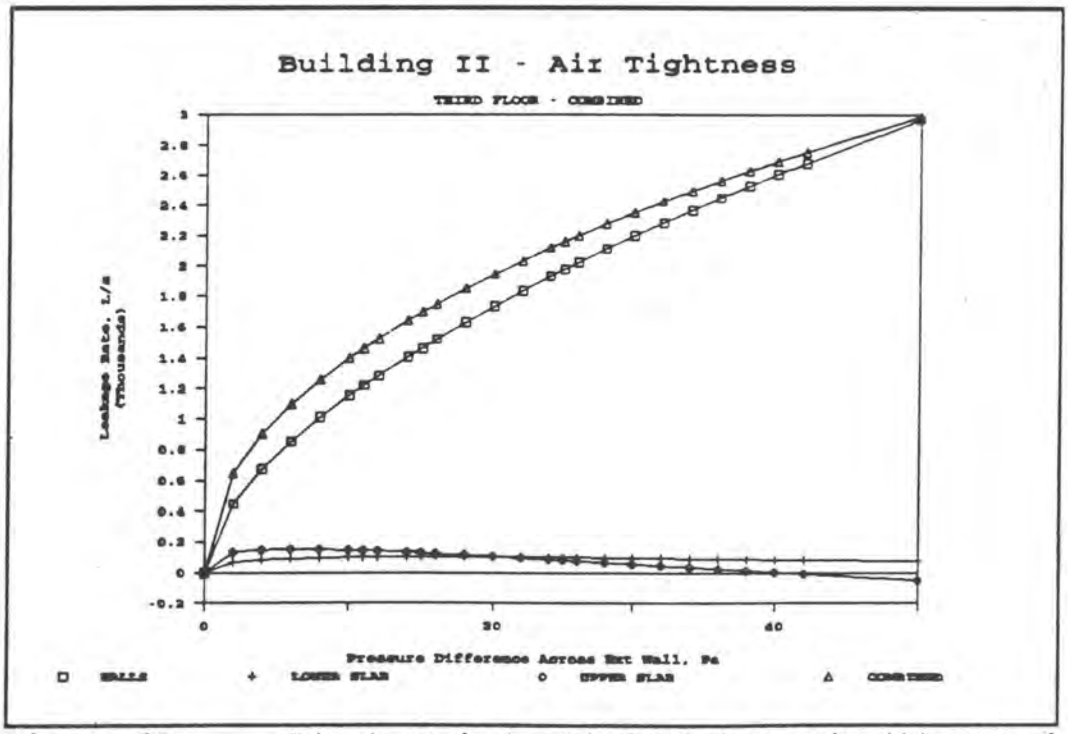

Figure 9B: Using the actual subtracted values leads to results which correspond more closely to the common flow equation.

FOURTH FLOOR:

The same testing procedure used on the second floor was used on the fourth floor. The forth-to-fifth-floor pressure differential was maintained at zero while the flow representing the flow through the walls and lower slab was measured on the fourth floor. These results are tabulated under 4-W,LS.

A paper test was then conducted whereby the flow through the third floor upper slab (3-US) was subtracted from the combined flow from the test above (4-W,LS). This is tabulated under test 4-W. In this case, the paper test passed the standard when the estimating equations were used. However, looking at Figure 10, it can be seen that the resulting curve for the wall does not correspond very well to the calculated points. This problem can be linked to the representative equation for the third floor upper slab. If the actual subtracted values for the third floor upper slab flows are used, a better correlation results.

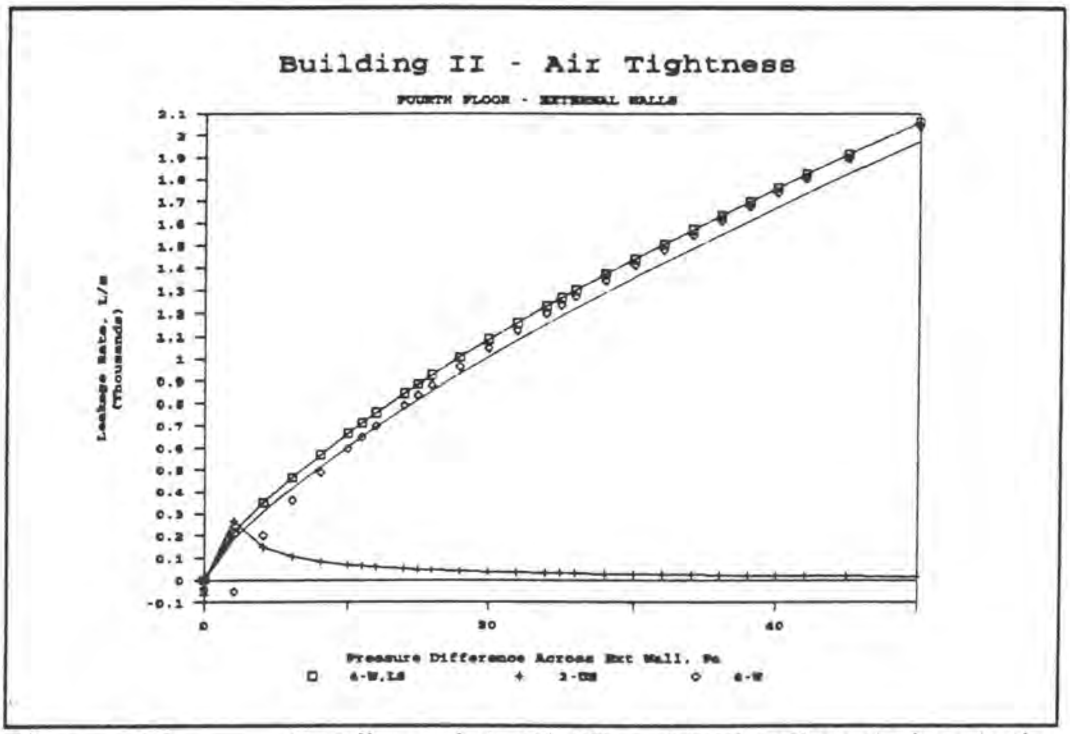

Figure 10: The influence of the third floor slabs also affects the determination of the fourth floor's external walls.

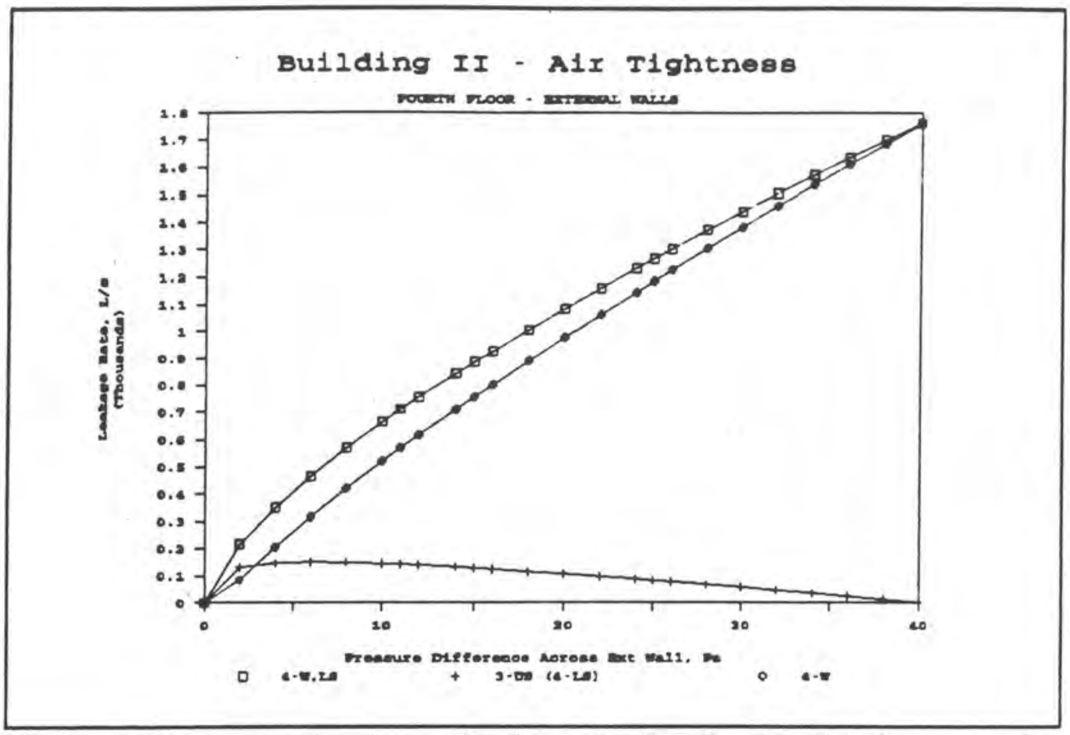

Figure 10B: Using the actual subtracted values for the third floor upper slab results in a more representative flow curve for the fourth floor external walls.

The combined fourth floor results are illustrated in Figure 11 and 11B. Again, it is clear that by using the actual values a more regular representation of the combined flow results.

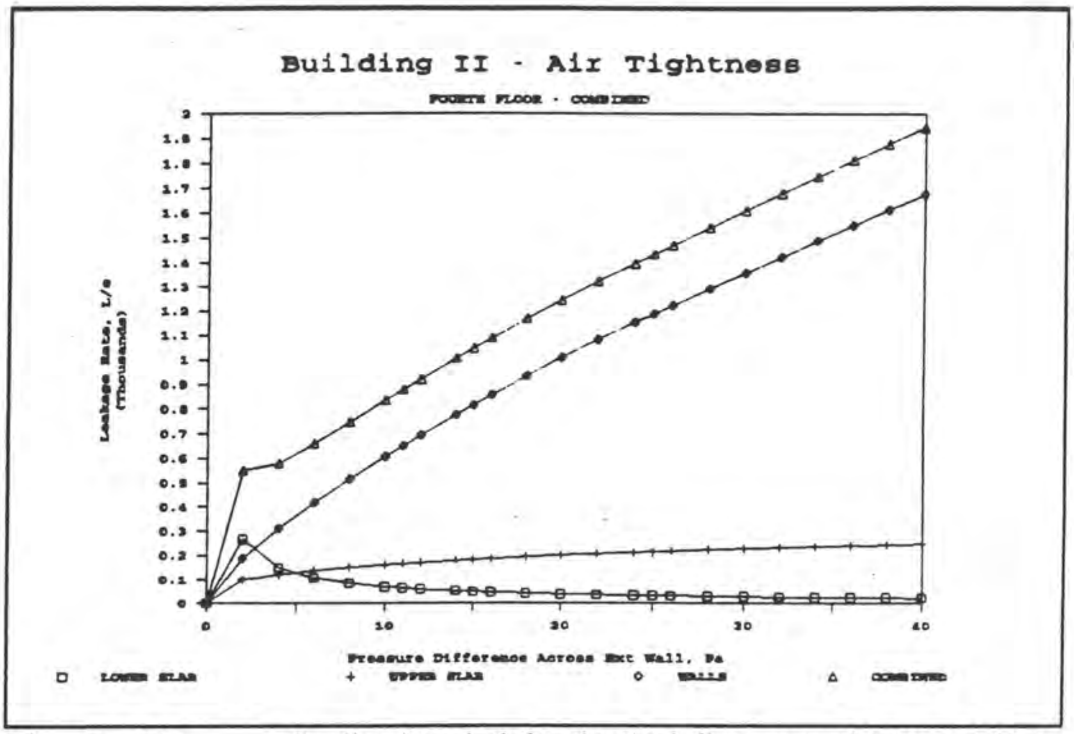

Figure 11: The flow determined for the third floor upper slab has a definite influence on the flows determined for the fourth floor.

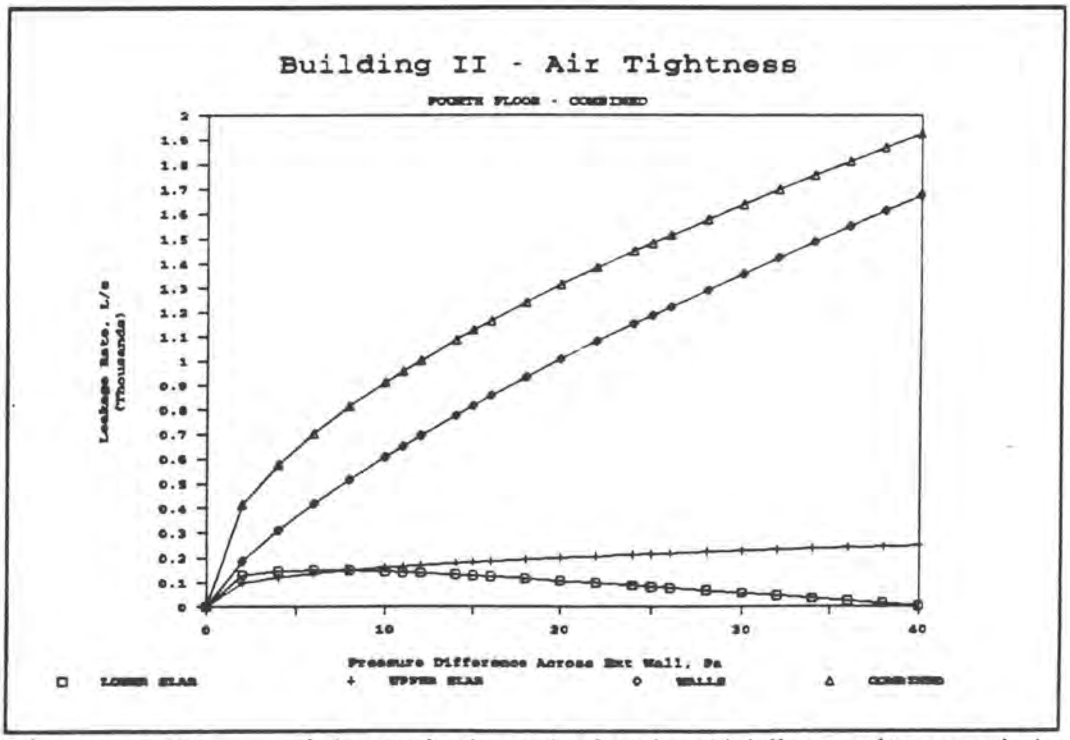

Figure 11B: If the actual subtracted values for third floor results are used, be tter curves corresponding more closely to common flow equations result on the fourth floor.

FIFTH FLOOR.

Three physical tests were conducted on the fifth floor.

In the first test the fourth-to-fifth-floor and fifth-to-sixth-floor pressure differentials were maintained at zero. The flows which were measured represented the flows through the fifth floor walls only. These results are tabulated in 5-W.

The next test entailed maintaining the fifth-to-sixth-floor pressure differential at zero and measuring the combined fifth floor lower slab and fifth floor wall flow. These results are tabulated in 5-W,LS.

A paper test was then conducted whereby the representative flow equation for the fifth floor wall flow was subtracted from the representative equation of the combined fifth floor walls and lower slab flow at specified pressure differentials. In this manner the flow through the fifth floor lower slab was determined. These results are tabulated in 5-LS and are illustrated in Figure 12.

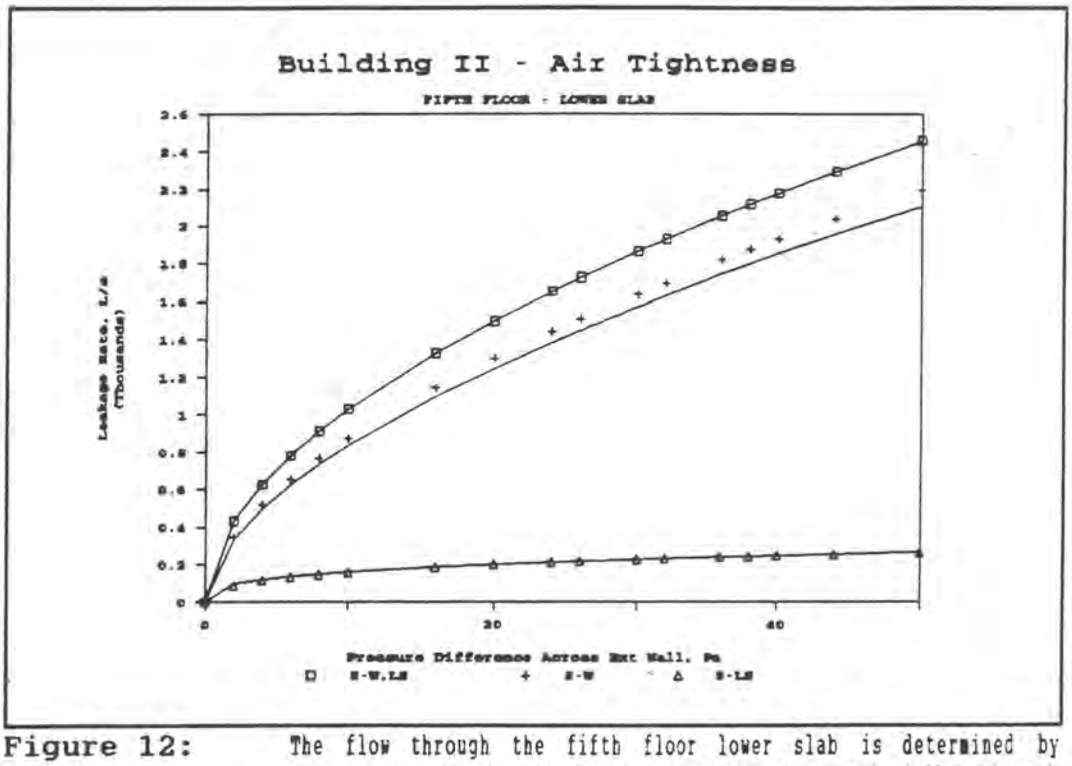

Figure 12: The flow through the fifth floor lower slab is determined by subtracting the flow through the wall from the combined flow through the walls and lower slab.

As indicated, the test failed to meet the standard because the calculated "n" value did not fall within the required limits. It should be noted that the representative curve did correspond reasonably well with the accepted norm for flow curves and so these representative curve values were used as is.

The next test entailed maintaining the fourth-to-fifth-floor pressure differential at zero and measuring the combined fifth floor lower slab and fifth floor wall flow. These results are tabulated in 5-W,US.

Again a paper test was conducted subtracting the wall flows from the combined flows to determine the flow through the upper slab. These results are tabulated in 5-US. Again the test failed to meet the standard but the graphical representation was close enough to the normal flow curve to be acceptable. These results are illustrated in Figure 13.

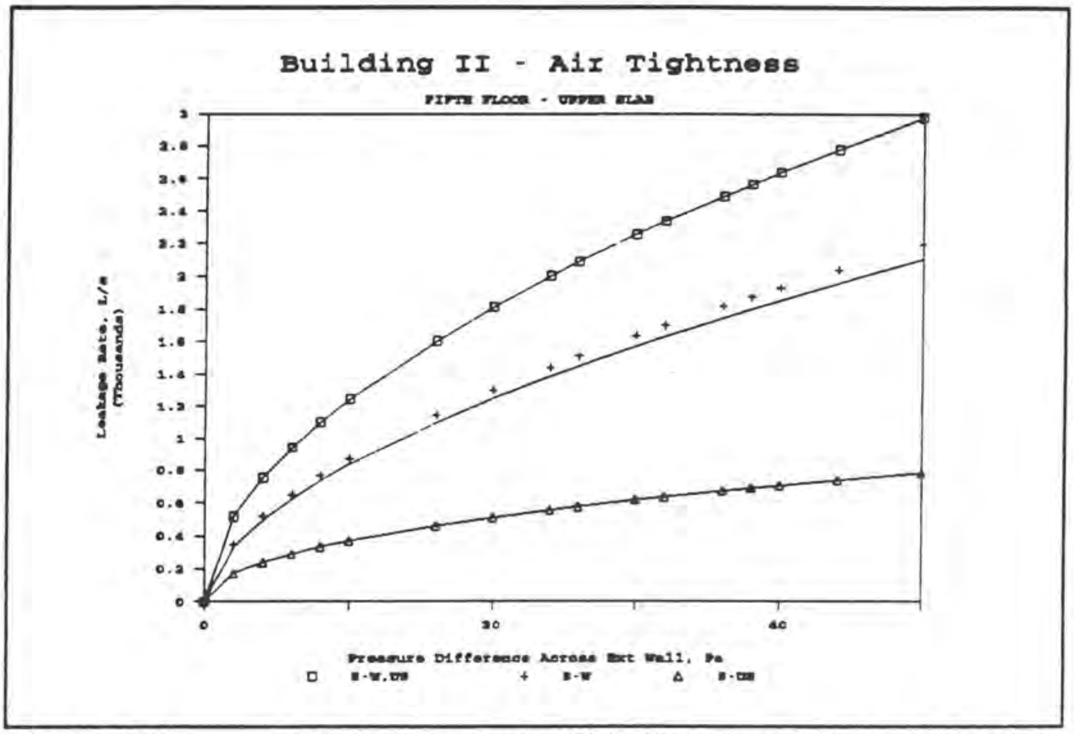

Figure 13: The flow through the fifth floor upper slab is determined by subtracting the flow through the wall from the combined flow through the wall and lower slab.

The combined flows for the fifth floor are illustrated on Figure 14.

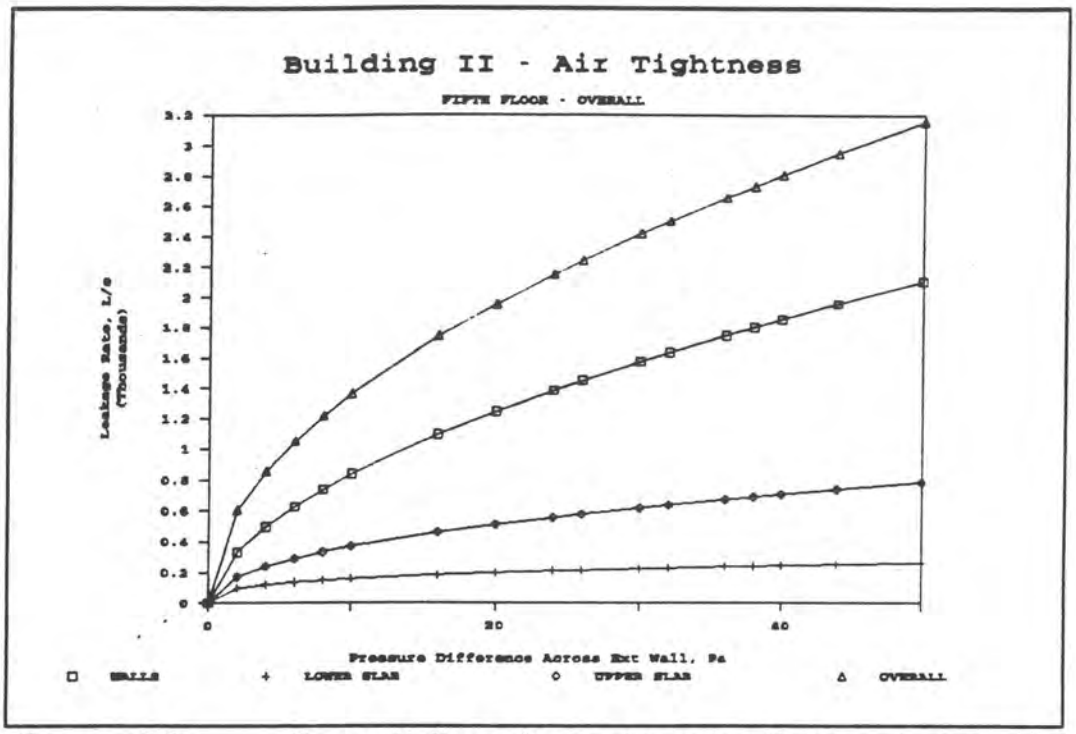

Figure 14: The overall flow is determined by summing the component parts.

SIXTH FLOOR:

The flow rate through the lower slab of the sixth floor is the same as the flow rate determined for the upper slab of the fifth floor.

The final test conducted maintained a zero pressure differential between the fifth and sixth floor and measured the flow on the sixth floor. In this case the flow represented the combined flow through the walls and the roof of the sixth floor including the penthouse. This test met the standard. The results are presented in table 6-W,US,PENT and are illustrated in Figure 15.

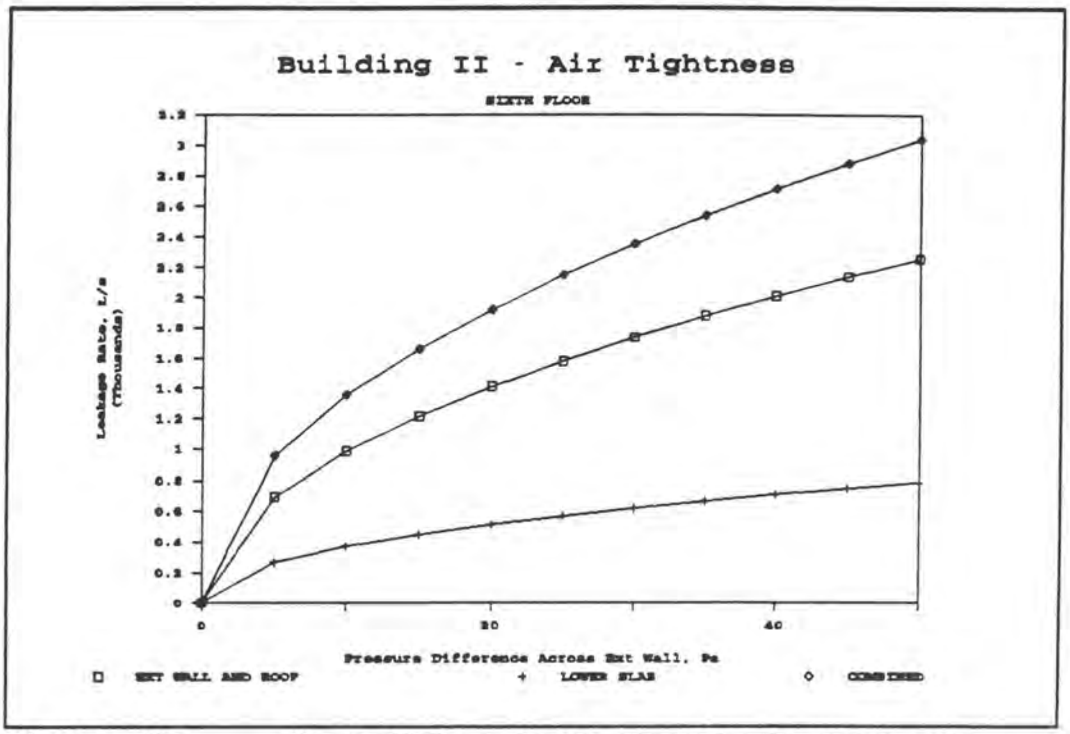

Figure 15: The overall flow is determined by summing the component parts.

COMPONENT AIR LEAKAGE:

For each floor, the percentage influence of each building component (lower slab, walls, upper slab) was determined. This was achieved by taking the flow associated with each component of each floor as a percentage of the total flow for that floor. This calculation was performed for external wall pressure differentials of 10, 20, 30, 40, and 50 Pa. The results appear in Figures 16 through 20.

In studying and comparing Figures 16 through 20, the following must be remembered:

- the wall component for the basement includes the basement's lower slab.
- the wall component for the first floor includes a portion the first floor's lower slab.
- the wall component for the sixth floor includes the roof.

With these factors taken into consideration, it is apparent that the component breakdown of air leakage for the basement, first, fifth and sixth floors, remains relatively constant from pressure to pressure. On the other hand, the second, third, and fourth floors' component breakdown tends to vary substantially from pressure to pressure. In fact, the data for a pressure differential of 50 Pa was so inconsistent that it was not appropriate to attempt to graph it for these floors.

The following briefly describes changes in the influence of each component of each floor as the pressure differential rises:

In the basement, the component flow distribution remained relatively constant for each of the pressures. When the other floors were examined, however, it was found that the percent influence for each building component tended to shift with an increase in the external pressure difference.

On the first floor, the influence of upper slab tended to increase steadily while the influence of the walls and lower slab both tended to decrease at about the same constant rate.

On the second floor, the influence of the lower slab increased at a constant rate while the influence of the upper slab decreased at about twice the rate at which the influence of walls decreased.

On the third floor, the influence of the walls increased drastically with the increased pressure while the influence of the upper slab decreased at about two and a half times the rate at which the influence of lower slab decreased.

On the fourth floor, the influence of the walls increased drastically while the influence of the upper slab decreased at about three times the rate at which the influence of the lower slab decreased.

On the fifth floor the influence of the walls increased while the influence of the upper and lower slabs decreased at about the same constant rate.

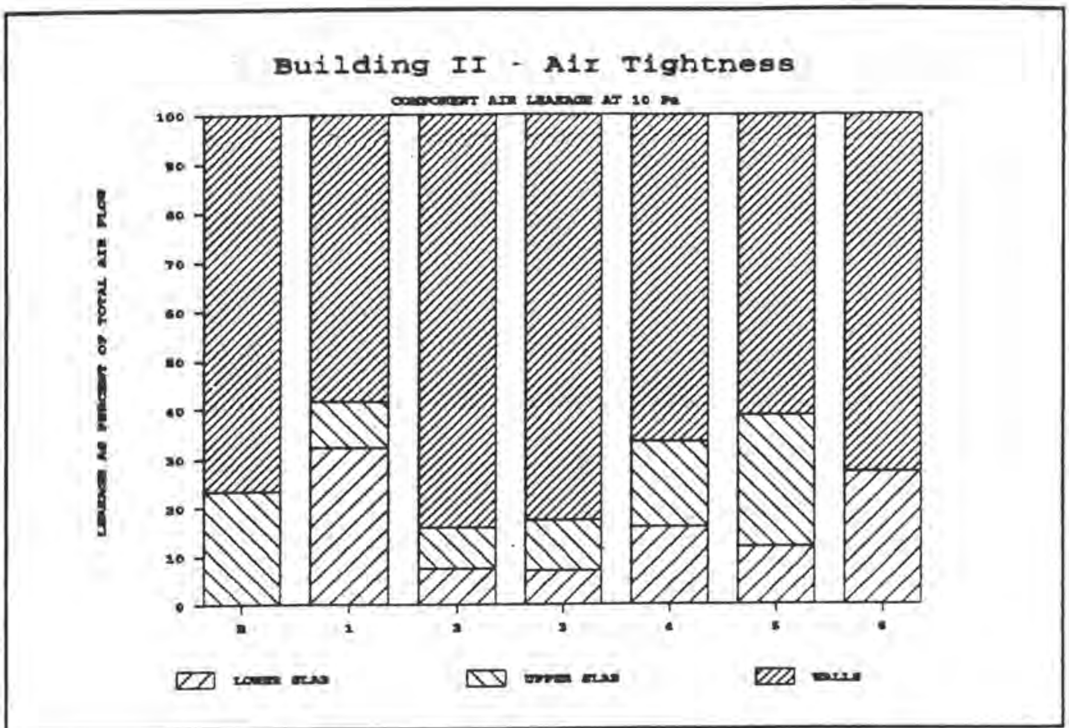

Figure 16: Influence of third floor slabs is relatively small.

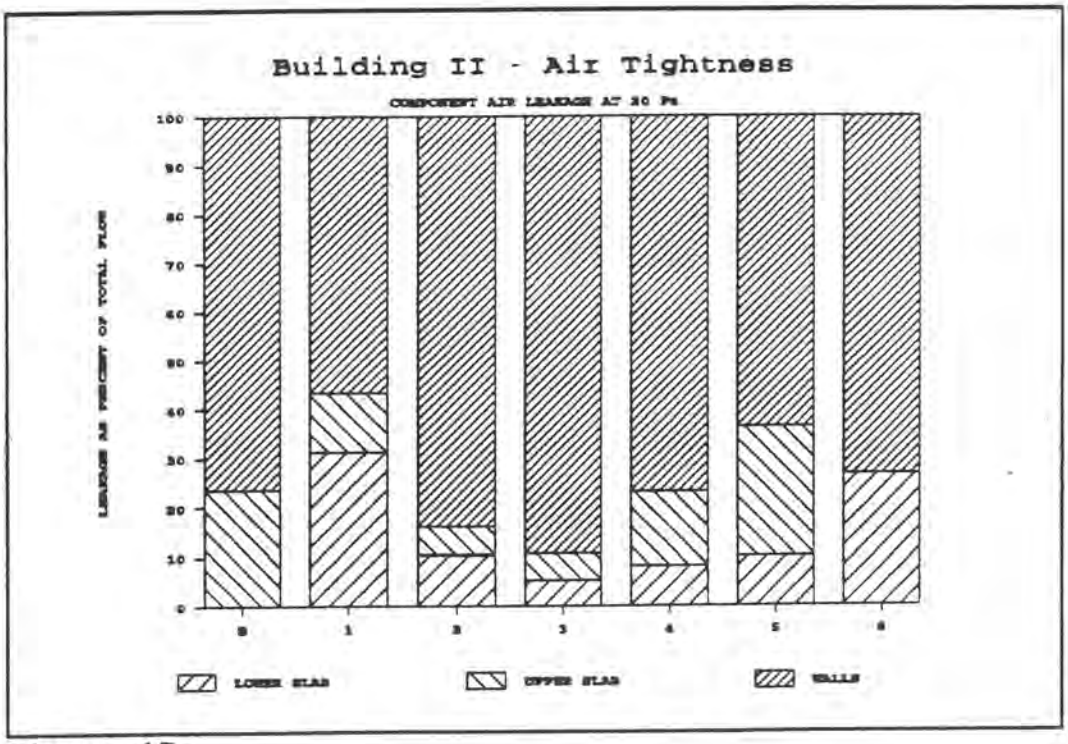

Figure 17:

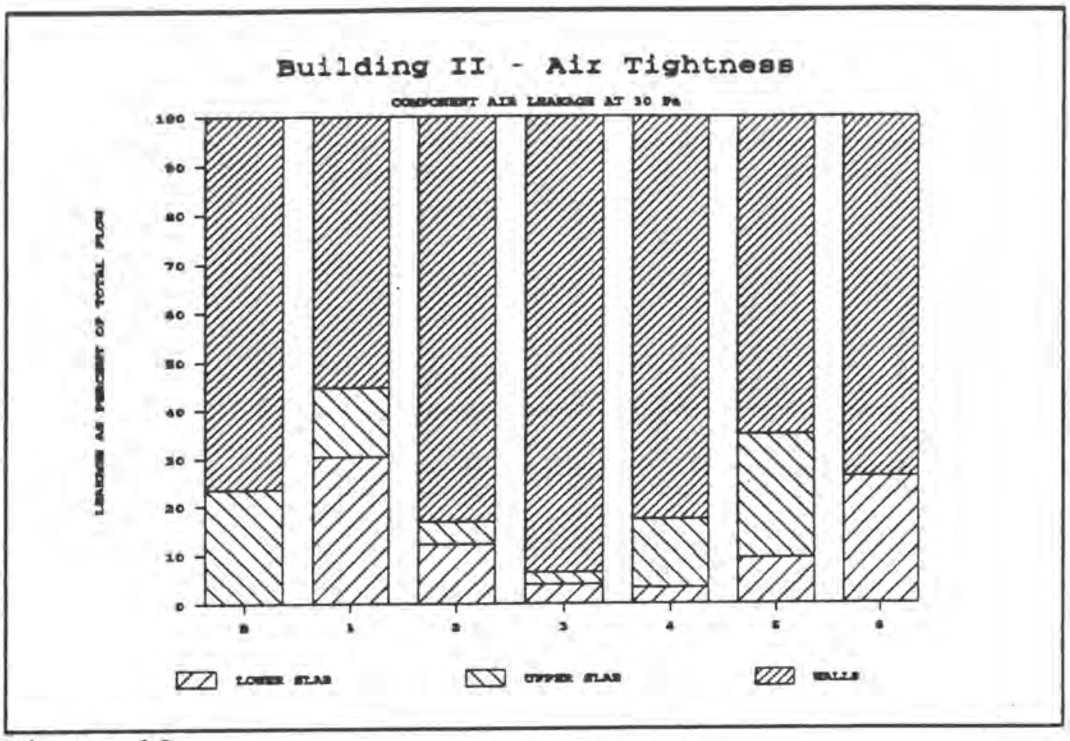

Figure 18:

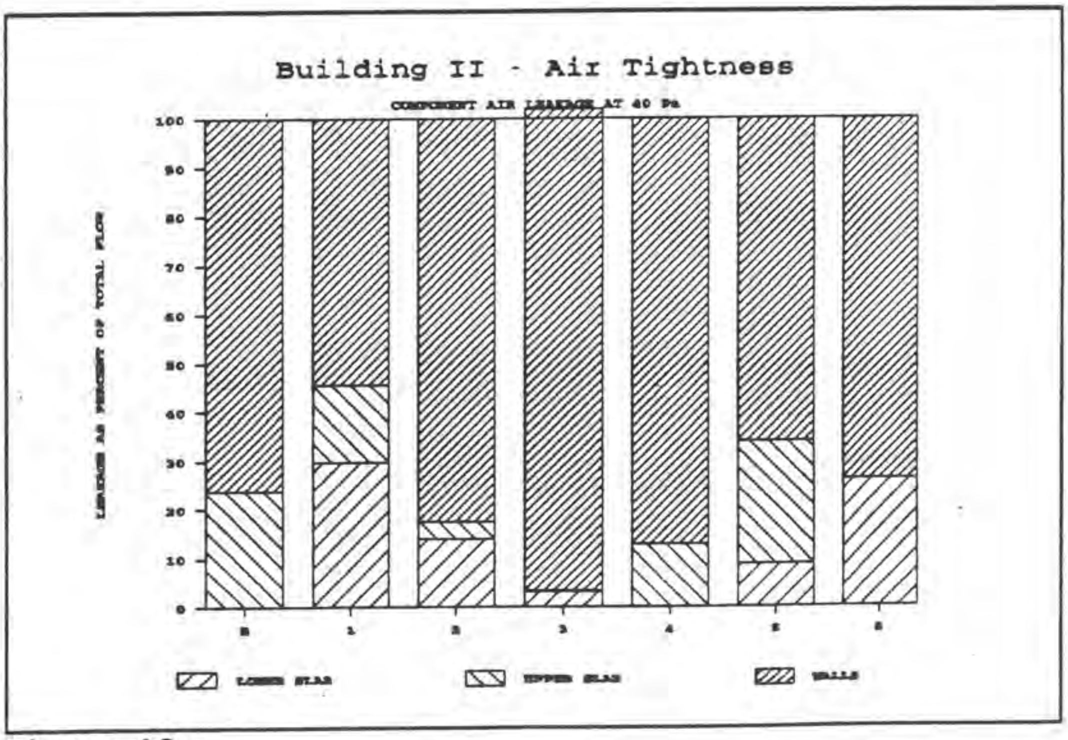

Figure 19:

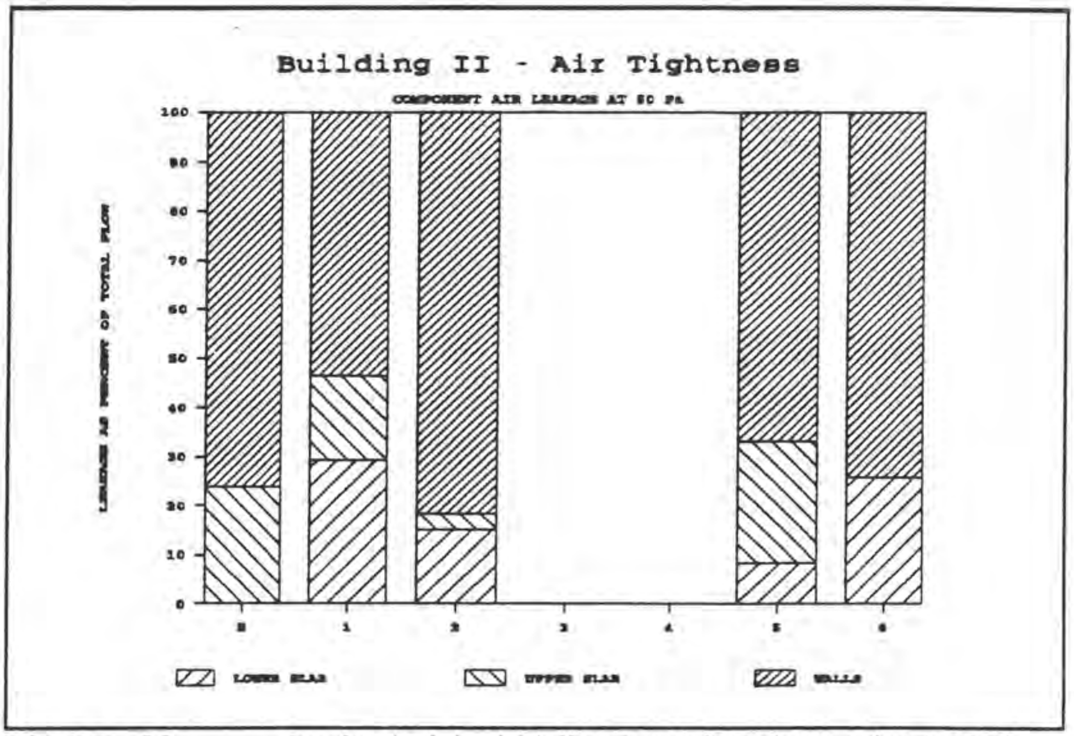

Figure 20: Data for the 3rd and 4th floor is very inconsistent and so is not shown.

On the sixth floor, the influence of both components remained relatively constant when compared to the other floors. It should be noted however, that the influence of the walls of the sixth floor did gradually increase as the influence of the lower slab gradually decreased.

The changes in the component percentages are directly echoed by the flow curves for the associated floors. By studying Figures 6B, 9B, and 10B, it becomes apparent that these trends directly reflect the influence of the third floor's upper and lower slabs.

EQUIVALENT LEAKAGE AREA:

The paper test 3-LS, where the flow rate through the third floor lower slab is determined by subtracting values from previous tests, did not meet standard CAN/CGSB-149.10-M86 even though the tests it was based on both met the standard.

Every calculated difference between 3-W,LS and 3-W was found to be below 5% of the original values. The flow measurements cannot be assumed to be more accurate than ±5%.

An alternate method for estimating the air tightness for the lower slab is to subtract the equivalent leakage area (ELA) of 3-W from 3-W,LS. Equivalent leakage area is calculated using the flow coefficient (C) and flow exponent (n) in the equation:

ELA = $.001157*C*10^{\text{[illegible]}}*\sqrt{\rho}$ where ELA is in units of m^2

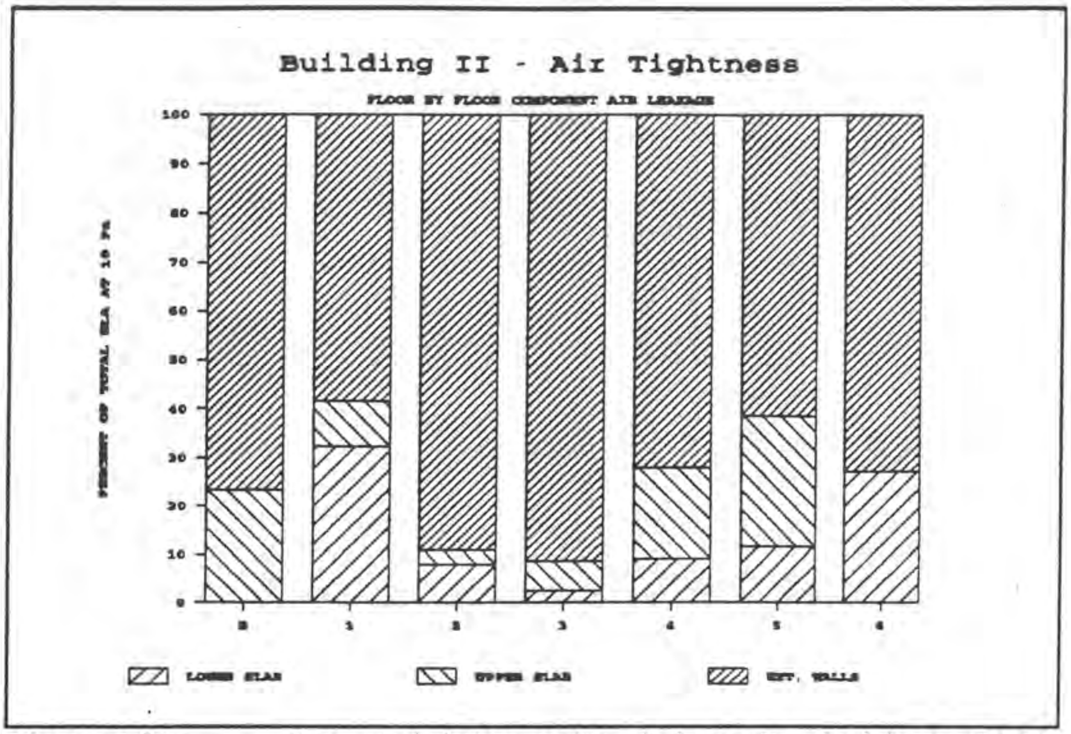

Figure 21: Component air leakage, as determined using ELA, also indicates that the influence of the third floor slabs is relatively small.

The equivalent leakage area of each of the building components was determined. For each floor, the ELA's were totalled and then the ELA of each component was taken as a percent of the total for the floor. When this calculation was performed, it was found that the component influence for the third floor upper and lower slabs corresponded more closely to the component influence of the other slabs. The floor by floor component air leakage, as calculated using ELA is displayed in Figure 21.

Again it can be seen from the figure that the percent participation of each individual component changes from floor to floor. What is particularly notable is that the significance of the leakage through the third floor slabs is relatively small.

COMPONENT COMPARISON:

The final step in the analyses of the data was to provide a direct comparison between the different building components in the different test floors. In order to achieve this, the corrected flows associated with each component were used to determine the flow coefficient (C) and the flow exponent (n) which are used to generate a representative equation relating the external wall pressure differential to the flow through the component. When this was performed, it was found that the resulting equations for the 2nd to 3rd, 3rd to 4th, 4th to 5th, and 5th to 6th, floor slabs all failed to meet the standard set out by CAN/CGSB 149.10-M86. In each case, the flow exponent was too small.

This, however, does not imply that the data obtained is invalid. This is, on the other hand, an indication that the margin of error of the measurements is having an important influence on the results.

Since the slabs are generally considered to be quite tight, the leakage through them only represents a small proportion of the overall leakage. The slab leakage is determined by subtracting leakage rates determined by physical tests. A small error in the determination of these measured leakage rates would result in a large error in the determination of the calculated leakage rate associated with the slab. The severity of the problem may be illustrated by the following example.

Two leakage rates, 1500 L/s and 1450 L/s, are subtracted to determine a slab leakage rate. Straight subtraction would result in a slab leakage rate of 50 L/s. When the margin of error of ± 5% is considered, however, drastic results develop. The 1500 L/s measured flow could range from 1425 L/s to 1575 L/s. The 1450 L/s measured flow could range from 1377.5 L/s to 1522.5 L/s. With these extremes considered, the possible slab flow rate range becomes 22.5 L/s to 197.5 L/s. This is equivalent to 1.5% to 13.6% of the measured flows.

Such a great range in possible flows results in a great range of possible flow exponents (n) when the flows associated with different pressures are considered. Thus, although the standard is not met, it is still valid to graph the results in order to compare the slab flow rates which were determined.

So that each floor's components could be compared on an equal bases, the flows were normalized by dividing each by the associated component area. Log-log plots of the normalized flows verses pressure were then generated to allow easy comparison and extrapolation.

Figure 22 shows the normalized leakage rates of the exterior walls. The results clearly indicate that the air tightness of the exterior walls varies from storey to storey. It is noted that the basement, first floor and sixth floor normalized leakage rates are all lower that the other floors. It cannot be assumed, however, that these floors are necessarily more air tight than the other floors. When studying this, it must be acknowledged that these leakage rates are for leakage through more than the exterior wall. Subsequently, the leakage area increases proportionally more than the leakage rate as the additional components are included. The slabs and roof are tighter than the walls thus, when they are included, the normalized leakage rate decreases.

From Figure 22, it is also noted that the normalized leakage rate for the other floors, although relatively closely grouped together, still varies from floor to floor.

Figure 23 illustrates the normalized leakage rates for the slabs. This clearly indicates the variability of the flows which are occurring from one slab to another. It also demonstrates the inaccuracies involved in the procedure. The figure indicates that the flow through the 3rd to 4th floor slab actually decreases with increased pressure. This is not possible even though this result is permitted within the margin of error allowed by the standard. The 2nd to 3rd floor slab also has a decreasing leakage rate with increasing pressure.

These results again echo the problems which exist with the third floor data. The conclusion must be drawn that either the third floor slabs are very tight and consequently the small measured flows are subject to great sensitivity, or that there was an unaccountable factor which influenced the measured readings. Something as simple as a person turning on a single exhaust fan of 15 L/s could have a major effect when slab flow rates of such a small magnitude are involved.

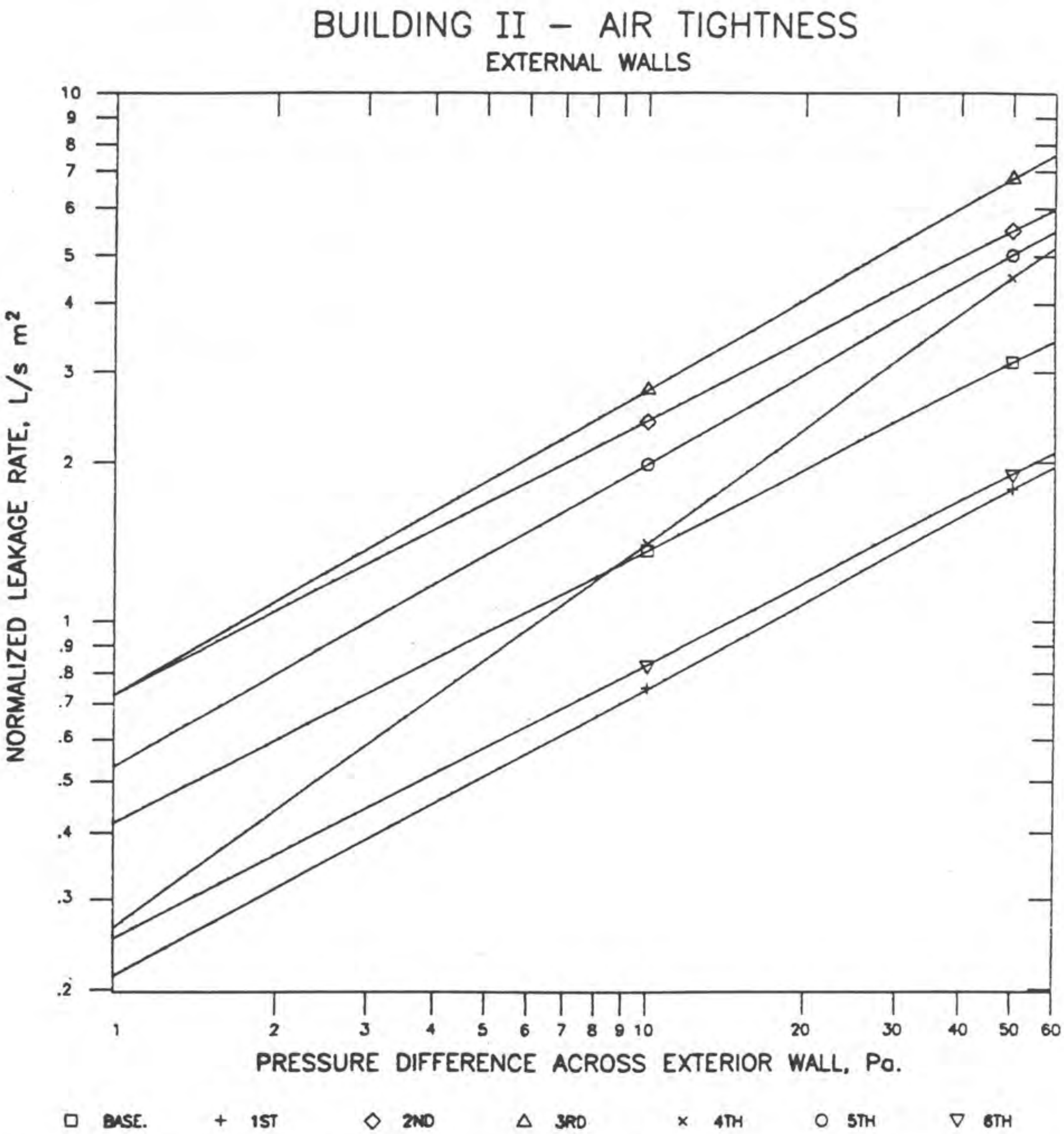

FIGURE 22: AIR TIGHTNESS OF EXTERIOR WALLS VARIES FROM FLOOR TO FLOOR.

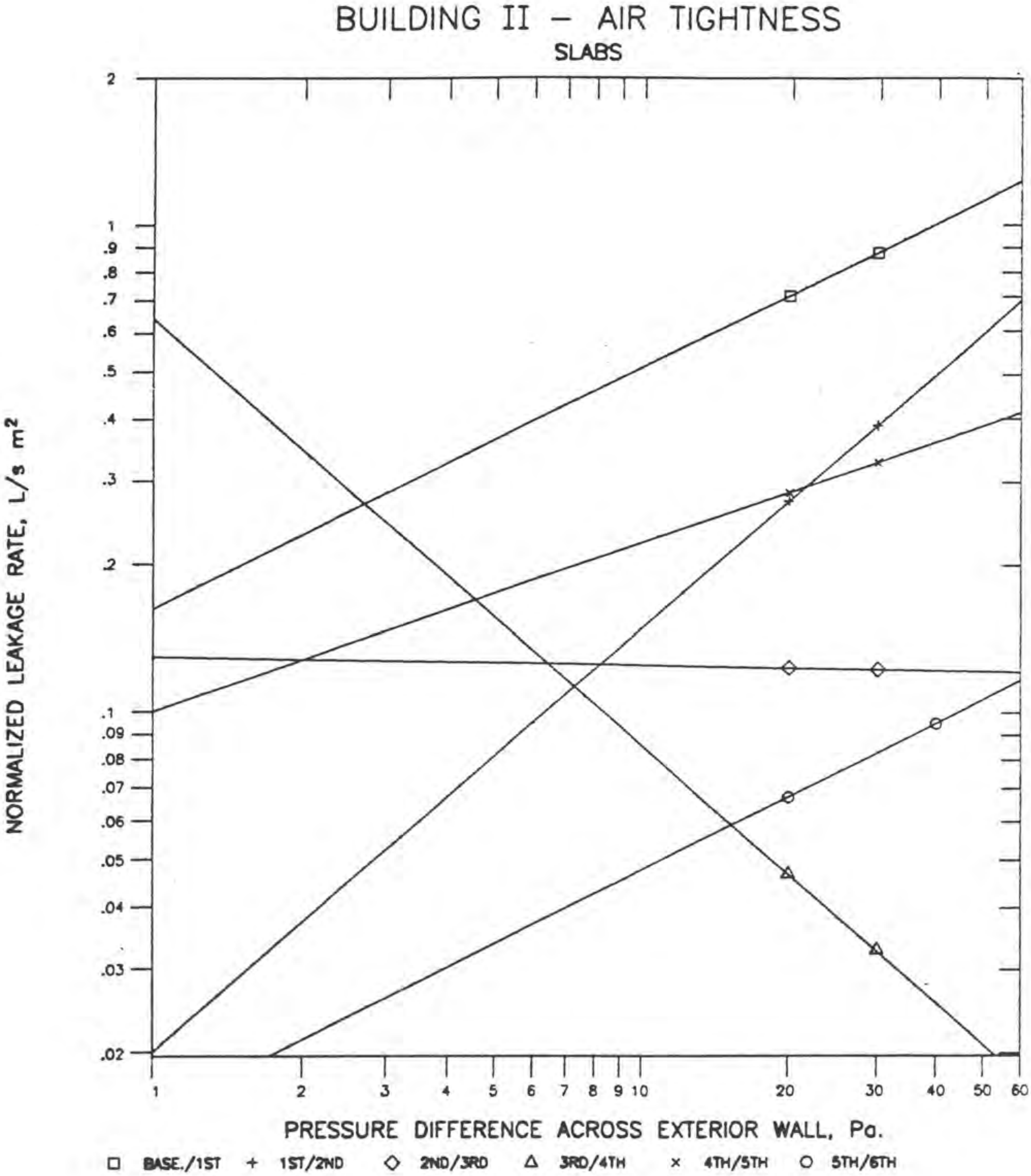

FIGURE 23: THE VARIABILITY OF THE FLOWS THROUGH THE SLABS IS CLEARLY DEMONSTRATED HERE. THE PROBLEM WITH THE 3RD STOREY'S SLABS ALSO BECOMES EVIDENT.

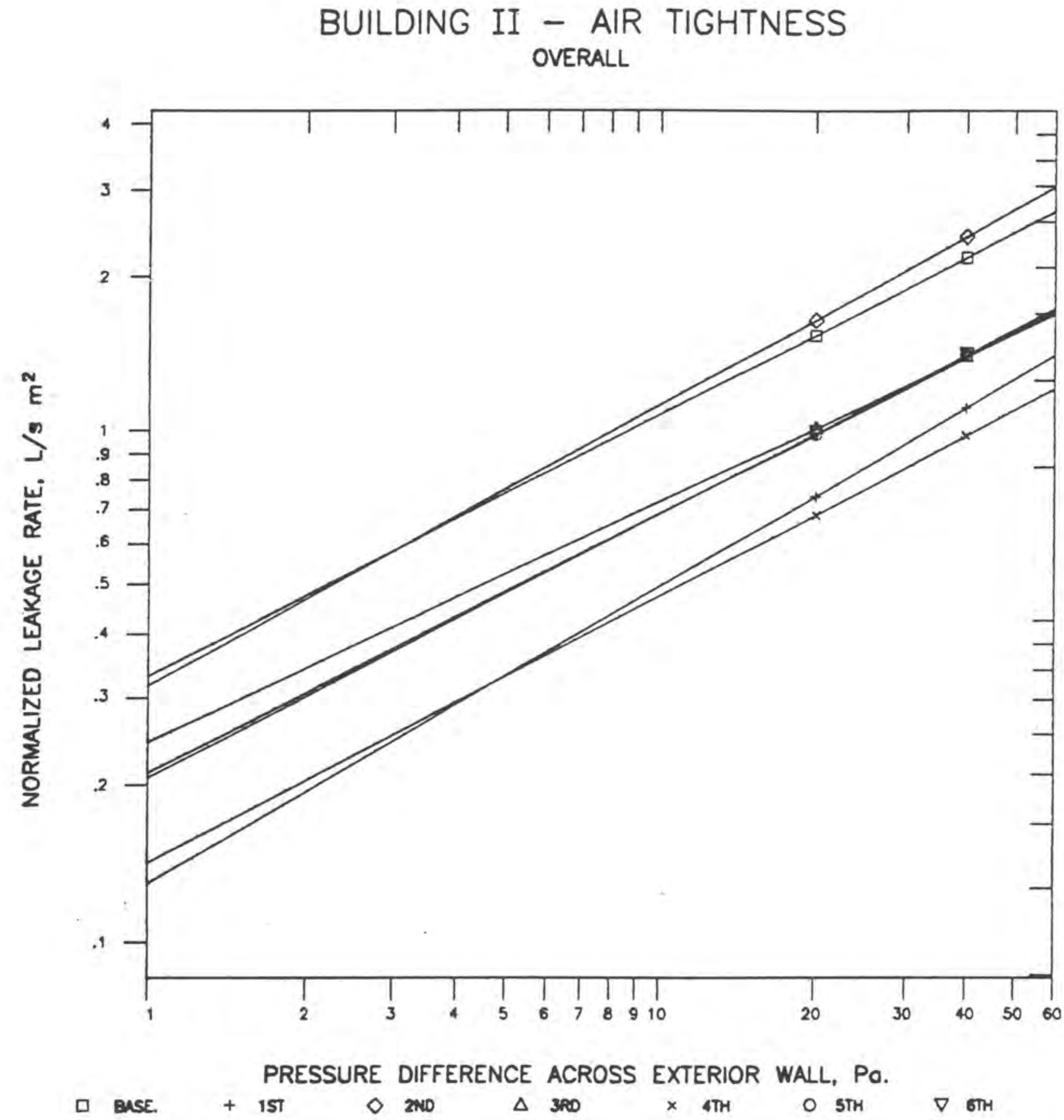

FIGURE 24: THERE IS A GREAT VARIANCE OF LEAKAGE RATE BETWEEN THE FLOORS.

As noted previously, the air tightness values for the slab separations were obtained indirectly by subtracting the exterior wall leakage from the combined leakage. Comparatively speaking, the influence of the slabs is relatively small compared to the influence of the walls. The flows determined for the slabs are therefore very sensitive to even the smallest error in the measurements of the combined flows

Something as simple as turning an exhaust fan on during a test could therefore have serious consequences in the slab flow determination.

Figure 24 illustrates the overall leakage rates. Again the great variance between floors is noted.

DATA TABLES:

Table 2, which follows, summarizes the calculations involved in determining the flow coefficient (C) and the flow exponent (n) for the various tests. A validity check is performed to verify if the standard is met. A detailed explanation of the calculations involved appear in Appendix III.

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: B-W,LS

ALL FANS ON

ENVELOPE AREA 751.09 m^2

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP AT FAN	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
30	0	0	19	1954.261	30	0	0	1858.055
25	0	0	19	1675.286	25	0	0	1592.814
20	0	0	19	1545.778	20	0	0	1469.681
15	0	0	19	1339.107	15	0	0	1273.184
10	0	0	19	1093.864	10	0	0	1040.014
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

USING CORRECTED VALUES FOR MEASURED FLOW AND PRESSURE DIFFERENCE

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
3452371.	3.401197	11742198	39937533	7.527286	25986990	2.0E+08	88386884	Sxx= 1.4E+13	1816.537	2.234489	--------	0
2537058.	3.218875	8166475.	26286870	7.373257	18706384	1.4E+08	60213529	Syy= 3.8E+12	1652.697	3.759597		0
2159964.	2.995732	6470675.	19384412	7.292801	15752193	1.1E+08	47189353	Sxy= 7.3E+12	1472.147	0.167734		0
1620999.	2.708050	4389747.	11887655	7.149276	11588971	82852761	31383515	Syx= 42.43615	1268.170	0.393845		0
1081630.	2.302585	2490546.	5734694.	6.946990	7514076.	52200213	17301800	n = 0.518442	1027.742	1.180005	REL ERR	0
0	0	0	0	0	0	0	0	C = 311.4879	0	0		0
0	0	0	0	0	0	0	0	r = 0.992334	0	0		0
0	0	0	0	0	0	0	0	ELA =0.412618 m^2	0	0	--------	0
								NLA =5.493592 cm^2 / m^2			n	0
SUMS: 10852024		33259642	1.0E+08		79548616	5.8E+08	2.4E+08				r	0
								RELATIVE STANDARD ERROR: 0.031198			rel std err	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C =============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -8 WIND VELOCITY: W24 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TEST: 1-W,PLS

ALL FANS ON

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
50	0	0	21	1446.156	50	0	0	1370.281
45	0	0	21	1316.648	45	0	0	1247.568
35	0	0	21	1147.134	35	0	0	1086.948
25	0	0	21	1023.366	25	0	0	969.6741
20	0	0	21	899.0898	20	0	0	851.9176
15	0	0	21	713.7838	15	0	0	676.3339
10	0	0	21	574.4424	10	0	0	544.3034
0	0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C =============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -8 WIND VELOCITY: WNW 22 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

ENVELOPE AREA: 739.1764 m^2

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
1877670.	3.912023	7345489.	28735722	7.222771	13561982	97955097	53054787	Sxx = 1.0E+13	1351.751	1.352264	--------	0
1556427.	3.806662	5924794.	22553694	7.128951	11095698	79100699	42237578	Syy = 3.0E+12	1276.600	2.327088		0
1181456.	3.555348	4200487.	14934195	6.991129	8259712.	57744713	29366151	Sxy = 5.5E+12	1113.783	2.468860		0
940267.8	3.218875	3026605.	9742267.	6.876960	6466184.	44467693	20813845	Syx= 33.77873	927.8290	4.315373		0
725763.7	2.995732	2174193.	6513302.	6.747489	4897083.	33043021	14670351	n = 0.542898	821.9693	3.515398	REL ERR	0
457427.6	2.708050	1238737.	3354562.	6.516687	2980912.	19425677	8072462.	C = 161.6322	703.1153	3.959775		0
296266.2	2.302585	682178.1	1570773.	6.299506	1866331.	11756965	4297386.	r = 0.993342	564.1918	3.653927		0
0	0	0	0	0	0	0	0	ELA =0.226511 m^2	0	0	--------	0
								NLA =3.064381 cm^2 / m^2			n	0
SUMS: 7035279.		24592486	87404518		49127905	3.4E+08	1.7E+08				r	0
								RELATIVE STANDARD ERROR: 0.035924			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND BUT USING CORR PRESSURE

ENVELOPE AREA: 739.1764 m^2

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
2091367.	3.912023	8181476.	32006124	7.276664	15218176	1.1E+08	59533858	Sxx = 1.3E+13	1426.600	1.352264	--------	0
1733564.	3.806662	6599093.	25120522	7.182845	12451922	89440230	47400266	Syy = 3.8E+12	1347.288	2.327088		0
1315917.	3.555348	4678543.	16633850	7.045022	9270665.	65312044	32960442	Sxy = 6.8E+12	1175.455	2.468860		0
1047279.	3.218875	3371062.	10851031	6.930853	7258539.	50307872	23364337	Syx= 35.64912	979.2046	4.315373		0
808362.6	2.995732	2421638.	7254579.	6.801383	5497983.	37393894	16470487	n = 0.542898	867.4832	3.515398	REL ERR	0
509487.3	2.708050	1379717.	3736343.	6.570580	3347627.	21995854	9065543.	C = 170.5821	742.0480	3.959775		0
329984.1	2.302585	759816.5	1749542.	6.353399	2096521.	13320038	4827418.	r = 0.993342	595.4321	3.653927		0
0	0	0	0	0	0	0	0	ELA =0.239054 m^2	0	0	--------	0
								NLA =3.234061 cm^2 / m^2			n	0
SUMS: 7835961.		27391347	97351993		55141437	3.9E+08	1.9E+08				r	0
								RELATIVE STANDARD ERROR: 0.035924			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 1-W,PLS,LS

BOTTOM FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
32	0	0	21	1692.976	32	0	0
26	0	0	21	1526.376	26	0	0
20	0	0	21	1339.107	20	0	0
16	0	0	21	1160.068	16	0	0
12	0	0	21	1008.673	12	0	0
9	0	0	21	847.7799	9	0	0
0	0	0	21	0	0	0	0
0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -8 WIND VELOCITY: WNW 21 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 1178.491 m^2

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND BUT USING CORR PRESSURE

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	2866168.	3.465735	9933382.	34426480	7.434243	21307793	1.6E+08	73847183	Sxx = 1.6E+13	1702.918	0.587290		0
	2329825.	3.258096	7590797.	24731551	7.330652	17079142	1.3E+08	55645495	Syy = 4.6E+12	1522.126	0.278419		0
	1793208.	2.995732	5371972.	16092991	7.199758	12910667	92953691	38676904	Sxy = 8.5E+12	1320.873	1.361646		0
	1345757.	2.772588	3731232.	10345174	7.056233	9495981.	67005869	26328452	Syx= 13.32324	1170.788	0.924145		0
	1017422.	2.484906	2528198.	6282337.	6.916391	7036888.	48669875	17486011	n = 0.540528	1002.179	0.643800	REL ERR	0
	718730.7	2.197224	1579212.	3469885.	6.742621	4846129.	32675613	10648034	C = 261.5874	857.8523	1.188093		0
	0	0	0	0	0	0	0	0	r = 0.999218	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.364594 m^2	0	0		0
									NLA =3.093738 cm^2 / m^2			n	0
SUMS:	10071113		30734797	95348421		72676603	5.2E+08	2.2E+08				r	0
						RELATIVE STANDARD ERROR:			0.009044			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TEST: 1-LS

PAPER TEST

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(ew) 1-W,PLS,LS	1-W,PLS	UNCORRECTED FLOW THROUGH UNBALANCED PARTITION	CORRECTED FLOW THROUGH UNBALANCED PARTITION	PARTITION FLOW AS % OF 1-W,PLS
32	1702.918	1119.637	583.2809	582.1178	51.99161
26	1522.126	1000.278	521.8487	520.8081	52.06632
20	1320.873	867.4832	453.3901	452.4860	52.16077
16	1170.788	768.5087	402.2800	401.4778	52.24116
12	1002.179	657.3848	344.7946	344.1071	52.34485
9	857.8523	562.3291	295.5231	294.9338	52.44861
0	0	0	0	0	
0	0	0	0	0	

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 442.3147 m^2

ESTIMATED FLOW RATE (L/s) CORRECTED TO REF. COND (UNBALANCED PARTITION)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	338861.1	3.465735	1174403.	4070171.	6.366672	2157418.	13735576	7477042.	Sxx = 2.2E+11	582.1190	0.000209		0
	271241.1	3.258096	883729.7	2879276.	6.255381	1696716.	10613610	5528066.	Syy = 6.3E+10	520.8076	0.000084		0
	204743.6	2.995732	613357.0	1837453.	6.114756	1251957.	7655415.	3750529.	Sxy = 1.2E+11	452.4848	0.000263		0
	161184.4	2.772588	446898.2	1239065.	5.995152	966325.5	5793268.	2679223.	Syx= 0.001264	401.4768	0.000245		0
	118409.7	2.484906	294237.1	731151.7	5.840953	691625.6	4039752.	1718625.	n = 0.535997	344.1071	0.000006	REL ERR	0
	86985.98	2.197224	191127.7	419950.5	5.686751	494667.6	2813051.	1086895.	C = 90.83546	294.9353	0.000515		0
	0	0	0	0	0	0	0	0	r = 0.999999	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.125290 m^2	0	0		0
									NLA =2.832601 cm^2 / m^2			n	0
SUMS:	1181426.		3603753.	11177069		7258711.	44650676	22240382				r	0
						RELATIVE STANDARD ERROR:			0.000002			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 1-W,PLS,US

TOP FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
40	0	0	21	1583.866	40	0	0
32	0	0	21	1404.320	32	0	0
24	0	0	21	1222.677	24	0	0
20	0	0	21	1066.227	20	0	0
16	0	0	21	882.3196	16	0	0
11	0	0	21	692.5181	11	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ==========> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -8 WIND VELOCITY: WNW 22 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s)
NOT CORRECTED TO REF. COND
BUT USING CORR PRESSURE

ENVELOPE AREA: 1486.145 m^2

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
2508634.	3.688879	9254049.	34137071	7.367624	18482674	1.4E+08	68180358	Sxx = 9.8E+12	1611.352	1.735356		0
1972115.	3.465735	6834832.	23687723	7.247308	14292531	1.0E+08	49534140	Syy = 3.8E+12	1402.276	0.145540		0
1494939.	3.178053	4750999.	15098932	7.108798	10627226	75546807	33773897	Sxy = 6.1E+12	1172.249	4.124375		0
1136840.	2.995732	3405669.	10202474	6.971881	7925917.	55258559	23743926	Syx= 36.60771	1046.417	1.857951		0
778487.9	2.772588	2158426.	5984429.	6.782554	5280136.	35812813	14639647	n = 0.622813	910.6426	3.210061	REL ERR	0
479581.4	2.397895	1149986.	2757546.	6.540334	3136623.	20514564	7521293.	C = 161.9590	721.1060	4.128100		0
0	0	0	0	0	0	0	0	r = 0.994132	0	0		0
0	0	0	0	0	0	0	0	ELA =0.272824 m^2	0	0		0
								NLA =1.835785 cm^2 / m^2			n	0
8370599.		27553963	91868178		59745109	4.3E+08	2.0E+08				r	0

SUMS: (last row above)

RELATIVE STANDARD ERROR: 0.035825 — rel std err 0

THIS TEST MEETS CAN/CGSB-149.10-M86 — 0

TEST: 1-US

PAPER TEST

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(ew) 1-W,PLS,US	1-W,PLS	UNCORRECTED FLOW THROUGH UNBALANCED PARTITION	CORRECTED FLOW THROUGH UNBALANCED PARTITION	PARTITION FLOW AS % OF 1-W,PLS
40	1611.352	1263.833	347.5188	346.8259	27.44236
32	1402.276	1119.637	282.6385	282.0749	25.19341
24	1172.249	957.7419	214.5075	214.0798	22.35255
20	1046.417	867.4832	178.9339	178.5771	20.58565
16	910.6426	768.5087	142.1339	141.8504	18.45789
11	721.1060	627.0531	94.05291	93.86536	14.96928
0	0	0	0	0	
0	0	0	0	0	

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s)
CORRECTED TO REF. COND
(UNBALANCED PARTITION)

ENVELOPE AREA: 749.9695 m^2

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
120288.2	3.688879	443728.6	1636861.	5.848822	703544.4	4114906.	2595290.	Sxx = 1.1E+10	349.1738	0.676972		0
79566.30	3.465735	275755.7	955696.7	5.642172	448926.8	2532922.	1555861.	Syy = 1.0E+10	280.5378	0.544954		0
45830.17	3.178053	145650.7	462885.9	5.366349	245940.7	1319803.	781612.8	Sxy = 1.0E+10	211.5681	1.173242		0
31889.79	2.995732	95533.29	286192.1	5.185020	165349.2	857339.2	495342.0	Syx= 3.039602	176.9247	0.925310		0
20121.56	2.772588	55788.81	154679.4	4.954773	99697.78	493979.9	276420.9	n = 0.980809	142.1472	0.209172	REL ERR	0
8810.706	2.397895	21127.15	50660.69	4.541861	40017.01	181751.7	95956.60	C = 9.369707	98.43144	4.864495		0
0	0	0	0	0	0	0	0	r = 0.999444	0	0		0
0	0	0	0	0	0	0	0	ELA =0.035991 m^2	0	0		0
								NLA =0.479905 cm^2 / m^2			n	0
306506.7		1037584.	3546976.		1703476.	9500704.	5800484.				r	0

SUMS: (last row above)

RELATIVE STANDARD ERROR: 0.018534 — rel std err 0

THIS TEST MEETS CAN/CGSB-149.10-M86 — 0

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s)
NOT CORRECTED TO REF. COND
(UNBALANCED PARTITION)

ENVELOPE AREA: 749.9695 m^2

A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
120769.3	3.688879	445503.6	1643409.	5.850818	706599.7	4134186.	2606561.	Sxx = 1.1E+10	349.8714	0.676972		0
79884.57	3.465735	276858.8	959519.6	5.644169	450882.0	2544854.	1562638.	Syy = 1.0E+10	281.0983	0.544954		0
46013.49	3.178053	146233.3	464737.5	5.368345	247016.3	1326068.	785031.2	Sxy = 1.0E+10	211.9908	1.173242		0
32017.35	2.995732	95915.43	287336.9	5.187016	166074.5	861431.5	497514.9	Syx= 3.045675	177.2782	0.925310		0
20202.05	2.772588	56011.97	155298.1	4.956769	100136.9	496355.6	277638.4	n = 0.980809	142.4312	0.209172	REL ERR	0
8845.950	2.397895	21211.66	50863.34	4.543857	40194.73	182639.1	96382.77	C = 9.388428	98.62811	4.864495		0
0	0	0	0	0	0	0	0	r = 0.999444	0	0		0
0	0	0	0	0	0	0	0	ELA =0.036063 m^2	0	0		0
								NLA =0.480864 cm^2 / m^2			n	0
307732.7		1041734.	3561164.		1710904.	9545536.	5825766.				r	0

SUMS: (last row above)

RELATIVE STANDARD ERROR: 0.018534 — rel std err 0

THIS TEST MEETS CAN/CGSB-149.10-M86 — 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 2-W,LS

LOWER FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
20	0	0	20	1727.809	20	0	0
18	0	0	20	1583.866	18	0	0
15	0	0	20	1404.320	15	0	0
12	0	0	20	1246.837	12	0	0
8	0	0	20	1037.851	8	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -7 WIND VELOCITY: WNW 20 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 1168.091 m^2

ESTIMATED FLOW RATE (L/s)
NOT CORRECTED TO REF. COND
BUT USING CORR PRESSURE

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	2985323.	2.995732	8943231.	26791526	7.454609	22254423	1.7E+08	66668296	Sxx = 8.3E+12	1693.312	1.996529	--------	0
	2508634.	2.890371	7250885.	20957754	7.367624	18482674	1.4E+08	53421800	Syy = 2.7E+12	1595.236	0.717823		0
	1972115.	2.708050	5340588.	14462581	7.247308	14292531	1.0E+08	38704893	Sxy = 4.7E+12	1438.749	2.451647		0
	1554603.	2.484906	3863044.	9599304.	7.128365	11081780	78994984	27537191	Syx= 35.89984	1267.960	1.694111		0
	1077134.	2.079441	2239839.	4657614.	6.944907	7480602.	51952092	15555475	n = 0.566293	1007.827	2.892861	REL ERR	0
	0	0	0	0	0	0	0	0	C = 310.4358	0	0		0
	0	0	0	0	0	0	0	0	r = 0.992772	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.459123 m^2	0	0	--------	0
									NLA =3.930548 cm^2 / m^2			n	0
SUMS:	10097812		27637588	76468781		73592013	5.4E+08	2.0E+08				r	0

RELATIVE STANDARD ERROR: 0.020552 rel std err 0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TEST: 2-W

PAPER TEST

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(ew) 2-W,LS	1-US	UNCORRECTED FLOW THROUGH EXT WALLS	CORRECTED FLOW THROUGH EXT WALLS	1-US FLOW AS % OF WALL
20	1693.312	177.2782	1516.034	1441.652	12.29688
18	1595.236	159.8733	1435.362	1364.938	11.71286
15	1438.749	133.6947	1305.054	1241.023	10.77294
12	1267.960	107.4147	1160.545	1103.604	9.733086
8	1007.827	72.16923	935.6582	889.7513	8.111168
0	0	0	0	0	
0	0	0	0	0	
0	0	0	0	0	

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 418.1212 m^2

ESTIMATED FLOW RATE (L/s)
CORRECTED TO REF. COND
(UNBALANCED PARTITION)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	2078361.	2.995732	6226213.	18652069	7.273545	15117053	1.1E+08	45286645	Sxx = 4.5E+12	1442.637	0.068316	--------	0
	1863057.	2.890371	5384928.	15564445	7.218864	13449159	97087664	38873071	Syy = 1.3E+12	1364.849	0.006534		0
	1540140.	2.708050	4170776.	11294672	7.123691	10971483	78157466	29711327	Sxy = 2.4E+12	1240.019	0.080898		0
	1217943.	2.484906	3026475.	7520508.	7.006337	8533321.	59787325	21204506	Syx= 1.165386	1102.670	0.084671		0
	791657.5	2.079441	1646205.	3423188.	6.790942	5376100.	36508787	11179286	n = 0.526085	890.8540	0.123930	REL ERR	0
	0	0	0	0	0	0	0	0	C = 298.3347	0	0		0
	0	0	0	0	0	0	0	0	r = 0.999987	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.402210 m^2	0	0	--------	0
									NLA =9.619476 cm^2 / m^2			n	0
SUMS:	7491159.		20454599	56454883		53447118	3.8E+08	1.5E+08				r	0

RELATIVE STANDARD ERROR: 0.000770 rel std err 0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING 11

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 3-W

ALL FANS ON

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
16	0	0	23	1621.056	16	0	0	1530.809
12	0	0	23	1339.107	12	0	0	1264.557
10	0	0	23	1222.677	10	0	0	1154.609
8	0	0	23	1066.227	8	0	0	1006.868
6	0	0	23	915.5517	6	0	0	864.5815
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C =============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -8 WIND VELOCITY: WNW 18 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

EST. FLOW RATE (L/s)
UNDER REF. CONDITIONS
(EXTERNAL SURFACES ONLY)

ENVELOPE AREA: 418.12 m^2

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	2343378.	2.772588	6497224.	18014131	7.333552	17185287	1.3E+08	47647735	Sxx = 5.1E+12	1519.727	0.723935	--------	0
	1599104.	2.484906	3973626.	9874090.	7.142477	11421569	81578303	28381535	Syy = 1.8E+12	1283.372	1.487924	|	0
	1333121.	2.302585	3069626.	7068076.	7.051517	9400532.	66288014	21645525	Sxy = 3.0E+12	1152.992	0.139974	|	0
	1013784.	2.079441	2108105.	4383682.	6.914600	7009915.	48470765	14576709	Syx= 14.23144	1011.307	0.440826	|	0
	747501.2	1.791759	1339342.	2399779.	6.762245	5054786.	34181709	9056962.	n = 0.587591	854.0242	1.221087	REL ERR	0
	0	0	0	0	0	0	0	0	C = 298.0129	0	0	|	0
	0	0	0	0	0	0	0	0	r = 0.998794	0	0	|	0
	0	0	0	0	0	0	0	0	ELA =0.462903 m^2	0	0	--------	0
									NLA =11.07107 cm^2 / m^2			n	0
SUMS:	7036891.		16987925	41739761		50072092	3.6E+08	1.2E+08				r	0
								RELATIVE STANDARD ERROR:	0.005677			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 -------- 0

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s)
NOT CORRECTED TO REF. COND
BUT USING CORR PRESSURE

ENVELOPE AREA: 418.12 m^2

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	2627823.	2.772588	7285875.	20200735	7.390833	19421809	1.4E+08	53848689	Sxx = 6.4E+12	1609.321	0.723935	--------	0
	1793208.	2.484906	4455955.	11072633	7.199758	12910667	92953691	32081804	Syy = 2.2E+12	1359.032	1.487924	|	0
	1494939.	2.302585	3442226.	7926019.	7.108798	10627226	75546807	24470092	Sxy = 3.8E+12	1220.965	0.139974	|	0
	1136840.	2.079441	2363993.	4915786.	6.971881	7925917.	55258559	16481482	Syx= 15.07043	1070.927	0.440826	|	0
	838234.9	1.791759	1501915.	2691071.	6.819526	5716365.	38982908	10242352	n = 0.587591	904.3720	1.221087	REL ERR	0
	0	0	0	0	0	0	0	0	C = 315.5819	0	0	|	0
	0	0	0	0	0	0	0	0	r = 0.998794	0	0	|	0
	0	0	0	0	0	0	0	0	ELA =0.490193 m^2	0	0	--------	0
									NLA =11.72375 cm^2 / m^2			n	0
SUMS:	7891047.		19049965	46806245		56601986	4.1E+08	1.4E+08				r	0
								RELATIVE STANDARD ERROR:	0.005677			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 -------- 0

TEST: 3-W,LS

BOTTOM FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
18	0	0	22	1761.950	18	0	0
16	0	0	22	1583.866	16	0	0
12	0	0	22	1404.320	12	0	0
10	0	0	22	1246.837	10	0	0
8	0	0	22	1066.227	8	0	0
6	0	0	22	978.6221	6	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C =============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -8 WIND VELOCITY: WNW 16 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s)
NOT CORRECTED TO REF. COND
BUT USING CORR PRESSURE

ENVELOPE AREA: 1168.09 m^2

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	3104469.	2.890371	8973069.	25935506	7.474176	23203349	1.7E+08	67066306	Sxx = 1.6E+13	1732.114	1.693343	--------	0
	2508634.	2.772588	6955410.	19284493	7.367624	18482674	1.4E+08	51244855	Syy = 4.8E+12	1623.270	2.487831	|	0
	1972115.	2.484906	4900523.	12177343	7.247308	14292531	1.0E+08	35515607	Sxy = 8.6E+12	1385.314	1.353400	|	0
	1554603.	2.302585	3579606.	8242348.	7.128365	11081780	78994984	25516743	Syx= 37.52075	1252.906	0.486740	|	0
	1136840.	2.079441	2363993.	4915786.	6.971881	7925917.	55258559	16481482	n = 0.551011	1107.949	3.913094	REL ERR	0
	957701.3	1.791759	1715970.	3074606.	6.886145	6594871.	45413243	11816422	C = 352.2956	945.5345	3.381044	|	0
	0	0	0	0	0	0	0	0	r = 0.993382	0	0	|	0
	0	0	0	0	0	0	0	0	ELA =0.503016 m^2	0	0	--------	0
									NLA =4.306320 cm^2 / m^2			n	0
SUMS:	11234364		28488574	73630085		81581125	5.9E+08	2.1E+08				r	0
								RELATIVE STANDARD ERROR:	0.013435			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 -------- 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 3-LS

PAPER TEST

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(ew) 3-W,LS	3-W	UNCORRECTED FLOW THROUGH UNBALANCED PARTITION	CORRECTED FLOW THROUGH UNBALANCED PARTITION	PARTITION FLOW AS % OF 3-W
18	1732.114	1724.644	7.470419	7.455522	0.432293
16	1623.270	1609.321	13.94973	13.92192	0.865080
12	1385.314	1359.032	26.28206	26.22965	1.930024
10	1252.906	1220.965	31.94028	31.87659	2.610768
8	1107.949	1070.927	37.02226	36.94844	3.450135
6	945.5345	904.3720	41.16251	41.08043	4.542426
0	0	0	0	0	
0	0	0	0	0	

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s) CORRECTED TO REF. COND (UNBALANCED PARTITION)

ENVELOPE AREA: 749.9695 m^2

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	55.58481	2.890371	160.6607	464.3694	2.008955	111.6674	224.3347	322.7603	Sxx =2128106.	17.31467	132.2395 *	--------	1
	193.8199	2.772588	537.3829	1489.941	2.633464	510.4179	1344.167	1415.179	Syy =2012272.	19.15453	37.58541 *		1
	687.9947	2.484906	1709.602	4248.203	3.266890	2247.603	7342.675	5585.085	Sxy =-1824603	24.51274	6.545670 *		1
	1016.117	2.302585	2339.697	5387.351	3.461872	3517.668	12177.72	8099.732	Syx= 4.729289	28.66029	10.08985 *		1
	1365.187	2.079441	2838.827	5903.176	3.609523	4927.676	17786.56	10246.81	n = -0.85738 *	34.70321	6.076659 *	REL ERR	1
	1687.602	1.791759	3023.777	5417.881	3.715531	6270.339	23297.64	11234.94	C = 206.3782	44.41095	8.107311 *		1
	0	0	0	0	0	0	0	0	r = 0.881715 *	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.011506 m^2	0	0	--------	0
									NLA =0.153426 cm^2 / m^2			n	1
SUMS:	5006.306		10609.94	22910.92		17585.37	62173.11	36904.51				r	1
							RELATIVE STANDARD ERROR:		0.078960 *			rel std err	1

THIS TEST DOES NOT MEET STANDARD --> SEE * ON CALCULATION TABLES

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TEST: 3-W,US

TOP FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
17	0	0	22	1710.481	17	0	0
14	0	0	22	1526.376	14	0	0
11	0	0	22	1339.107	11	0	0
8	0	0	22	1172.850	8	0	0
6	0	0	22	1008.673	6	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ==========> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = -8 WIND VELOCITY: WNW 14 km/hr
ATMOSPHERIC PRESSURE: 102.8 kPa

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND BUT USING CORR PRESSURE

ENVELOPE AREA: 1168.09 m^2

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	2925747.	2.833213	8289266.	23485261	7.444530	21780815	1.6E+08	61709698	Sxx = 1.1E+13	1694.902	0.910789	--------	0
	2329825.	2.639057	6148543.	16226360	7.330652	17079142	1.3E+08	45072836	Syy = 2.7E+12	1537.245	0.712038		0
	1793208.	2.397895	4299926.	10310772	7.199758	12910667	92953691	30958429	Sxy = 5.4E+12	1361.682	1.685825		0
	1375597.	2.079441	2860473.	5948187.	7.067199	9721618.	68704612	20215536	Syx= 18.69303	1160.189	1.080211		0
	1017422.	1.791759	1822975.	3266333.	6.916391	7036888.	48669875	12608411	n = 0.502860	1003.926	0.470589	REL ERR	0
	0	0	0	0	0	0	0	0	C = 407.7558	0	0		0
	0	0	0	0	0	0	0	0	r = 0.998184	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.521104 m^2	0	0	--------	0
									NLA =4.461170 cm^2 / m^2			n	0
SUMS:	9441800.		23421186	59236915		68529133	5.0E+08	1.7E+08				r	0
							RELATIVE STANDARD ERROR:		0.006836			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86

0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING 11

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 3-US

PAPER TEST

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(ew) 3-W,US	3-W	UNCORRECTED FLOW THROUGH UNBALANCED PARTITION	CORRECTED FLOW THROUGH UNBALANCED PARTITION	PARTITION FLOW AS % OF 3-W
17	1694.902	1667.682	27.22035	27.16607	1.628971
14	1537.245	1487.877	49.36778	49.26934	3.311385
11	1361.682	1291.295	70.38718	70.24682	5.440028
8	1160.189	1070.927	89.26169	89.08370	8.318369
6	1003.926	904.3720	99.55465	99.35614	10.98620
0	0	0	0	0	
0	0	0	0	0	
0	0	0	0	0	

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 749.9695 m^2

ESTIMATED FLOW RATE (L/s) CORRECTED TO REF. COND (UNBALANCED PARTITION)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	737.9956	2.833213	2090.899	5923.963	3.301968	2436.838	8046.365	6904.084	Sxx =64272074	43.95022	61.78348 *		1
	2427.468	2.639057	6406.228	16906.40	3.897302	9460.578	36870.73	24967.00	Syy =53484940	51.75387	5.042749		0
	4934.616	2.397895	11832.69	28373.56	4.252015	20982.06	89216.05	50312.79	Sxy =-5.4E+07	63.40298	9.742559 *		1
	7935.906	2.079441	16502.25	34315.47	4.489576	35628.85	159958.4	74088.12	Syx= 10.10691	82.89603	6.945909 *		1
	9871.643	1.791759	17687.60	31691.94	4.598710	45396.83	208766.8	81340.20	n = -0.84180 *	105.6106	6.295083 *	REL ERR	1
	0	0	0	0	0	0	0	0	C = 477.2656	0	0		0
	0	0	0	0	0	0	0	0	r = 0.922799 *	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.027581 m^2	0	0		0
									NLA =0.367768 cm^2 / m^2			n	1
SUMS:	25907.63		54519.68	117211.3		113905.1	502858.5	237612.2				r	1
							RELATIVE STANDARD ERROR:		0.074567 *			rel std err	1

THIS TEST DOES NOT MEET STANDARD --> SEE * ON CALCULATION TABLES 7

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 749.9695 m^2

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND (UNBALANCED PARTITION)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	740.9476	2.833213	2099.262	5947.659	3.303965	2448.065	8088.321	6935.890	Sxx =64787287	44.03803	61.78348 *		1
	2437.178	2.639057	6431.854	16974.03	3.899298	9503.286	37056.14	25079.71	Syy =53913682	51.85728	5.042749		0
	4954.355	2.397895	11880.02	28487.05	4.254011	21075.88	89657.04	50537.76	Sxy =-5.5E+07	63.52966	9.742559 *		1
	7967.650	2.079441	16568.26	34452.73	4.491572	35787.28	160741.1	74417.55	Syx= 10.12710	83.06166	6.945909 *		1
	9911.130	1.791759	17758.36	31818.71	4.600706	45598.20	209783.9	81701.01	n = -0.84180 *	105.8217	6.295083 *	REL ERR	1
	0	0	0	0	0	0	0	0	C = 478.2192	0	0		0
	0	0	0	0	0	0	0	0	r = 0.922799 *	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.027636 m^2	0	0		0
									NLA =0.368503 cm^2 / m^2			n	1
SUMS:	26011.26		54737.76	117680.1		114412.7	505326.6	238671.9				r	1
							RELATIVE STANDARD ERROR:		0.074567 *			rel std err	1

THIS TEST DOES NOT MEET STANDARD --> SEE * ON CALCULATION TABLES 7

TEST: 4-W,LS

LOWER FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
42	0	0	22	1860.949	42	0	0
38	0	0	22	1691.978	38	0	0
35	0	0	22	1547.618	35	0	0
29	0	0	22	1402.066	29	0	0
24	0	0	22	1263.977	24	0	0
20	0	0	22	1078.497	20	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = 1 WIND VELOCITY: SW 32 km/hr
ATMOSPHERIC PRESSURE: 99.95 kPa

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 1168.09 m^2

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND BUT USING CORR PRESSURE

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	3463131.	3.737669	12944041	48380551	7.528841	26073370	2.0E+08	97453644	Sxx = 1.0E+13	1823.752	1.998806		0
	2862789.	3.637586	10413644	37880528	7.433653	21280987	1.6E+08	77411423	Syy = 5.1E+12	1700.045	0.476776		0
	2395122.	3.555348	8515493.	30275543	7.344472	17590910	1.3E+08	62541808	Sxy = 7.1E+12	1604.701	3.688452		0
	1965790.	3.367295	6619397.	22289468	7.245702	14243530	1.0E+08	47962181	Syx= 37.91921	1406.293	0.301478		0
	1597638.	3.178053	5077382.	16136193	7.142018	11410366	81493049	36262758	n = 0.701828	1231.388	2.578314	REL ERR	0
	1163156.	2.995732	3484504.	10438642	6.983323	8122696.	56723418	24333423	C = 132.3500	1083.486	0.462576		0
	0	0	0	0	0	0	0	0	r = 0.992336	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.267433 m^2	0	0		0
									NLA =2.289495 cm^2 / m^2			n	0
SUMS:	13447628		47054463	1.7E+08		98721860	7.3E+08	3.5E+08				r	0
							RELATIVE STANDARD ERROR:		0.053293			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

```
Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt( (Syy - nSxy)/((SUM A)(N-2)))
```

TEST: 4-W

PAPER TEST

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(em) 4-W,LS	3-US	UNCORRECTED FLOW THROUGH EXT WALLS	CORRECTED FLOW THROUGH EXT WALLS	3-US FLOW AS % OF WALL
42	1823.752	20.56678	1803.185	1734.388	1.185823
38	1700.045	22.37463	1677.670	1613.661	1.386575
35	1604.701	23.97847	1580.722	1520.413	1.577102
29	1406.293	28.09130	1378.202	1325.619	2.119108
24	1231.388	32.94254	1198.445	1152.720	2.857807
20	1083.486	38.40717	1045.078	1005.205	3.820827
0	0	0	0	0	
0	0	0	0	0	

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 418.1212 m^2

CORRECTED PRESSURE EXT WALL	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C	
42	3008102.	3.737669	11243291	42023709	7.458409	22435658	1.7E+08	83857077	Sxx = 7.8E+12
38	2603904.	3.637586	9471925.	34454945	7.386261	19233116	1.4E+08	69962117	Syy = 4.2E+12
35	2311656.	3.555348	8218742.	29220490	7.326737	16936898	1.2E+08	60216568	Sxy = 5.7E+12
29	1757265.	3.367295	5917234.	19925078	7.189634	12634100	90834568	42542753	Syx= 2.112853
24	1328765.	3.178053	4222888.	13420565	7.049880	9367637.	66040723	29770856	n = 0.733205
20	1010438.	2.995732	3027003.	9068090.	6.912947	6985107.	48287683	20925513	C = 112.0631
0	0	0	0	0	0	0	0	0	r = 0.999974
0	0	0	0	0	0	0	0	0	ELA =0.243406 m^2
									NLA =5.821442 cm^2 / m^2
SUMS:	12020132		42101085	1.5E+08		87592518	6.4E+08	3.1E+08	

RELATIVE STANDARD ERROR: 0.003198

ESTIMATED FLOW RATE (L/s) CORRECTED TO REF. COND (UNBALANCED PARTITION)

CORRECTED PRESSURE EXT WALL	FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK
42	1736.355	0.113450	0
38	1613.501	0.009919	0
35	1519.086	0.087243	0
29	1323.431	0.164989	0
24	1151.971	0.064993	0
20	1007.826	0.260699	0
0	0	0	0
0	0	0	0

VALIDITY CHECK:

REL ERR 0
n 0
r 0
rel std err 0

0

THIS TEST MEETS CAN/CGSB-149.10-M86

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(M-2)))

TEST: 5-W, ALL FANS ON

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE
54	0	0	22	2316.800	54	0	0	2224.339
40	0	0	22	1880.493	40	0	0	1805.444
32	0	0	22	1711.320	32	0	0	1643.023
26	0	0	22	1509.389	26	0	0	1449.150
21	0	0	22	1354.680	21	0	0	1300.616
16	0	0	22	1136.052	16	0	0	1090.713
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = 0 WIND VELOCITY: W 26 km/hr
ATMOSPHERIC PRESSURE: 100 kPa

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 418.1212 m^2

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	4947684.	3.988984	19736234	78727526	7.707215	38132869	2.9E+08	1.5E+08	Sxx = 3.8E+13	2202.421	0.985348	--------	0
	3259628.	3.688879	12024378	44356482	7.498561	24442529	1.8E+08	90165545	Syy = 1.2E+13	1854.317	2.707007		0
	2699525.	3.465735	9355841.	32424876	7.404293	19988076	1.5E+08	69273395	Sxy = 2.2E+13	1631.656	0.691835		0
	2100038.	3.258096	6842127.	22292311	7.278733	15285618	1.1E+08	49802019	Syx= 28.90499	1448.548	0.041533		0
	1691603.	3.044522	5150124.	15679671	7.170593	12129801	86977881	36929453	n = 0.573268	1281.622	1.460382	REL ERR	0
	1189656.	2.772588	3298429.	9145187.	6.994587	8321159.	58203076	23071151	C = 223.7550	1096.623	0.541797		0
	0	0	0	0	0	0	0	0	r = 0.997857	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.336283 m^2	0	0	--------	0
									NLA =8.042734 cm^2 / m^2			n	0
SUMS:	15888137		56407136	2.0E+08		1.2E+08	8.8E+08	4.2E+08				r	0
							RELATIVE STANDARD ERROR:		0.024543			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 418.1212 m^2

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND BUT USING CORR PRESSURE

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	5367565.	3.988984	21411131	85408663	7.747942	41587586	3.2E+08	1.7E+08	Sxx = 4.4E+13	2293.972	0.985348	--------	0
	3536254.	3.688879	13044815	48120753	7.539289	26660844	2.0E+08	98348641	Syy = 1.5E+13	1931.398	2.707007		0
	2928617.	3.465735	10149816	35176583	7.445020	21803620	1.6E+08	75565591	Sxy = 2.5E+13	1699.481	0.691835		0
	2278256.	3.258096	7422778.	24184127	7.319460	16675605	1.2E+08	54330731	Syx= 30.10651	1508.762	0.041533		0
	1835159.	3.044522	5587185.	17010311	7.211321	13233927	95434099	40290988	n = 0.573268	1334.897	1.460382	REL ERR	0
	1290615.	2.772588	3578347.	9921285.	7.035315	9079889.	63879885	25174799	C = 233.0561	1142.207	0.541797		0
	0	0	0	0	0	0	0	0	r = 0.997857	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.350262 m^2	0	0	--------	0
									NLA =8.377055 cm^2 / m^2			n	0
SUMS:	17236469		61194075	2.2E+08		1.3E+08	9.7E+08	4.6E+08				r	0
							RELATIVE STANDARD ERROR:		0.024543			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TEST: 5-W,LS BOTTOM FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
44	0	0	22	2313.472	44	0	0
32	0	0	22	1906.522	32	0	0
30	0	0	22	1873.835	30	0	0
25	0	0	22	1656.903	25	0	0
17	0	0	22	1379.864	17	0	0
14	0	0	22	1254.844	14	0	0
0	0	0	22	0	0	0	0
0	0	0	22	0	0	0	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = 0 WIND VELOCITY: SW 33 km/hr
ATMOSPHERIC PRESSURE: 99.99 kPa

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 1168.09 m^2

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND BUT USING CORR PRESSURE

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	5352154.	3.784189	20253566	76643336	7.746504	41460488	3.2E+08	1.6E+08	Sxx = 4.5E+13	2293.184	0.876946	--------	0
	3634829.	3.465735	12597358	43659117	7.553036	27453998	2.1E+08	95148306	Syy = 1.3E+13	1930.788	1.272781		0
	3511258.	3.401197	11942483	40618744	7.535742	26459941	2.0E+08	89995482	Sxy = 2.4E+13	1864.640	0.490711		0
	2745329.	3.218875	8836873.	28444798	7.412705	20350317	1.5E+08	65505143	Syx= 25.42755	1689.760	1.983063		0
	1904026.	2.833213	5394514.	15283810	7.229740	13765621	99521873	39000941	n = 0.540150	1372.002	0.569785	REL ERR	0
	1574633.	2.639057	4155548.	10966730	7.134766	11234643	80156559	29648868	C = 296.9803	1235.403	1.549208		0
	0	0	0	0	0	0	0	0	r = 0.998163	0	0		0
	0	0	0	0	0	0	0	0	ELA =0.413563 m^2	0	0	--------	0
									NLA =3.540508 cm^2 / m^2			n	0
SUMS:	18722231		63180345	2.2E+08		1.4E+08	1.1E+09	4.8E+08				r	0
							RELATIVE STANDARD ERROR:		0.018526			rel std err	0

THIS TEST MEETS CAN/CGSB-149.10-M86 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 5-LS

PAPER TEST

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(mm) 5-W,LS	5-W	UNCORRECTED FLOW THROUGH UNBALANCED PARTITION	CORRECTED FLOW THROUGH UNBALANCED PARTITION	PARTITION FLOW AS % OF 5-W
44	2293.184	2039.862	253.3215	252.8164	12.39379
32	1930.788	1699.481	231.3076	230.8464	13.58335
30	1864.640	1632.752	226.8874	226.4350	13.82596
25	1689.760	1475.217	214.5430	214.1152	14.51414
17	1372.002	1182.602	189.4002	189.0225	15.98361
14	1235.403	1058.035	177.3685	177.0148	16.73052
0	0	0	0	0	
0	0	0	0	0	

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 749.9695 m^2

ESTIMATED FLOW RATE (L/s) CORRECTED TO REF. COND (UNBALANCED PARTITION)

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	63916.15	3.704189	241870.8	915285.2	5.532663	353626.6	1956497.	1338190.	Sxx = 1.1E+10	254.1216	0.516246	--------	0
	53290.08	3.465735	184689.3	640084.5	5.441752	289991.4	1578061.	1005033.	Syy = 1.1E+09	230.1884	0.285052	|	0
	51272.82	3.401197	174389.0	593131.4	5.422458	278024.7	1507577.	945617.0	Sxy = 3.4E+09	225.6199	0.359966	|	0
	45845.33	3.218875	147570.4	475010.9	5.366514	246029.6	1320321.	791938.9	Syx= 1.088486	213.1979	0.428402	|	0
	35729.53	2.833213	101229.3	286804.4	5.241866	187289.4	981746.1	530630.9	n = 0.310609 *	189.1292	0.056449	REL ERR	0
	31334.27	2.639057	82692.94	218231.4	5.176233	162193.5	839551.6	428038.0	C = 78.44580	178.0606	0.590755	|	0
	0	0	0	0	0	0	0	0	r = 0.999365	0	0	|	0
	0	0	0	0	0	0	0	0	ELA =0.064393 m^2	0	0	--------	0
									NLA =0.858617 cm^2 / m^2			n	1
SUMS:	281388.2		932442.0	3128548.		1517155.	8183756.	5039448.				r	0
						RELATIVE STANDARD ERROR:			0.005959			rel std err	0

THIS TEST DOES NOT MEET STANDARD --> SEE * ON CALCULATION TABLES | 1

TEST: 5-W,US

TOP FAN OFF

FIXED VALUES IN HERE JUST NOW

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW
34	0	0	22	2391.072	34	0	0
30	0	0	22	2259.322	30	0	0
28	0	0	22	2207.700	28	0	0
25	0	0	22	2040.084	25	0	0
22	0	0	22	1905.662	22	0	0
16	0	0	22	1591.608	16	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

USING UNCORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 1168.09 m^2

ESTIMATED FLOW RATE (L/s) NOT CORRECTED TO REF. COND BUT USING CORR PRESSURE

	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
	5717227.	3.526360	20161006	71094978	7.779497	44477158	3.5E+08	1.6E+08	Sxx = 3.2E+13	2415.475	1.020586	--------	0
	5104536.	3.401197	17361535	59050010	7.722820	39421416	3.0E+08	1.3E+08	Syy = 9.5E+12	2256.441	0.127493	|	0
	4873941.	3.332204	16240970	54118234	7.699706	37527921	2.9E+08	1.3E+08	Sxy = 1.7E+13	2173.300	1.558198	|	0
	4161943.	3.218875	13396778	43122566	7.620746	31717113	2.4E+08	1.0E+08	Syx= 21.98993	2043.327	0.158963	|	0
	3631550.	3.091042	11225275	34697804	7.552585	27427591	2.1E+08	84779850	n = 0.544146	1906.023	0.018955	REL ERR	0
	2533219.	2.772588	7023574.	19473484	7.372500	18676159	1.4E+08	51781309	C = 354.5305	1602.770	0.701288	|	0
	0	0	0	0	0	0	0	0	r = 0.997360	0	0	|	0
	0	0	0	0	0	0	0	0	ELA =0.498269 m^2	0	0	--------	0
									NLA =4.265677 cm^2 / m^2			n	0
SUMS:	26022418		85409142	2.8E+08		2.0E+08	1.5E+09	6.5E+08				r	0
						RELATIVE STANDARD ERROR:			0.019875			rel std err	0

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = 0 WIND VELOCITY: SW 33 km/hr
ATMOSPHERIC PRESSURE: 99.99 kPa

THIS TEST MEETS CAN/CGSB-149.10-M86 | 0

TABLE 2: CALCULATION OF REPRESENTATIVE FLOW EQUATION

BUILDING II

A = FLOW SQUARED
B = LN OF PRESSURE DIFF
C = LN OF FLOW

Sxx = (SUM A)(SUM(A*B^2))-(SUM(A*B))^2
Syy = (SUM A)(SUM(A*C^2))-(SUM(A*C))^2
Sxy = (SUM A)(SUM(A*C*B))-(SUM(A*C))(SUM(A*B))
Syx = sqrt((Syy - nSxy)/((SUM A)(N-2)))

TEST: 5-US

PAPER TEST

USING CORRECTED FLOW RATE AND CORRECTED EXTERNAL WALL PRESSURE DIFFERENCE

ENVELOPE AREA: 749.9695 m^2

ESTIMATED FLOW RATE (L/s) CORRECTED TO REF. COND (UNBALANCED PARTITION)

CORRECTED PRESSURE EXT WALL	ESTIMATED UNCORRECTED FLOW RATES @ CORRECTED P(ew) 5-W,US	5-W	UNCORRECTED FLOW THROUGH UNBALANCED PARTITION	CORRECTED FLOW THROUGH UNBALANCED PARTITION	PARTITION FLOW AS % OF 5-W	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
34	2415.475	1759.583	655.8919	654.5841	37.20108	428480.3	3.526360	1510976.	5328246.	6.484000	2778266.	18014281	9797170.	Sxx = 2.0E+11	654.7584	0.026630	--------	0
30	2256.441	1637.752	618.6889	617.4552	37.70137	381250.9	3.401197	1296709.	4410366.	6.425606	2449768.	15741250	8332147.	Syy = 4.3E+10	617.4377	0.002835		0
28	2173.300	1574.241	599.0587	597.8642	37.97792	357441.6	3.332204	1191068.	3968884.	6.393363	2285254.	14610462	7614934.	Sxy = 9.1E+10	597.2830	0.013572		0
25	2043.327	1475.217	568.1092	566.9764	38.43340	321462.2	3.218875	1034747.	3330722.	6.340317	2038172.	12922663	6560625.	Syx= 0.155360	566.8467	0.022876		0
22	1906.023	1370.975	535.0480	533.9811	38.94898	285135.8	3.091042	881366.9	2724342.	6.280360	1790755.	11246592	5535302.	n = 0.468893 *	533.8680	0.021174	REL ERR	0
16	1602.770	1142.207	460.5628	459.6444	40.24175	211273.0	2.772588	585773.2	1624108.	6.130453	1295199.	7940159.	3591055.	C = 125.3086	459.8167	0.037477		0
0	0	0	0	0		0	0	0	0	0	0	0	0	r = 0.999997	0	0		0
0	0	0	0	0		0	0	0	0	0	0	0	0	ELA =0.148094 m^2	0	0	--------	0
														NLA =1.974671 cm^2 / m^2			n	1
					SUMS:	1985044.		6500641.	21386670		12637417	80475409	41431235				r	0
												RELATIVE STANDARD ERROR:		0.000494			rel std err	0
																		1

THIS TEST DOES NOT MEET STANDARD --> SEE * ON CALCULATION TABLES

TEST: 6-W,US,PENT

ALL FANS ON

ENVELOPE AREA: 1172.740 m^2

EST. FLOW RATE (L/s) UNDER REF. CONDITIONS (EXTERNAL SURFACES ONLY)

USING CORRECTED VALUES FOR MEASURED FLOW AND PRESSURE DIFFERENCE

MEASURED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	MEASURED TEMP AT FAN	MEASURED FLOW	CORRECTED PRESSURE DIFF EXTERNAL WALL	FLOOR ABOVE	FLOOR BELOW	ACTUAL CORRECTED FLOW RATE	A	B	A*B	A*B^2	C	A*C	A*C^2	A*B*C		FLOW RATE(L/s)	RELATIVE ERROR (%)	VALIDITY CHECK	
45	0	0	22	2205.338	45	0	0	2117.325	4483066.	3.806662	17065522	64962683	7.657908	34330917	2.6E+08	1.3E+08	Sxx= 2.7E+13	2136.040	0.883880	--------	0
34	0	0	22	1946.960	34	0	0	1869.259	3494130.	3.526360	12321564	43450278	7.533297	26322326	2.0E+08	92822011	Syy= 7.2E+12	1849.421	1.061285		0
25	0	0	22	1651.459	25	0	0	1585.551	2513973.	3.218875	8092168.	26047686	7.368687	18524685	1.4E+08	59628663	Sxy= 1.4E+13	1579.043	0.410451		0
20	0	0	22	1480.738	20	0	0	1421.643	2021069.	2.995732	6054582.	18137907	7.259568	14672090	1.1E+08	43953655	Syx= 22.82271	1407.927	0.964749		0
14	0	0	22	1195.337	14	0	0	1147.632	1317061.	2.639057	3475799.	9172835.	7.045456	9279297.	65376888	24488597	n = 0.514020	1172.081	2.130313	REL ERR	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	C = 301.8731	0	0		0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	r = 0.998504	0	0		0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ELA =0.395830 m^2	0	0	--------	0
																	NLA =3.375257 cm^2 / m^2			n	0
								SUMS:	13829301		47009637	1.6E+08		1.0E+08	7.7E+08	3.5E+08				r	0
														RELATIVE STANDARD ERROR:			0.018848			rel std err	0
																					0

THIS TEST MEETS CAN/CGSB-149.10-M86

BASE PRESSURE DIFFERENCE:
EXTERNAL WALL: 0 FLOOR ABOVE: 0 FLOOR BELOW: 0
FAN NOZZEL: C ============> Pc = 101.3 kPa AND Tc = 21.1 C
AVERAGE OUTSIDE TEMP: = 0 WIND VELOCITY: W 33 km/hr
ATMOSPHERIC PRESSURE: 99.99 kPa

APPENDIX VI

TRACER GAS METHODS TO DETERMINE QUALITATIVELY CONTAMINANT AIR FLOW PATTERNS IN HIGH RISE BUILDINGS

APPENDIX VI

TRACER GAS METHODS

TO DETERMINE QUALITATIVELY

CONTAMINANT AIR FLOW PATTERNS

IN HIGH RISE BUILDINGS

APPENDIX VI

TRACER GAS METHODS

TO DETERMINE QUALITATIVELY

CONTAMINANT AIR FLOW PATTERNS

IN HIGH RISE BUILDINGS

The following test procedure is based on testing procedures presented in "ESTABLISHING THE PROTOCOL FOR MEASURING AIR LEAKAGE AND AIR FLOW PATTERNS IN HIGH RISE APARTMENT BUILDINGS" and ASTM standard # F741-83[3] -"STANDARD TEST METHOD FOR DETERMINING AIR LEAKAGE BY TRACER DILUTION". This procedure assumes that gas sample analyses will be performed at a lab rather than at the test site.

The objective of this procedure is to determine qualitatively the contaminant air flow patterns within the building. A designated amount of tracer gas is released at a single predetermined location at the beginning of the test in order to create a local "contaminant" source. Immediately after the injection, tracer gas concentrations are measured at designated intervals at locations throughout the building. The measured tracer gas concentrations at each sampling location are then plotted against time. Based on the results, the air flow directions within the building can be determined.

1.0 TEST PREPARATION:

- Calculate internal volume of test building, V_b (m^3)
- Calculate internal volume of the release site, V_r (m^3)
- In order to increase the detectability of the tracer gas at the sampling locations, the maximum allowable SF_6 concentration at the release site was determined. The maximum safe concentration of SF_6 is 1000 ppm. Assuming a factor of safety of four, a concentration of 250 ppm was selected to be the maximum allowable concentration anywhere in the building. Based on these numbers, the maximum volume of gas which could be released at the release site was determined using the following equation:

$$m = V_r * C_1 * 10^{-6}$$

where:

m = amount of SF_6 tracer gas, L
V_r = release space volume, m^3
C_1 = maximum concentration, ppb (250 ppm)

- Based on these calculations, the volume of gas required to generate a building concentration of 500 ppb was determined.

$$m = V_b * C_t * 10^{-6}$$

where:

m = amount of SF_6 tracer gas, L
V_b = building volume, m^3
C_t = maximum concentration, ppb (500 ppb)

- Prepare required volume of pure SF_6 and store in tightly sealed syringe(s), pressurized cylinder or balloon.

- Prepare 15 mL draw Vacutainers (e.g. Fisher 02-683-54) for sampling by taping septums securely in place

- Note: each test will require approximately 10 Vacutainers per sampling location

- Prepare one sampling tube for each member of sampling team for insertion under doors (use approximately 1 m lengths of approximately 2 mm ID stainless steel tubing bent in L- shape) Cap one end of each sampling tube with rubber septum.

- Assemble following equipment for each member of the sampling team:

  - stopwatch
  - marking pen capable of writing on Vactutainers
  - vacutainers
  - 2 - 60 cc hypodermic syringes with luer - Lok tips
  - 21GI hypodermic needles.
  - sampling tube
  - 5 spare septums for sampling tube

- In addition assemble the following equipment for the tracer gas release

  - 12" industrial balloons
  - flowmeter
  - pressurized gas cylinder

2.0 TEST PROCEDURE:

- Make sure all exterior windows and doors are closed for the duration of the test.

- Record test date and start time

- Measure and record:
  - outdoor air temperature, $t_{out,i}$ (oC)
  - indoor air temperature, $t_{in,i}$ (oC)
  - wind speed, $V_{w,i}$ (km/h)
  - wind direction, $D_{w,i}$
  - initial ambient atmospheric pressure, $P_{a,i}$ (kPa)

(Note: weather information can be obtained from local weather station; P_a must <u>not</u> be corrected to sea leveL)

- Prior to testing assemble the sampling team at a pre- determined location within the building in order to zero all stop watches.

- Disperse sampling team to their selected sampling locations

- At a designated time prior to tracer gas release, a sample should be taken at each designated location.

3.0 TRACER GAS RELEASE:

A predetermined quantity of the tracer gas is instantaneously injected into the building so that the initial concentration of the tracer gas is below safety limits but within the optimum detection range of the gas monitor used. Graduated syringes or balloons can be used for this injection. These can be prepared before the test or filled from a bottle of compressed tracer gas, using a flowmeter and a stopwatch, at the site. Since the objective is to determine qualitatively air contaminant flow patterns within the building, the tracer gas is released at a single designated location. (Note: make sure the tracer gas container is tightly sealed and do not bring it into the building until the time of release.)

In multi story structures there seems to be a tendency for the tracer concentration to be higher on the upper floors. This is probably due to natural convection currents caused by rising warm air. Since it is air contaminant flow that is being measured, it is not necessary to take special measures to assure uniform gas distribution. Regular mechanical system operations should be maintained

Label each air sample container as follows:

- identification of building (address)
- time of injection
- time of sample
- section of building from which sample was taken
- outdoor weather conditions
- indoor temperature.

A suitable alternative procedure is to record the data on a log sheet and identify the sample by numbers corresponding to log entries.

Wait a prior arranged amount of time after the tracer gas was released before taking the next sample. This will allow the concentration of the tracer gas at the release location to decay. Note the activities of occupants and the operation mode of mechanical equipment during this period.

At specified intervals after the tracer gas is released, fill the sample containers at each location according to the sampling procedure described below. Continue this for the duration of the test (at least 2 hours). At all times note the activities of the occupants and the operation mode of the mechanical equipment.

Tracer gas concentrations are determined in an off site laboratory using gas monitor equipment. The concentrations at each location are then plotted against time.

4.0 TRACER GAS SAMPLING PROCEDURE:

- Insert sampling tube under door. Mount hypodermic needle on syringe and remove needle cover. Purge the syringe by completely depressing the plunger. Insert needle through septum into sampling tube.

- Draw a 60 ml sample of air into syringe.

- After pausing several seconds to allow the syringe to reach atmospheric pressure, remove syringe and needle from tube, push the plunger forward to the 50 ml mark.

- Insert the syringe needle into the rubber septum-type stopper of Vacutainer.

- WHILE NOT EXERTING ANY PRESSURE ON THE PLUNGER, observe the syringe plunger to be drawn forward to approximately the 30-35 ml mark of the syringe. If the plunger fails to draw near the 30 ml mark, discard the tube and repeat the purging process.

- Push the plunger forward to the end of the syringe to inject the remaining sample into the sampling tube.

- While maintaining pressure on the syringe plunger, remove the needle from the tube, and record the sampling time and location of the tube.

- Move to the next sampling location and repeat until all locations have been sampled

- Repeat the procedure at the specified intervals (approximately 20 minutes) for the specified period of time (at least 2 hours) following release of the tracer gas. Replace sampling tube septum every 10-20 samples.

- When the test is completed measure and record:
  - outdoor air temperature, $t_{out,f}$ (OC)
  - indoor air temperature, $t_{in,f}$ (OC)
  - wind speed, $V_{w,f}$ (km/h)
  - wind direction, $D_{w,f}$
  - ambient atmospheric pressure, $P_{a,f}$ (kPa)

5.0 *DATA ANALYSIS:*

- Analyze SF_6 concentrations using gas chromatography equipped with electron capture detector

- For each sampling location, plot SF_6 concentration vs elapsed time from SF_6 release.

6.0 *CALIBRATION:*

SF_6 standards were prepared by injecting aliquot of the gas into 15 mL vacutainer tubes. The vacuums were first released by removing the caps and then replacing them in the laboratory. The primary standard sample was prepared by injecting via a gas-tight syringe, 300 uL of SF_6. This corresponds to a standard of 20,000 ppm. Four serial dilutions of this primary standard were made by successive dilutions of 300 uL aliquot into 15 mL vacutainer tubes. The standards thus prepared contained 400 ppm, 8 ppm, 160 ppb respectively. From the last standard (160 ppb) 1.5 mL was diluted into a fifth vacutainer. This corresponded to a standard of 16 ppb from which successive dilutions corresponding to 1.6, 0.16, and 0.016 ppb were prepared. The calibration curve was prepared by analyzing the electron-capture responses to duplicate samples corresponding to SF_6 amounts of .016 - 9.6 ppb. This gave a linear regression correlation coefficient r=0.94.

7.0 *GAS-CHROMATOGRAPHIC ANALYSES:*

A Varian 3700 with an electron-capture detector was employed using N_2 as the carrier gas, at a pressure of 18 psi. A steel packed (Porapak N) 4 ft column was employed with an oven temperature setting of 60 •C, detector temperature of 150 •C and an inlet temperature of 100 •C.

8.0 PRECISION AND BIAS:

At present, insufficient data exists for purposes of precision and accuracy determination. A reasonable estimate of the uncertainty in a given change rate determination is about 10% or less.

Note that the indoor air flow is a strong function of indoor-outdoor temperature difference and wind speed and direction. When interpreting or comparing data, the fact that a pressure and temperature dependence does exist should be considered. It can have a strong effect on the results.

APPENDIX VII

DATA AND ANALYSIS

AIR MOVEMENT TESTING

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AIR MOVEMENT TESTING

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AIR MOVEMENT TESTING

1.0 GENERAL:

The objective of the tracer gas testing was to qualitatively establish airflow patterns within the test building under normal building operating conditions. This entailed allowing the building occupants to go about their regular activities during the test. In addition, building equipment, such as elevators and exhaust fans, were maintained in their normal operational mode.

In the analyses which follows it becomes apparent that the magnitude of the SF_6 concentrations which were determined for the samples fall short of the tracer gas concentrations which were expected. Enough gas was released at the release site to create a tracer gas concentration in the neighbourhood of 250 ppm. When the release site samples were analyzed, the maximum SF_6 concentration encountered was found to be in the range of 70 ppb. This would indicate a drastic decline in concentration over such a very short period.

The results determined were therefore brought into question. The calibration technique used for the analyses was therefore re-evaluated and repeated. Using procedures which were similar to those used to gather the samples, vacutainer samples containing pre-determined SF_6 concentrations were prepared. The samples were then analyzed to determine the SF_6 concentration. The samples were then put aside and re-tested the next day. It was determined that the tracer gas concentration in the samples dropped by a factor of ten overnight. Vacutainers previously punctured with a syringe needle appear to have SF_6 loss due to diffusion through the syringe needle holes in the septa. Analysis of the samples checked on successive days demonstrates this.

It is evident therefore, that the tracer gas concentrations detected in the samples during the analyses is not a true representation of the concentrations which existed at the sampling location at the time the sample was taken. Assuming the diffusion rate is the same for all samples however, it can be assumed that the magnitude of the sample concentrations remain the same relative to one another. In such a case, the sample concentrations determined still provide the relative information necessary to qualitatively study air flow patterns.

The results of the tracer gas tests are presented and discussed below.

2.0 BUILDING I:

Based on the information obtained from the questionnaires, two tracer gas release sites were selected. Odours and apparent mold growth had been reported by those occupants whose apartments were adjacent to the garbage chute. The garbage room on the first floor was therefore selected as the first release site. Severe drafts in kitchen cabinets were reported in several of the apartments on the North-East corner of the building. In an attempt to monitor the influence of these drafts on air movement in the building, the ground floor apartment directly below the effected apartments was selected as the second release site.

Due to budgetary constraints, only four sampling locations on four floors of the building could be selected. The samples were taken from under the entry door of the selected apartments. In apartment 705, where particular noise and draft problems had been noted in the kitchen, the kitchen was selected as the sampling location. In this case the kitchen door was kept closed and the samples were taken from under that door.

The release sites and sampling locations are identified in Figure 1A and in Figure 1B.

In cases where the apartment occupant opened the door while the sample was being taken, a sample was taken directly from the entry way without using the sampling tube.

A control sample was taken at each location prior to the gas release. Instantaneous tracer gas release was achieved by bursting a gas filled balloon at the release site. Samples were then taken ten minutes after the release and every twenty minutes thereafter. The time at which each sample was taken was recorded.

The activities on the sampling floors were recorded so that the information could be correlated with the changes in tracer gas concentration.

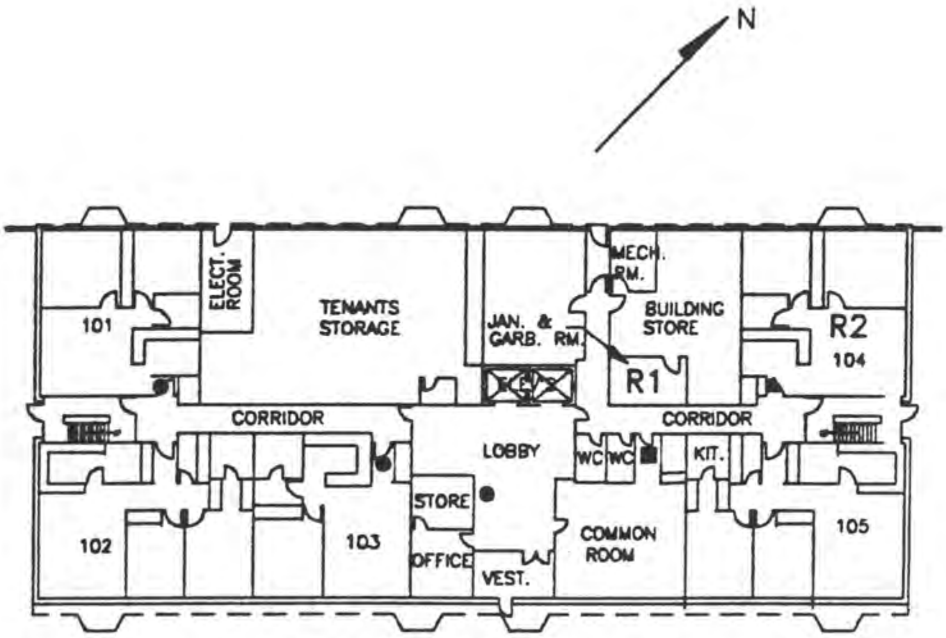
Sample tracer gas concentrations were determined using gas chromatography.

The analyses if the changes in tracer gas concentration was simplified by assuming that all the samples taken during a sampling interval (ie 10 minutes after the gas was released) were taken instantaneously. The sample concentrations associated with each sampling location on a test floor were subsequently plotted so that comparisons could be made. Any gaps occurring in these graphs indicate places where the samples were lost.

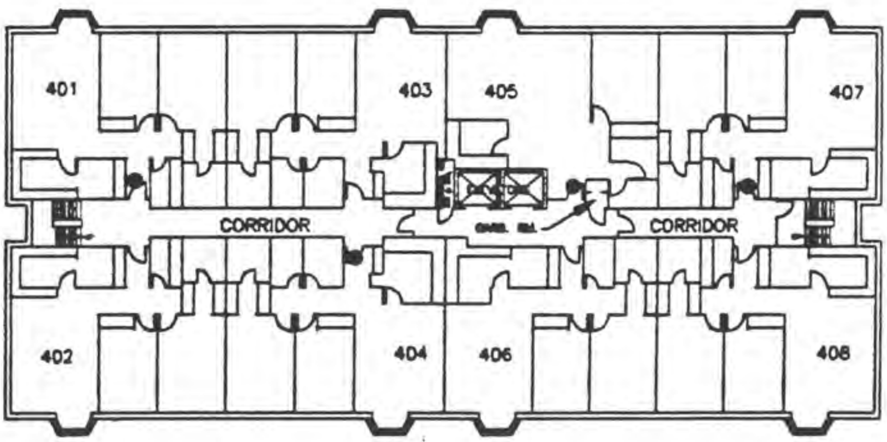
FIGURE 1A

BUILDING 1 – TRACER GAS TESTING

RELEASE SITES AND SAMPLING LOCATIONS



FIRST FLOOR PLAN



FOURTH FLOOR PLAN

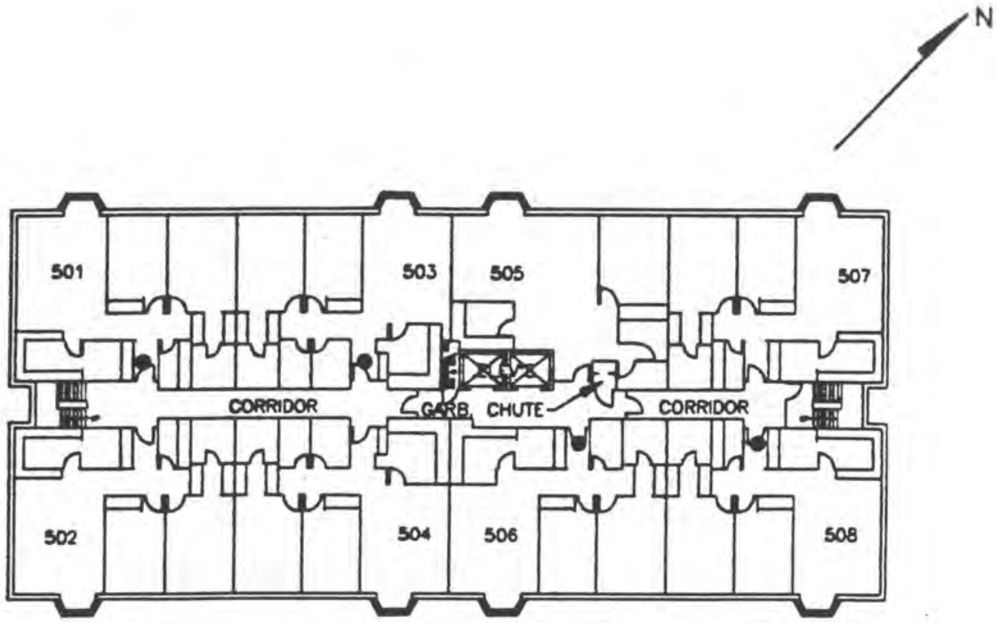
KEY

R1 RELEASE SITE 1 ● SAMPLING LOCATION – BOTH TESTS

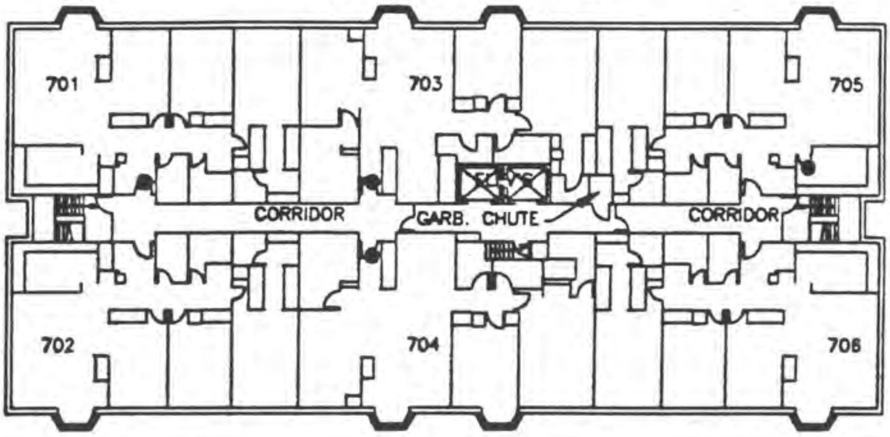
R2 RELEASE SITE 2 ▲ SAMPLING LOCATION – TEST 1 ONLY

■ SAMPLING LOCATION – TEST 2 ONLY

FIGURE 1B
BUILDING 1 – TRACER GAS TESTING
RELEASE SITES AND SAMPLING LOCATIONS



FIFTH FLOOR PLAN



PENTHOUSE FLOOR PLAN

KEY

R1 RELEASE SITE 1
R2 RELEASE SITE 2
● SAMPLING LOCATION – BOTH TESTS
▲ SAMPLING LOCATION – TEST 1 ONLY
■ SAMPLING LOCATION – TEST 2 ONLY

2.1 RELEASE SITE 1: GARBAGE ROOM

During the test the outside temperature fluctuated around 0 •C ± 1 •C, and the wind speed remained steady around 10 km/hr ranging in direction from due East to East-South-East.

As indicated by Figure 2, the tracer gas concentration at the release site decreased rapidly.

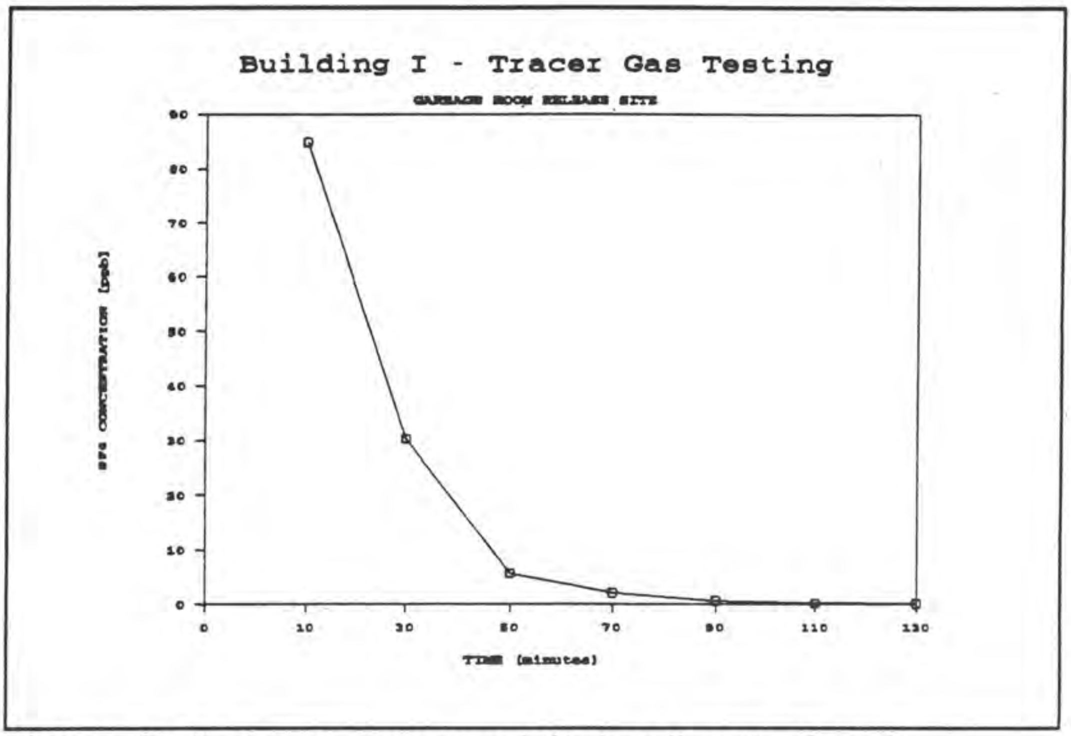


Figure 2: The tracer gas concentration declined rapidly at the release site.

2.11 First Floor:

Figure 3 illustrates the tracer gas concentrations logged on the first floor.

Apartment 104, which is adjacent to the release site on the North-East side of the building, experienced two peaks in concentration. A concentration decline is noted in the thirty two to seventy two minute interval. During this period, it was noted that the apartment occupant was coming and going from the apartment several times. This action of opening and closing doors may have "flushed" the apartment. After this activity ceased, however, the tracer gas concentration again grew at a steady rate and peaked.

The door between the South-East corridor and the lobby was always kept open. During the test, no appreciable concentration of SF_6 gathered in the lobby. This could be due to the fact that the lobby was consistently "flushed" with fresh air as occupants entered into and departed from the building.

The sampling locations on the South-West side of the building were always isolated from the release site by a corridor door which remained closed. These locations experienced a moderate increase and then decrease in SF_6 concentration. The tracer gas concentrations recorded at these locations amounted to only a minute proportion of the concentrations recorded near the release site.

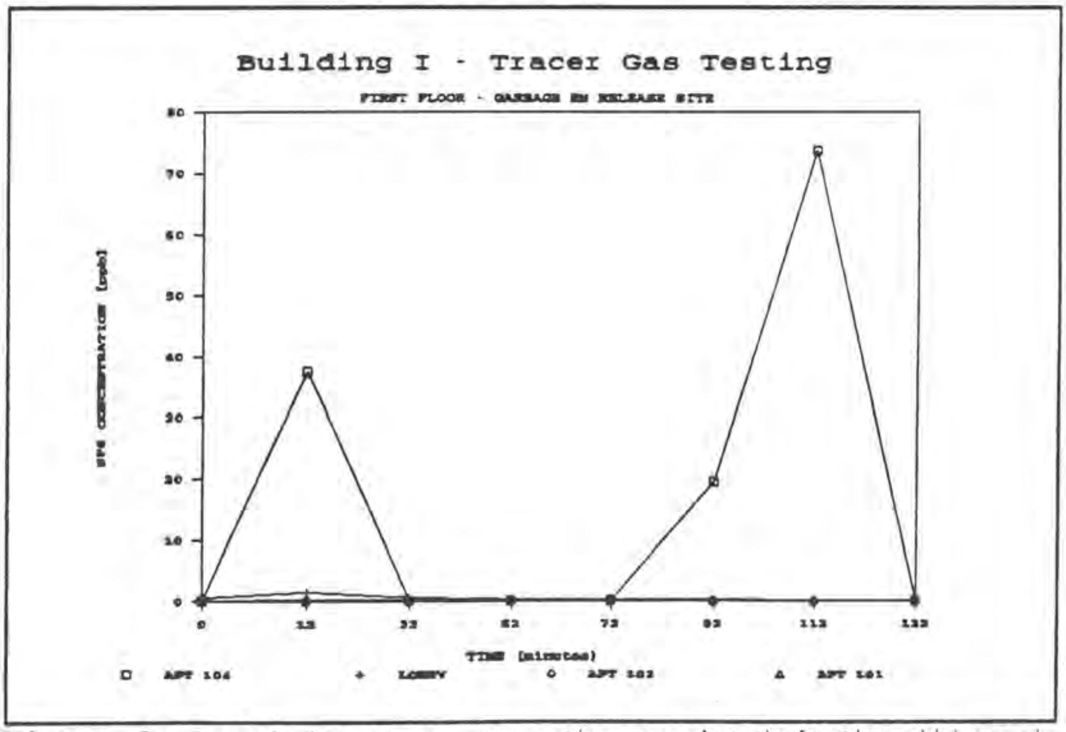


Figure 3: Two peaks in tracer gas concentration occurred at the locations which were in close proximity to the release site. The other locations experienced relatively small concentrations.

2.12 Fourth Floor:

Figure 4 illustrates the tracer gas concentrations logged on the fourth floor. It is evident that each location experienced an increase and then a decrease in tracer gas concentration. Apartment 405, directly over the release site, and which enclosed the garbage chute, showed the greatest peak in concentration.

Apartment 404, to the South of the garbage chute, showed the next highest peak. Apartment 401 had a concentration curve which echoed the concentration curve of apartment 404 but did not reach the same maximum concentration.

It is interesting to note that apartment 407, to the North-East of the release site, although closer to the release site than either apartment 401 or apartment 404, showed the minimum tracer gas concentration. It should be noted, however, that apartment 407 did experience a steady increase and then a steady decline in tracer gas concentration.

In comparing the concentrations noted, and the location within the building, it becomes evident that higher gas concentrations were resulting at the leeward sampling locations.

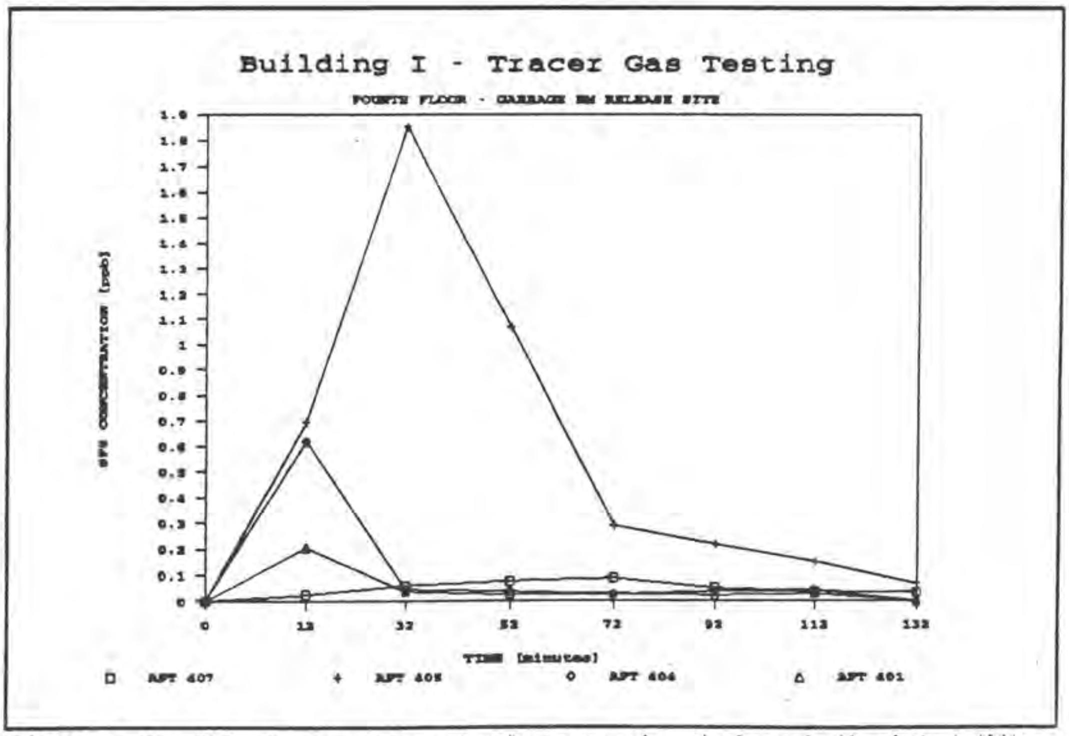


Figure 4: Higher tracer gas concentrations occurred on the leeward side of the building.

2.13 Fifth Floor:

Figure 5 illustrates the tracer gas concentrations logged on the fifth floor. All the concentrations on the fifth floor seemed to peak and then decline and then peak again. The concentration peaks noted are only about one tenth of the peak concentrations noted on the fourth floor.

Apartment 506, South-East from the garbage chute, experienced the greatest rise and fall in tracer gas concentration. Apartments 503 and 501, to the South-West of the garbage chute, experienced concentrations which were quite close to each other but still varied considerably over the duration of the test.

Again the apartment to the North-East of the garbage chute experienced the lowest tracer gas concentrations.

All the concentrations noted on the fifth floor were comparable to the concentrations encountered in apartments 401 and 407 on the fourth floor.

Again when comparing concentrations and the location within the building, trends regarding wind direction become evident.

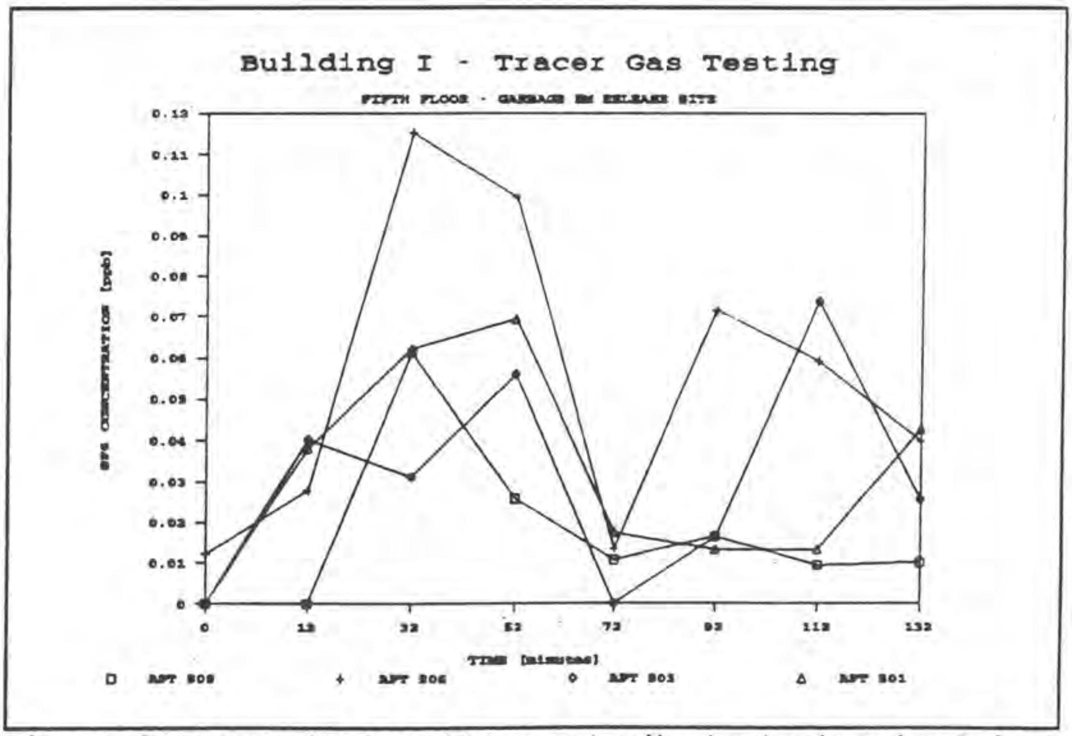


Figure 5: Concentrations detected here are much smaller than those detected on the fourth floor.

2.14 Seventh Floor:

Figure 6 illustrates the tracer gas concentrations logged on the seventh floor. Apartment 701, to the South-West of the release site experienced a dramatic increase in tracer gas concentration while the other locations on the floor maintained relatively consistent tracer gas levels. It should be noted that the concentration peak occurred much later than the peaks encountered on the other test floors.

The other seventh floor sampling locations experienced tracer gas concentrations which rose up and down within the same concentration ranges experienced on the fifth floor.

These findings indicates that the influence of the drafts noted in the kitchen of apartment 705 is minimal when compared to the influence of other factors such as the wind and the stack effect.

Again it is noted that the location where the highest tracer gas concentrations were encountered is on the leeward side of the building.

When the concentrations for each location in the building are correlated with the weather data, it becomes apparent that the air movement is greatly influenced by the wind and outside temperatures. Higher concentrations occur on the upper floors on the leeward side of the building.

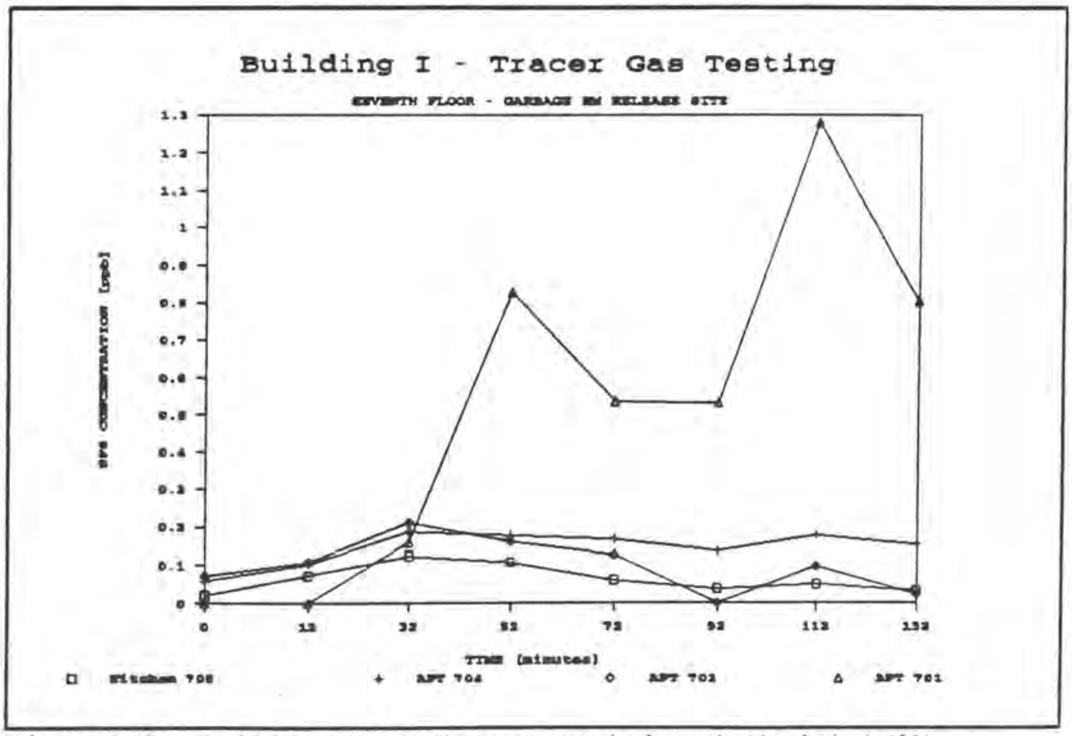


Figure 6: The highest concentrations occur on the leeward side of the building.

2.2 RELEASE SITE 2: APARTMENT 104

During the test the outside temperature fluctuated around -3 °C ± 1 °C, and the wind speed gusted from 20 km/hr to 30 km/hr from the North.

It is interesting to note, as shown in Figure 7, that the tracer gas did not disperse at such a dramatic rate as at the garbage chute. In fact, over the duration of the test (from 10 to 130 minutes after release) the tracer gas concentration only decayed by half.

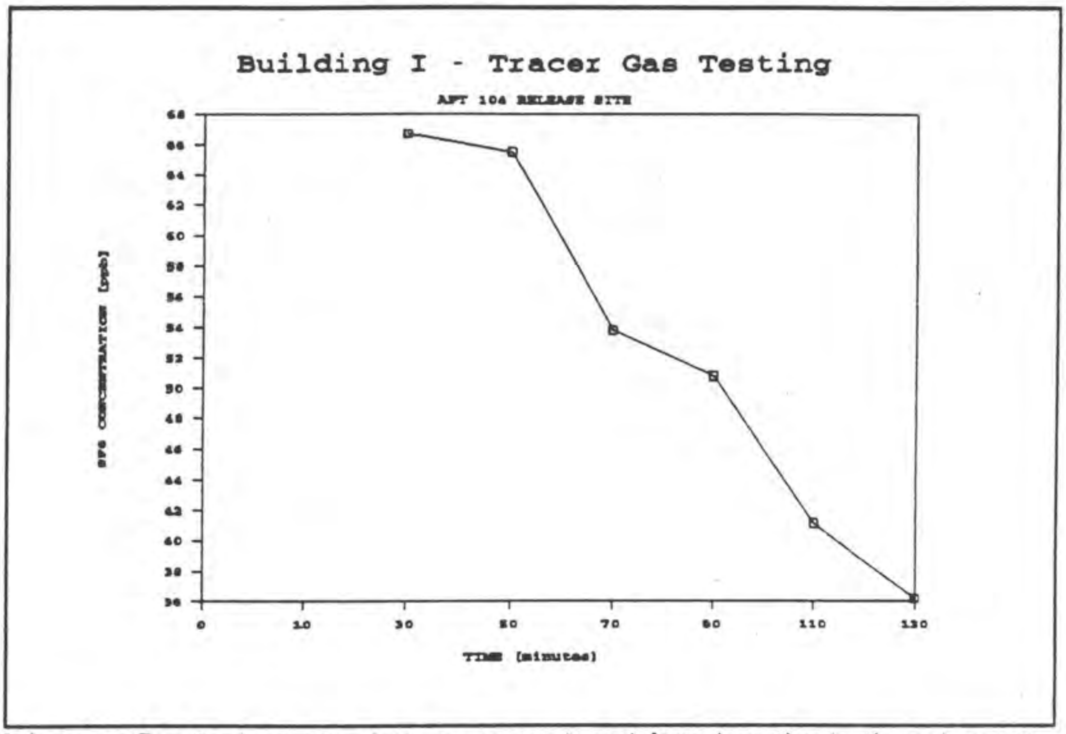


Figure 7: The decay rate of the tracer gas is much lower here than in the garbage room.

2.21 First Floor:

Figure 8 illustrates the tracer gas concentrations logged on the first floor. At the sampling location in the common room, South of the release site, the concentration increased rapidly and then started a gradual decrease. During one interval, the concentration appeared to remain relatively constant. This coincided to a period when the common room door to the lobby was closed.

The corridor door to the lobby, and the common room door to the lobby are usually kept open. It appears possible that the normal route for the air to take is through the common room to the lobby where it is "flushed" by fresh air entering the building through the operation of the doors.

More weight is added to this assertion when it is noted that the concentration detected in the lobby was also quite high but not as high as the concentration detected in the common room.

The other sampling locations on the first floor experienced concentrations which were relatively low when compared to the common room and lobby. The concentrations were, however, relatively high when compared to the concentrations recorded on the other floors.

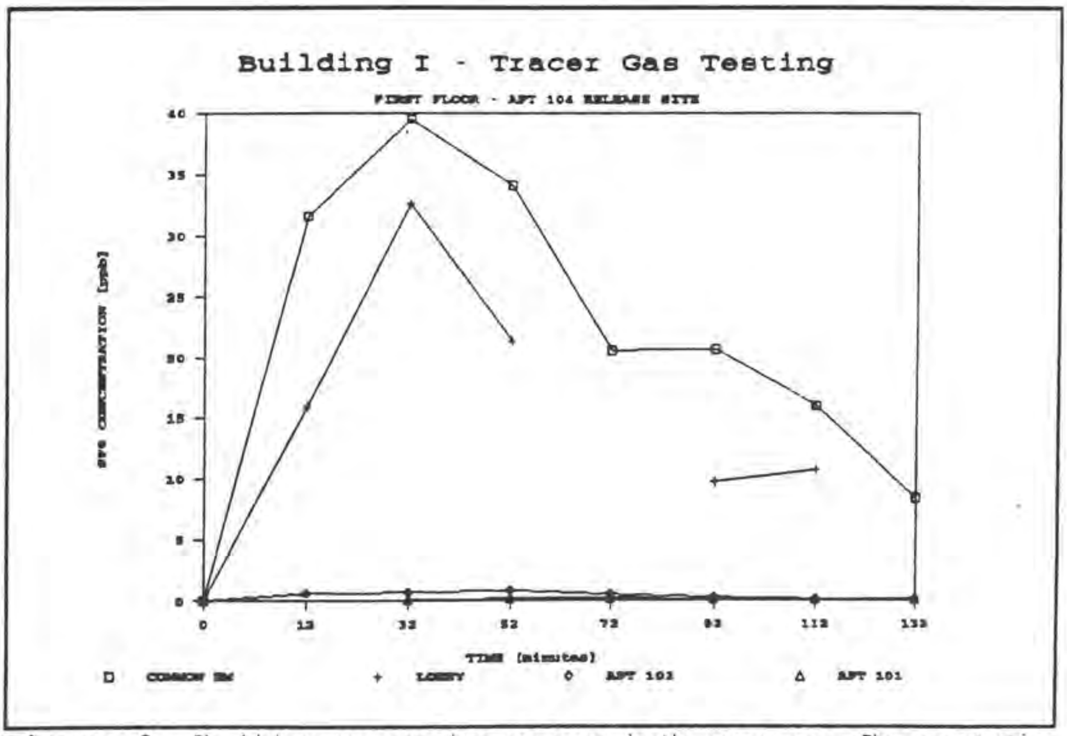


Figure 8: The highest concentrations are occur in the common room. The concentration remained constant when the common room door to the lobby remained closed.

2.22 Fourth Floor:

Figure 9 illustrates the tracer gas concentrations logged on the fourth floor. It can be seen that the peaks on the fourth floor occur at a later time than the peaks on the first floor. No particular sampling location dominated over the others for retaining tracer gas concentrations.

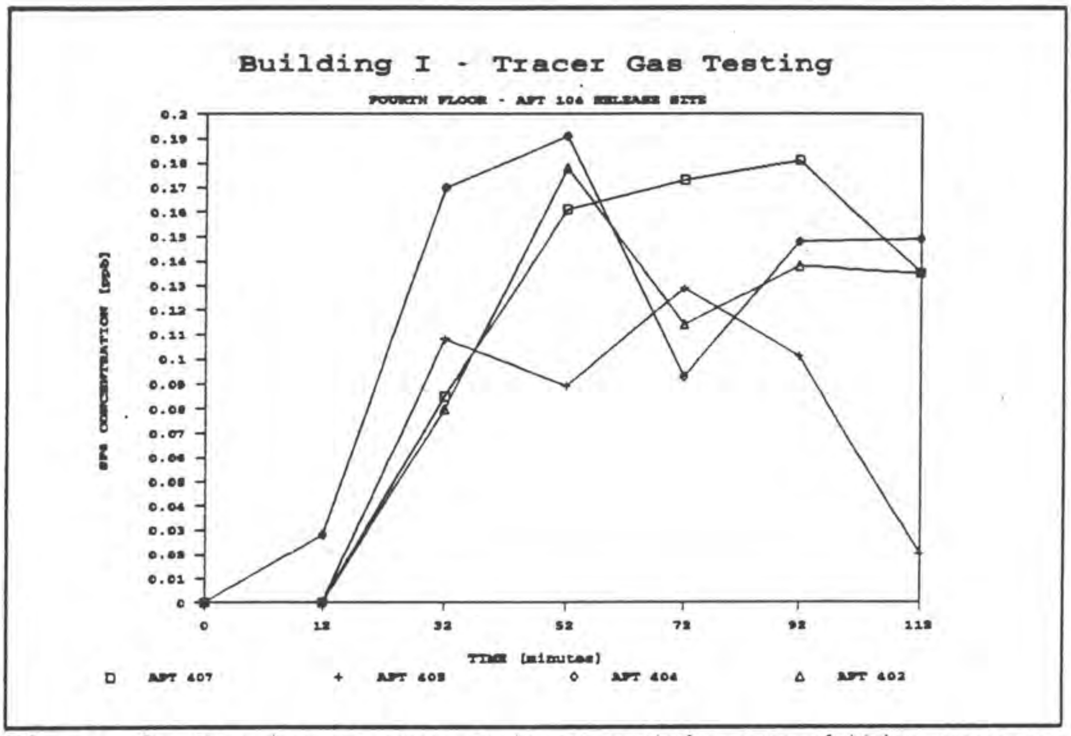


Figure 9: There does not appear to be any particular areas of higher tracer gas concentration.

2.23 Fifth Floor:

Figure 10 illustrates the tracer gas concentrations logged on the fifth floor. It is notable that the concentration curves here tend to have a steadier climb and fall than they did on the fourth floor. The peak concentration occurred later on the fifth floor than on the fourth floor. In addition the peak concentrations on the fifth were higher than the peak concentrations on the fourth.

The concentrations encountered on both floors are of about the same magnitude and are lower than the magnitude of the concentrations encountered on the first and seventh floors.

Apartment 506 demonstrated the largest concentrations while apartments 503 and 508 experienced concentrations of about the same level. Apartment 501, South-West of the release site, encountered the lowest concentrations.

These observations again correspond to the direction of the wind. The leeward apartment, in this case apartment 506, encountered the highest tracer gas concentration, while the apartment furthest away from the release site on the windward side of the building was bypassed by the higher concentrations.

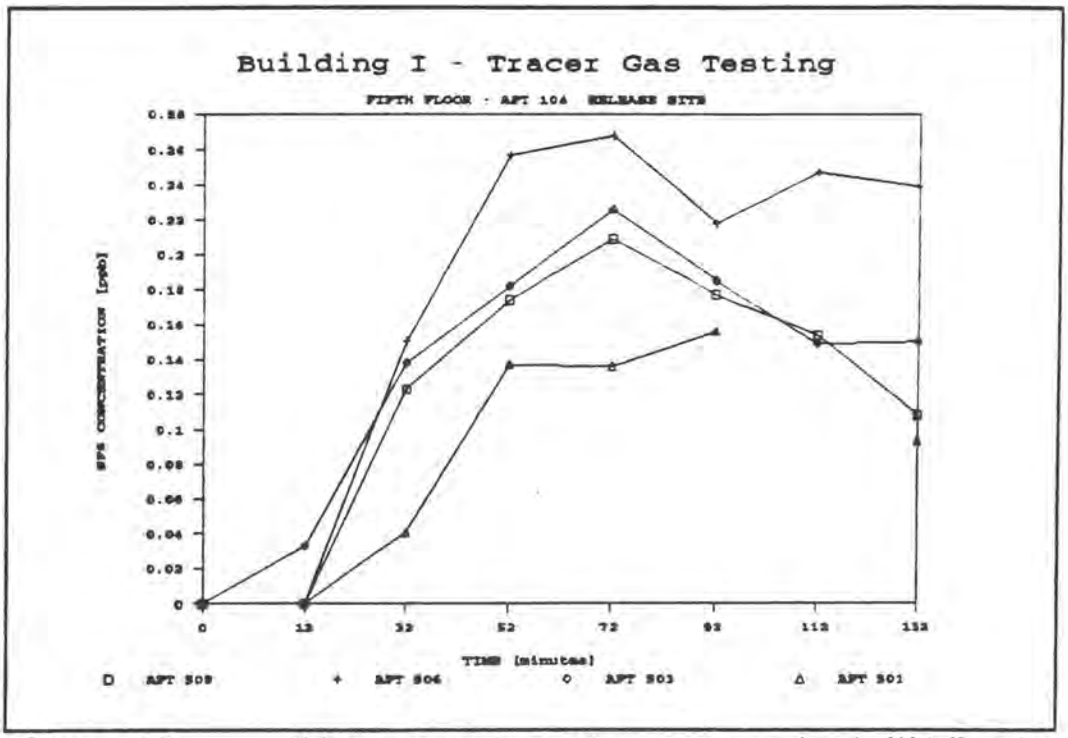


Figure 10: Higher tracer gas concentrations are encountered on the fifth floor than on the fourth floor.

2.24 Seventh Floor:

Figure 11 illustrates the tracer gas concentrations logged on the seventh floor.

As with the first release site, the concentrations observed in the kitchen of apartment 705 is very small when compared to the other concentrations on the floor.

It is interesting to note that the concentrations peaked earlier on the seventh floor than on the fifth floor however the seventh floor peaks are of much greater magnitude than the peaks encountered on the fifth floor.

Although apartment 701 experienced the highest concentration peak, it also experienced a rapid decline. Apartments 703 and 704 both experienced higher average tracer gas concentrations. Apartment 704 gained a higher concentration peak than 703, but it peaked at a later time.

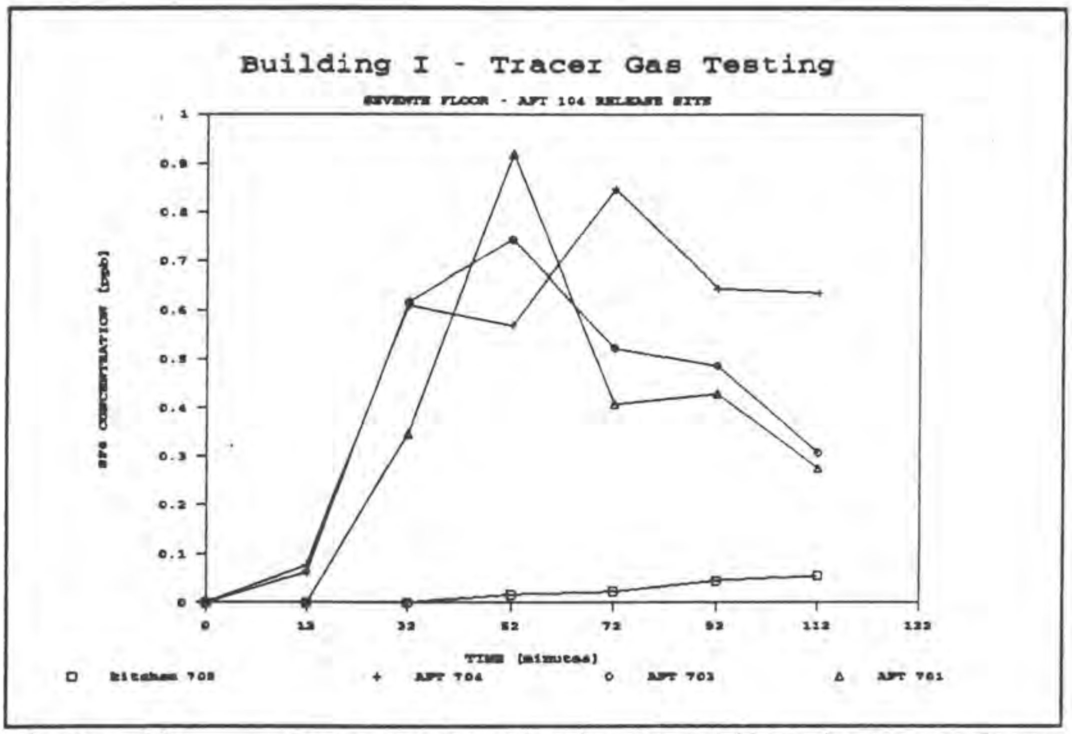


Figure 11: Tracer gas concentrations here are much higher than concentrations on the middle floors. In addition, the leeward apartments maintain higher concentrations than the windward apartments.

In studying the trend from this test, it again becomes evident that the most important influence on the air movement inside the building is the weather conditions outside the building. It is evident that a shift in the wind is accompanied by a shift in the location where the higher tracer gas concentrations would occur on each floor.

Higher tracer gas concentrations occurred on the top floor than in the middle floors. Only certain areas on the floors where the gas was released had higher gas concentrations than the top floor. The fact that the tracer gas has a tendency to rise and accumulate on the top floor indicates that the stack effect has some influence on the airflow within the building.

It was also apparent that apartment 104 experiences less air movement compared to the other release site since the tracer gas dilution rate appeared to be so much smaller.

3.0 BUILDING II:

Smells from the garbage chute had been reported by several occupants and so the garbage room was selected for the first release site.

The occupants of the apartments around the fourth floor North-West corridor complained about bad smells from the corridor carpet. In order to investigate the significance of this, the fourth floor North-West corridor was chosen as the second release site.

Due to budgetary constraints, only four sampling locations on four floors of the building could be selected. The samples were taken from under the entry door of the selected apartments.

The locations of the release sites and sampling locations are indicated in Figure 12A and Figure 12B

In cases where the apartment occupant opened the door while the sample was being taken, a sample was taken directly from the entry way without using the sampling tube.

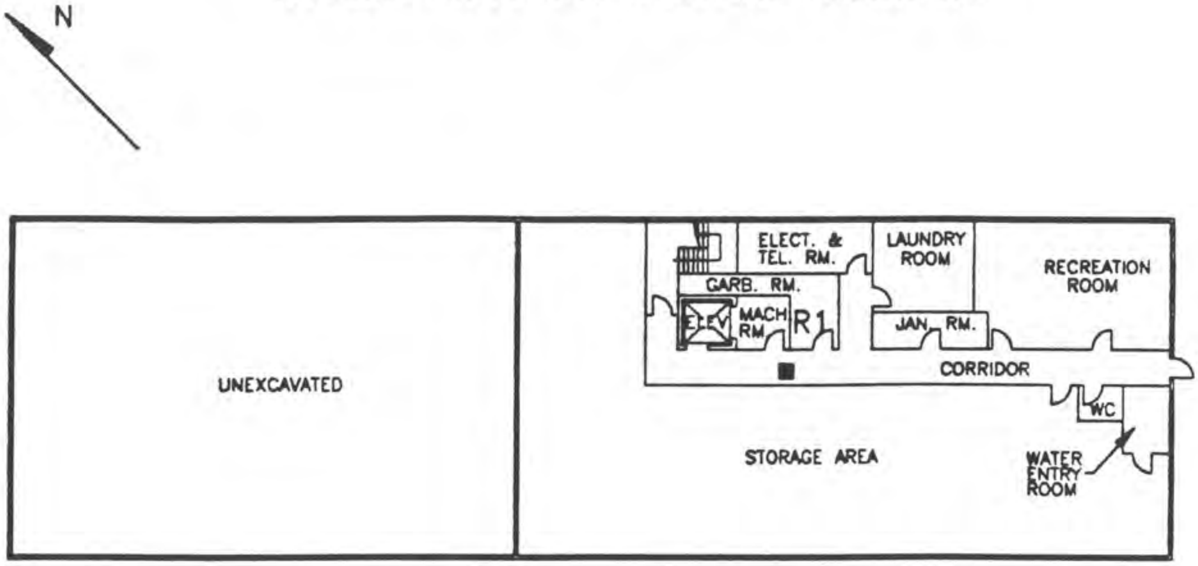
A control sample was taken at each location prior to the gas release. Instantaneous tracer gas release was achieved by bursting a gas filled balloon at the release site. Samples were then taken ten minutes after the release and every twenty minutes thereafter. The time at which each sample was taken was recorded.

The activities on the sampling floors were recorded so that the information could be correlated with the changes in tracer gas concentration.

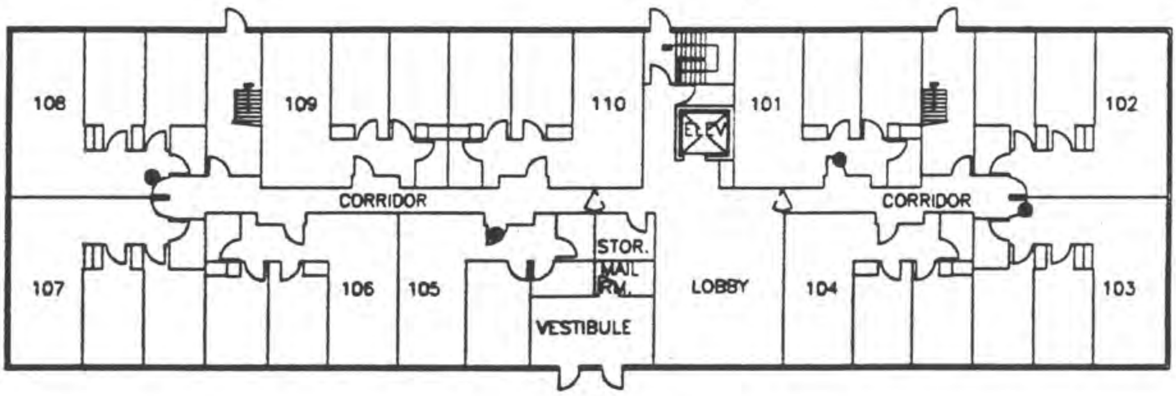
Sample tracer gas concentrations were determined using gas chromatography.

The analyses if the changes in tracer gas concentration was simplified by assuming that all the samples taken during a sampling interval (ie 10 minutes after the gas was released) were taken instantaneously. The sample concentrations associated with each sampling location on a test floor were subsequently plotted so that comparisons could be made. Any gaps occurring in these graphs indicate places where the samples were lost.

FIGURE 12A
BUILDING II - TRACER GAS TESTING
RELEASE SITES AND SAMPLING LOCATIONS



BASEMENT FLOOR PLAN



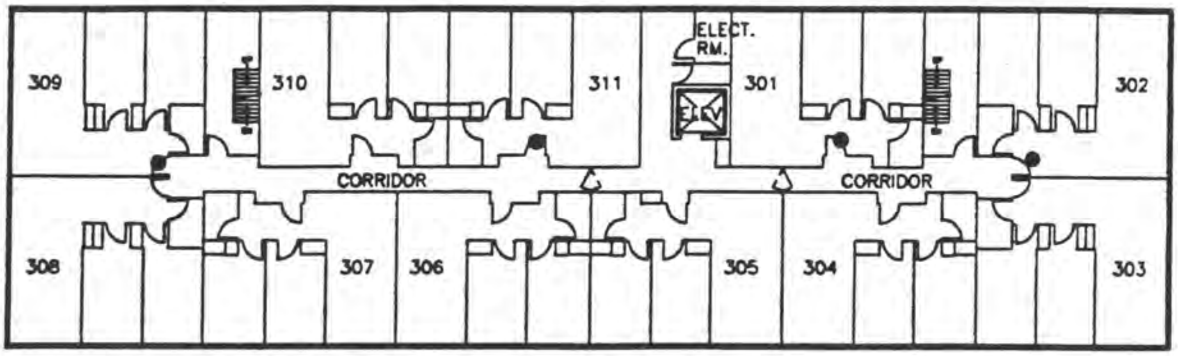
FIRST FLOOR PLAN

KEY

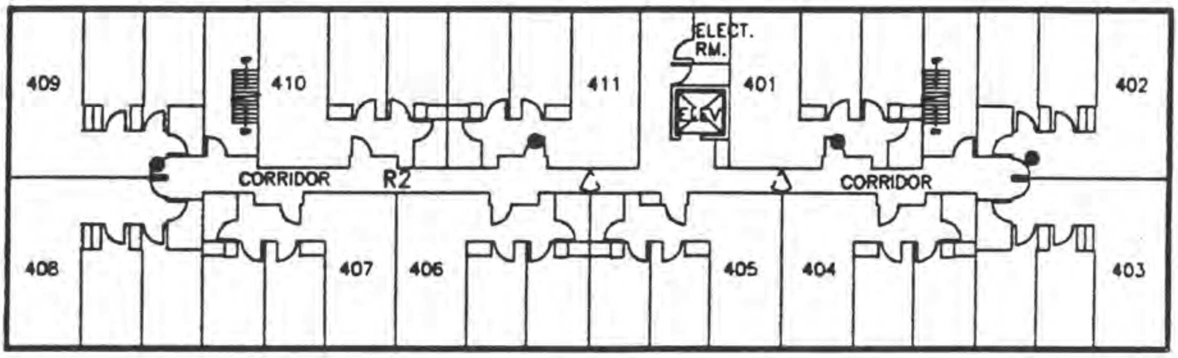
R1 RELEASE SITE 1 ● SAMPLING LOCATION - BOTH TESTS

R2 RELEASE SITE 2 ■ SAMPLING LOCATION - TEST 2 ONLY

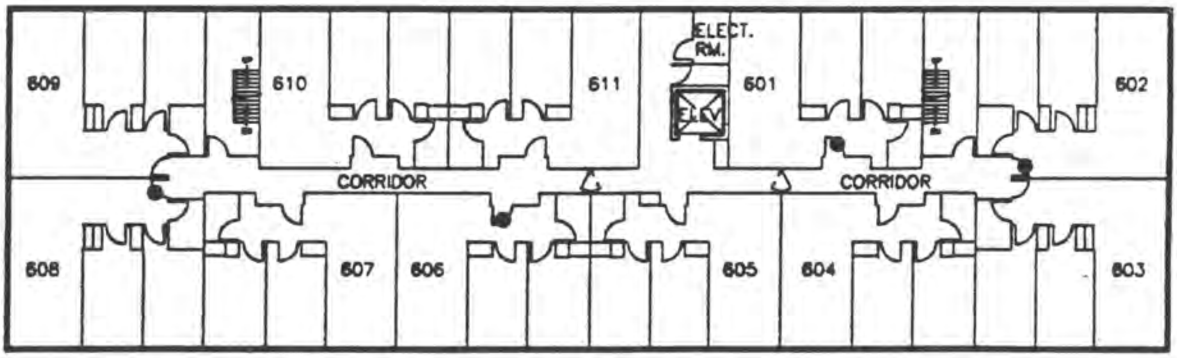
FIGURE 12B
BUILDING II – TRACER GAS TESTING
RELEASE SITES AND SAMPLING LOCATIONS



THIRD FLOOR PLAN



FOURTH FLOOR PLAN



SIXTH FLOOR PLAN

KEY

R1 RELEASE SITE 1 ● SAMPLING LOCATION – BOTH TESTS

R2 RELEASE SITE 2 ■ SAMPLING LOCATION – TEST 2 ONLY

3.1 RELEASE SITE 1: GARBAGE ROOM

The first release site chosen was the garbage room located in the half basement of the building.

During the test the outside temperature fluctuated around 0 •C ± 1 •C, and the wind speed ranged from 5 km/hr to 15 km/hr from the East to East-South-East

As shown in Figure 13, the tracer gas concentration decreased rapidly at the release site.

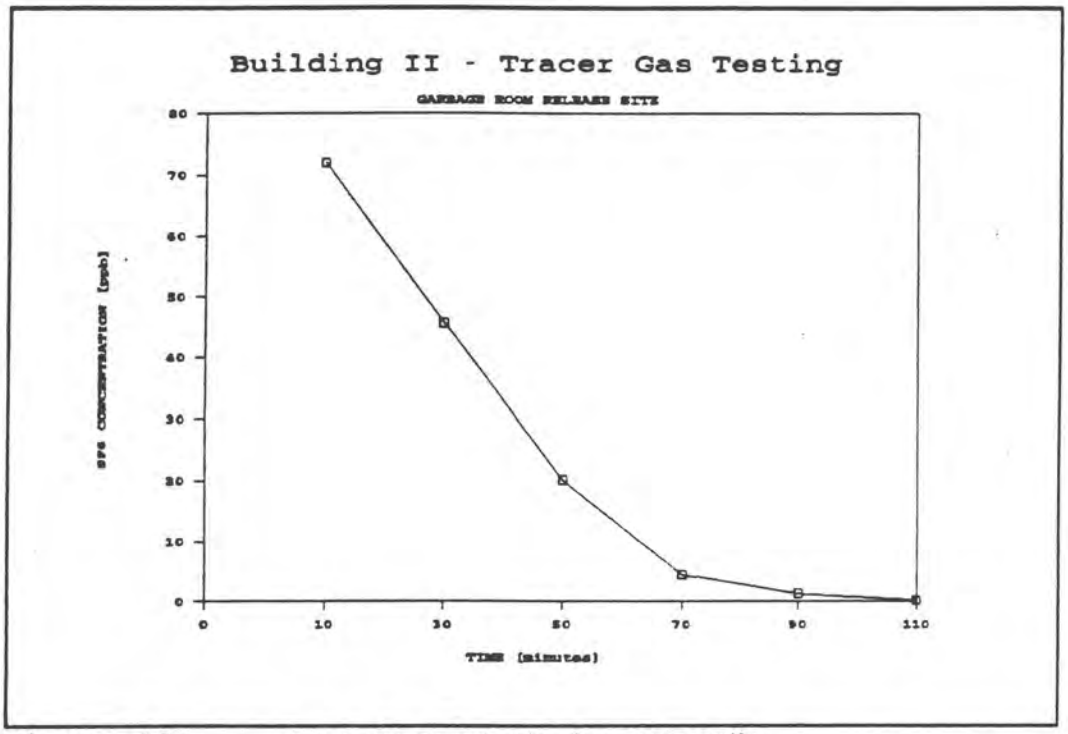


Figure 13: Tracer gas concentration decreases rapidly.

3.11 First Floor:

Figure 14 illustrates the trends in tracer gas concentration noted on the first floor. Those locations which were over the half basement showed substantially larger concentrations than those locations which were isolated from the half basement.

Apartment 108 only showed trace amounts of tracer gas during the latter portion of test. Apartment 105 only had detectable tracer gas concentrations during 30 to 50 minute period during the test. Both of these apartments are separated from the garbage chute by corridor doors.

Apartment 101, which is directly above the garbage room and adjacent to the garbage chute recorded the greatest tracer gas concentrations. Apartment 103, which is West of the release site, peaked quickly and then experienced a steady decline in tracer gas concentration.

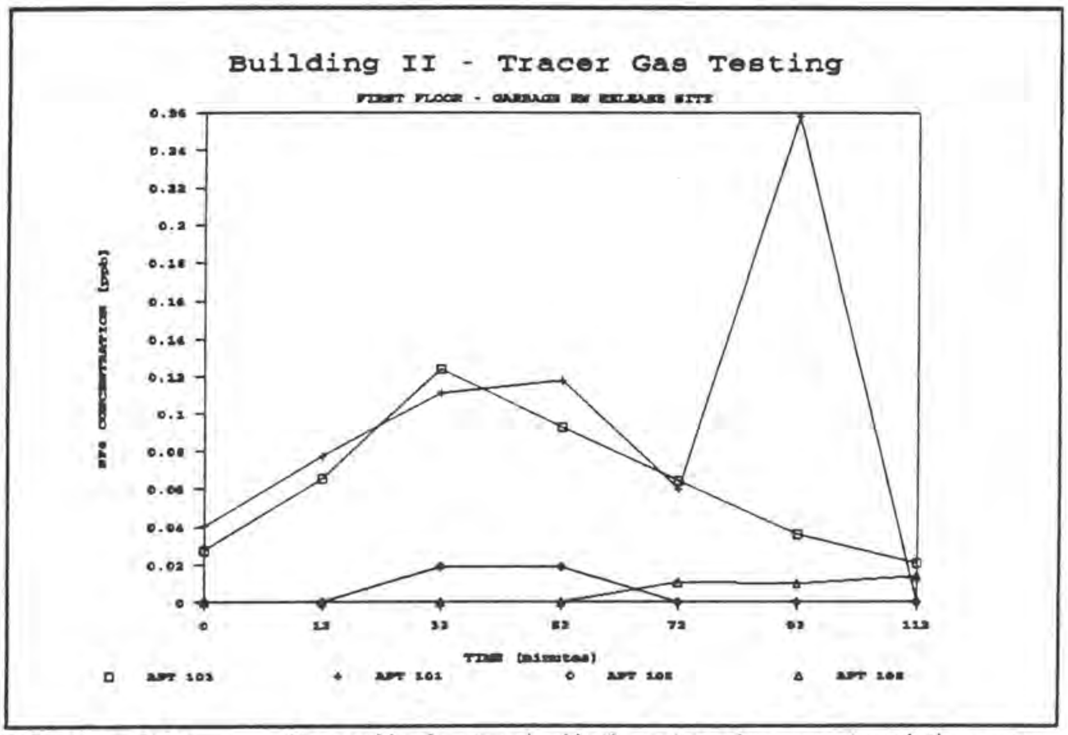


Figure 14: The sampling location beside the garbage chute experienced the greatest peak in tracer gas concentration.

3.12 Third Floor:

Figure 15 illustrates the trends in tracer gas concentration noted on the third floor.

Apartments 303 and 308 showed no traces of SF_6 at all. Apartment 305, West and across the hall from the garbage chute, recorded the largest concentration.

During the second time interval the garbage chute door was opened. During the same period the concentration recorded for apartment 301 went to zero, and the concentration reported for apartment 305 increased substantially. Once the door was closed again, the concentration reported for 305 decreased again and the concentration recorded for apartment 301 rose again. This result may be due to wind blowing through the corridor window, across the hall and into apartment 305

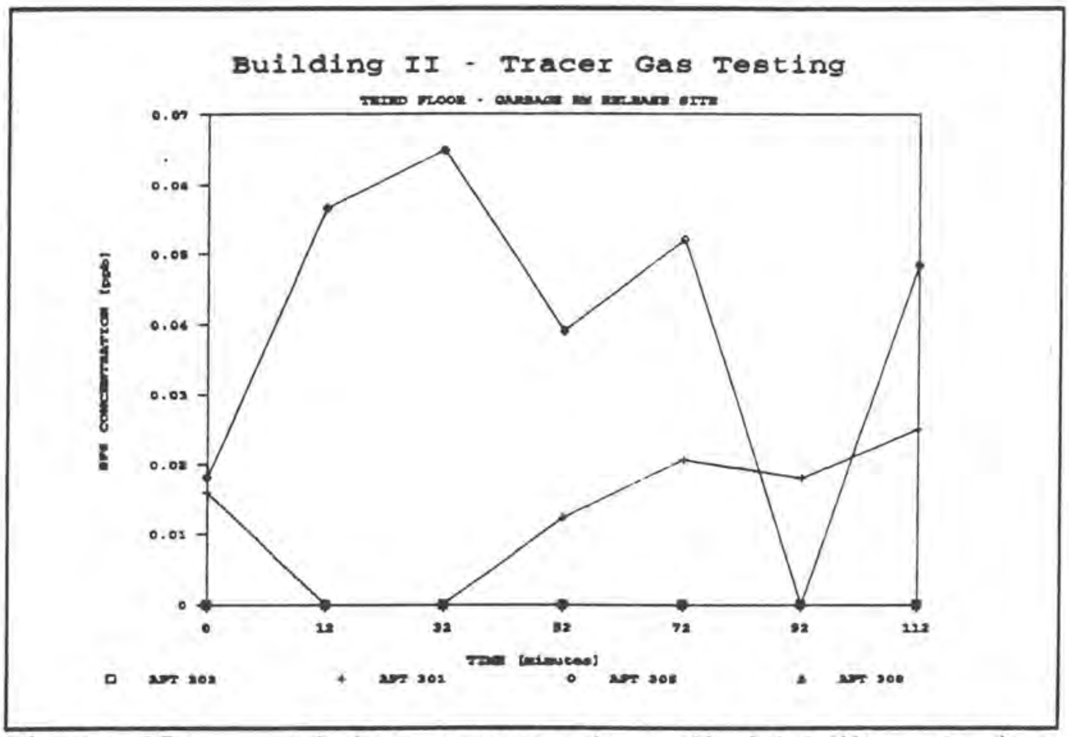


Figure 15: Only the two apartments on the same side of the building as the release site had detectable tracer gas concentrations.

3.13 Fourth Floor:

Figure 16 illustrates the trends in tracer gas concentration noted on the fourth floor. The concentrations noted in apartment 411, North-West of the garbage chute, experienced a very rapid increase and then decline. The concentrations recorded for the other apartments seemed to fluctuate substantially with no discernable trends being noted.

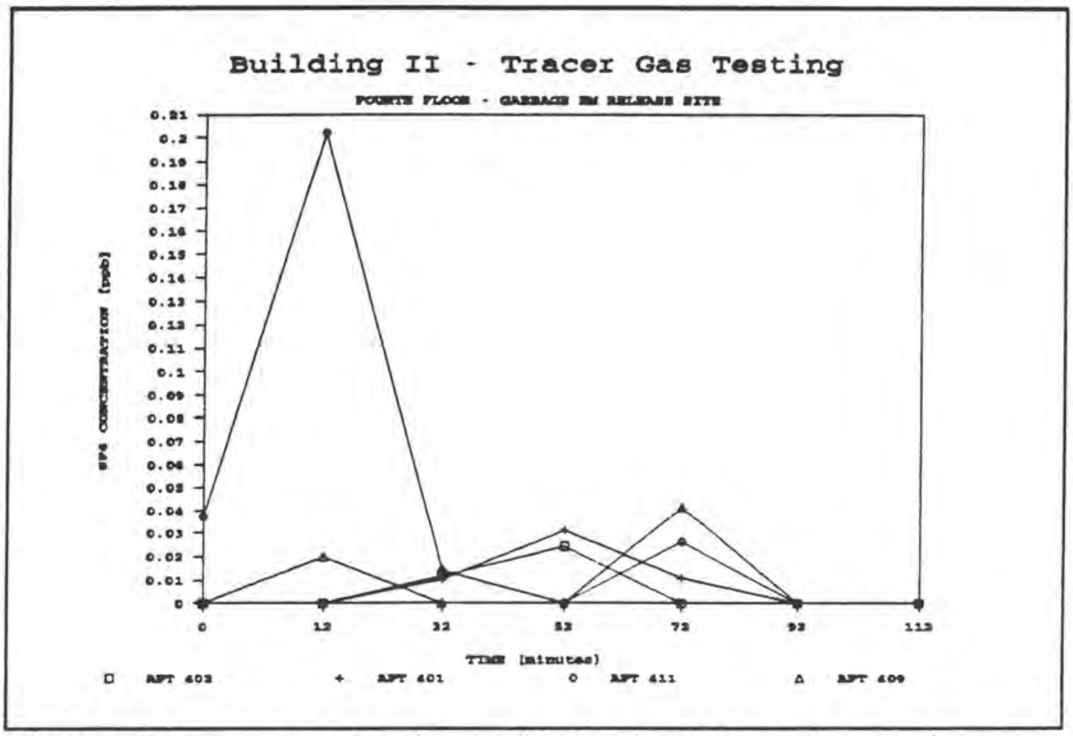


Figure 16: Apart from the initial increase in tracer gas concentration in apartment 411, no discernable trends in the concentration data is noted.

3.14 Sixth Floor:

Figure 17 provides a clear example of concentrations increasing and then decreasing. Apartment 601, adjacent to the garbage chute peaked with the highest concentration. Apartment 602 encountered the next highest concentration and apartments 608 and 606 concentrations were very close.

The concentrations recorded on this floor were higher than any of the concentrations recorded on the other floors. This indicates that the stack effect is still having an influence on the air flow in the building. It is apparent, however, there is little correspondence between high concentrations and wind direction.

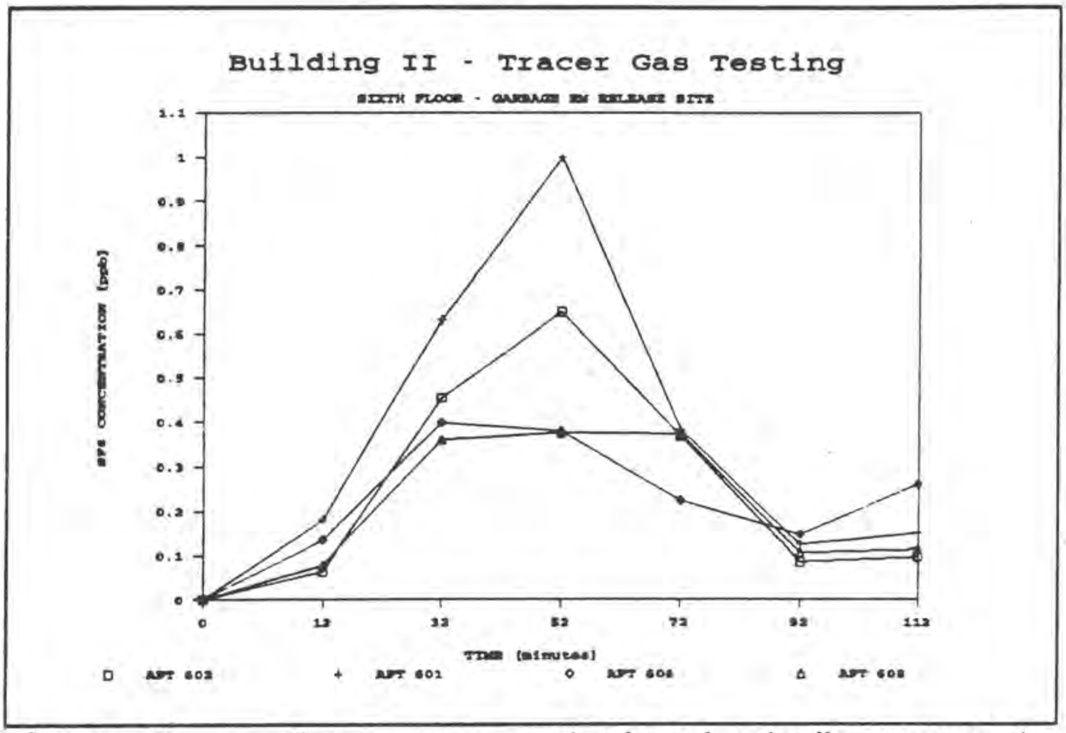


Figure 17: The tracer gas concentrations detected on this floor are greater than the concentrations detected on any of the other floors.

3.2 RELEASE SITE 2: FOURTH FLOOR NORTH-WEST CORRIDOR

During the test the outside temperature fluctuated around -1 °C ± 1 °C, and the wind speed ranged from 10 km/hr to 22 km/hr from the South-East to South-South-East

As shown in Figure 18, the tracer gas concentration decreased more rapidly at this release site than in the garbage room.

None of the samples taken from sampling locations below the fourth floor contained detectable concentrations of gas.

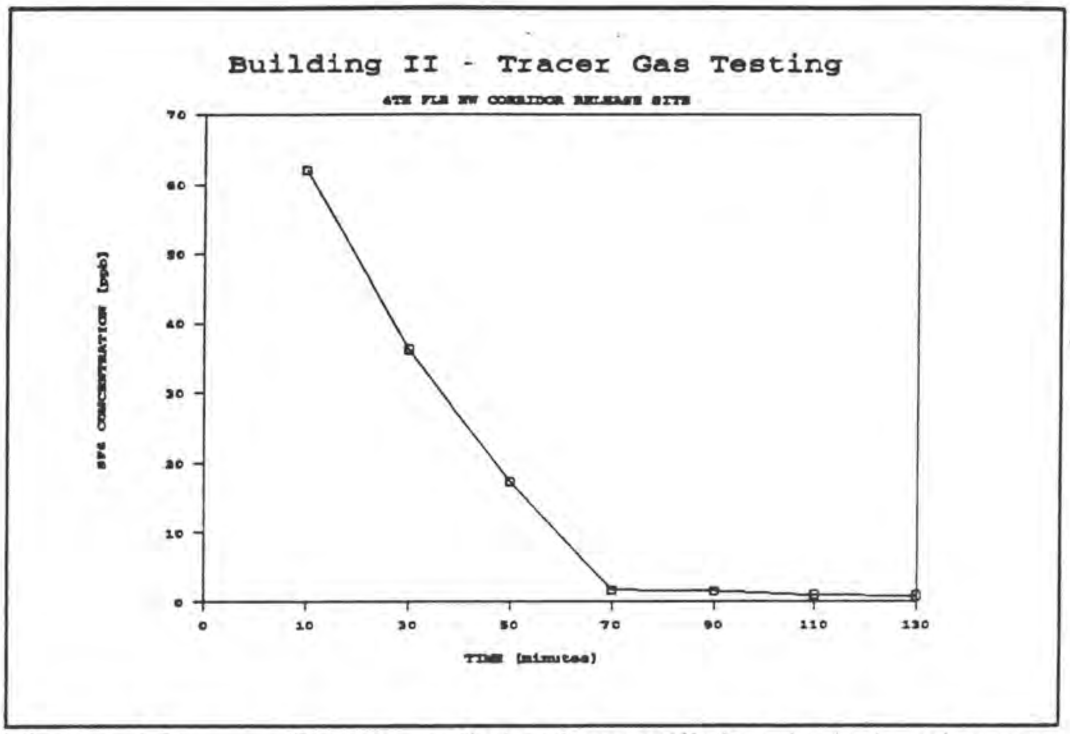


Figure 18: The tracer gas dissipated more rapidly here than in the garbage room.

3.21 Fourth Floor:

As shown in Figure 19, those apartments on the same side of the building as the release site had very large concentrations of tracer gas while those apartments on the other side of the building, separated by corridor doors, only had small amounts of the tracer gas.

As seen, apartment 411, on the eastern side of the release site, had a greater concentration than apartment 409 which was on the northern side of the release site. The wind was blowing from the South-South-East and so the opposite of this was expected.

The rapid decline in tracer gas concentration indicates a rapid dissipation rate. It is noted, however, that apartment 411 had a second increase in concentration during the latter portion of the test. This corresponded to elevator activity which was occurring at the time.

Although much smaller than the other concentrations which were detected, the concentrations detected in apartments 401 and 402 peaked early and then declined steadily.

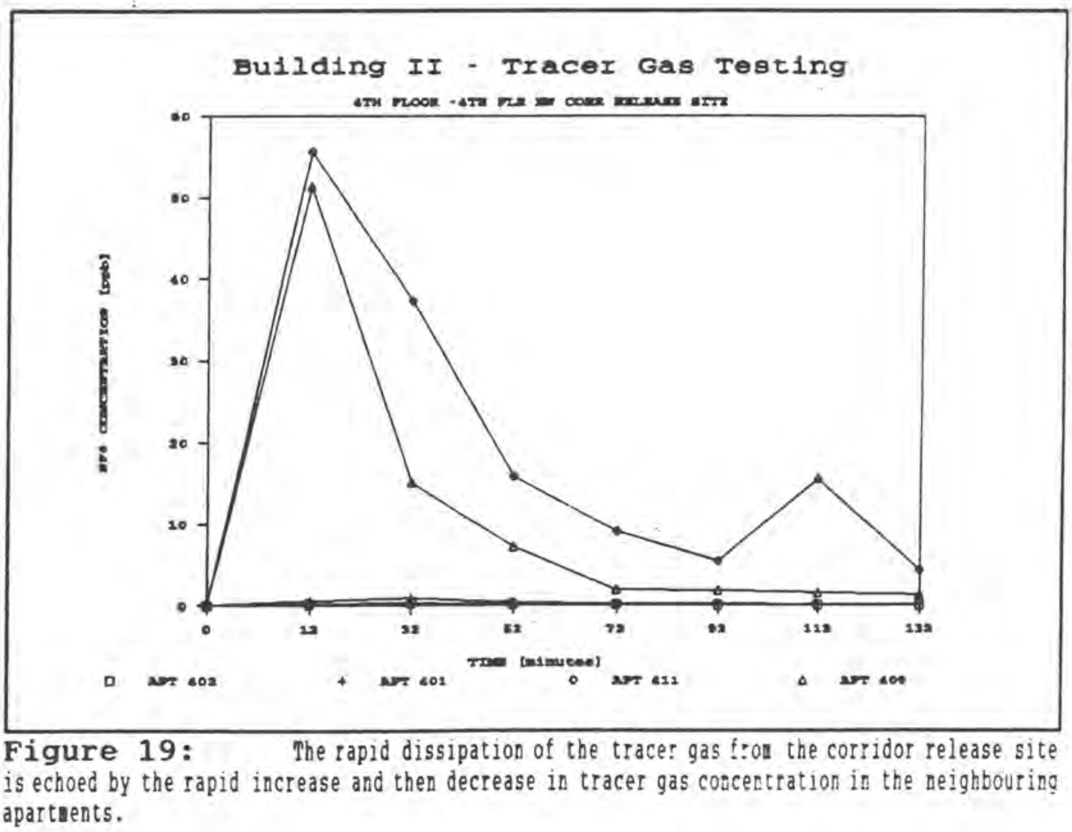


Figure 19: The rapid dissipation of the tracer gas from the corridor release site is echoed by the rapid increase and then decrease in tracer gas concentration in the neighbouring apartments.

3.22 Sixth Floor:

As shown in Figure 20, the concentrations detected on the sixth floor are of the same magnitude detected in apartments 401 and 402. Again the apartments on the opposite side of the building from the release site experience a lower concentration rate.

Apartment 608 peaked with the greatest concentration of tracer gas. This peak had a higher concentration than apartments 401 and 402. The peak associated with apartment 606 was only one third as high as the peak associated with apartment 608.

Apartment 601, next to garbage chute, experienced an early increase in tracer gas concentration at a greater rate than the other locations. Once a certain concentration level was attained, however, the concentration level remained relatively stable compared to the others.

Apartment 602 recorded the lowest concentration levels but did experience a rise to a peak and then experienced a steady decline.

There are a great number of fluctuations in the data for the sixth floor. These fluctuations correspond to the activity which was occurring on the floor at the time of the test.

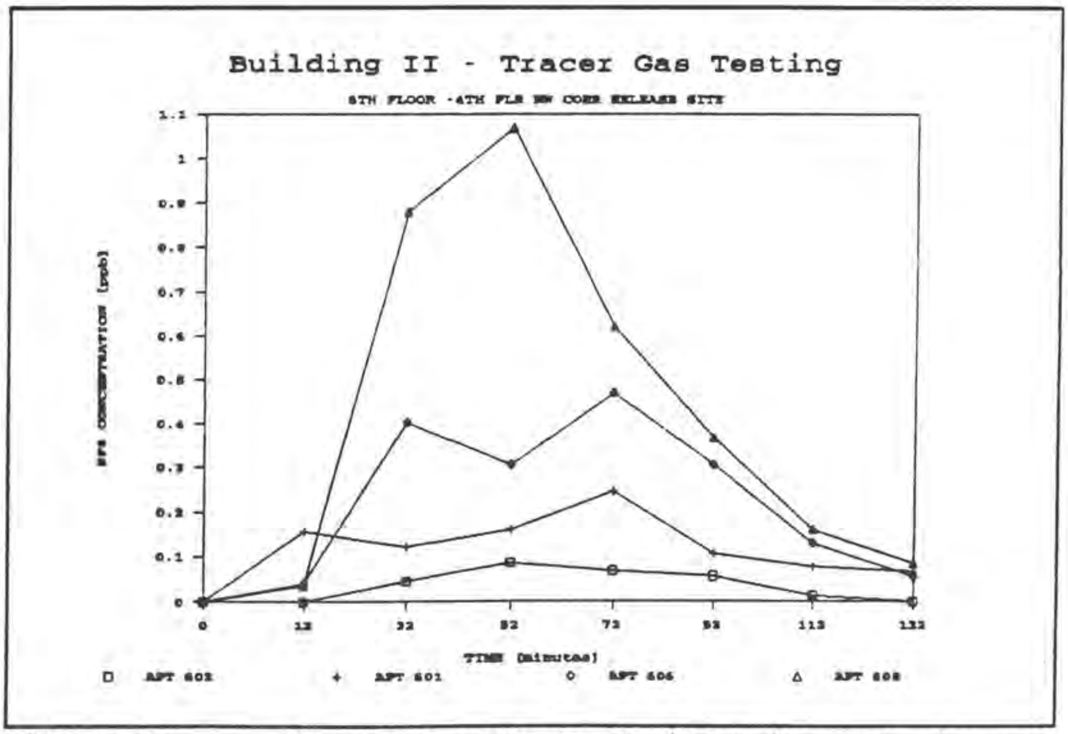


Figure 20: The apartments on the same side of the building as the release site experience the greatest increase in tracer gas concentration.

4.0 DISCUSSION

It is apparent that the controlling factors on the internal air flow in Building I is the stack effect combined with the outside wind direction. No matter which way the wind blew, the tracer gas congregated on the upper floors on the leeward side of the building.

Although the wind conditions encountered during the testing of Building II were stronger than those encountered during the testing of Building I, the wind had less of an effect on Building II.

In Building II the influence of the wind was not very great. Higher tracer gas concentrations on the upper floors indicated that the stack effect was influencing air flow, however no clear correspondence between higher tracer gas concentrations and wind direction could be established. Internal building activity seemed to have a greater influence on air movement as elevators moving, doors opening and people moving seemed to drag air around. One of the air flow paths which is notable is through the garbage chute.

APPENDIX VIII

AIR QUALITY ASSESSMENT

APPENDIX VIII

AIR QUALITY ASSESSMENT

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APPENDIX VIII
AIR QUALITY ASSESSMENT

1.0 INTRODUCTION

In October 1990, BFL Consultants Limited invited Newfoundland EnviroTech to join a proposed study of air tightness, air movement and indoor air quality in high rise apartment buildings in the Atlantic region, to be sponsored by Canada Mortgage and Housing Corporation. Upon acceptance by CMHC of the BFL proposal, work on the project began in December.

BFL chose 2 buildings for the investigation - Building I, a 7 story condominium project in the east end of St. John's and Building II, a 6 story non -profit housing unit downtown. The first stage of the investigation was a building assessment which included a survey of occupant complaints. Information gleaned from the building assessment was used in determining subsequent stages of the investigation.

2.0 SAMPLING PROGRAM

2.1 Strategy

Although there were few complaints of symptoms typical of indoor air quality problems, an air sampling program was undertaken to evaluate air quality, typical of apartments in both buildings.

Bioaerosol sampling was included. In Building II, some occupants noted the presence of mold and some of these apartments were included. In Building I, some occupants felt the garbage chute was a source of odour and mold. Apartments adjacent to the garbage chute were sampled. In both buildings, the garbage room and lobby were included.

Carbon dioxide (CO_2) and Relative Humidity (RH) were monitored in typical apartments to investigate complaints of stuffiness and condensation by some occupants. Stuffiness and stale air may result from overcrowding and/or lack of ventilation. Apartments do not have mechanical ventilation. Building II may be overcrowded, being a non-profit housing unit.

Carbon monoxide (CO) was included because Building I has a parking garage. Smokers occupy a number of apartments in both buildings.

Formaldehyde (CH_2O)was included to investigate complaints of eye and respiratory tract irritation. Sources of formaldehyde include new carpet and furniture.

Both building are constructed of concrete, potential sources of radon. Building I does not have basement below grade. Building II has a half basement which is partially below grade.

Total Suspended Particulate (TSP) was included to investigate complaints of dust accumulation on furniture by some occupants of Building I.

Three sampling locations were chosen in each building for the measurement of CO_2, CO, CH_2O, Radon, RH, T and TSP. Typical occupancies were chosen. Two series of bioaerosol samples were taken in each building.

2.2 Methods

Descriptions of the instrumentation used in testing for the various contaminants appears in Attachment I of this appendix.

2.2.1 Bioaerosols

The RCS Biotest sampler with Rose-Bengal strip was used.

At Building II, 8 minute samples were taken at 7 locations throughout the building on April 1 and 4, 1991. Locations included 5 apartments, the garbage room and the lobby. On April 4, sampling time for apartment 406 was reduced to 4 minutes because the first sample was overloaded and difficult to count.

Samples were incubated at 30 •C for 5 days and then the number of colony-forming-units were counted. Concentrations were then calculated using the technique outlined in the manufacturers instructions:

cfu/m3 = # colonies * 25 / sampling time

At Building I, 4 minute duration samples were collected on March 15, 1991, at the apartments along the garbage chute, in the garbage room and in the lobby . Eight minute duration samples were collected on March 21 at the same locations.

Samples were incubated for 5 days at Public Health Laboratories, St. John's. The incubation temperature was 35°C for the March 15 samples and 30°C for the March 21 samples.

2.2.2 Carbon Dioxide, Relative Humidity and Temperature

The EGM-1 Environmental Gas Monitor was used to monitor CO_2, RH and T.

The instrument was set up at a central location and CO_2, RH and T logged at 10 minute intervals for 20-24 hours. The instrument was subsequently moved to another location. The instrument was calibrated prior to setup.

2.2.3 Carbon Monoxide

The Exotox 55 Portable Gas Monitor and GL-15 Data Logger were used to monitor CO.

The instrument was set up alongside the EGM-1 and CO was logged at 10 minute intervals for 20-24 hours. The instrument was subsequently moved to another location. Instrument zero and span were verified before and after each sample.

2.2.4 Formaldehyde

PF-1 Passive Formaldehyde Monitors were used to measure CH_2O levels.

Samplers were suspended from the ceiling at each sampling location. After 5-7 days exposure, samplers were sent back to Ortech International for analysis.

2.2.5 Radon

RADPAC cannisters were used to monitor radon.

The sampler was exposed 5-7 days at each location. Generally,the cannister rested on top of furniture at a central location in the apartment. After exposure, the cannister was resealed and returned to Alphanuclear, a testing laboratory, for analysis.

2.2.6 Total Suspended Particulate

The Turner Designs Particulate Sampler was used to sample TSP.

The sampler was positioned adjacent to the EGM-1 and Exotox samplers. Samples were collected at a flow rate of 10.3 Lpm for 20-24 hours. PTFE membrane filters (37 mm, 2 um) were weighed using a Cahn microbalance before and after sampling.

3.0 SAMPLING RESULTS

3.1 Bioaerosols

Table 1 contains the bioaerosol monitoring data.

TABLE 1: BIOAEROSOL DATA

BUILDING II		
	BIOAEROSOL LEVEL cfu/m³	
	April 1/91	April 4/91
Lobby	9	16
Garbage Rm	31	19
Apt 105	6	9
Apt 107	22	31
Apt 403	41	13
Apt 406	>225	>269
Apt 508	22	53
BUILDING I		
	BIOAEROSOL LEVEL cfu/m^3	
	March 15/91	March 21/91
Lobby	no growth	no growth
Garbage Rm	no growth	no growth
Apt 104	no growth	no growth
Apt 205	no growth	no growth
Apt 305	no growth	no growth
Apt 405	no growth	no growth
Apt 505	no growth	no growth
Apt 605	no growth	no growth
Apt 705	no growth	no growth

Generally, typical bioaerosol levels were measured at Building II. Except for apartment 406, measured levels on both days were 53 cfu/m³ or less. Apartment 406 had 4 occupants (2 children) and many plants. One variety of fungal colony appeared to predominate. Budgetary constraints did not allow further identification of this colony.

No growth was found on any samples obtained from Building I. The high incubation temperature (35°C) and short sampling time (4 min.) may have affected the first series. However, the second series had an 8 minute sampling time and were incubated at 30°C.

3.2 Carbon Dioxide, Relative Humidity and Temperature

Tables 2 through 7 contains CO_2, RH and T monitoring data. Results are tabulated with a 30 minute interval.

Measured CO_2 levels at Building II ranged from 413 - 1896 ppm. Apartments 101 and 601 were occupied by single elderly women and levels ranged from 413 - 1002 ppm. Apartment 407 was occupied by an elderly couple and levels ranged from 701 - 1896 ppm.

At Building I, apartments 301 and 705 were unoccupied during sampling and levels did not exceed 436 ppm. Apartment 301 is a rental unit which is infrequently occupied. Apartment 705 has a permanent resident who just happened to be away during sampling.

Building I, apartment 104 is a single unit with one occupant. Measured levels were similar to Building II, 101 and 601, 488 - 998 ppm.

Apartments at both buildings have electric heat and temperatures did not vary more than 2 degrees. Generally, temperatures ranged from 21 - 25°C. Relative humidity ranged from 25 - 50 % depending on weather conditions.

Table 2: Carbon Dioxide, Relative Humidity and Temperature, Building II, Apartment 101, Mar. 11-12/91

Time	CO_2 (ppm)	RH (%)	T (•C)
17:15	458	29.6	21.1
17:45	436	30.0	21.1
18:15	438	29.5	21.2
18:45	436	29.2	21.6
19:15	425	29.0	21.1
19:45	414	28.1	21.1
20:15	414	28.9	21.1
20:45	413	28.6	21.8
21:15	424	29.1	21.7
21.45	433	27.6	21.1
22:15	447	28.5	21.7
22.45	436	28.8	21.1
23:15	435	29.4	21.1
23:45	436	29.3	21.1
00:15	436	29.4	21.3
00:45	437	29.7	21.1
01:45	435	29.3	21.1
02:45	436	30.1	21.8
03:15	436	29.6	21.1
03:45	446	30.1	21.8
04:15	458	30.7	21.5
04:45	480	30.6	21.8
05:15	467	30.6	21.1
05:45	468	30.2	21.1
06:15	468	30.2	21.3
06:45	473	30.6	21.6
07:15	479	30.3	21.6
07:45	468	30.7	21.1
08:15	528	31.3	21.2
08:45	599	31.1	21.5
09:15	607	32.4	21.9
09:45	674	32.8	21.1
10:15	662	31.9	21.8
10:45	714	34.4	22.0
11:15	715	38.2	22.6
11:45	713	39.7	22.7
12:15	703	39.4	22.6
12:45	696	37.4	22.8
13:15	707	36.3	22.8
13:45	695	35.2	22.6
14:15	663	35.2	22.1
14:45	604	34.7	22.8
15:15	550	33.4	22.0

Table 3: Carbon Dioxide, Relative Humidity and Temperature, Building II, Apartment 407, Mar. 13-14/91

Time	CO_2 (ppm)	RH (%)	T (°C)
15:29	1896	49.6	23.5
19:29	1423	43.8	25.4
19:59	1383	43.7	25.7
20:29	1342	43.2	25.8
20:59	1306	43.1	25.5
21:29	1287	43.1	25.6
21:59	1304	42.7	25.9
22:29	1249	43.1	25.1
22:59	1230	43.2	25.1
23:29	1200	43.3	25.9
23:59	1197	43.2	25.1
00:29	1191	43.1	25.1
00:59	1188	43.0	25.1
01:29	1178	43.3	25.1
01:59	1177	43.7	25.1
02:29	1176	42.8	25.1
02:59	1165	43.2	24.3
03:29	1174	43.2	25.1
03:59	1174	43.0	25.1
04:29	1178	43.3	25.7
04:59	1178	43.4	25.2
05:29	1176	43.6	24.7
05:59	1186	43.4	24.9
06:29	1189	43.6	24.7
06:29	1193	43.5	24.4
07:29	1196	43.4	24.2
07:59	1187	43.8	24.9
08:29	1027	41.9	25.3
08:59	993	43.5	25.7
09:29	964	42.5	25.2
09:29	964	42.5	25.2
09:59	1043	43.2	25.2
10:29	1057	43.2	25.7
10:59	1072	43.4	25.2
11:29	1092	42.6	26.1
11:59	1091	43.0	26.1
12:29	1059	42.2	25.1
12:59	742	37.0	23.1
13:29	704	37.7	23.6
13:59	1019	42.8	24.7
14:29	925	41.8	24.1
14:59	731	37.3	24.1
15:29	701	37.2	24.1

Table 4: Carbon Dioxide, Relative Humidity and Temperature, Building II, Apartment 601, Mar. 12-13/91

Time	CO_2 (ppm)	RH (%)	T (°C)
18:03	1002	37.4	23.1
18:33	942	34.3	24.1
19:03	934	33.2	24.4
19:33	918	32.5	25.6
20:03	886	32.5	24.1
20:33	880	32.8	24.6
21:03	886	32.7	24.2
21:33	901	32.5	24.2
22:03	872	32.2	24.1
22:33	844	32.4	25.4
23:03	816	32.3	25.2
23:33	813	32.5	25.1
00:03	769	32.5	25.4
01:03	698	31.9	25.2
02:03	638	32.1	24.6
02:33	626	31.8	24.2
03:03	606	31.9	24.7
03:33	596	31.7	24.1
04:03	576	31.8	24.6
04:33	540	31.4	24.1
05:03	527	31.5	24.3
05:33	527	31.7	24.2
06:03	527	31.5	24.3
06:33	521	31.5	24.8
07:03	514	31.5	24.8
07:33	506	31.2	24.6
08:03	544	31.8	24.4
08:33	554	31.4	24.5
09:03	575	32.1	24.6
09:33	623	32.3	24.5
10:03	624	31.8	24.1
10:33	611	31.9	24.7
11:03	611	32.1	24.6
11:33	675	32.6	25.0
12:03	652	32.2	25.5
12:33	648	32.1	25.2
13:03	624	32.0	24.1
13:33	625	32.2	25.1
14:03	623	32.0	25.5
14:33	623	32.2	25.2
15:03	624	32.8	25.3
15:33	626	32.7	25.2
16:03	803	33.5	25.6

Table 5: Carbon Dioxide, Relative Humidity and Temperature, Building I, Apartment 104, Mar. 8-9/91

Time	CO_2 (ppm)	RH (%)	T (°C)
17:15	799	36.2	24.3
18:15	843	36.3	24.1
19:15	811	36.6	23.2
20:15	813	36.6	23.3
21:15	757	36.1	22.6
22:15	732	35.5	23.1
23:15	611	35.0	23.2
00:15	550	34.6	23.9
01:15	526	34.9	23.4
02:15	516	35.0	23.2
03:15	538	34.1	22.1
04:15	514	34.5	23.3
05:15	505	33.7	23.4
06:15	488	33.8	23.2
07:15	622	34.8	23.1
08:15	674	36.0	23.1
09:15	656	36.1	23.1
10:15	623	36.4	23.1
10:45	600	35.2	23.6
11:15	648	37.1	23.1
11:45	648	35.8	23.1
12:15	785	36.3	24.0
12:45	846	37.1	23.2
13:15	594	34.1	24.2
13:45	704	36.5	23.1
14:15	651	34.7	24.7
14:45	602	35.9	23.4
15:15	582	34.1	23.6
16:15	562	34.1	23.3
16:55	689	35.1	23.0
17:35	926	38.5	23.3
17:55	998	38.3	23.2

Table 6: Carbon Dioxide, Relative Humidity and Temperature, Building I, Apartment 301, Mar. 4-5/91

Time	CO_2 (ppm)	RH (%)	T (•C)
22:00	378	24.4	21.1
23:00	393	25.2	21.2
00:00	392	25.2	21.1
01:00	392	25.6	21.1
02:00	392	25.3	21.4
03:00	381	25.9	21.6
04:00	382	25.3	21.1
05:00	378	26.2	21.1
06:00	375	25.7	21.1
07:00	373	25.9	21.2
08:00	372	25.8	21.8
09:00	372	25.9	21.1
10:00	372	25.6	21.5
11:00	373	26.2	21.1
12:00	374	26.0	21.6
13:00	377	26.1	21.9
14:00	373	26.2	21.7
15:00	376	26.4	21.1
16:00	374	26.9	21.1

Table 7: Carbon Dioxide, Relative Humidity and Temperature, Building I, Apartment 705, Mar. 9-10/91

Time	CO_2 (ppm)	RH (%)	T (°C)
20:46	433	30.9	20.1
21:16	436	28.0	23.3
21:46	418	27.8	23.8
22:16	391	27.7	22.1
22:46	381	27.8	22.0
23:16	374	27.6	22.7
23:46	381	27.6	22.2
00:16	362	27.8	22.6
00:46	361	27.9	22.2
01:16	351	27.9	22.8
01:46	353	27.7	22.5
02:16	351	27.7	22.1
02:46	349	27.4	22.1
03:16	351	27.1	22.1
03:46	343	27.8	21.6
04:16	340	27.6	21.4
04:46	341	27.8	21.5
05:16	347	27.6	21.6
05:46	340	27.1	21.0
06:16	341	27.9	21.0
06:46	342	27.8	21.1
07:16	352	27.2	22.1
07:46	351	27.3	21.3
08:16	351	27.2	22.5
08:46	351	27.2	22.6
09:16	353	27.2	22.1
09:46	354	27.2	22.1
10:16	352	27.1	22.1
10:46	352	26.8	22.1
11:16	361	27.3	22.4
11:46	353	27.3	22.3
12:16	362	27.2	22.9
12:46	362	27.5	22.7
13:16	354	27.4	22.4
13:46	362	27.4	22.4
14:15	362	27.2	22.1
14:46	362	27.8	22.1
15:16	362	27.5	22.7
15:46	363	27.5	22.4
16:16	369	27.5	22.8
16:46	368	27.8	22.1
17:16	369	27.1	22.1
17:46	365	27.6	22.6

3.3 Carbon Monoxide

Tables 8 through 12 contains the CO monitoring data. Data is tabulated with a 10 minute interval.

Apartments with smokers - Building II, 101 and 407, Building I, 104 - had measurable CO levels. Levels ranged up to 6 ppm.

Building I, 104 had the highest CO level (6 ppm). The occupant claims not to be a heavy smoker. The apartment is adjacent to the parking garage which may be a factor.

Table 8: Carbon Monoxide Data, Building II, Apartment 407, Mar. 13-14/91

Time	CO Level
17:18	0 ppm
.	.
.	.
05:33	0 ppm
05:38	2 ppm
05:48	2 ppm
05:58	2 ppm
06:08	2 ppm
06:18	2 ppm
06:38	2 ppm
06:43	0 ppm
.	.
.	.
.	.
09:58	0 ppm
10:03	2 ppm
10:13	2 ppm
10:33	2 ppm
10:43	2 ppm
10:53	2 ppm
11:03	2 ppm
11:08	2 ppm
11:13	0 ppm
.	.
.	.
16:13	0 ppm

Table 9: Carbon Monoxide Data, Building II, Apartment 101, Mar. 11-12/91

Time	CO Level
15:50	0 ppm
.	.
.	.
.	.
18:10	0 ppm
18:20	2 ppm
.	.
.	.
.	.
11:10	2 ppm
11:20	4 ppm
.	.
.	.
.	.
13:50	4 ppm

Table 10: Carbon Monoxide Data, Building II, Apartment 601, Mar. 12-13/91

Time	CO Level
18:20	0 ppm
.	.
.	.
.	.
16:20	0 ppm

Table 11: Carbon Monoxide Data, Building I, Apartment 104, Mar. 8-9/91

Time	CO Level
16:06	6 ppm
.	.
.	.
.	.
17:26	6 ppm
17:36	4 ppm
.	.
.	.
.	.
21:16	4 ppm
21:26	2 ppm
.	.
.	.
.	.
23:46	2 ppm
23:56	0 ppm
.	.
.	.
.	.
11:26	0 ppm
11:36	2 ppm
11:46	4 ppm
.	.
.	.
.	.
14:46	4 ppm
14:56	2 ppm

Table 12: Carbon Monoxide Data, Building I, Apartment 705, Mar. 9-10/91

Time	CO Level
20:40	0 ppm
.	.
.	.
.	.
20:20	0 ppm

3.4 Formaldehyde

Table 13 contains the CH_2O monitoring data. Typical indoor CH_2O levels were measured to be 0.02 ppm to 0.04 ppm.

TABLE 13: FORMALDEHYDE DATA

Date	Building	Location	Formaldehyde Level
Mar. 11-18/91	Building II	Lobby	< 0.01 ppm
Mar. 11-18/91		Apt. 101	0.033 ppm
Mar. 4-11/91		Apt. 407	0.022 ppm
Mar. 4-11/91		Apt. 601	0.044 ppm
Mar. 4-11/91	Building I	Lobby	0.020 ppm
Mar. 4-11/91		Apt. 104	0.038 ppm
Mar. 4-11/91		Apt. 301	0.022 ppm
Mar. 4-11/91		Apt. 705	0.022 ppm

3.5 Radon

Table 14 contains the radon monitoring data.

Measured radon levels did not exceed typical background levels. The samplers were exposed for a longer period than recommended. As a result, there is a high level of imprecision in the data. If the measured levels had been significant, it would have been advisable to repeat sampling.

TABLE 14: RADON DATA

Date	Building	Apartment	Radon Level
Mar. 12-14/91	Building II	Lobby	sample lost
Mar. 11-18/91		Apt. 101	18.4 Bq/m^3
Mar. 4-11/91		Apt. 407	17.7 Bq/m^3
Mar. 4-11/91		Apt. 601	7.8 Bq/m^3
Mar. 4-11/91	Building I	Lobby	8.1 Bq/m^3
Mar. 4-11/91		Apt. 104	3.7 Bq/m^3
Mar. 4-11/91		Apt. 301	11.4 Bq/m^3
Mar. 4-11/91		Apt. 705	18.3 Bq/m^3

3.6 Total Suspended Particulate

Table 15 contains TSP levels.

Levels measured in apartments occupied by smokers ranged from 45 - 200 ug/m^3. Building I, 104 had the highest level at 200.3 ug/m^3.

Apartments occupied by non-smokers had less than 10 ug/m^3. During sampling at Building I, 705 the sampler stopped prematurely, which normally happens with excessive pressure drop across the filter.

TABLE 15: TOTAL SUSPENDED PARTICULATE (TSP) DATA

Date	Building	Apartment	TSP Level
Mar. 11-12/91	Building II	Apt. 101	77.3 ug/m^3
Mar. 13-14/91		Apt. 407	45.9 ug/m^3
Mar. 12-13/91		Apt. 601	3.9 ug/m^3
Mar. 8-9/91	Building I	Apt. 104	200.3 ug/m^3
Mar. 4-5/91		Apt. 301	5.2 ug/m^3
Mar. 9-10/91		Apt. 705	0.3 ug/m3
	Blank		0.2 ug/m^3

4.0 Conclusions/Discussion

Sampling results and Health and Welfare Canada guidelines are be summarized in the Table 16:

TABLE 16: EXPOSURE GUIDELINES AND SAMPLE RESULTS

AGENT	EXPOSURE GUIDELINE	BUILDING I	BUILDING II
Bioaerosol*	< 50 cfu/m^3, 1 sp < 150 cfu/m^3, 2 sp < 500 cfu/m^3	0	> 269 cfu/m^3 6 - 53 cfu/m^3
CO_2	3500 ppm	340 - 998 ppm	413 - 1896 ppm
CO	11 ppm	0 - 6 ppm	0 - 4 ppm
CH_2O	0.1 ppm	< 0.04 ppm	< 0.04 ppm
Radon	150; 800 Bq/m^3	< 18.3 Bq/m^3	< 18.4 Bq/m^3
TSP	40 ug/m^3	5.2 - 200.3	3.9 - 77.3
T	20 - 24 •C	21.1 - 24.3 •C	21.1 - 25.9 •C
RH	30 - 55 %	24.4 - 38.5 %	27.6 - 49.6 %
* Agriculture Canada recommendation			

Apart from apartment 406, Building II bioaerosol levels were within Agriculture Canada recommended guideline. Apartment 406 contained a lot of plants which may be the cause of the excessive level. It also had 4 occupants. Building II did not have quantifiable bioaerosols.

Measured CO_2 levels were within the Health and Welfare Canada guideline. As expected, levels increased with occupancy. Although 2000 ppm was measured in an apartment in Building II with 2 occupants, higher levels are likely in apartments with 3 or 4 occupants (apt. 406, for example).

Measured CO levels did not exceed the recommended guideline. However, there were noticeable transient increases in CO levels particularly in Building I, apartment 104. The adjacent parking garage may be contributing to the CO level in the apartment. The occupant also smokes.

Figure 1 and Figure 2 illustrate the trends noted in CO_2 and CO levels in apartment 104 of Building I. Levels seem to peak during periods when the parking garage would be busy.

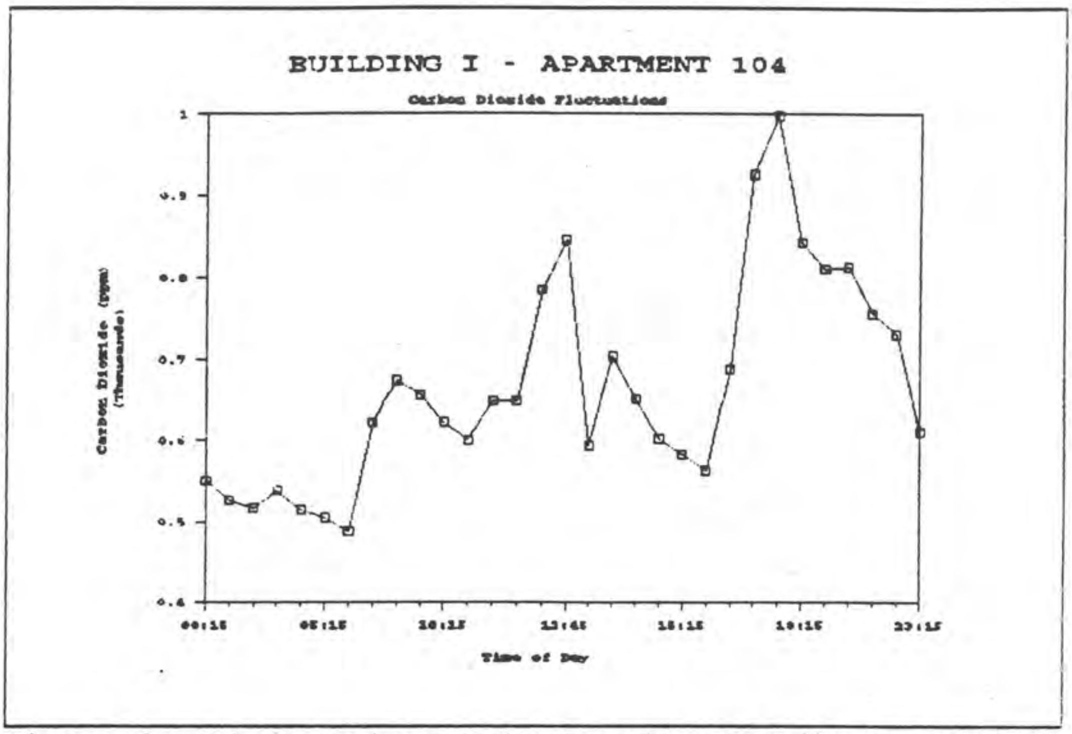

Figure 1: Peak concentrations occur when the parking garage would be busy and at night when the apartment would be occupied for longer periods of time.

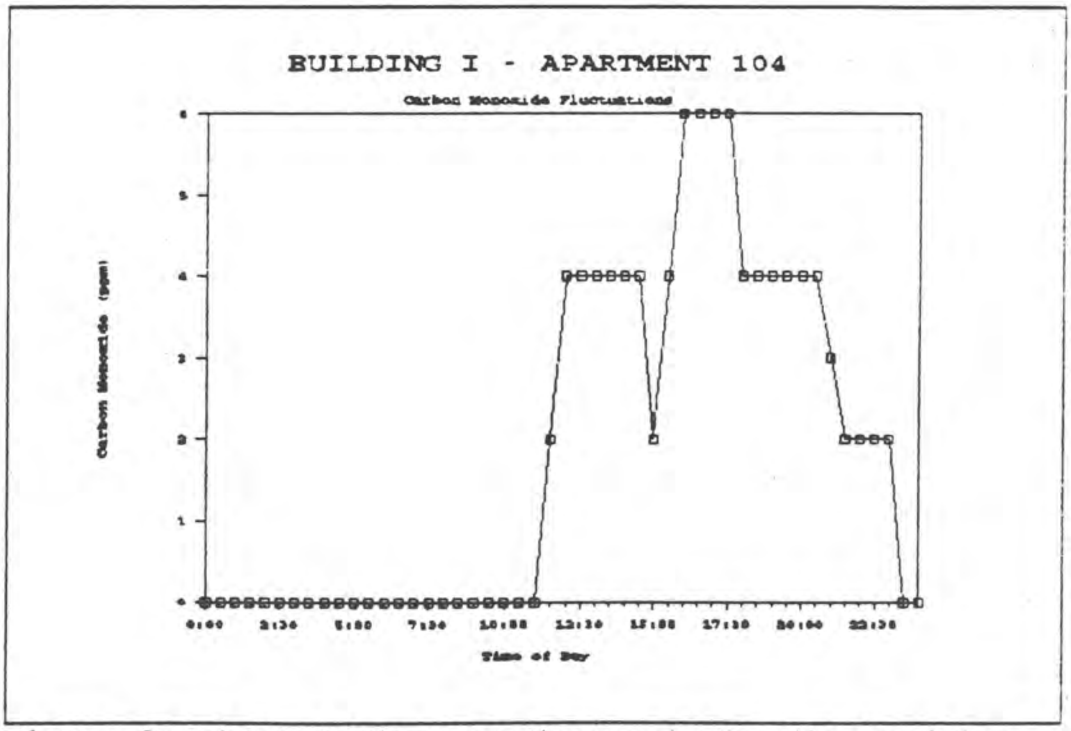

Figure 2: Peak Carbon Monoxide concentrations occur when the parking garage is busy.

Measured CH_2O and radon levels were within the recommended guidelines.

TSP levels were excessive in the apartments of smokers in both buildings. The level measured in apartment 104 in Building I was particularly high. As with CO, the adjacent parking garage may be the cause.

Generally, air quality is acceptable for occupants of both buildings. This is reasonable, given the few complaints of poor air quality and symptoms associated with poor air quality.

CO_2 levels will, however, approach and exceed 1000 ppm in apartments with 2 or more occupants. Some apartments in this study have 4 occupants. Studies of office air quality have indicated that complaints appear to increase with CO_2 levels at or above 1000 ppm.

Apartments occupied by smokers will have higher TSP and CO levels. Apartment 104 in Building I may have higher than expected TSP and CO levels because it is adjacent to the parking garage.

ATTACHMENT I

INSTRUMENTATION DESCRIPTIONS

Carbon Monoxide (CO)

Instrumentation:	Neotronics EXOTOX Gas Detector, Model 55
Principle of Operation:	Air is pumped or diffuses onto an electrochemical detector. Instantaneous or average CO level is displayed or logged using a datalogger. Sampling results are available in real-time.
Calibration:	Instrument response is verified before and after sampling using standard gases.
Range:	0 - 999 ppm
Precision:	± 2.5%

Carbon Dioxide (CO_2), Temperature (T) and Relative Humidity (RH)

Instrumentation:	EGM-1 Environmental Gas Monitor
Principle of Operation:	Air is passed through an infrared beam. CO_2 is detected and the level displayed and/or logged. Results are available in real-time.
Calibration:	Zero and span verified with appropriate standards before, during (continuous sampling) and after sampling.
Range:	0 - 5000 ppm (CO_2)
Precision:	± 5%
Alternate Methods:	Hygrothermograph (RH,T)

Radon

Instrumentation: RADPAC Radon Detection Kit

Principle of Operation: Radon absorbs onto activated charcoal in a cannister. Gamma radiation emitted by radon progeny is measured by gamma spectroscopy to estimate the radon concentration. Sampling results are available within 14 days.

Calibration:

Range: > 1 pCi/L

Precision: Variable

Bioaerosols (eg. bacteria, fungi)

Instrumentation: BIOTEST RCS Centrifugal Air Sampler with Rose-Bengal Agar Strips.

Principle of Operation: Viable particles are impacted on nutrient agar and incubated. The number of colonies grown are counted and result expressed as colony-forming-units per unit volume air sampled. Sampling results (CFU count) are available within 72 hrs.

Calibration:

Range:

Precision:

Formalldehyde (CH_2O)

Instrumentation: AQRI FP1 Passive Dosimeter

Principle of Operation: CH_2O diffuse into the sampler and absorbs onto a chemically treated paper. Subsequent laboratory analysis yields the TWA CH_2O level. Sampling results are available within 14 days.

Calibration:

Range: 0.02 - 10 ppm

Precision: ± 25%

Alternate Methods: Colorimetric detector tubes MIRAN 1B2

Total Suspended Particulate (TSP)

Instrumentation: Gravimetric sampling with Turner Designs sampler, (10.3 L/min) with 2 um 37 mm PTFE filter; gravimetric analysis with CAHN microbalance.

Principle of Operation: Air is drawn through a pre-weighed filter (10 ug) at 10 Lpm for 20 - 24 hours. After sample collection the filter is weighed and TSP level calculated as the increase in weight due to sampling per unit sample volume. Sampling results are available within 48 hrs.

Calibration: Air flow rate is verified before and after sampling with a Gilibrator calibration system (Gilian Instruments, Wayne, NJ 07470).

Range: 10 ug/m^3 - 1000 ug/m^3

Precision: ± 10%

APPENDIX IX

SURVEYS AND QUESTIONNAIRES

APPENDIX IXA

BUILDING I

BUILDING AND MECHANICAL SYSTEMS QUESTIONNAIRE

BUILDING AND MECHANICAL SYSTEMS QUESTIONNAIRE

BUILDING: BUILDING I

BUILDING COMMON AREAS:

1. What year was the building constructed? 1982
   a) Are the as-built design diagrams for this building missing? NO
   b) Are the current design diagrams for this building missing? N/A
   c) Are the operating and maintenance manuals for the building's HVAC system missing? N/A
   d) Is there no routine maintenance program for the HVAC system. N/A

2. Have any areas been recarpeted recently? YES
   a) If YES, did odours persist for more than a week after carpet was laid? NO
   b) If YES, describe locations:

3. Have any areas been repainted recently? YES
   a) If YES, did odours persist for more than a week after the paint was applied? NO
   b) If YES, describe locations:

4. Has there been a recent or is there a regular cleaning process which uses large amounts of chemicals or solvents? NO
   a) If YES, what were the chemicals?

5. Is there a fuel-fired central heating unit or Domestic Hot Water system? NO

a) Is there any physical evidence of leakage or combustion gasses from the furnace or flue room or nearby areas? N/A

b) Is there the odour of combustion fumes in the room? N/A

6. Is there an enclosed parking garage? YES

a) Was the ventilation system found in an operative state? YES

b) Is the ventilation system turned off for periods? NO

c) Is the ventilation system controlled? NO

d) Are there carbon monoxide sensors in the garage which control ventilation? NO

e) If so, have they been recently calibrated? N/A

f) Are there obstructions in the exhaust or air inlets? NO

g) Are stack forces pulling air from the garage into the building? (check at access doors) NO

7. Is there a garbage handling facility? YES

a) Is the vent system off or ineffective? NO

b) Is there an air flow pattern from garbage rooms or chutes into the rest of the building? NO

c) Is there an unusually bad odour or mouldy smell associated with system? NO

8. Is there a pool, hot tub, sauna, or work-out room? NO

a) Does maintenance and cleaning appear to be irregular or inadequate. N/A

b) Are there any "mildew" stains on walls, ceilings, floors, fixtures or items such as like shower curtains? N/A

c) Is there any condensation on walls, floors, windows or ceiling? N/A

d) Does humidity appear very high? N/A

e) Do any biodegradable products (wood, etc.) get wet regularly? N/A

9. Are there any basement or sub-basement areas or crawl spaces with dirt floors? NO
   a) Are there occupied areas nearby? N/A
      If YES, describe locations:

      ____

      ____

   b) Do these spaces lack ventilation? N/A
   c) Are there musty odours in these areas or nearby? N/A

10. Are there rooms with sizeable holes in the walls or floor, such as sump pits, gas and water entrances, cracks, etc.? NO
   a) If YES, describe location(s):

      ____

      ____

   b) Do these spaces lack ventilation? N/A
   c) Are there musty odours in these areas or nearby? N/A

11. Is there foam insulation in the walls of the building? NO
   a) The type of insulation is polyurethane/polystyrene/urea formaldehyde/unknown.

12. Do drawings show asbestos insulation for pipes, fire protection of structure, etc.? NO
   a) If YES, does inspection reveal loose fibre especially near air handling equipment and ducts? N/A

13. Has there ever been a "water crisis" such as a flood or overflow? NO

14. Are there any signs of moisture problems such as:
   a) stains or dampness on walls, floors or ceilings? YES
   b) stained, streaked, or damp carpets? NO
   c) mouldy odours, or musty smells? NO

SPECIFIC COMPLAINT AREA OBSERVATIONS:

15. Where in the building do these observations apply? Please give the floor, room or apartment number or briefly describe (e.g. main lobby, everywhere):

NO SPECIFIC COMPLAINT AREAS BUT

ANSWERS APPLY TO BUILDING PUBLIC AREAS

Please answer all questions by circling of filling in the answers as required.

16. General Observations

a)	Are there damp spots or mould on the walls or ceiling/	NO
b)	Are any of the carpets, curtains, etc. damp?	NO
c)	Are there any potted plants in this area?	NO
d)	Is there mould on the plants or their pots or soil?	NO
e)	Do mites appear to be on the plants?	NO
f)	Are there pets in the unit?	NO
g)	Are there odours here?	NO
h)	Which of the following best describes the odour?	

auto exhaust / diesel fumes / furnace room / heating system / pet odours / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty / chalky

i)	Are people using fans to create more air movement?	NORMAL EXAUST FANS
j)	Is there much dust visible on flat surfaces?	NO
k)	Is there evidence of condensation on windows or walls?	NO

17. Are there air supply diffusers? NO

a) Can you see any of the following around the diffusers?

mould / chalky dust / dirt marks NO

	b) Are any of the air supply diffusers blocked by furniture, paper, or other obstructions?	NO
18.	Are there any air exhaust fans or louvres in unit of complaint area?	YES
	a) Do you have a poor drain rate?	NO
	b) Are there dirt marks around the air exhaust louvres?	NO
	c) Are any of the air exhaust louvres block by furniture, papers or other obstructions?	NO
19.	Has carpeting or furniture been installed in the last three months?	YES
20.	Are there large areas of particleboard sheathing or furnishings?	NO
21.	Is there a gas stove?	NO
	a) Are there exhausts to remove combustion gasses produced by the stoves?	N/A
	b) Are the stoves operated without exhaust fans on?	N/A
22.	Is there a wood or gas fireplace in the area?	NO
	a) Does it appear to be poorly vented?	N/A
	b) Does it appear to have inadequate supply air?	N/A
23.	If there a freestanding heater (gas or kerosene)? If YES,	NO
	a) Are these heaters used in anything but well ventilated spaces?	N/A
	b) Is there an odour of combustion fumes in the room?	N/A
	c) Is the room exhaust recirculated rather than directly expelled outdoors?	N/A
24.	Is there a refrigerator in the unit?	YES
	a) Does anything in the fridge look mouldy?	NO
	b) Is the refrigerator drain blocked?	NO
	c) Is the drain pan wet and mouldy?	NO
	d) Are the heat exchangers dusty?	NO

25. Is there mould on bathroom tiles, walls or ceilings? NO

26. Are there humidifiers or dehumidifiers in the unit? NO
    a) Do the drip pans, coils, and water in these units have accumulation of dust, slime, sludge or mould? N/A

27. Are there small but steady leaks in, around, under or behind sinks, toilets, tubs and/or showers? NO

28. Are there poorly vented mechanical/electrical chases or other entry paths for contaminants from outside the unit? NO

MECHANICAL SYSTEMS AND HVAC OPERATION:

If the building contains two or more towers or wings, each controlled by a different HVAC system, a copy of this sheet should be filled out for each.

29. Describe ventilation system:

    MAKEUP AIR SYSTEM PROVIDING 100% OUTSIDE AIR
    TO BUILDING CORRIDORS TO MAKEUP VARIOUS DEDICATED
    EXHAUST FANS AND APARTMENT EXHAUSTS

30. Is the amount of fresh air used by the ventilation system the same all year round? YES

31. Is the ventilation system of the recirculating type? NO
    a) Does the HVAC system use an economizer cycle? NO
    b) What is the maximum percentage of fresh air used? 100%

c) What is the minimum percentage of fresh air used? 100%

d) What is the fresh air percentage just now? 100%

32. Air supplied to the floors by:

[CONSTANT VOLUME SYSTEM] / variable air volume (VAV) system / heat pumps / other / unknown?

33.	Is there a corridor pressurization system?	YES
a)	Is the "corridor-to-apartment" flow reversed?	NO
34.	At what temperature is the tank supplying hot water to the building maintained?	N/A
35.	Are there distinct fresh-air intakes for the building HVAC system?	NO
a)	Are there intakes below third floor level and above a busy street?	NO
b)	Are there intakes within 10 metres (30 feet) of the exhausts of this or a parking garage?	NO
c)	Are there intakes within 10 metres (30 feet) of the exhausts of this or an adjacent building?	NO
d)	Are intakes near standing water or a cooling tower?	NO
e)	Is there a built up of organic debris near the intakes?	NO
f)	Are there any other sources or pollution near any of the intakes?	NO
36.	Does this building have a particular (dust) filter system installed in the fresh air intake?	YES
a)	Are the filters missing?	NO
b)	Are the filters changed less frequently than recommended by the manufacturer?	YES
c)	Do the filters fit so poorly that air bypasses them at the edges?	NO
d)	Are the filters matted or dirty?	NO
e)	Are the filters wet?	NO
37.	Are spray humidifiers used in this building?	NO
a)	Are the spray humidifiers supposed to operate at this time of year?	NO

b) Are the spray humidifiers operating now? NO

If YES, answer the questions below:

- b_a) Are the spray humidifier pans plugged so that they are not draining properly? N/A
- b_b) Is there slime in the humidifier pans? N/A
- b_c) Are there mouldy odours? N/A
- b_d) Is there mould in the ducts near the humidifiers? N/A
- b_e) Is there evidence of foaming in the humidifiers? N/A
- b_f) Is the water hard in this region? N/A
- b_g) If so, are there hard water deposits on the vanes? N/A
- b_h) Are the hard water deposits removed by scraping the vanes and blowing the dust into the ducts? N/A

38. Are steam humidifiers used in this building? NO

a) Are the steam humidifiers supposed to operate this time of year? N/A

b) Are the steam humidifiers operating now? N/A

If YES, answer the questions below:

- b_a) Are chemicals used in the boiler or the pipes to protect against corrosion? N/A

  If YES, state the names of chemicals:

  ____

  ____

  ____

39. Does this building have an air chilling system? NO

a) Is the chilling system supposed to operate at this time of year? N/A

b) Is the chilling system operating now? N/A

If YES, answer the questions below:

- b_a) Are the condensate trays cleaned less often than once a week? N/A
- b_b) Is there slime or growth in the condensate trays? N/A
- b_c) Is there dirt on the cooling coils? N/A
- b_d) Are there mouldy odours in the system? N/A

40. Are the ventilation ducts or plenums insulated? YES

a) Is the insulation on the inside and directly exposed to the moving air? YES

b) Is it more than five years since the ducts or plenums were last cleaned? NO

41. Are there any signs of condensation in ducts? (Check cold spots such as near inlets and after cooling coils first.) NO

APPENDIX IXB

BUILDING II

BUILDING AND MECHANICAL SYSTEMS QUESTIONNAIRE

BUILDING AND MECHANICAL SYSTEMS QUESTIONNAIRE

BUILDING: BUILDING II

BUILDING COMMON AREAS:

1. What year was the building constructed? 1982
   a) Are the as-built design diagrams for this building missing? YES
   b) Are the current design diagrams for this building missing? NO
   c) Are the operating and maintenance manuals for the building's HVAC system missing? YES
   d) Is there no routine maintenance program for the HVAC system. YES

2. Have any areas been recarpeted recently? NO
   a) If YES, did odours persist for more than a week after carpet was laid? N/A
   b) If YES, describe locations:

   ____

   ____

3. Have any areas been repainted recently? NO
   a) If YES, did odours persist for more than a week after the paint was applied? N/A
   b) If YES, describe locations:

   ____

   ____

4. Has there been a recent or is there a regular cleaning process which uses large amounts of chemicals or solvents? NO
   a) If YES, what were the chemicals?

   ____

5.	Is there a fuel-fired central heating unit or Domestic Hot Water system?		NO
	a)	Is there any physical evidence of leakage or combustion gasses from the furnace or flue room or nearby areas?	N/A
	b)	Is there the odour of combustion fumes in the room?	N/A
6.	Is there an enclosed parking garage?		NO
	a)	Was the ventilation system found in an operative state?	N/A
	b)	Is the ventilation system turned off for periods?	N/A
	c)	Is the ventilation system controlled?	N/A
	d)	Are there carbon monoxide sensors in the garage which control ventilation?	N/A
	e)	If so, have they been recently calibrated?	N/A
	f)	Are there obstructions in the exhaust or air inlets?	N/A
	g)	Are stack forces pulling air from the garage into the building? (check at access doors)	N/A
7.	Is there a garbage handling facility?		YES
	a)	Is the vent system off or ineffective?	NO
	b)	Is there an air flow pattern from garbage rooms or chutes into the rest of the building?	NO
	c)	Is there an unusually bad odour or mouldy smell associated with system?	NO
8.	Is there a pool, hot tub, sauna, or work-out room?		NO
	a)	Does maintenance and cleaning appear to be irregular or inadequate.	N/A
	b)	Are there any "mildew" stains on walls, ceilings, floors, fixtures or items such as like shower curtains?	N/A
	c)	Is there any condensation on walls, floors, windows or ceiling?	N/A
	d)	Does humidity appear very high?	N/A
	e)	Do any biodegradable products (wood, etc.) get wet regularly?	N/A

9.	Are there any basement or sub-basement areas or crawl spaces with dirt floors?	NO
	a) Are there occupied areas nearby? If YES, describe locations:	N/A
	b) Do these spaces lack ventilation?	N/A
	c) Are there musty odours in these areas or nearby?	N/A
10.	Are there rooms with sizeable holes in the walls or floor, such as sump pits, gas and water entrances, cracks, etc.?	NO
	a) If YES, describe location(s):	
	b) Do these spaces lack ventilation?	N/A
	c) Are there musty odours in these areas or nearby?	N/A
11.	Is there foam insulation in the walls of the building?	NO
	a) The type of insulation is polyurethane/polystyrene/urea formaldehyde/unknown.	
12.	Do drawings show asbestos insulation for pipes, fire protection of structure, etc.?	NO
	a) If YES, does inspection reveal loose fibre especially near air handling equipment and ducts?	N/A
13.	Has there ever been a "water crisis" such as a flood or overflow?	NO
14.	Are there any signs of moisture problems such as:	
	a) stains or dampness on walls, floors or ceilings?	YES
	b) stained, streaked, or damp carpets?	NO
	c) mouldy odours, or musty smells?	NO

SPECIFIC COMPLAINT AREA OBSERVATIONS:

15. Where in the building do these observations apply? Please give the floor, room or apartment number or briefly describe (e.g. main lobby, everywhere):

NO SPECIFIC COMPLAINT AREAS BUT

ANSWERS APPLY TO BUILDING PUBLIC AREAS

Please answer all questions by circling of filling in the answers as required.

16. General Observations
   a) Are there damp spots or mould on the walls or ceiling/ NO
   b) Are any of the carpets, curtains, etc. damp? NO
   c) Are there any potted plants in this area? NO
   d) Is there mould on the plants or their pots or soil? NO
   e) Do mites appear to be on the plants? NO
   f) Are there pets in the unit? NO
   g) Are there odours here? NO
   h) Which of the following best describes the odour?

      auto exhaust / diesel fumes / furnace room / heating system / pet odours / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty / chalky

   i) Are people using fans to create more air movement? NO
   j) Is there much dust visible on flat surfaces? NO
   k) Is there evidence of condensation on windows or walls? BROKEN SEALED UNITS

17. Are there air supply diffusers? YES
   a) Can you see any of the following around the diffusers?

      mould / chalky dust / dirt marks NO

	b) Are any of the air supply diffusers blocked by furniture, paper, or other obstructions?	NO
18.	Are there any air exhaust fans or louvres in unit of complaint area?	YES
	a) Do you have a poor drain rate?	NO
	b) Are there dirt marks around the air exhaust louvres?	NO
	c) Are any of the air exhaust louvres block by furniture, papers or other obstructions?	NO
19.	Has carpeting or furniture been installed in the last three months?	NO
20.	Are there large areas of particleboard sheathing or furnishings?	NO
21.	Is there a gas stove?	NO
	a) Are there exhausts to remove combustion gasses produced by the stoves?	N/A
	b) Are the stoves operated without exhaust fans on?	N/A
22.	Is there a wood or gas fireplace in the area?	NO
	a) Does it appear to be poorly vented?	N/A
	b) Does it appear to have inadequate supply air?	N/A
23.	If there a freestanding heater (gas or kerosene)? If YES,	NO
	a) Are these heaters used in anything but well ventilated spaces?	N/A
	b) Is there an odour of combustion fumes in the room?	N/A
	c) Is the room exhaust recirculated rather than directly expelled outdoors?	N/A
24.	Is there a refrigerator in the unit?	YES
	a) Does anything in the fridge look mouldy?	NO
	b) Is the refrigerator drain blocked?	NO
	c) Is the drain pan wet and mouldy?	NO
	d) Are the heat exchangers dusty?	NO

25. Is there mould on bathroom tiles, walls or ceilings? NO
(GENERALLY NOT)

26. Are there humidifiers or dehumidifiers in the unit? NO
   a) Do the drip pans, coils, and water in these units have accumulation of dust, slime, sludge or mould? N/A

27. Are there small but steady leaks in, around, under or behind sinks, toilets, tubs and/or showers? NO

28. Are there poorly vented mechanical/electrical chases or other entry paths for contaminants from outside the unit? NO

MECHANICAL SYSTEMS AND HVAC OPERATION:

If the building contains two or more towers or wings, each controlled by a different HVAC system, a copy of this sheet should be filled out for each.

29. Describe ventilation system:

ROOF MOUNTED EXHAUST/ SUPPLY FAN SYSTEM FOR

THE SUPPLY OF FRESH AIR THROUGHOUT THE BUILDING

INDEPENDENT CORRIDOR SUPPLY DUCTS

30. Is the amount of fresh air used by the ventilation system the same all year round? YES

31. Is the ventilation system of the recirculating type? NO
   a) Does the HVAC system use an economizer cycle? NO
   b) What is the maximum percentage of fresh air used? 100%

c) What is the minimum percentage of fresh air used? **100%**

d) What is the fresh air percentage just now? **100%**

32\. Air supplied to the floors by:

[CONSTANT VOLUME SYSTEM] / variable air volume (VAV) system / heat pumps / other / unknown?

33\. Is there a corridor pressurization system? **NO**

a) Is the "corridor-to-apartment" flow reversed? **NO**

34\. At what temperature is the tank supplying hot water to the building maintained? **N/A**

35\. Are there distinct fresh-air intakes for the building HVAC system? **NO**

a) Are there intakes below third floor level and above a busy street? **NO**

b) Are there intakes within 10 metres (30 feet) of the exhausts of this or a parking garage? **NO**

c) Are there intakes within 10 metres (30 feet) of the exhausts of this or an adjacent building? **NO**

d) Are intakes near standing water or a cooling tower? **NO**

e) Is there a built up of organic debris near the intakes? **NO**

f) Are there any other sources or pollution near any of the intakes? **NO**

36\. Does this building have a particular (dust) filter system installed in the fresh air intake? **YES**

a) Are the filters missing? **NO**

b) Are the filters changed less frequently than recommended by the manufacturer? **NO**

c) Do the filters fit so poorly that air bypasses them at the edges? **NO**

d) Are the filters matted or dirty? **NO**

e) Are the filters wet? **NO**

37\. Are spray humidifiers used in this building? **NO**

a) Are the spray humidifiers supposed to operate at this time of year? **NO**

	b) Are the spray humidifiers operating now?	NO
	If YES, answer the questions below:	
	b_a) Are the spray humidifier pans plugged so that they are not draining properly?	N/A
	b_b) Is there slime in the humidifier pans?	N/A
	b_c) Are there mouldy odours?	N/A
	b_d) Is there mould in the ducts near the humidifiers?	N/A
	b_e) Is there evidence of foaming in the humidifiers?	N/A
	b_f) Is the water hard in this region?	N/A
	b_g) If so, are there hard water deposits on the vanes?	N/A
	b_h) Are the hard water deposits removed by scraping the vanes and blowing the dust into the ducts?	N/A
38.	Are steam humidifiers used in this building?	NO
	a) Are the steam humidifiers supposed to operate this time of year?	N/A
	b) Are the steam humidifiers operating now?	N/A
	If YES, answer the questions below:	
	b_a) Are chemicals used in the boiler or the pipes to protect against corrosion? If YES, state the names of chemicals:	N/A

____

____

____

39.	Does this building have an air chilling system?	NO
	a) Is the chilling system supposed to operate at this time of year?	N/A
	b) Is the chilling system operating now?	N/A
	If YES, answer the questions below:	
	b_a) Are the condensate trays cleaned less often than once a week?	N/A
	b_b) Is there slime or growth in the condensate trays?	N/A
	b_c) Is there dirt on the cooling coils?	N/A
	b_d) Are there mouldy odours in the system?	N/A

40. Are the ventilation ducts or plenums insulated? YES

  a) Is the insulation on the inside and directly exposed to the moving air? YES

  b) Is it more than five years since the ducts or plenums were last cleaned? YES

41. Are there any signs of condensation in ducts? (Check cold spots such as near inlets and after cooling coils first.) NO

APPENDIX IXC

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BUILDING AND MECHANICAL SYSTEMS QUESTIONNAIRE

BUILDING AND MECHANICAL SYSTEMS QUESTIONNAIRE

BUILDING: ______________________________

BUILDING COMMON AREAS:

1. What year was the building constructed? ________
   a) Are the as-built design diagrams for this building missing? YES/NO
   b) Are the current design diagrams for this building missing? YES/NO
   c) Are the operating and maintenance manuals for the building's HVAC system missing? YES/NO
   d) Is there no routine maintenance program for the HVAC system. YES/NO

2. Have any areas been recarpeted recently? YES/NO
   a) If YES, did odours persist for more than a week after carpet was laid? YES/NO
   b) If YES, describe locations:

   ____

   ____

3. Have any areas been repainted recently? YES/NO
   a) If YES, did odours persist for more than a week after the paint was applied? YES/NO
   b) If YES, describe locations:

   ____

   ____

4. Has there been a recent or is there a regular cleaning process which uses large amounts of chemicals or solvents? YES/NO
   a) If YES, what were the chemicals?

   ____

5. Is there a fuel-fired central heating unit or Domestic Hot Water system? YES/NO

a) Is there any physical evidence of leakage or combustion gasses from the furnace or flue room or nearby areas? YES/NO

b) Is there the odour of combustion fumes in the room? YES/NO

6. Is there an enclosed parking garage? YES/NO

a) Was the ventilation system found in an operative state? YES/NO

b) Is the ventilation system turned off for periods? YES/NO

c) Is the ventilation system controlled? YES/NO

d) Are there carbon monoxide sensors in the garage which control ventilation? YES/NO

e) If so, have they been recently calibrated? YES/NO

f) Are there obstructions in the exhaust or air inlets? YES/NO

g) Are stack forces pulling air from the garage into the building? (check at access doors) YES/NO

7. Is there a garbage handling facility? YES/NO

a) Is the vent system off or ineffective? YES/NO

b) Is there an air flow pattern from garbage rooms or chutes into the rest of the building? YES/NO

c) Is there an unusually bad odour or mouldy smell associated with system? YES/NO

8. Is there a pool, hot tub, sauna, or work-out room? YES/NO

a) Does maintenance and cleaning appear to be irregular or inadequate. YES/NO

b) Are there any "mildew" stains on walls, ceilings, floors, fixtures or items such as like shower curtains? YES/NO

c) Is there any condensation on walls, floors, windows or ceiling? YES/NO

d) Does humidity appear very high? YES/NO

e) Do any biodegradable products (wood, etc.) get wet regularly? YES/NO

9. Are there any basement or sub-basement areas or crawl spaces with dirt floors? YES/NO

   a) Are there occupied areas nearby? YES/NO

      If YES, describe locations:

      ____

      ____

   b) Do these spaces lack ventilation? YES/NO

   c) Are there musty odours in these areas or nearby? YES/NO

10. Are there rooms with sizeable holes in the walls or floor, such as sump pits, gas and water entrances, cracks, etc.? YES/NO

   a) If YES, describe location(s):

      ____

      ____

   b) Do these spaces lack ventilation? YES/NO

   c) Are there musty odours in these areas or nearby? YES/NO

11. Is there foam insulation in the walls of the building? YES/NO

   a) The type of insulation is polyurethane/polystyrene/urea formaldehyde/unknown.

12. Do drawings show asbestos insulation for pipes, fire protection of structure, etc.? YES/NO

   a) If YES, does inspection reveal loose fibre especially near air handling equipment and ducts? YES/NO

13. Has there ever been a "water crisis" such as a flood or overflow? YES/NO

14. Are there any signs of moisture problems such as:

   a) stains or dampness on walls, floors or ceilings? YES/NO

   b) stained, streaked, or damp carpets? YES/NO

   c) mouldy odours, or musty smells? YES/NO

SPECIFIC COMPLAINT AREA OBSERVATIONS:

15. Where in the building do these observations apply? Please give the floor, room or apartment number or briefly describe (e.g. main lobby, everywhere):

____

____

Please answer all questions by circling of filling in the answers as required.

16. General Observations

a)	Are there damp spots or mould on the walls or ceiling/	YES/NO
b)	Are any of the carpets, curtains, etc. damp?	YES/NO
c)	Are there any potted plants in this area?	YES/NO
d)	Is there mould on the plants or their pots or soil?	YES/NO
e)	Do mites appear to be on the plants?	YES/NO
f)	Are there pets in the unit?	YES/NO
g)	Are there odours here?	YES/NO
h)	Which of the following best describes the odour?	

auto exhaust / diesel fumes / furnace room / heating system / pet odours / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty / chalky

i)	Are people using fans to create more air movement?	YES/NO
j)	Is there much dust visible on flat surfaces?	YES/NO
k)	Is there evidence of condensation on windows or walls?	YES/NO

17. Are there air supply diffusers? YES/NO

a) Can you see any of the following around the diffusers?

mould / chalky dust / dirt marks YES/NO

b) Are any of the air supply diffusers blocked by furniture, paper, or other obstructions? YES/NO

18. Are there any air exhaust fans or louvres in unit of complaint area? YES/NO
    a) Do you have a poor drain rate? YES/NO
    b) Are there dirt marks around the air exhaust louvres? YES/NO
    c) Are any of the air exhaust louvres block by furniture, papers or other obstructions? YES/NO

19. Has carpeting or furniture been installed in the last three months? YES/NO

20. Are there large areas of particleboard sheathing or furnishings? YES/NO

21. Is there a gas stove? YES/NO
    a) Are there exhausts to remove combustion gasses produced by the stoves? YES/NO
    b) Are the stoves operated without exhaust fans on? YES/NO

22. Is there a wood or gas fireplace in the area? YES/NO
    a) Does it appear to be poorly vented? YES/NO
    b) Does it appear to have inadequate supply air? YES/NO

23. If there a freestanding heater (gas or kerosene)? YES/NO
    If YES,
    a) Are these heaters used in anything but well ventilated spaces? YES/NO
    b) Is there an odour of combustion fumes in the room? YES/NO
    c) Is the room exhaust recirculated rather than directly expelled outdoors? YES/NO

24. Is there a refrigerator in the unit? YES/NO
    a) Does anything in the fridge look mouldy? YES/NO
    b) Is the refrigerator drain blocked? YES/NO
    c) Is the drain pan wet and mouldy? YES/NO
    d) Are the heat exchangers dusty? YES/NO

25. Is there mould on bathroom tiles, walls or ceilings? YES/NO

26. Are there humidifiers or dehumidifiers in the unit? YES/NO
    a) Do the drip pans, coils, and water in these units have accumulation of dust, slime, sludge or mould? YES/NO

27. Are there small but steady leaks in, around, under or behind sinks, toilets, tubs and/or showers? YES/NO

28. Are there poorly vented mechanical/electrical chases or other entry paths for contaminants from outside the unit? YES/NO

MECHANICAL SYSTEMS AND HVAC OPERATION:

If the building contains two or more towers or wings, each controlled by a different HVAC system, a copy of this sheet should be filled out for each.

29. Describe ventilation system:

____

____

____

____

30. Is the amount of fresh air used by the ventilation system the same all year round? YES/NO

31. Is the ventilation system of the recirculating type? YES/NO
    a) Does the HVAC system use an economizer cycle? YES/NO
    b) What is the maximum percentage of fresh air used? ______%

c) What is the minimum percentage of fresh air used? ______ %

d) What is the fresh air percentage just now? ______ %

32. Air supplied to the floors by:

constant volume systems / variable air volume (VAV) system / heat pumps / other / unknown?

33. Is there a corridor pressurization system? YES/NO

a) Is the "corridor-to-apartment" flow reversed? YES/NO

34. At what temperature is the tank supplying hot water to the building maintained? ______ °C

35. Are there distinct fresh-air intakes for the building HVAC system? YES/NO

a) Are there intakes below third floor level and above a busy street? YES/NO

b) Are there intakes within 10 metres (30 feet) of the exhausts of this or a parking garage? YES/NO

c) Are there intakes within 10 metres (30 feet) of the exhausts of this or an adjacent building? YES/NO

d) Are intakes near standing water or a cooling tower? YES/NO

e) Is there a built up of organic debris near the intakes? YES/NO

f) Are there any other sources or pollution near any of the intakes? YES/NO

36. Does this building have a particular (dust) filter system installed in the fresh air intake? YES/NO

a) Are the filters missing? YES/NO

b) Are the filters changed less frequently than recommended by the manufacturer? YES/NO

c) Do the filters fit so poorly that air bypasses them at the edges? YES/NO

d) Are the filters matted or dirty? YES/NO

e) Are the filters wet? YES/NO

37. Are spray humidifiers used in this building? YES/NO

a) Are the spray humidifiers supposed to operate at this time of year? YES/NO

b) Are the spray humidifiers operating now? YES/NO

If YES, answer the questions below:

- b_a) Are the spray humidifier pans plugged so that they are not draining properly? YES/NO
- b_b) Is there slime in the humidifier pans? YES/NO
- b_c) Are there mouldy odours? YES/NO
- b_d) Is there mould in the ducts near the humidifiers? YES/NO
- b_e) Is there evidence of foaming in the humidifiers? YES/NO
- b_f) Is the water hard in this region? YES/NO
- b_g) If so, are there hard water deposits on the vanes? YES/NO
- b_h) Are the hard water deposits removed by scraping the vanes and blowing the dust into the ducts? YES/NO

38. Are steam humidifiers used in this building? YES/NO

a) Are the steam humidifiers supposed to operate this time of year? YES/NO

b) Are the steam humidifiers operating now? YES/NO

If YES, answer the questions below:

- b_a) Are chemicals used in the boiler or the pipes to protect against corrosion? YES/NO

  If YES, state the names of chemicals:

____

____

____

39. Does this building have an air chilling system? YES/NO

a) Is the chilling system supposed to operate at this time of year? YES/NO

b) Is the chilling system operating now? YES/NO

If YES, answer the questions below:

- b_a) Are the condensate trays cleaned less often than once a week? YES/NO
- b_b) Is there slime or growth in the condensate trays? YES/NO
- b_c) Is there dirt on the cooling coils? YES/NO
- b_d) Are there mouldy odours in the system? YES/NO

40. Are the ventilation ducts or plenums insulated? YES/NO

a) Is the insulation on the inside and directly exposed to the moving air? YES/NO

b) Is it more than five years since the ducts or plenums were last cleaned? YES/NO

41. Are there any signs of condensation in ducts? (Check cold spots such as near inlets and after cooling coils first.) YES/NO

APPENDIX IXD

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OCCUPANT SURVEY

OCCUPANT SURVEY

BUILDING: ______________________________ APT #: _______

OCCUPANT PROFILE:

The following questions are directed towards constructing a general profile of the "typical" occupant of this building.

1) Please state the number of males and the number of females in each age range living in this apartment.

age range	# males	# females
15-20	________	__________
20-25	________	__________
25-35	________	__________
35-55	________	__________
55-65	________	__________
over 65	________	__________

For children under 15 please state ages:

2) Please state occupations of any adults living in the household. Student, Unemployed, Retired, and Homemaker may each be considered as an occupation.

____

____

3) How many smokers are in the household ? _____

Where do the smokers tend to smoke ?

In the apartment/ In the hall/ Outside the building

BFL

BFL Consultants Limited

4) How many hours is the apartment occupied ?

weekdays - __________ hrs/day x 5

weekends - __________ hrs/day x 2

5) Are windows opened regularly ? YES/NO

If yes, how often ? ________ hrs/day

For what reason ? ______________________________

This next set of questions will help determine any typical types of moisture generation for the building.

6) WASHROOM USAGE:

How many Bathrooms are in this apartment ? ______
Is there an Exhaust fan in each Bathroom ? YES/NO
Does the exhaust fan work ? YES/NO
Is the exhaust fan used ? If not, Why ? YES/NO

____

Is the shower used each day ? YES/NO
Approximately how many times a day is the shower used ? ______
At what point in the day is the shower usually used ?

EARLY MORNING / MID-DAY / LATE EVENING

Is the bath used each day? YES/NO
Approximately how many times a day is the bath used ? ______
At what point in the day is the bath usually used ?

EARLY MORNING / MID-DAY / LATE EVENING

7) KITCHEN USAGE:

How often do you eat out ?

seldom / once a month/
several times a month/ several times a week

Do you have an exhaust hood in your kitchen ? YES/NO
Does it work ? YES/NO
Do you use it when you cook? If not why? YES/NO

____

When you cook, do you tend to boil a lot of food ? YES/NO
Do you often make soup or stew ? YES/NO
Do you often cook spicy foods which would have a spicy aroma ? YES/NO

8) LAUNDRY:

How often do you do laundry ? ______________
When do you usually do laundry. ?

Day(s) of the week: ______________
Time: morning / afternoon / evening

Do you have your own laundry facilities in your apartment ? YES/NO
Is the dryer vented ? YES/NO
Do you hang cloths out to dry in your apartment ? YES/NO

9) During the initial testing procedures it may be necessary to access your apartment in order to open your door a small amount or, if you are in a central apartment, to place a measuring instrument outside your window.
Do you have any objection to this ? YES/NO

OCCUPANT COMPLAINTS:

10) Where in the building are your complaints worst? Please give the floor, room or apartment number or briefly describe (e.g., main lobby, everywhere):

____

____

Your answers to the questions below apply to this location. Where a choice is given, please circle the most appropriate answer. Enter your own answer where requested. Space for comment is provided.

11) Describe the usual temperature at this location:

okay / too hot / too cold / sometime too hot, sometimes too cold

12) How would you usually describe the air here?

okay / drafty / stagnant / stuffy / stale / dry

13) Are you bothered by odour at this location? YES/NO

If YES, how often do you smell this odour?

rarely / occasionally / frequently / all the time

Which of the following best describes the odour?

auto exhaust / diesel fumes / furnace smell / heating system / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty or chalky smell

What do you think causes the odour?

____

____

14) Can you "fix" any of the problems noted above? YES/NO

15) Has there ever been a "water crisis", such as flood or overflow, in this area or on the floor(s) above it? YES/NO

16) Do you have a history of allergies? YES/NO

If YES, the type of allergy is:

respiratory / skin / food / other

Are your allergies worse while you are in this building? YES/NO

17) From which of the following do you suffer that you think are due to the building?

headache / tiredness / faintness / dizziness / nausea / stomach problems / skin irritation / dry eyes / itching eyes / watery eyes / blurred vision / stuffy nose / runny nose / sneezing / sore throat / dry throat / chest problems / coughing / asthma

18) What time of day are your complaints worse?

morning / afternoon / evening / night / the same all the time

What day of the week are your complaints worse?

weekday / weekend / the same all week

19) Do the symptoms coincide with or occur soon after cleaning or maintenance activities in this area? YES/NO

If YES describe this activity:

____

____

____

____

20) Please state any additional comments or complaints.

INDIVIDUAL APARTMENT OBSERVATION:

The following set of questions and observations are meant to help identify typical air quality problems within the building. The answers to these questions have no reflection on you, the tenant, so please do not take any of these questions personally and please do not be offended by them.

Please answer all questions by circling or filling in the answers as required.

21) General Observations

a)	Are there damp spots or mould on the walls or ceiling/	YES/NO
b)	Are any of the carpets, curtains, etc. damp?	YES/NO
c)	Are there any potted plants in this area?	YES/NO
d)	Is there mould on the plants or their pots or soil?	YES/NO
e)	Do mites appear to be on the plants?	YES/NO
f)	Are there pets in the unit?	YES/NO
g)	Are there odours here?	YES/NO
h)	Which of the following best describes the odour? auto exhaust / diesel fumes / furnace room / heating system / pet odours / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty / chalky	
i)	Are fans used to create more air movement?	YES/NO
j)	Is there much dust visible on flat surfaces?	YES/NO

k) Is there evidence of condensation on windows or walls? YES/NO

l) Are there any indications of moisture accumulation around windows ? (frosting, condensation, moulds, moisture stains) YES/NO

22) Are there air supply diffusers ? (vent grills) YES/NO

a) Can you see any of the following around the diffusers?
mould / chalky dust / dirt marks YES/NO

b) Are any of the air supply diffusers blocked by furniture, paper, or other obstructions? YES/NO

23) Are there any air exhaust fans or louvres (vented openings to the outside) in this unit ? YES/NO

a) Do you have a poor drain rate? YES/NO

b) Are there dirt marks around the air exhaust louvres? YES/NO

c) Are any of the air exhaust louvres block by furniture, papers or other obstructions? YES/NO

24) Has carpeting or furniture been installed in the last three months? YES/NO

25) Are there large areas of particleboard sheathing or furnishings? YES/NO

26) Is there a gas stove? YES/NO

a) Are there exhausts to remove combustion gasses produced by the stoves? YES/NO

b) Are the stoves operated without exhaust fans on? YES/NO

27) Is there a wood or gas fireplace in the area? YES/NO

a) Does it appear to be poorly vented? YES/NO

b) Does it appear to have inadequate supply air? YES/NO

28) If there a freestanding heater (gas or kerosene)? YES/NO
If YES,

a) Are these heaters used in anything but well ventilated spaces? YES/NO

b) Is there an odour of combustion fumes in the room? YES/NO

c) Is the room exhaust recirculated rather than directly expelled outdoors? YES/NO

29) Is there a refrigerator in the unit? YES/NO

a) Does anything in the fridge look mouldy? YES/NO

b) Is the refrigerator drain blocked? YES/NO

c) Is the drain pan wet and mouldy? YES/NO

d) Are the heat exchangers dusty? YES/NO

30) Is there mould on bathroom tiles, walls or ceilings? YES/NO

31) Are there humidifiers or dehumidifiers in the unit? YES/NO

a) Do the drip pans, coils, and water in these units have accumulation of dust, slime, sludge or mould? YES/NO

32) Are there small but steady leaks in, around, under or behind sinks, toilets, tubs and/or showers? YES/NO

33) Are there any mechanical or electrical shafts or access areas in this unit ? YES/NO

a) Do you notice any odours or drafts in that area ? YES/NO

b) Which of the following best describes the odour?

auto exhaust / diesel fumes / furnace room / heating system / pet odours / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty / chalky

APPENDIX X

MONTHLY METEOROLOGICAL SUMMARY

Environment Canada / Environnement Canada
Atmospheric Environment Service / Service de l'environnement atmosphérique

MONTHLY METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE MENSUEL

MONTH/MOIS: JANUARY/JANVIER 1991

AT/A: ST. JOHN'S NFLD./T.N.

LAT 47 ° 37 'N LONG 52 ° 45 'W ELEVATION / ALTITUDE 140 (ASL) (MER) STANDARD TIME USED / HEURE NORMALE UTILISEE NST

DATE	TEMPERATURE / TEMPÉRATURE: MAXIMUM / MAXIMALE °C	MINIMUM / MINIMALE °C	MEAN / MOYENNE °C	DEGREE-DAYS / DEGRÉS-JOURS: HEATING / DE CHAUFFE BASE 18.0°C	GROWING / DE CROISSANCE BASE 5.0°C	COOLING / DE RÉFRIGÉRATION BASE 18.0°C	REL HUMIDITY / HUMIDITÉ REL: MAXIMUM / MAXIMALE %	MINIMUM / MINIMALE %	THUNDERSTORM / ORAGE	PRECIPITATION / PRÉCIPITATIONS: RAINFALL / PLUIE (HAUTEUR) mm	SNOWFALL / NEIGE (HAUTEUR) cm	TOTAL PRECIP / PRÉCIP. TOTALE mm	SNOW ON GROUND / NEIGE AU SOL cm	WIND / VENT: AVERAGE SPEED / VITESSE MOYENNE km/h	PREVAILING DIRECTION / DIRECTION DOMINANTE	MAX 2 MIN MEAN SPEED & DIRECTION / VITESSE MOYENNE MAX. SUR 2 MIN & DIRECTION km/h	BRIGHT SUNSHINE / INSOLATION EFFECTIVE HOURS / HEURES
1	-7.6	-12.0	-9.8	27.8			74	58						42.0	W	W 50	7.1
2	2.1	-10.1	-4.0	22.0			93	61		TR	0.4	0.4		25.8	SSW	W 45	4.2
3	2.0	-12.5	-5.3	23.3			94	69		0.4	1.6	2.0	TR	18.5	W	SW 34*	0.0
4	-8.9	-14.5	-11.7	29.7			86	69			0.4	0.4	1	15.0	W	W 30	0.7
5	-4.3	-10.5	-7.4	25.4			93	55			0.8	0.8	2	27.6	W	W 50	4.9
6	-4.8	-13.8	-9.3	27.3			95	59			8.4	8.4	1	11.1	WNW	WNW 28*	3.9
7	-9.2	-17.0	-13.1	31.1			87	60			0.6	0.6	9	25.2	WNW	WNW 50	6.6
8	-15.1	-17.9	-16.5	34.5			78	57			0.6	0.6	7	36.4	WNW	WNW 45*	0.6
9	-9.4	-15.9	-12.7	30.7			78	55			0.2	0.2	7	27.8	W	WNW 45	6.8
10	-2.0	-11.3	-6.7	24.7			99	69			17.8	17.8	7	20.6	S *	ESE 39	0.0
11	-2.8	-13.4	-8.1	26.1			98	91			12.0	12.0	32	70.0	WNW	WNW 89	0.0
12	-4.1	-9.6	-6.9	24.9			91	53			0.4	0.4	35	36.1	NW*	WNW 75	4.9
13	-1.6	-9.3	-5.5	23.5			100	71		1.4	6.0	7.4	26	20.3	ESE	ESE 41	0.0
14	-6.1	-12.5	-9.3	27.3			85	69			TR	TR	29	33.4	W	W 41*	6.3
15	-9.9	-13.4	-11.7	29.7			86	67					28	18.2	WNW	WNW 30	8.2
16	-7.1	-14.1	-10.6	28.6			89	58					28	16.6	W	W 24*	8.6
17	4.6	-11.6	-3.5	21.5			100	82		1.4	8.8	10.2	28	22.3	SSE	SE 48	0.0
18	0.2	-5.9	-2.9	20.9			93	73			TR	TR	29	27.8	W	W 35	0.7
19	-3.1	-9.6	-6.4	24.4			94	75			0.8	0.8	28	8.2	W	W 22	1.5
20	0.1	-12.7	-6.3	24.3			94	60		0.2	TR	0.2	28	16.8	S	S 30	4.8
21	2.4	-8.5	-3.1	21.1			100	86		25.0	2.0	27.0	27	32.3	S	ENE 47	0.0
22	-8.3	-10.8	-9.6	27.6			89	77			0.8	0.4	17	21.4	W	WSW 45*	0.0
23	-10.1	-15.7	-12.9	30.9			85	79			2.4	0.6	18	18.1	WNW	WNW 26*	1.7
24	-1.8	-17.1	-9.5	27.5			97	60			5.6	1.2	25	13.1	SSE	SE 39	6.5
25	-0.5	-17.0	-8.8	26.8			89	68			4.8	4.0	29	30.0	WSW	SW 34*	2.4
26	-12.3	-17.5	-14.9	32.9			86	58					29	45.6	W	W 58	7.9
27	-1.0	-14.7	-7.9	25.9			95	62			0.2	0.2	28	17.8	SSW	S 34	2.3
28	0.0	-8.5	-4.3	22.3			99	59			5.4	5.4	28	16.8	S	S 34	5.7
29	0.0	-11.1	-5.6	23.6			99	67					32	17.7	W	W 43*	8.6
30	2.2	-14.6	-6.2	24.2			98	57		5.4	5.2	10.6	31	15.5	NW*	WNW 41	2.7
31	8.5	-7.9	0.3	17.7			100	66		17.0	TR	17.0	24	29.1	SSW*	WSW 73	0.0
MEAN / MOYENNE	-3.5	-12.6	-8.1	TOTAL 808.2	TOTAL 0.0	TOTAL 0.0	92	66	TOT 0	TOTAL 50.8	TOTAL 85.2	TOTAL 128.6		25.1	PREVAILING / DOMINANTE W	MAXIMALE WNW 89	TOTAL 107.6
NORMAL / NORMALE	-0.5	-7.2	-3.9	678.0	1.0	0.0			0.0	77.9	81.4	155.8		27.5	W		70.6

DEGREE-DAY SUMMARY/SOMMAIRE DE DEGRÉS JOURS

	BELOW 18°C / AU-DESSOUS DE 18°C: THIS YEAR / ANNÉE EN COURS	PREVIOUS YEAR / ANNÉE PRÉCÉDENTE	NORMAL / NORMALE		ABOVE 5°C / AU-DESSUS DE 5°C: THIS YEAR / ANNÉE EN COURS	PREVIOUS YEAR / ANNÉE PRÉCÉDENTE	NORMAL / NORMALE
TOTAL FOR MONTH / TOTAL DU MOIS	808.2	695.4	678.0	TOTAL FOR MONTH / TOTAL DU MOIS	0.0	0.9	1.0
ACCUMULATED SINCE JULY 1 / ACCUMULÉE DEPUIS LE 1er JUILLET	2479.1	2463.8	2447.7	ACCUMULATED SINCE APRIL 1 / ACCUMULÉE DEPUIS LE 1er AVRIL	1277.4	2463.8	1194.0

DAYS WITH TOTAL PRECIPITATION / JOURS AVEC PRÉCIPITATIONS TOTALES (mm): 0.2 OR MORE / OU PLUS	1.0 OR MORE / OU PLUS	2.0 OR MORE / OU PLUS	10.0 OR MORE / OU PLUS	50.0 OR MORE / OU PLUS	DAYS WITH SNOWFALL / JOURS AVEC CHUTE DE NEIGE (cm): 0.2 OR MORE / OU PLUS	1.0 OR MORE / OU PLUS	2.0 OR MORE / OU PLUS	10.0 OR MORE / OU PLUS	50.0 OR MORE / OU PLUS
24	12	11	6	0	22	12	11	2	0

UDC 551.506.1 ( ) Note/Avis

1. Climatological Day/Journée climatologique 0231 NST - 0230 NST
2. Normal/Normale 1951-1980
3. TR = Trace
4. M = Missing/Manquant
5. No entry/Pas de valeur = No occurrence/Pas d'événement
6. * Indicates first of more than one prevailing direction and/or maximum 2 minute mean speed (see page 4)/Indique la première de plusieurs des directions dominantes et/ou la vitesse moyenne maximale sur 2 minutes (voir page 4)
7. C = Calm/Calme
8. Price: single issue $3.00 annual (Jan. to Dec.) $29.50 Prix numéro individuel $3.00 ann. $29.50 (janv. à déc.)

Canada

COMPARATIVE RECORDS AT: / RELEVÉS COMPARATIFS À: ST. JOHN'S NFLD — MONTH / MOIS: JAN./ JAN. — 1991

Temperature/Température — ° Celsius
Precipitation/Précipitation — Millimetres/millimètres (mm)
Rainfall/Hauteur de pluie — Millimetres/millimètres (mm)
Snowfall/Hauteur de neige — Centimetres/centimètres (cm)
Wind speed/Vitesse du vent — Kilometres/h / kilomètres/h (km/h)
Station pressure/Pression à la station — Kilopascals (kPa)

	THIS MONTH / CE MOIS-CI		PREVIOUS YEAR / ANNÉE PRÉCÉDENTE		NORMAL / NORMALE	RECORD FOR THE MONTH / RECORD POUR LE MOIS: HIGHEST EVER / MAXIMUM ABSOLU			LOWEST EVER / MINIMUM ABSOLU			NO OF YEARS / NO D'ANNÉES
	VALUE / RELEVÉ	DAY / JOUR	VALUE / RELEVÉ	DAY / JOUR		VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	
HIGHEST TEMPERATURE (MAXIMUM) / TEMPÉRATURE MAXIMALE	8.5	31	13.5	27		15.2	9	1979				50
LOWEST TEMPERATURE (MINIMUM) / TEMPÉRATURE MINIMALE	-17.9	8	-15.9	20					-23.1	29	1957	50
MEAN MONTHLY TEMPERATURE / TEMPÉRATURE MENSUELLE MOYENNE	-8.1		-4.4		-3.9	0.6		1981	-8.2		1974	50
TOTAL MONTHLY RAINFALL / HAUTEUR TOTALE MENSUELLE DE PLUIE	50.8		52.5		69.1	197.9		1942	1.5		1970	50
TOTAL MONTHLY SNOWFALL / HAUTEUR TOTALE MENSUELLE DE NEIGE	85.2		54.3		77.7	162.1		1960	10.2		1958	50
TOTAL MONTHLY PRECIPITATION / PRÉCIPITATION TOTALE MENSUELLE	128.6		101.1		145.0	264.7		1955	70.6		1950	50
NO OF DAYS WITH MEASURABLE PRECIPITATION / NOMBRE DE JOURS AVEC PRÉCIPITATION MESURABLE	24		21		22	27		1979	12		1943	50
GREATEST RAINFALL IN ONE DAY / HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE	25.0	21	23.0	1		84.6	30	1942				50
GREATEST SNOWFALL IN ONE DAY / HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE	17.8	10	12.6	30		38.4	9	1966				50
GREATEST PRECIPITATION IN ONE DAY / PRÉCIPITATION MAXIMALE EN UNE JOURNÉE	27.0	21	25.2	1		84.6	30	1942				50
MAXIMUM RAINFALL RECORDED IN / HAUTEUR DE PLUIE MAXIMALE ENREGISTRÉE EN												
5 MINUTES	N/A		0.2	2		3.8	5	1977				29
10 MINUTES	N/A		0.4	2		5.1	5	1977				29
15 MINUTES	N/A		0.6	2		6.4	5	1977				29
30 MINUTES	N/A		0.8	2		8.1	5	1977				29
60 MINUTES	N/A		1.0	2		14.7	7	1977				29
24 CONSECUTIVE HOURS / HEURES CONSÉCUTIVES	27.0	21	24.0	2		84.6	30	1942				50
MEAN WIND SPEED (km/h) / VITESSE MOYENNE DU VENT (km/h)	25.1		31.0		27.5	41.8		1946	20.3		1967	50
MAXIMUM SPEED (2 min mean) (km/h) / VITESSE MAXIMALE (moyenne sur 2 min) (km/h)	WNW 89	11	W 76	2		W 129	15	1946				50
MAXIMUM GUST SPEED (km/h) / POINTE DU VENT MAXIMALE (km/h)	W 121	11	W 116	27		WSW156	21	1961				42
TOTAL HOURS OF SUNSHINE / TOTAL DES HEURES INSOLATION	107.6		76.9		70.6	122.9		1974	29.1		1956	46
MEAN STATION PRESSURE (kPa) / PRESSION MOYENNE À LA STATION (kPa)	99.27		99.15		98.96	99.95		1949	97.81		1955	50
GREATEST STATION PRESSURE (kPa) / PRESSION MAXIMALE À LA STATION (kPa)	101.45	2	101.18	15		102.81	25	1986				50
LEAST STATION PRESSURE (kPa) / PRESSION MINIMALE À LA STATION (kPa)	95.82	11	95.92	2					92.57	20	1977	50

CLIMATOLOGICAL DATA THIS MONTH FOR THE PAST 10 YEARS
DONNÉES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIÈRE ANNÉES

YEAR / ANNÉE	MAXIMUM TEMP / TEMP MAXIMALE	MINIMUM TEMP / TEMP MINIMALE	MEAN TEMP / TEMP MOYENNE	RAINFALL / HAUTEUR DE PLUIE	SNOWFALL / HAUTEUR DE NEIGE	TOTAL PRECIP / PRECIP TOTALE	MEAN WIND SPEED / VITESSE MOYENNE DES VENTS	MAXIMUM WIND SPEED / VITESSE MAXIMALE DES VENTS	SUNSHINE HOURS / HEURES INSOLATION	HEATING DEGREE-DAYS / DEGRÉS-JOURS DE CHAUFFE	GROWING DEGREE-DAYS / DEGRÉS-JOURS DE CROISSANCE	COOLING DEGREE-DAYS / DEGRÉS-JOURS DE RÉFRIGÉRATION
1982	7.4	-17.3	-4.2	78.1	142.6	227.8	30.9	82	62.7	687.9	0.0	0.0
1983	10.5	-16.4	-2.8	98.3	62.7	150.1	26.9	82	57.9	646.3	3.0	0.0
1984	13.3	-17.2	-5.5	124.6	53.2	188.8	24.6	85	73.7	726.4	0.2	0.0
1985	5.2	-15.2	-5.2	39.4	83.5	111.6	30.0	82	78.3	720.0	0.0	0.0
1986	13.4	-18.0	-2.7	68.7	52.7	117.3	31.9	80	72.4	637.4	7.6	0.0
1987	5.6	-15.6	-5.5	55.2	129.2	174.4	27.0	59	54.3	727.7	0.0	0.0
1988	10.2	-19.1	-5.2	23.1	58.0	79.7	30.5	83	98.0	719.3	0.0	0.0
1989	8.8	-17.6	-6.0	51.0	93.3	141.7	29.7	82	88.0	743.8	0.0	0.0
1990	13.5	-15.9	-4.4	52.5	54.3	101.1	31.0	76	76.9	695.4	0.9	0.0
1991	E.5	-17.9	-8.1	50.8	85.2	128.6	25.1	89	107.6	808.2	0.0	0.0

Note/Avis
1 Climatological Day/Journée climatologique 0231 - 0230 NST
2 Normal/Normale 1951-1980
3 Extremes for period of record/Extrêmes pour la période de registre
4 Maximum rainfall recorded in may overlap calendar days/Hauteur de pluie maximale enregistrée en peut-être pour plus d'une journée du calendrier
5 ** indicates most recent occurrence/indique le plus récent
6 * indicates first of more than one occurrence/indique le premier de plusieurs

DRY BULB TEMPERATURES AT/TEMPERATURES DU THERMOMETRE SEC A: ST. JOHN'S NFLD.

JAN. JAN. 1991

HEURE/ HOUR / DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	-105	-115	-120	-119	-119	-116	-114	-113	-107	-97	-87	-82	-79	-79	-78	-84	-86	-89	-88	-92	-94	-100	-101	-102
2	-102	-98	-97	-99	-100	-97	-94	-92	-86	-75	-62	-55	-49	-40	-36	-35	-38	-42	-38	-31	-25	-14	-7	0
3	8	15	18	16	10	7	3	-1	-1	-2	-3	-16	-26	-34	-32	-47	-57	-57	-61	-73	-87	-93	-101	-113
4	-116	-122	-124	-117	-111	-114	-111	-114	-106	-103	-98	-94	-95	-95	-91	-90	-94	-106	-115	-116	-124	-136	-134	-134
5	-119	-127	-105	-88	-81	-71	-65	-69	-72	-75	-71	-63	-58	-60	-51	-50	-53	-62	-68	-75	-84	-90	-95	-96
6	-98	-102	-103	-106	-109	-111	-114	-131	-133	-101	-96	-78	-75	-76	-64	-75	-77	-77	-67	-59	-54	-55	-49	-68
7	-78	-81	-92	-101	-105	-114	-129	-143	-140	-134	-130	-124	-119	-116	-109	-106	-105	-100	-105	-119	-130	-143	-157	-167
8	-167	-170	-170	-170	-171	-171	-172	-174	-170	-164	-163	-160	-157	-153	-154	-155	-156	-160	-169	-174	-178	-177	-176	-174
9	-170	-163	-159	-158	-153	-145	-141	-142	-141	-134	-124	-120	-112	-105	-99	-96	-97	-101	-101	-101	-106	-107	-99	-101
10	-105	-110	-113	-99	-97	-95	-101	-99	-90	-79	-68	-46	-37	-34	-27	-25	-24	-26	-23	-22	-22	-26	-23	-22
11	-21	-22	-28	-31	-82	-101	-113	-119	-124	-125	-132	-130	-123	-111	-111	-102	-97	-93	-89	-87	-83	-79	-76	-71
12	-77	-65	-54	-44	-43	-48	-54	-61	-63	-68	-63	-62	-58	-58	-61	-64	-71	-73	-84	-90	-91	-95	-91	-90
13	-93	-91	-92	-90	-93	-88	-77	-69	-65	-57	-51	-43	-32	-25	-22	-18	-17	-17	-18	-25	-31	-34	-38	-44
14	-54	-59	-61	-65	-69	-76	-83	-91	-93	-93	-93	-86	-82	-91	-95	-90	-96	-100	-103	-105	-105	-108	-112	-118
15	-121	-123	-125	-126	-126	-127	-130	-132	-130	-119	-116	-115	-108	-105	-102	-101	-112	-125	-127	-118	-127	-134	-129	-126
16	-130	-124	-122	-125	-128	-133	-131	-136	-123	-112	-91	-88	-81	-77	-74	-74	-83	-86	-97	-94	-101	-101	-100	-108
17	-108	-120	-107	-114	-107	-98	-94	-89	-63	-60	-48	-39	-34	-25	-21	-11	-6	1	12	21	36	41	33	24
18	17	6	2	-1	-4	-8	-9	-14	-14	-20	-21	-19	-19	-21	-22	-25	-30	-34	-36	-43	-44	-47	-47	-50
19	-50	-57	-59	-61	-60	-65	-81	-85	-90	-61	-58	-39	-36	-36	-36	-43	-51	-66	-82	-82	-87	-74	-81	-88
20	-84	-91	-95	-102	-112	-117	-123	-113	-123	-122	-118	-113	-102	-91	-80	-69	-71	-73	-70	-56	-49	-43	-28	-20
21	-13	-10	1	1	4	8	11	10	9	7	10	7	7	3	-2	0	1	-1	4	13	17	10	8	-12
22	-45	-69	-85	-89	-93	-95	-100	-99	-96	-93	-89	-88	-91	-92	-94	-94	-92	-92	-92	-95	-107	-101	-92	-90
23	-88	-93	-101	-117	-127	-132	-137	-140	-142	-139	-128	-126	-122	-122	-126	-127	-128	-136	-134	-134	-141	-142	-150	-152
24	-152	-155	-157	-153	-158	-155	-159	-169	-160	-131	-122	-109	-97	-83	-87	-89	-84	-75	-66	-56	-50	-39	-33	-36
25	-33	-28	-18	-14	-7	-9	-11	-16	-16	-24	-26	-40	-50	-57	-63	-90	-96	-101	-105	-117	-137	-152	-155	-167
26	-169	-164	-158	-156	-156	-164	-170	-174	-173	-169	-165	-159	-158	-153	-153	-155	-154	-155	-155	-152	-150	-148	-145	-140
27	-129	-124	-123	-120	-134	-132	-144	-137	-128	-90	-74	-69	-56	-61	-57	-47	-51	-51	-39	-35	-30	-25	-22	-15
28	-14	-20	-11	-19	-36	-46	-59	-83	-80	-56	-42	-28	-22	-24	-29	-30	-35	-34	-35	-31	-22	-13	-13	-14
29	-7	0	-1	-3	-25	-41	-51	-54	-63	-41	-33	-30	-29	-22	-14	-21	-28	-34	-28	-25	-29	-60	-79	-89
30	-101	-104	-111	-117	-123	-127	-128	-138	-145	-123	-110	-101	-97	-92	-84	-83	-79	-72	-69	-65	-50	-41	-32	-17
31	-4	8	21	26	19	26	29	30	29	41	44	40	26	30	59	71	70	82	80	57	43	24	21	-7

Note/Avis 1. Climatological Day/Journee climatologique 0231 N.S.T.- 0230 N.S.T.
2. Hours are L.S.T./Les heures sont a l'heure normale de la localite
3. Unit/Unite = 0.1 C

WIND SUMMARY / SOMMAIRE DES VENTS

ST. JOHN'S, NFLD./T.N. JANUARY/JANVIER, 1991

HOUR HEURE DAY	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	PEAK GUST RAFALE	HOUR HEURE
1	WNW	W	WNW	W	W	W	W	W	W	WNW	W	W	W	W	W	W	W	W	W	W	W	W	WNW	W	W	0600
	28	37	45	41	43	47	47	43	45	45	48	48	50	41	45	43	34	34	34	41	39	47	41	41	67	
2	W	W	W	WNW	W	W	W	W	W	W	WSW	WSW	WSW	SSW	SSW	SSW	SSW	S	SSW	SSW	SSW	SSW	SSW	SSW	W	0000
	45	28	32	34	30	34	28	28	19	24	22	22	17	22	22	19	15	22	24	24	30	32	22	24	56	
3	SSW	SW	WSW	WSW	W	W	W	W	W	W	WNW	W	W	WNW	NNW	N	NNW	NW	NNW	NW	NW	NW	NW	NW	SW	0100
	26	34	32	34	32	34	28	26	19	13	15	13	15	15	9	11	11	9	13	9	13	6	4	22	52	
4	W	WNW	WNW	W	W	W	W	W	W	W	W	W	NW	W	W	W	W	W	W	WSW	WSW	SW	SSW	SW	W	0400
	24	26	22	22	30	20	17	13	17	15	15	20	13	15	15	13	9	6	7	11	11	7	7	6	43	
5	SW	SSW	SW	SSW	SSW	W	W	WNW	WNW	W	W	WSW	WSW	WSW	W	W	W	W	W	W	W	W	WNW	W	W	1700
	13	7	11	13	15	35	22	22	19	19	17	17	20	22	30	34	35	47	47	43	45	50	39	41	65	
6	WNW	WNW	WNW	WNW	NW	WNW	C	SSW	SSW	SW	WSW	W	WSW	SW	S	S	SE	SE	SE	SSE	SSE	NNW	NNE	N	N	2300
	28	28	19	9	11	4		4	4	7	6	9	11	7	7	9	9	9	19	19	6	2	17	22	32	
7	N	N	NNW	NNW	NNW	C	NW	NW	NW	WNW	WNW	WNW	WNW	W	WSW	W	W	W	WNW	WNW	W	W	WNW	WNW	WNW	2200
	22	9	17	19	9		15	13	22	24	30	28	24	24	26	30	26	24	34	30	41	47	50	41	61	
8	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	W	WNW	WNW	NW	NW	NW	WNW	WNW	WNW	NNW	NW	WNW	WNW	SSW	WNW	WNW	1000
	37	39	41	39	45	45	39	34	37	34	45	43	32	30	30	39	37	34	28	26	35	37	30	37	76	
9	WNW	WNW	WNW	WNW	WNW	WNW	W	W	WNW	WNW	W	W	WNW	W	W	W	W	W	W	W	W	WNW	W	W	W	0600
	37	37	28	34	32	45	41	34	34	34	34	30	30	24	26	26	24	19	13	15	15	15	30	11	60	
10	WSW	SW	SW	WSW	SSW	SSW	SSE	S	S	S	SE	SSE	S	SSE	S	SE	SSE	SE	SE	SE	ESE	ESE	ENE	ENE	ESE	2100
	11	4	7	9	6	7	7	7	19	13	4	26	28	26	34	28	37	34	37	30	32	39	30	19	58	
11	NW	NW	NW	NW	WNW	W	W	W	W	W	W	W	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	NW	W	1100
	11	30	34	37	60	75	75	78	75	84	86	88	88	88	89	84	82	80	71	75	75	71	75	69	121	
12	WNW	WNW	WNW	NW	NW	NNW	NW	NW	NW	WNW	NW	NW	WNW	WNW	NW	NW	NW	WNW	WNW	NW	WNW	WNW	WNW	W	NW	2007
	75	65	65	56	61	56	52	47	43	41	22	34	28	28	28	28	17	20	20	19	19	19	6	17	99	
13	S	C	ESE	C	SSE	ESE	ESE	ESE	ESE	ESE	ESE	ESE	ESE	E	E	ENE	N	NW	NW	NNW	NNW	NW	NW	NW	ESE	1200
	2		4		6	4	13	26	26	34	35	32	41	22	34	19	9	9	7	32	32	37	34	30	56	
14	NW	WNW	W	W	W	WNW	W	WNW	WNW	WNW	WNW	W	W	W	WNW	WNW	W	W	WNW	W	W	W	WNW	WNW	WNW	1800
	30	28	34	41	37	41	41	30	37	28	34	34	30	34	32	32	32	37	30	32	34	34	32	28	52	
15	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	W	W	W	W	W	WNW	WNW	W	W	W	WNW	W	SSW	W	W	WNW	0400
	24	24	24	28	30	22	24	19	4	11	22	13	26	22	19	15	22	15	11	15	20	4	9	13	41	
16	W	W	W	W	WSW	WSW	WSW	WSW	SW	SW	W	W	W	W	W	W	SW	WSW	W	W	W	W	W	W		
	24	19	19	24	22	24	20	19	15	11	19	22	22	22	15	19	6	6	4	9	13	11	15	19		
17	WSW	WSW	W	S	SSE	SSW	C	SW	SSW	SSE	SSE	SE	SE	SE	SE	SE	SSE	SSE	SSE	S	SSW	SSW	SW	SW	SE	1500
	6	4	15	4	4	7		9	15	7	26	22	30	37	37	48	41	37	37	30	28	32	28	30	65	
18	WSW	WSW	W	WSW	WSW	WSW	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	WSW	0400
	32	34	30	32	32	28	32	30	28	35	34	20	19	24	28	30	28	28	30	26	22	24	20	20	58	
19	W	W	W	WSW	WSW	SSW	C	SSW	SSW	SW	SSE	W	W	W	NE	NE	N	N	NNW	NNW	NNW	NNW	N	NNW		
	22	20	9	6	13	4		6	6	7	2	6	2	4	6	9	6	6	6	7	13	15	15	7		
20	NNW	NNW	NNW	NW	NW	NW	NW	WNW	WNW	W	W	W	W	WSW	SW	SW	SSW	S	S	S	S	SSW	S	S	S	2320
	19	13	9	17	11	15	11	15	13	15	15	19	15	15	22	22	11	13	11	17	28	19	30	28	47	
21	S	S	S	S	S	S	S	S	S	SSE	SSE	SSE	SE	ESE	ESE	E	ENE	ENE	E	E	E	SW	SW	WSW	ENE	1816
	34	34	32	32	32	26	34	34	35	32	34	30	19	22	26	28	34	47	43	34	35	19	34	45	73	
22	WSW	WSW	WSW	W	W	W	WNW	WNW	WNW	NW	NW	WNW	W	W	W	W	WSW	W	W	WSW	SW	SW	SW	SW	W	0243
	39	45	45	41	34	32	22	7	15	11	19	19	22	19	15	19	19	9	19	9	11	7	15	20	67	
23	WSW	W	W	W	WNW	WNW	WNW	WNW	WNW	NW	NW	NW	NW	NW	WNW	WNW	WNW	NW	WNW	NW	WNW	WNW	WNW	NW		
	22	13	15	15	13	24	19	22	15	22	17	19	24	24	26	26	26	17	11	13	15	13	9	15		
24	NW	NNW	NW	NW	WNW	W	SW	WSW	SSW	W	W	W	SW	S	SSE	S	SSE	SSE	SSE	SSE	SSE	SSE	SE	SE	SE	2251
	6	4	9	13	7	6	2	6	6	9	9	6	9	7	15	13	20	11	19	26	17	34	22	39	50	
25	SE	SSE	SSW	S	S	SSW	SW	SW	SW	WSW	WSW	WSW	WSW	WSW	WSW	W	W	W	WSW	WSW	W	W	W	W	WSW	1022
	32	26	20	26	28	28	30	34	32	28	32	34	34	24	34	34	24	28	30	32	28	34	34	34	56	
26	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	1000
	39	41	41	43	43	43	47	50	47	47	52	58	54	54	45	50	39	43	43	39	43	47	43	43	75	
27	W	W	WSW	SW	SSW	SSW	SSW	SSW	SSW	SW	SSW	SW	SSW	S	S	SSW	S	S	S	SSE	S	S	S	SSW		
	32	19	13	13	7	7	9	9	4	9	13	15	15	34	20	19	17	20	30	28	26	26	26	15		
28	SW	SW	WSW	WSW	W	W	W	W	W	W	W	S	SSE	SSE	S	S	S	SSE	S	S	S	S	S	S	S	2000
	19	13	15	11	15	9	11	15	13	13	13	7	7	7	19	19	20	20	26	24	34	26	24	24	48	
29	SSW	SW	W	WNW	W	WNW	W	C	W	C	W	W	SSW	SW	WSW	WSW	WSW	WSW	WSW	WSW	WNW	W	WNW	WNW	W	2100
	13	11	11	20	22	17	15		4		6	6	7	13	13	22	19	20	30	22	28	43	39	43	52	
30	WNW	WNW	NW	NW	C	NW	NW	NW	C	SW	SW	SSW	S	S	SSE	SE	SSE	SSE	SE	ESE	SE	SE	SE	SSE	WNW	0000
	41	32	19	19		9	7	7		7	9	4	7	7	6	9	17	28	24	20	28	26	26	20	50	
31	C	SSW	SSW	SSW	SW	SSW	SW	SSW	S	S	S	SSE	SSE	S	SSW	SW	SSW	SW	SW	SW	WSW	SW	WSW	WSW	WSW	2300
		4	22	20	7	15	11	6	15	19	28	30	37	32	32	37	30	28	37	47	56	58	54	73	97	

Note/Avis
1. Climatological day/Journee climatologique 0231AST - 0230AST
2. Hours are L.S.T./Les heures sont a l'heure normale de la localite
3. Unit/Unite = 1.0 km/h 4. C = Calm/Calm 5. M = Missing/Manquant
6. * Indicates more than one occurrence of same speed/
   * Indique le premier de plusieurs de la meme vitesse
7. $ Gust in next calender day/ $ Rafale dans le prochain jour de calendrier

Environment Canada / Environnement Canada
Atmospheric Environment Service / Service de l'environnement atmosphérique

MONTHLY METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE MENSUEL

MONTH/MOIS: FEBRUARY/FEVRIER 1991

AT/A: ST. JOHN'S NFLD. /T.N

LAT: 47 ° 37 'N LONG 52 ° 45 'W ELEVATION/ALTITUDE 140 (ASL)/(MER) STANDARD TIME USED/HEURE NORMALE UTILISÉE NST

DATE	TEMPERATURE/TEMPÉRATURE: MAXIMUM/MAXIMALE °C	MINIMUM/MINIMALE °C	MEAN/MOYENNE °C	DEGREE-DAYS/DEGRÉS-JOURS: HEATING/DE CHAUFFE BASE 18.0°C	GROWING/DE CROISSANCE BASE 5.0°C	COOLING/DE RÉFRIGÉRATION BASE 18.0°C	REL HUMIDITY/HUMIDITÉ REL: MAXIMUM/MAXIMALE %	MINIMUM/MINIMALE %	THUNDERSTORM/ORAGE	PRECIPITATION/PRÉCIPITATIONS: RAINFALL/PLUIE (HAUTEUR) mm	SNOWFALL/NEIGE (HAUTEUR) cm	TOTAL PRECIP./PRÉCIP. TOTALE mm	SNOW ON GROUND/NEIGE AU SOL cm	WIND/VENT: AVERAGE SPEED/VITESSE MOYENNE km/h	PREVAILING DIRECTION/DIRECTION DOMINANTE	MAX 2 MIN MEAN SPEED & DIRECTION/VITESSE MOYENNE MAX. SUR 2 MIN & DIRECTION km/h	BRIGHT SUNSHINE/INSOLATION EFFECTIVE HOURS/HEURES
1	-7.6	-17.5	-12.6	30.6			73	47			TR	TR	16	44.8	W	WSW 70	7.4
2	-2.1	-17.3	-9.7	27.7			94	56			2.0	1.8	12	36.7	W	W 50	4.7
3	-0.3	-12.8	-6.6	24.6			99	85			6.0	5.8	14	24.4	WSW*	W 44	0.0
4	-12.5	-20.0	-16.3	34.3			83	65			0.2	0.2	19	18.1	NNW	N 33	8.1
5	0.5	-18.2	-8.9	26.9			98	47		TR	1.0	1.0	20	16.3	SW	SW 26*	1.1
6	0.4	-14.8	-7.2	25.2			98	71		TR	3.5	3.0	24	13.5	NNW	N 28	6.3
7	-0.1	-15.8	-8.0	26.0			86	49					24	20.6	WSW	WSW 31*	9.0
8	2.3	-4.7	-1.2	19.2			97	78		2.0		2.0	23	20.4	SSW	SW 31	0.0
9	2.4	-6.9	-2.3	20.3			95	64					19	6.6	S	SW 13	5.3
10	2.4	-7.1	-2.4	20.4			97	77		TR		TR	17	4.3	S	S 11	0.0
11	1.8	-2.4	-0.3	18.3			99	95					9	4.2	ESE*	N 9*	0.0
12	-1.6	-7.4	-4.5	22.5			96	88		0.2	11.7	8.4	6	16.1	NNE	N 31	0.0
13	-7.2	-12.9	-10.1	28.1			91	77			7.6	7.0	20	36.5	W	NW 46*	0.0
14	-3.5	-11.0	-7.3	25.3			95	70			0.9	0.5	20	24.1	WSW	W 48	5.5
15	11.2	-3.5	3.9	14.1			98	91		27.2	TR	27.2	19	37.9	S	S 46	0.0
16	11.5	1.9	6.7	11.3	1.7		99	93		18.4		18.4	5	27.8	S	S 48	0.0
17	1.9	-5.4	-1.8	19.8			92	66			TR	TR	2	24.2	WSW	WSW 33	6.2
18	-1.4	-9.9	-5.7	23.7			92	50			1.0	1.0	2	30.3	W	W 44	6.1
19	-2.7	-10.1	-6.4	24.4			74	43					2	32.9	W	W 44*	9.6
20	2.5	-6.5	-2.0	20.0			99	80		1.9	5.2	7.1	4	22.5	W	S 41	0.0
21	0.6	-10.2	-4.8	22.8			93	71			0.2	TR	3	25.3	NNW	WNW 33	3.5
22	-2.0	-12.4	-7.2	25.2			93	57			1.7	1.9	3	12.8	W	S 26	7.8
23	1.3	-13.9	-6.3	24.3			97	74		TR	8.4	8.1	7	45.2	W	W 63*	0.3
24	-8.3	-13.4	-10.9	28.9			86	59					10	36.7	WNW	W 56	7.0
25	-6.0	-13.6	-9.8	27.8			83	58					10	21.1	WNW	WNW 39	9.8
26	-4.2	-7.7	-6.0	24.0			89	71			0.6	0.2	10	5.1	ENE	NE 11*	4.1
27	-1.4	-11.4	-6.4	24.4			98	84		1.2	11.0	12.2	10	17.9	E	E 37	0.0
28	-4.4	-11.5	-8.0	26.0			92	62			1.4	1.4	22	35.6	WNW	NW 52	7.3
MEAN/MOYENNE	-0.9	-10.6	-5.8	TOTAL 666.1	TOTAL 1.7	TOTAL 0.0	92	69	TOT 0	TOTAL 50.9	TOTAL 62.4	TOTAL 107.2		23.7	PREVAILING/DOMINANTE W	MAXIMALE WSW 70	TOTAL 109.1
NORMAL/NORMALE	-1.0	-7.9	-4.5	635.4	0.5	0.0			0.1	69.7	74.6	140.1		27.5	W		83.4

DEGREE-DAY SUMMARY/SOMMAIRE DE DEGRÉS JOURS

BELOW 18°C/AU-DESSOUS DE 18°C	THIS YEAR/ANNÉE EN COURS	PREVIOUS YEAR/ANNÉE PRÉCÉDENTE	NORMAL/NORMALE	ABOVE 5°C/AU-DESSUS DE 5°C	THIS YEAR/ANNÉE EN COURS	PREVIOUS YEAR/ANNÉE PRÉCÉDENTE	NORMAL/NORMALE
TOTAL FOR MONTH/TOTAL DU MOIS	666.1	766.2	635.4	TOTAL FOR MONTH/TOTAL DU MOIS	1.7	0.0	0.5
ACCUMULATED SINCE JULY 1/ACCUMULÉE DEPUIS LE 1er JUILLET	3145.2	3230.0	3083.1	ACCUMULATED SINCE APRIL 1/ACCUMULÉE DEPUIS LE 1er AVRIL	1279.1	1377.6	1194.5

DAYS WITH TOTAL PRECIPITATION/JOURS AVEC PRÉCIPITATIONS TOTALES (mm): 0.2 OR MORE/OU PLUS	1.0 OR MORE/OU PLUS	2.0 OR MORE/OU PLUS	10.0 OR MORE/OU PLUS	50.0 OR MORE/OU PLUS	DAYS WITH SNOWFALL/JOURS AVEC CHUTE DE NEIGE (cm): 0.2 OR MORE/OU PLUS	1.0 OR MORE/OU PLUS	2.0 OR MORE/OU PLUS	10.0 OR MORE/OU PLUS	50.0 OR MORE/OU PLUS
18	15	10	3	0	16	12	8	2	0

UDC 551 506 1 ( ) Note/Avis

1. Climatological Day/Journée climatologique 0231 NST - 0230 NST.
2. Normal/Normale 1951-1980
3. TR = Trace
4. M = Missing/Manquant
5. No entry/Pas de valeur = No occurrence/Pas d'événement
6. * Indicates first of more than one prevailing direction and/or maximum 2 minute mean speed (see page 4)/Indique la première de plusieurs des directions dominantes et/ou la vitesse moyenne maximale sur 7 minutes (voir page 4)
7. C = Calm/Calme
8. Price: single issue $3.00 annual (Jan. to Dec.) $29.50 Prix: numéro individuel $3.00 ; annuel $29.50 (janv. à déc.)

Canada

COMPARATIVE RECORDS AT: / RELEVÉS COMPARATIFS À: ST. JOHN'S NFLD — MONTH / MOIS: FEB. FEV. 1991

Temperature/Température — °Celsius
Precipitation/Précipitation — Millimetres/millimètres (mm)
Rainfall/Hauteur de pluie — Millimetres/millimètres (mm)
Snowfall/Hauteur de neige — Centimetres/centimètres (cm)
Wind speed/Vitesse du vent — Kilometres/h / kilomètres/h (km/h)
Station pressure/Pression à la station — Kilopascals (kPa)

	THIS MONTH / CE MOIS-CI		PREVIOUS YEAR / ANNÉE PRÉCÉDENTE		NORMAL / NORMALE	RECORD FOR THE MONTH / RECORD POUR LE MOIS — HIGHEST EVER / MAXIMUM ABSOLU			LOWEST EVER / MINIMUM ABSOLU			NO OF YEARS / Nº D'ANNÉES
	VALUE / RELEVÉ	DAY / JOUR	VALUE / RELEVÉ	DAY / JOUR		VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	
HIGHEST TEMPERATURE (MAXIMUM) / TEMPÉRATURE MAXIMALE	11.5	16	10.8	10		15.6	5	1984				50
LOWEST TEMPERATURE (MINIMUM) / TEMPÉRATURE MINIMALE	-20.0	4	-23.8	18					-23.8	18	1990	50
MEAN MONTHLY TEMPERATURE / TEMPÉRATURE MENSUELLE MOYENNE	-5.8		-9.4		-4.5	-1.0		1954	-10.7		1975	50
TOTAL MONTHLY RAINFALL / HAUTEUR TOTALE MENSUELLE DE PLUIE	50.9		75.9		69.7	201.9		1970	2.4		1978	50
TOTAL MONTHLY SNOWFALL / HAUTEUR TOTALE MENSUELLE DE NEIGE	62.4		72.1		74.6	144.8		1949	7.8		1984	50
TOTAL MONTHLY PRECIPITATION / PRÉCIPITATION TOTALE MENSUELLE	107.2		133.7		140.1	233.9		1970	63.0		1966	50
NO OF DAYS WITH MEASURABLE PRECIPITATION / NOMBRE DE JOURS AVEC PRÉCIPITATION MESURABLE	18		22		20	27		1942	16		1969	50
GREATEST RAINFALL IN ONE DAY / HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE	27.2	15	30.9	24		67.1	22	1973				50
GREATEST SNOWFALL IN ONE DAY / HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE	11.7	12	28.2	17		54.9	15	1959				50
GREATEST PRECIPITATION IN ONE DAY / PRÉCIPITATION MAXIMALE EN UNE JOURNÉE	27.2	15	31.6	10		68.3	22	1973				50
MAXIMUM RAINFALL RECORDED IN / HAUTEUR DE PLUIE MAXIMALE ENREGISTRÉE EN												
5 MINUTES	N/A		0.8	24		2.8	28	1988				26
10 MINUTES	N/A		1.6	24		5.6	9	1968				26
15 MINUTES	N/A		2.0	24		6.9	9	1968				26
30 MINUTES	N/A		3.4	24		7.9	22	1973				26
60 MINUTES	N/A		6.6	10		15.0	22	1973				26
24 CONSECUTIVE HOURS / HEURES CONSÉCUTIVES	27.2	15	30.9	24		67.1	22	1973				50
MEAN WIND SPEED (km/h) / VITESSE MOYENNE DU VENT (km/h)	23.7		28.5		27.5	36.0		1946	21.7		1968	50
MAXIMUM SPEED (2 min mean) (km/h) / VITESSE MAXIMALE (moyenne sur 2 min.) (km/h)	WSW 70	1	WNW 71	18		N 137	21	1959				50
MAXIMUM GUST SPEED (km/h) / POINTE DU VENT MAXIMALE (km/h)	WSW 95	1	WSW106	11		SW193	9	1964				43
TOTAL HOURS OF SUNSHINE / TOTAL DES HEURES INSOLATION	109.1		80.5		83.4	140.1		1959	17.8		1969	45
MEAN STATION PRESSURE (kPa) / PRESSION MOYENNE À LA STATION (kPa)	99.16		99.13		99.11	100.57		1981	97.88		1964	50
GREATEST STATION PRESSURE (kPa) / PRESSION MAXIMALE À LA STATION (kPa)	101.30	4	101.72	27		103.65	11	1981				50
LEAST STATION PRESSURE (kPa) / PRESSION MINIMALE À LA STATION (kPa)	95.40	27	96.81	24					93.49	14	1968	50

CLIMATOLOGICAL DATA THIS MONTH FOR THE PAST 10 YEARS
DONNÉES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIÈRE ANNÉES

YEAR / ANNÉE	MAXIMUM TEMP / TEMP MAXIMALE	MINIMUM TEMP / TEMP MINIMALE	MEAN TEMP / TEMP MOYENNE	RAINFALL / HAUTEUR DE PLUIE	SNOWFALL / HAUTEUR DE NEIGE	TOTAL PRECIP / PRECIP TOTALE	MEAN WIND SPEED / VITESSE MOYENNE DES VENTS	MAXIMUM WIND SPEED / VITESSE MAXIMALE DES VENTS	SUNSHINE HOURS / HEURES INSOLATION	HEATING DEGREE-DAYS / DEGRÉS-JOURS DE CHAUFFE	GROWING DEGREE-DAYS / DEGRÉS-JOURS DE CROISSANCE	COOLING DEGREE-DAYS / DEGRÉS-JOURS DE RÉFRIGÉRATION
1982	8.6	-18.7	-7.0	70.0	94.9	159.0	29.2	89	90.0	701.8	0.0	0.0
1983	7.2	-19.4	-4.2	61.3	79.6	146.2	24.3	65	72.3	622.4	0.0	0.0
1984	15.6	-17.2	-1.9	143.7	7.8	151.1	27.4	74	75.2	577.3	12.7	0.0
1985	8.2	-20.7	-5.9	23.9	72.7	96.3	22.4	65	70.8	667.8	0.0	0.0
1986	6.3	-16.3	-5.5	102.3	65.6	184.9	31.9	83	109.5	657.6	0.0	0.0
1987	3.9	-15.3	-5.0	44.0	132.4	175.1	25.1	67	60.5	643.4	0.0	0.0
1988	9.6	-18.7	-3.9	144.3	31.3	172.6	29.3	80	82.7	633.4	2.0	0.0
1989	10.7	-19.5	-7.1	55.2	67.6	118.9	27.1	65	98.9	702.8	1.9	0.0
1990	10.8	-23.8	-9.4	75.9	72.1	133.7	28.5	71	80.5	766.2	0.0	0.0
1991	11.5	-20.0	-5.8	50.9	62.4	107.2	23.7	70	109.1	666.1	1.7	0.0

Note/Avis
1 Climatological Day-Journée climatologique
2 Normal-Normale 1951-1980
3 Extremes for period of record/Extrêmes pour la période de registre
4 Maximum rainfall recorded in may overlap calendar days/Hauteur de pluie maximale enregistrée en peut-être pour plus d'une journée du calendrier
5 ** Indicates most recent occurrence/Indique le plus récent
6 * Indicates first of more than one occurrence/Indique le premier de plusieurs

DRY BULB TEMPERATURES AT/TEMPERATURES DU THERMOMETRE SEC A: ST.JOHN'S, NFLD

FEBRUARY/FEVRIER, 1991

HEURE/ HOUR / DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	-34	-58	-79	-76	-89	-95	-97	-103	-113	-117	-112	-109	-102	-100	-110	-120	-130	-136	-141	-145	-151	-162	-163	-167
2	-172	-175	-172	-170	-166	-157	-145	-141	-131	-117	-110	-105	-94	-92	-89	-87	-83	-78	-82	-81	-73	-64	-48	-38
3	-30	-24	-33	-36	-45	-54	-54	-45	-43	-37	-33	-11	-4	-5	-4	-7	-7	-7	-7	-7	-21	-32	-40	-47
4	-78	-107	-125	-146	-158	-163	-168	-173	-173	-169	-164	-162	-153	-148	-146	-148	-148	-161	-172	-191	-195	-184	-187	-188
5	-182	-188	-182	-176	-162	-152	-139	-120	-101	-92	-71	-55	-48	-32	-30	-26	-21	-18	-12	-7	-2	0	1	0
6	3	4	4	2	-2	-27	-49	-54	-62	-59	-59	-57	-58	-55	-58	-61	-67	-87	-116	-103	-103	-109	-122	-134
7	-138	-138	-142	-134	-137	-113	-117	-113	-106	-73	-53	-37	-18	-8	-10	-11	-16	-27	-32	-34	-29	-32	-38	-29
8	-27	-32	-31	-25	-23	-20	-16	-5	5	12	20	22	22	17	14	12	6	4	-7	-9	-14	-14	-23	-22
9	-32	-42	-46	-58	-57	-56	-60	-60	-37	-20	-1	1	15	9	22	22	15	-4	-14	-19	-32	-38	-50	-51
10	-57	-63	-63	-65	-54	-47	-42	-38	-31	-21	-5	10	22	16	13	3	-1	-10	-14	-14	-17	-16	-18	-18
11	-20	-23	-22	-23	-23	-23	-23	-21	-18	-12	-4	-1	0	8	14	17	11	-3	-5	-3	2	1	-7	-8
12	-10	-11	-16	-20	-25	-29	-34	-39	-39	-40	-42	-42	-45	-46	-52	-56	-58	-57	-57	-54	-49	-52	-58	-61
13	-65	-68	-73	-76	-80	-86	-91	-101	-106	-105	-106	-109	-105	-104	-97	104	-108	-120	-125	-127	-127	-123	-121	-116
14	-109	-111	-110	-106	-105	-104	-101	-99	-95	-87	-72	-66	-67	-61	-62	-61	-66	-75	-79	-90	-89	-94	-66	-62
15	-49	-43	-35	-25	-19	-4	11	37	54	63	72	76	74	82	84	77	76	98	92	88	102	103	102	106
16	109	101	89	107	109	110	107	92	94	98	100	95	83	101	99	89	90	84	74	72	51	42	44	39
17	42	25	19	15	5	5	1	-3	-3	-6	-2	-9	-4	-4	-14	-20	-26	-36	-41	-42	-44	-48	-47	-46
18	-48	-50	-54	-54	-45	-43	-37	-22	-21	-30	-35	-36	-32	-25	-32	-29	-41	-52	-60	-67	-75	-79	-85	-85
19	-92	-98	-97	-97	-99	-100	-96	-93	-84	-70	-58	-50	-34	-32	-33	-34	-38	-51	-56	-60	-58	-60	-62	-59
20	-64	-66	-62	-61	-58	-48	-42	-43	-38	-28	-20	-14	-4	21	20	18	17	15	17	15	10	6	4	4
21	6	8	5	4	2	-5	-13	-31	-42	-45	-57	-56	-58	-62	-67	-68	-71	-71	-76	-82	-85	-89	-90	-96
22	-99	-100	-101	-101	-107	-112	-123	-101	-82	-71	-63	-51	-38	-27	-23	-27	-29	-30	-38	-48	-60	-60	-55	-36
23	-30	-25	-29	-21	-15	-5	6	11	10	6	2	-4	-10	-23	-35	-52	-68	-81	-94	-107	-132	-139	-134	-122
24	-112	-102	-102	-105	-107	-114	-116	-118	-114	-112	-108	-106	-101	-90	-87	-92	-98	-105	-114	-118	-122	-124	-129	-130
25	-132	-131	-134	-134	-130	-126	-124	-125	-117	-108	-96	-88	-81	-70	-65	-61	-62	-74	-88	-97	-92	-92	-87	-84
26	-83	-76	-73	-72	-68	-65	-64	-63	-59	-57	-56	-49	-53	-44	-52	-56	-60	-67	-73	-76	-72	-65	-67	-72
27	-63	-60	-65	-83	-98	-105	-106	-90	-72	-61	-52	-44	-46	-50	-49	-48	-49	-48	-48	-50	-46	-34	-26	-23
28	-17	-28	-44	-58	-67	-68	-79	-87	-92	-95	-101	-102	-103	-98	-92	-88	-91	-97	-96	-95	-98	-100	-99	-102
29	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999
30	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999
31	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999

Note/Avis 1. Climatological Day/Journee climatologique 0231 N.S.T.- 0230 N.S.T.

Environment Canada / Environnement Canada
Atmospheric Environment Service / Service de l'environnement atmosphérique

MONTHLY METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE MENSUEL

MONTH/MOIS: MARCH/MARS 1991

AT/A: ST. JOHN'S "A" NFLD. / T.N.

LAT 47 ° 37 ' N LONG 52 ° 45 ' W ELEVATION / ALTITUDE 140 (ASL) (MER) STANDARD TIME USED / HEURE NORMALE UTILISÉE NST / NST

DATE	TEMPERATURE / TEMPÉRATURE: Maximum / Maximale °C	Minimum / Minimale °C	Mean / Moyenne °C	DEGREE-DAYS / DEGRÉS-JOURS: Heating / De chauffe (base 18.0°C)	Growing / De croissance (base 5.0°C)	Cooling / De réfrigération (base 18.0°C)	REL. HUMIDITY / HUMIDITÉ REL.: Maximum / Maximale %	Minimum / Minimale %	Thunderstorm / Orage	PRECIPITATION / PRÉCIPITATIONS: Rainfall / Pluie (hauteur) mm	Snowfall / Neige (hauteur) cm	Total precip. / Précip. totale mm	Snow on ground / Neige au sol cm	WIND / VENT: Average speed / Vitesse moyenne km/h	Prevailing direction / Direction dominante	Max 2 min mean speed & direction / Vitesse moyenne max. sur 2 min & direction km/h	Bright sunshine / Insolation effective Hours / Heures
1	-6.9	-12.2	-9.6	27.6			77	49					22	21.2	WNW	W 31	10.3
2	8.4	-9.2	-0.4	18.4			98	54		7.2	TR	7.2	22	20.5	S	S 35	5.1
3	9.9	-6.8	1.6	16.4			98	71		3.8		3.8	7	27.8	W	WSW 61	1.5
4	-5.1	-8.7	-6.9	24.9			93	56		0.2	6.6	9.4	5	12.6	NNW	ESE 22	5.9
5	7.0	-5.1	1.0	17.0			100	92		4.0	4.4	9.1	15	18.9	ESE	ESE 31*	0.0
6	4.6	-4.9	-0.2	18.2			97	73					9	29.3	WSW	WSW 41	2.9
7	2.5	-5.1	-1.3	19.3			89	66					8	26.0	W	W 43	9.5
8	-0.3	-1.9	-1.1	19.1			97	91		0.4	TR	0.4	6	9.2	E	W 19	0.6
9	0.1	-2.2	-1.1	19.1			98	95		0.4	0.2	0.6	6	14.2	N	NNE 22	0.0
10	0.0	-2.5	-1.3	19.3			98	91		0.2	1.6	1.8	7	17.9	N	N 22*	0.0
11	0.1	-2.4	-1.2	19.2			100	88		1.4	8.2	9.6	7	29.8	ENE	ENE 44	0.0
12	0.1	-1.1	-0.5	18.5			100	98		1.8		1.8	15	13.0	E	E 28*	0.0
13	0.0	-1.3	-0.7	18.7			100	93		2.4	2.0	4.4	14	9.8	N	NE 19	0.0
14	-1.0	-4.2	-2.6	20.6			100	84		TR	1.4	2.0	16	27.2	NW	NW 44	0.0
15	-1.4	-4.1	-2.8	20.8			100	97		TR	0.4	0.2	16	20.1	N	NNE 24	0.0
16	-0.3	-2.5	-1.4	19.4			100	99		TR	3.4	3.4	18	24.1	N	N 35	0.0
17	-1.8	-6.1	-4.0	22.0			98	92			0.4	0.2	19	32.3	N	N 43	0.0
18	0.4	-9.0	-4.3	22.3			94	72					19	19.8	W	NW 24*	10.8
19	1.3	-7.2	-3.0	21.0			98	85		0.4		0.4	19	13.1	SSE	SSE 26*	5.8
20	5.6	1.1	3.4	14.6			100	96		26.6		26.6	9	32.1	S	S 52	0.0
21	3.5	-6.8	-1.7	19.7			98	65			1.2	0.8	2	21.6	SSW*	WSW 39	2.5
22	-2.8	-9.1	-6.0	24.0			70	53			TR	TR	3	26.6	W	W 39	8.5
23	-6.8	-9.9	-8.4	26.4			77	52			TR	TR	3	17.0	WNW	NW 24*	5.8
24	1.1	-9.8	-4.4	22.4			93	46					3	14.3	W	W 24*	8.2
25	-1.0	-4.4	-2.7	20.7			89	75					3	21.8	ENE	ENE 30	6.9
26	0.8	-4.1	-1.7	19.7			100	88		10.4	8.2	18.2	4	30.5	NE	NE 48	0.0
27	0.4	-0.3	0.1	17.9			100	98		0.6	4.2	4.8	9	34.8	N	N 41*	0.0
28	1.8	-0.3	0.8	17.2			100	98		TR		TR	8	16.2	N	N 28*	0.0
29	6.2	-0.6	2.8	15.2			100	63		0.2		0.2	7	15.4	N	N 33	2.8
30	11.9	2.3	7.1	10.9	2.1		100	63		11.7		11.7	5	23.4	SSW	S 43	0.0
31	9.3	-4.7	2.3	15.7			100	59		0.2		0.2	TR	24.6	W	WSW 44	6.3
MEAN / MOYENNE	1.5	-4.6	-1.6	Total 606.2	Total 2.1	Total 0.0	96	77	Tot 0	Total 71.9	Total 42.2	Total 116.0		21.5	Dominant W	Maximale WSW 61	Total 92.6
NORMAL / NORMALE	0.9	-5.5	-2.3	630.1	1.6	0.0			0.1	67.0	65.0	131.9		26.9	W		94.6

DEGREE-DAY SUMMARY/SOMMAIRE DE DEGRÉS JOURS

Below 18°C / Au-dessous de 18°C	This year / Année en cours	Previous year / Année précédente	Normal / Normale	Above 5°C / Au-dessus de 5°C	This year / Année en cours	Previous year / Année précédente	Normal / Normale
TOTAL FOR MONTH / TOTAL DU MOIS	606.2	710.9	630.1	TOTAL FOR MONTH / TOTAL DU MOIS	2.1	2.7	1.6
ACCUMULATED SINCE JULY 1 / ACCUMULÉE DEPUIS LE 1er JUILLET	3751.4	3940.9	3713.1	ACCUMULATED SINCE APRIL 1 / ACCUMULÉE DEPUIS LE 1er AVRIL	1281.2	1380.3	1194.5

DAYS WITH TOTAL PRECIPITATION / JOURS AVEC PRÉCIPITATIONS TOTALES (mm): 0.2 or more / ou plus	1.0 or more / ou plus	2.0 or more / ou plus	10.0 or more / ou plus	[illegible] or more / ou plus	DAYS WITH SNOWFALL / JOURS AVEC CHUTE DE NEIGE (cm): 0.2 or more / ou plus	1.0 or more / ou plus	2.0 or more / ou plus	10.0 or more / ou plus	[illegible] or more / ou plus
22	14	12	3	0	13	10	7	0	0

UDC 551.508.1 ( )

Note/Avis
1. Climatological Day/Journée climatologique 0231 NST - 0230 NST
2. Normal/Normale 1951 - 1980
3. TR = Trace
4. M = Missing/Manquant
5. No entry/Pas de valeur = No occurrence/Pas d'événement
6. * Indicates first of more than one prevailing direction and/or maximum 2 minute mean speed (see page 4)/Indique la première de plusieurs des directions dominantes et/ou la vitesse moyenne maximale sur 2 minutes (voir page 4)
7. C = Calm/Calme
8. Price: single issue $3.00, annual (Jan. to Dec.) $29.50 /Prix: numéro individuel $3.00 ; annuel $29.50 (janv. à déc.)

Canada

COMPARATIVE RECORDS AT / RELEVÉS COMPARATIFS À: **ST. JOHN'S NFLD** — MONTH / MOIS: **MARCH / MARS** **1991**

Temperature/Température — °Celsius
Precipitation/Précipitation — Millimetres/millimètres (mm)
Rainfall/Hauteur de pluie — Millimetres/millimètres (mm)
Snowfall/Hauteur de neige — Centimetres/centimètres (cm)
Wind speed/Vitesse du vent — Kilometres/h / kilomètres/h (km/h)
Station pressure/Pression à la station — Kilopascals (kPa)

	THIS MONTH / CE MOIS-CI		PREVIOUS YEAR / ANNÉE PRÉCÉDENTE		NORMAL / NORMALE	RECORD FOR THE MONTH / RECORD POUR LE MOIS — HIGHEST EVER / MAXIMUM ABSOLU			LOWEST EVER / MINIMUM ABSOLU			No. OF YEARS / Nº D'ANNÉES
	VALUE / RELEVÉ	DAY / JOUR	VALUE / RELEVÉ	DAY / JOUR		VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	
HIGHEST TEMPERATURE (MAXIMUM) / TEMPÉRATURE MAXIMALE	11.9	30	13.4	18		18.1	31	1962				50
LOWEST TEMPERATURE (MINIMUM) / TEMPÉRATURE MINIMALE	-12.2	1	-17.8	2					-23.8	10	1986	50
MEAN MONTHLY TEMPERATURE / TEMPÉRATURE MENSUELLE MOYENNE	-1.6		-5.0		-2.3	0.7		1979	-6.2		1948	50
TOTAL MONTHLY RAINFALL / HAUTEUR TOTALE MENSUELLE DE PLUIE	71.9		53.8		65.8	168.2		1983	3.6		1963	50
TOTAL MONTHLY SNOWFALL / HAUTEUR TOTALE MENSUELLE DE NEIGE	42.2		17.8		65.0	139.2		1943	9.4		1983	50
TOTAL MONTHLY PRECIPITATION / PRÉCIPITATION TOTALE MENSUELLE	116.8		68.8		132.6	219.2		1943	51.1		1945	50
NO OF DAYS WITH MEASURABLE PRECIPITATION / NOMBRE DE JOURS AVEC PRÉCIPITATION MESURABLE	22		17		20	28		1965	14		SVRL	50
GREATEST RAINFALL IN ONE DAY / HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE	26.6	20	18.8	4		53.3	1	1962				50
GREATEST SNOWFALL IN ONE DAY / HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE	8.2	11	3.2	26		45.7	11	1974				50
GREATEST PRECIPITATION IN ONE DAY / PRÉCIPITATION MAXIMALE EN UNE JOURNÉE	26.6	20	20.0	21		53.3	1	1962				50
MAXIMUM RAINFALL RECORDED IN / HAUTEUR DE PLUIE MAXIMALE ENREGISTRÉE EN: [4]												
5 MINUTES	M	M	M	M		2.3	3	1970				27
10 MINUTES	M	M	M	M		3.6	27	1982				27
15 MINUTES	M	M	M	M		4.1	2	1968				27
30 MINUTES	M	M	M	M		7.4	24	1974				27
60 MINUTES	M	M	M	M		11.3	24	1988				27
24 CONSECUTIVE HOURS / HEURES CONSÉCUTIVES	27.0	20	28.4	4		53.3	1	1962				50
MEAN WIND SPEED (km/h) / VITESSE MOYENNE DU VENT (km/h)	21.5		24.7		26.9	35.3		1974	21.4		1970	50
MAXIMUM SPEED (2 min. mean) (km/h) / VITESSE MAXIMALE (moyenne sur 2 min.) (km/h)	WSW 61	24	S 61	24		NW 121	15	1956				50
MAXIMUM GUST SPEED (km/h) / POINTE DU VENT MAXIMALE (km/h)	WSW 89	19	WSW 89	19		NW 193	15	1956				50
TOTAL HOURS OF SUNSHINE / TOTAL DES HEURES INSOLATION	92.6		168.1		94.6	168.1		1990	39.9		1958	44
MEAN STATION PRESSURE (kPa) / PRESSION MOYENNE À LA STATION (kPa)	98.99		100.00		99.02	100.24		1979	97.79		1965	49
GREATEST STATION PRESSURE (kPa) / PRESSION MAXIMALE À LA STATION (kPa)	101.10	1	101.72	25		103.09	14	1984				50
LEAST STATION PRESSURE (kPa) / PRESSION MINIMALE À LA STATION (kPa)	99.61	8	97.73	21					94.03	6	1959	50

CLIMATOLOGICAL DATA THIS MONTH FOR THE PAST 10 YEARS / DONNÉES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIÈRE ANNÉES

YEAR / ANNÉE	MAXIMUM TEMP / TEMP MAXIMALE	MINIMUM TEMP / TEMP MINIMALE	MEAN TEMP / TEMP MOYENNE	RAINFALL / HAUTEUR DE PLUIE	SNOWFALL / HAUTEUR DE NEIGE	TOTAL PRECIP / PRÉCIP. TOTALE	MEAN WIND SPEED / VITESSE MOYENNE DES VENTS	MAXIMUM WIND SPEED / VITESSE MAXIMALE DES VENTS	SUNSHINE HOURS / HEURES INSOLATION	HEATING DEGREE-DAYS / DEGRÉS-JOURS DE CHAUFFE	GROWING DEGREE-DAYS / DEGRÉS-JOURS DE CROISSANCE	COOLING DEGREE-DAYS / DEGRÉS-JOURS DE RÉFRIGÉRATION
1982	13.2	-19.4	-4.0	47.8	45.5	89.1	28.1	72	135.1	675.3	1.3	0.0
1983	12.8	-20.3	-1.2	168.2	9.4	186.6	24.0	87	75.9	594.1	2.9	0.0
1984	12.5	-12.7	-1.6	37.0	112.6	142.7	23.8	87	91.1	606.0	4.5	0.0
1985	5.6	-22.5	-5.1	48.8	51.1	102.3	27.5	74	137.0	717.2	0.0	0.0
1986	11.6	-23.8	-3.8	127.0	46.3	175.3	27.7	74	115.0	673.8	1.6	0.0
1987	6.0	-18.7	-3.4	107.6	50.8	149.7	22.8	65	82.2	663.9	0.0	0.0
1988	14.5	-12.2	-1.6	140.1	38.4	171.8	27.5	83	111.1	606.5	5.2	0.0
1989	10.1	-15.4	-5.1	16.8	84.2	102.5	30.4	84	146.8	714.2	1.3	0.0
1990	13.4	-17.8	-5.0	53.8	17.8	68.8	24.7	61	168.1	710.9	2.7	0.0
1991	11.9	-12.2	-1.6	71.9	42.2	116.8	21.5	61	92.6	606.2	2.1	0.0

Note/Avis
1. Climatological Day/Journée climatologique 0231 NST - 0230 NST
2. Normal/Normale 1951-1980
3. Extremes for period of record/Extrêmes pour la période de registre
4. Maximum rainfall recorded in, may overlap calendar days/Hauteur de pluie maximale enregistrée en: peut-être pour plus d'une journée du calendrier
5. ** Indicates most recent occurrence/Indique le plus récent
6. * Indicates first of more than one occurrence/Indique le premier de plusieurs

DRY BULB TEMPERATURES AT/TEMPERATURES DU THERMOMETRE SEC A: ST. JOHN'S NFLD.

MAR. MAR. 1991

HEURE/ HOUR DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	-105	-113	-113	-113	-112	-110	-118	-118	-101	-94	-83	-83	-77	-75	-72	-71	-74	-81	-91	-92	-85	-94	-91	-80
2	-80	-76	-83	-77	-76	-71	-62	-66	-47	-32	-18	-8	-4	-9	-7	-13	-22	-21	-21	-17	-7	1	12	17
3	60	69	81	83	73	59	52	50	51	47	49	49	48	43	37	33	10	3	-14	-19	-33	-40	-49	-56
4	-58	-62	-65	-73	-77	-81	-85	-82	-77	-72	-62	-65	-57	-61	-69	-71	-74	-76	-76	-76	-81	-85	-78	-72
5	-63	-57	-51	-49	-49	-47	-39	-35	-28	-23	-19	-15	-12	-10	-13	-9	-9	-9	-7	14	21	49	56	65
6	52	49	43	31	16	8	8	6	5	5	10	13	4	0	-1	-11	-12	-19	-24	-27	-30	-33	-34	-36
7	-45	-47	-47	-50	-50	-49	-49	-42	-34	-22	-8	0	14	21	21	20	22	15	4	-3	-4	-1	-3	-6
8	-13	-7	-3	-10	-14	-16	-14	-13	-12	-10	-11	-13	-10	-14	-16	-14	-19	-17	-18	-17	-17	-16	-17	-15
9	-14	-15	-17	-21	-21	-21	-18	-21	-16	-8	-4	-1	-1	-3	-5	-5	-3	-6	-5	-4	-3	-2	-1	1
10	1	1	-1	-1	-2	-3	-3	-3	-4	-4	-6	-7	-7	-6	-7	-5	-5	-7	-10	-10	-11	-11	-14	-18
11	-21	-25	-23	-23	-13	-17	-14	-16	-14	-9	-6	-5	-6	-10	-8	-7	-6	-3	-2	-2	-2	-1	0	0
12	0	0	0	-2	-3	-4	-4	-4	-3	-1	-1	-2	1	1	-2	-1	-4	-6	-9	-10	-6	-8	-8	-7
13	-6	-4	-4	-2	-4	-3	-2	-4	-7	-4	-5	-4	-3	-3	-1	-1	-2	-3	-6	-6	-7	-9	-10	-11
14	-13	-13	-12	-11	-12	-14	-10	-10	-13	-13	-13	-13	-20	-23	-25	-27	-27	-30	-31	-32	-33	-36	-39	-42
15	-42	-41	-41	-38	-36	-36	-35	-36	-35	-32	-29	-25	-24	-20	-16	-18	-20	-20	-19	-19	-20	-21	-18	-20
16	-20	-18	-17	-17	-14	-14	-12	-8	-8	-7	-5	-4	-3	-3	-5	-8	-10	-12	-14	-17	-18	-20	-21	-22
17	-23	-24	-25	-27	-29	-30	-29	-29	-29	-27	-25	-23	-22	-21	-22	-30	-32	-35	-39	-42	-44	-47	-50	-52
18	-55	-57	-61	-70	-75	-85	-90	-82	-73	-64	-43	-23	-21	-14	-4	1	2	-2	-13	-17	-24	-25	-28	-32
19	-40	-50	-55	-55	-72	-58	-59	-40	-37	-26	-3	-6	-18	-12	-7	-14	-18	-20	-23	-22	-21	-16	-13	-10
20	-2	5	13	16	18	20	23	27	32	33	36	37	40	40	46	51	51	40	33	37	33	34	27	24
21	19	23	24	19	17	14	8	11	12	14	19	16	27	1	-8	-15	-27	-36	-42	-45	-48	-53	-58	-63
22	-68	-66	-65	-69	-72	-71	-68	-62	-54	-58	-49	-43	-36	-32	-30	-31	-35	-47	-55	-57	-60	-65	-70	-71
23	-77	-83	-90	-93	-94	-95	-98	-93	-84	-89	-82	-79	-85	-78	-83	-76	-72	-73	-86	-89	-84	-71	-68	-72
24	-73	-74	-76	-91	-87	-86	-91	-77	-63	-36	-18	-10	-4	8	7	2	0	-9	-14	-19	-23	-26	-30	-38
25	-36	-36	-38	-40	-41	-42	-42	-39	-32	-25	-22	-22	-21	-17	-21	-30	-36	-41	-43	-43	-43	-42	-42	-41
26	-41	-41	-41	-40	-39	-37	-33	-30	-26	-22	-18	-11	-7	-5	-2	0	1	2	4	5	4	5	8	[illegible]
27	1	1	1	1	1	1	0	0	1	1	1	1	3	3	1	1	1	1	1	1	0	-1	-1	[illegible]
28	-2	-2	-2	-1	0	-1	-3	-1	0	2	4	9	8	8	12	12	15	14	9	7	0	0	4	[illegible]
29	2	0	-1	-4	0	5	4	8	8	19	19	6	8	16	27	30	34	36	26	22	19	19	21	[illegible]
30	49	55	41	27	34	49	46	37	38	51	55	55	56	62	55	62	55	50	47	49	72	106	107	[illegible]
31	110	102	91	77	70	51	26	21	14	21	19	30	37	37	26	22	12	2	-7	-15	-20	-25	-31	[illegible]

Note/Avis 1. Climatological Day/Journee climatologique 0231 N.S.T.- 0230 N.S.T.
2. Hours are L.S.T./Les heures sont a l'heure normale de la localite
3. Unit/Unite = 0.1 C

WIND SUMMARY / SOMMAIRE DES VENTS

ST. JOHN'S "A", NFLD. / T.N. MARCH/MARS, 1991

HOUR/ HEURE DATE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	RAFALE MAX GUST	HOUR/ HEURE
1	WNW	WNW	WNW	WNW	W	WNW	W	WNW	W	WNW	WNW	W	W	WNW	WNW	WNW	WNW	WNW	W	W	W	W	W	W	W	1230
	30	30	28	26	26	26	20	9	17	22	28	31	24	24	19	20	15	13	13	9	15	19	19	26	43	
2	W	W	WSW	W	WSW	WSW	SSW	SW	S	SW	SW	SW	SW	SSW	SSW	SSW	S	S	S	S	S	S	SSW	SSW	S	1815*
	20	13	13	13	11	13	6	11	7	15	19	24	26	20	26	24	28	30	35	24	30	28	31	24	48	
3	SSW	SSW	SW	WSW	W	W	W	W	W	W	W	WNW	WNW	WNW	NNW	NNW	NNE	N	NNE	NNE	NNE	NNE	N	NNW	WSW	0330
	31	33	44	61	59	56	48	41	33	37	41	43	22	11	9	6	7	11	15	15	17	9	9	9	89	
4	NNW	N	NNW	NW	NNW	N	NNW	NNW	NW	NNW	NNW	NNW	NNW	NNE	NNE	NNE	NNE	NNE	NNE	NNE	ENE	E	ESE	ESE	ESE	2356
	9	11	9	7	6	11	11	15	17	19	15	7	9	15	9	9	13	9	15	17	9	19	22	20	37	
5	ESE	ESE	ESE	ESE	ESE	ESE	SE	E	E	ESE	E	E	E	E	ESE	E	E	ESE	SE	SSW	SW	SW	SW	SW	ESE	0446
	20	26	28	30	31	31	26	24	26	26	15	7	15	13	13	13	9	9	9	9	9	22	20	22	52	
6	WSW	WSW	SW	WSW	WSW	W	WSW	WSW	WSW	WSW	WSW	WSW	W	WSW	WSW	WSW	WSW	WSW	W	W	W	W	W	W	WSW	0413
	22	24	28	35	35	24	24	22	31	31	28	31	26	33	33	41	26	26	28	37	37	33	22	26	56	
7	W	W	W	W	W	W	W	W	W	W	W	W	WSW	WSW	W	WSW	W	W	W	W	W	W	W	W		
	43	41	33	26	26	22	26	31	26	30	22	31	31	31	31	24	19	20	19	19	19	17	20	17		
8	W	NNW	NNW	N	C	C	N	N	NE	NE	ENE	E	E	ENE	E	E	NE	ENE	NNE	NNE	NNE	NNE	NNE	NNE		
	19	11	9	13			2	6	9	9	6	13	11	17	11	13	7	13	11	7	7	11	9	7		
9	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	N	N	N	N	NNE	NNE	NNE	NNE	NNE	N	N	N	N	NNW	NNW	N		
	6	13	13	15	11	22	11	17	13	15	13	17	17	20	19	13	13	13	15	13	11	11	15	15		
10	N	N	N	NNE	NNE	NNE	N	N	NNE	NNE	NNE	N	N	N	N	N	N	N	N	NNE	NNE	NNE	NE	NE		
	20	15	13	13	17	15	19	22	20	20	22	19	22	15	22	19	15	19	19	13	13	19	19	19		
11	NE	NE	NE	NE	NE	NE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	E	E	E	E	E	E		
	19	11	11	15	20	22	22	22	26	28	26	37	33	43	43	44	41	37	39	41	39	41	28	28		
12	E	E	ESE	ESE	E	E	E	ESE	E	E	E	ESE	E	ENE	E	E	ENE	NE	NNE	ENE	ENE	NE	NE	NE		
	28	28	28	24	22	15	13	9	9	6	13	9	6	9	9	9	11	6	6	7	11	13	9	11		
13	NE	NE	NE	NE	NE	NE	NE	NE	NE	NNE	NNE	NNE	NNE	N	N	N	N	N	N	N	N	N	N	N		
	9	11	13	9	15	11	13	19	13	9	9	11	9	11	4	6	4	4	7	7	9	9	11	13		
14	N	N	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NNW	NW	NW	1330
	13	7	11	15	15	26	26	22	28	28	33	37	43	44	37	37	37	30	26	31	31	26	30	19	58	
15	NNW	NW	NNW	NNW	NNW	N	N	N	N	N	N	N	N	N	N	NNE	NNE	NNE	NNE	NNE	NNE	NE	NE	NNE	N	1230
	19	22	22	17	19	17	19	17	19	22	20	20	22	20	22	22	24	22	22	20	20	20	19	17	35	
16	NNE	NNE	NNE	NNE	NNE	NNE	NNE	N	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	N	N	N	[illegible]	1722*
	17	13	19	13	15	11	15	19	19	19	24	26	28	28	28	31	33	33	30	33	30	31	28	35	6[illegible]	
17	N	N	N	N	N	N	N	N	N	N	N	N	N	NNW	N	WSW	WSW	NNW	NNW	NNW	NNW	NNW	NW	NNW	N	1130
	30	33	33	31	33	31	35	31	35	33	37	41	43	33	33	31	30	33	31	33	26	24	26	30	6[illegible]	
18	NW	NW	NW	WNW	WNW	W	W	W	WNW	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W		
	20	24	17	20	20	11	13	15	20	24	20	22	24	24	24	24	19	17	20	20	20	20	19	17		
19	W	W	W	W	W	W	C	N	C	C	C	SE	SE	SE	SSE	SSE	SSE	SSE	SSE	SSE	SSE	SSE	SSE	SSE		
	15	11	13	11	9	9		4				7	11	13	19	11	22	26	19	17	26	22	26	24		
20	SSE	SSE	SSE	S	S	S	SSE	S	S	S	S	SSE	SSE	SSE	SSE	S	S	S	S	S	S	SSW	SW	SW	S	1530
	26	28	33	33	31	33	33	37	30	41	46	41	48	44	44	48	52	35	30	20	13	7	9	9	86	
21	SSE	SSW	SSW	S	SSW	SSW	SSW	SW	WSW	SW	SSW	SSW	SSW	SW	WSW	WSW	W	WSW	WSW	WSW	SW	WSW	WSW	W	W	1558
	13	11	13	6	11	13	9	7	11	13	13	17	20	26	26	31	30	37	37	39	33	33	37	33	61	
22	W	W	W	W	W	W	W	WSW	W	W	W	W	W	W	W	W	WSW	WSW	WSW	WSW	W	WNW	WNW	W	W	1145
	39	31	37	31	30	26	26	26	33	31	33	35	37	30	30	24	24	24	22	22	17	11	7	13	56	
23	WNW	WNW	WNW	WNW	WNW	WNW	WNW	WNW	NW	NW	NW	NW	NNW	NNW	NNW	NNW	NW	NW	NW	W	W	W	W	NW	NW	1020
	17	15	15	15	11	9	13	20	22	22	22	24	24	24	19	19	22	19	9	7	6	17	19	17	37	
24	WNW	WNW	WNW	W	W	WSW	WSW	WSW	SW	W	W	W	WSW	W	W	W	WNW	W	W	E	C	NE	NE	ENE	W	0850
	15	15	13	9	17	11	17	17	20	19	20	24	22	24	20	19	9	13	7	2		4	11	15	35	
25	ENE	ENE	E	ENE	E	E	E	E	E	ENE	E	E	ENE	ENE	NE	ENE	ENE	ENE	ENE	ENE	ENE	NE	NE	NE	NE	2330
	15	17	17	17	17	20	15	15	20	17	22	22	20	22	26	30	26	24	24	26	26	28	28	28	39	
26	NE	NE	NE	NE	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NE	NNE	NE	2225
	28	30	28	30	28	31	28	24	30	33	33	33	28	26	28	24	24	22	26	37	37	41	48	35	76	
27	NNE	N	N	NNE	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	1155
	37	37	37	37	37	33	35	33	37	37	41	33	41	37	35	30	30	33	41	35	31	30	31	28	69	
28	N	N	N	N	N	N	N	N	N	N	NNE	N	N	NNW	N	NNW	N	NNE	NE	NW	WNW	NNW	NNW	WNW	N	0411
	28	28	26	26	24	24	19	20	9	13	15	19	19	15	11	11	13	7	9	7	17	7	9	13	39	
29	W	W	W	C	W	C	S	S	SSE	SSW	S	SSE	S	SSW	WSW	WNW	W	W	W	W	W	WSW	SSW	SW	NW	1453
	9	11	11		9		7	7	7	15	7	17	26	24	26	28	33	26	20	17	24	13	13	19	47	
30	WSW	SSW	SSW	S	SSW	S	S	S	SSW	WSW	W	W	W	W	WSW	SSW	SSW	S	S	SSW	SSW	SW	SSW	SW	SW	2330
	19	24	19	33	30	28	43	39	31	28	28	22	22	15	9	4	7	6	11	9	24	37	33	41	67	
31	SW	WSW	WSW	WSW	W	WNW	W	WNW	NW	W	W	W	W	W	W	W	W	WNW	W	WSW	WSW	W	WSW	C	WSW	0330
	33	37	41	44	33	37	22	19	11	15	19	20	26	30	31	28	31	28	26	26	15	13	6		58	

Note/Avis
1. Climatological day/Journee climatologique 0231 NST - 0230 NST
2. Hours are L.S.T./Les heures sont a l'heure normale de la localite
3. Unit/Unite = 1.0 km/h 4. C = Calm/Calm 5. M = Missing/Manquant
6. * Indicates more than one occurrence of same speed/
* Indique le premier de plusieurs de la meme vitesse
7. $ Gust in next calender day/ $ Rafale dans le prochain jour de calendrier

Environment Canada / Environnement Canada
Atmospheric Environment Service / Service de l'environnement atmosphérique

MONTHLY METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE MENSUEL

MONTH/MOIS: APRIL/AVRIL 1991

AT/A: ST. JOHN'S "A" NFLD. / T.N.

LAT 47 ° 37 ' N LONG 52 ° 45 ' W ELEVATION / ALTITUDE 140 (ASL) (MER) STANDARD TIME USED / HEURE NORMALE UTILISÉE NST

DATE	TEMPERATURE / TEMPÉRATURE: MAXIMUM / MAXIMALE °C	MINIMUM / MINIMALE °C	MEAN / MOYENNE °C	DEGREE-DAYS / DEGRÉS-JOURS: HEATING / DE CHAUFFE BASE 18.0°C	GROWING / DE CROISSANCE BASE 5.0°C	COOLING / DE RÉFRIGÉRATION BASE 18.0°C	REL HUMIDITY / HUMIDITÉ REL: MAXIMUM / MAXIMALE %	MINIMUM / MINIMALE %	THUNDERSTORM / ORAGE	PRECIPITATION / PRÉCIPITATIONS: RAINFALL / PLUIE (HAUTEUR) mm	SNOWFALL / NEIGE (HAUTEUR) cm	TOTAL PRECIP / PRÉCIP. TOTALE mm	SNOW ON GROUND / NEIGE AU SOL cm	WIND / VENT: AVERAGE SPEED / VITESSE MOYENNE km/h	PREVAILING DIRECTION / DIRECTION DOMINANTE	MAX 2 MIN MEAN SPEED & DIRECTION / VITESSE MOYENNE MAX. SUR 2 MIN & DIRECTION km/h	BRIGHT SUNSHINE / INSOLATION EFFECTIVE HOURS / HEURES
1	1.4	-5.6	-2.1	20.1			98	41		0.2	4.0	4.0	TR	11.8	WNW*	WNW 22	5.5
2	3.1	-4.4	-0.7	18.7			98	72		2.8	TR	2.8	4	30.3	W	W 50	0.2
3	5.0	-3.5	0.8	17.2			89	52					2	17.7	W	W 33	9.3
4	3.3	-2.0	0.7	17.3			98	57					2	20.8	W	W 28	8.3
5	11.4	-1.8	4.8	13.2			82	47					TR	25.4	W	WSW 44	10.2
6	7.6	-3.4	2.1	15.9			100	74		0.2	0.2	0.4	TR	17.7	W	WSW 26	0.6
7	-1.9	-3.8	-2.9	20.9			95	88			0.6	0.4	TR	13.5	NE	NE 22	0.1
8	-1.8	-4.1	-3.0	21.0			97	81			2.0	2.2	TR	8.4	SSE	SSE 15	0.0
9	0.2	-3.3	-1.6	19.6			99	82			0.4	TR	2	5.5	NE	NE 13	0.0
10	0.0	-3.2	-1.6	19.6			92	70			TR	TR	2	13.8	E	E 22	4.4
11	8.0	-2.0	3.0	15.0			100	92		11.1		11.1	1	17.5	SE	SE 28*	0.0
12	1.6	-6.2	-2.3	20.3			95	79		TR	1.2	1.2	TR	27.3	WSW	N 35*	0.4
13	-2.3	-6.4	-4.4	22.4			90	74			TR	TR	TR	19.4	N	NNW 26*	6.5
14	-3.0	-5.4	-4.2	22.2			94	83			10.8	9.4	TR	36.7	N	NW 56	0.0
15	4.5	-3.6	0.5	17.5			90	45			0.2	0.2	11	26.4	W *	NW 46	10.8
16	2.9	-4.7	-0.9	18.9			100	53					6	7.3	SE	W 13	0.0
17	-2.6	-4.4	-3.5	21.5			97	90			TR	TR	4	12.0	E *	NE 19*	0.0
18	0.7	-3.6	-1.5	19.5			99	70		1.6	TR	1.6	4	25.3	NE	NE 31	2.3
19	2.9	-0.4	1.3	16.7			100	99		0.4		0.4	3	17.8	NE	NNE 28*	0.0
20	6.6	1.7	4.2	13.8			100	100		TR		TR	TR	8.6	NNE*	NE 13*	0.0
21	5.0	-1.5	1.8	16.2			100	100		TR		TR	TR	13.1	N	NNE 19*	0.0
22	1.3	-1.4	-0.1	18.1			100	100		1.7		1.7	TR	15.3	E	NE 19*	0.0
23	10.9	-0.2	5.4	12.6	0.4		100	99		3.7		3.7		17.7	SSE	S 31	0.0
24	12.9	1.8	7.4	10.6	2.4		100	63		21.2		21.2		16.7	W	WNW 30*	5.7
25	6.8	0.4	3.6	14.4			94	66		1.4		1.4		7.8	W	SSE 24	0.8
26	3.3	-3.9	-0.3	18.3			100	84						12.4	W	W 24	3.9
27	12.9	-3.0	5.0	13.0			89	55		TR		TR		17.2	W	W 33	8.4
28	6.2	-2.1	2.1	15.9			87	44			TR	TR		14.3	NW	WNW 22	6.5
29	3.1	-4.9	-0.9	18.9			91	46		TR	TR	TR		11.1	NW	WNW 22	10.0
30	1.5	-2.6	-0.6	18.6			97	69			0.6	0.6	TR	17.4	NNW	WNW 24	0.0
MEAN / MOYENNE	3.7	-2.9	0.4	TOTAL 527.9	TOTAL 2.8	TOTAL 0.0	96	73	TOT 0	TOTAL 44.3	TOTAL 20.0	TOTAL 62.3		16.9	PREVAILING / DOMINANTE W	MAXIMALE NW 56	TOTAL 101.9
NORMAL / NORMALE	4.5	-2.2	1.2	504.6	6.0	0.0			0.1	78.1	34.6	115.6		24.4	WSW		115.5

DEGREE-DAY SUMMARY/SOMMAIRE DE DEGRÉS JOURS

BELOW 18°C / AU-DESSOUS DE 18°C	THIS YEAR / ANNÉE EN COURS	PREVIOUS YEAR / ANNÉE PRÉCÉDENTE	NORMAL / NORMALE	ABOVE 5°C / AU-DESSUS DE 5°C	THIS YEAR / ANNÉE EN COURS	PREVIOUS YEAR / ANNÉE PRÉCÉDENTE	NORMAL / NORMALE
TOTAL FOR MONTH / TOTAL DU MOIS	527.9	458.5	504.6	TOTAL FOR MONTH / TOTAL DU MOIS	2.8	13.3	6.0
ACCUMULATED SINCE JULY 1 / ACCUMULÉE DEPUIS LE 1er JUILLET	4279.3	4399.4	4217.8	ACCUMULATED SINCE APRIL 1 / ACCUMULÉE DEPUIS LE 1er AVRIL	2.8	13.3	6.0

DAYS WITH TOTAL PRECIPITATION / JOURS AVEC PRÉCIPITATIONS TOTALES (mm): 0.2 OR MORE / OU PLUS	1.0 OR MORE / OU PLUS	2.0 OR MORE / OU PLUS	10.0 OR MORE / OU PLUS	30.0 OR MORE / OU PLUS	DAYS WITH SNOWFALL / JOURS AVEC CHUTE DE NEIGE (cm): 0.2 OR MORE / OU PLUS	1.0 OR MORE / OU PLUS	2.0 OR MORE / OU PLUS	10.0 OR MORE / OU PLUS	30.0 OR MORE / OU PLUS
16	11	7	2	0	9	4	3	1	0

UDC 551.506.1 ( ) Note/Avis

1. Climatological Day/Journée climatologique 0231 NST - 0230 NST
2. Normal/Normale 1951 - 1980
3. TR = Trace
4. M = Missing/Manquant
5. No entry/Pas de valeur = No occurrence/Pas d'événement
6. * Indicates first of more than one prevailing direction and/or maximum 2 minute mean speed (see page 4)/Indique la première de plusieurs des directions dominantes et/ou la vitesse moyenne maximale sur 2 minutes (voir page 4)
7. C = Calm/Calme
8. Price: single issue $3.00, annual (Jan. to Dec.) $29.50 / Prix: numéro individuel $3.00; annuel $29.50 (janv. à déc.)

Canada

COMPARATIVE RECORDS AT:
RELEVÉS COMPARATIFS À: ST. JOHN'S NFLD

MONTH / MOIS: APRIL/AVRIL 1991

Temperature/Température — °Celsius
Precipitation/Précipitation — Millimetres/millimètres (mm)
Rainfall/Hauteur de pluie — Millimetres/millimètres (mm)
Snowfall/Hauteur de neige — Centimetres/centimètres (cm)
Wind speed/Vitesse du vent — Kilometres/h / kilomètres/h (km/h)
Station pressure/Pression à la station — Kilopascals (kPa)

	THIS MONTH / CE MOIS-CI		PREVIOUS YEAR / ANNÉE PRÉCÉDENTE		NORMAL / NORMALE	RECORD FOR THE MONTH / RECORD POUR LE MOIS — HIGHEST EVER / MAXIMUM ABSOLU			LOWEST EVER / MINIMUM ABSOLU			NO. OF YEARS / NO D'ANNÉES
	VALUE / RELEVÉ	DAY / JOUR	VALUE / RELEVÉ	DAY / JOUR		VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	VALUE / RELEVÉ	DAY / JOUR	YEAR / ANNÉE	
HIGHEST TEMPERATURE (MAXIMUM) / TEMPÉRATURE MAXIMALE	12.9	24	14.6	4		24.1	24	1986				50
LOWEST TEMPERATURE (MINIMUM) / TEMPÉRATURE MINIMALE	-6.4	13	-9.4	1					-14.8	4	1978	50
MEAN MONTHLY TEMPERATURE / TEMPÉRATURE MENSUELLE MOYENNE	0.4		2.7		1.2	4.2		1986	-1.4		1967	50
TOTAL MONTHLY RAINFALL / HAUTEUR TOTALE MENSUELLE DE PLUIE	44.3		96.6		78.1	260.1		1951	10.9		1960	50
TOTAL MONTHLY SNOWFALL / HAUTEUR TOTALE MENSUELLE DE NEIGE	20.0		6.4		34.6	150.1		1955	1.3		1987	50
TOTAL MONTHLY PRECIPITATION / PRÉCIPITATION TOTALE MENSUELLE	62.3		103.6		115.6	299.5		1951	29.0		1960	50
NO OF DAYS WITH MEASURABLE PRECIPITATION / NOMBRE DE JOURS AVEC PRÉCIPITATION MESURABLE	16		17		18	25		1951	11		1942	50
GREATEST RAINFALL IN ONE DAY / HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE	21.2	24	24.0	17		91.7	11	1951				50
GREATEST SNOWFALL IN ONE DAY / HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE	10.8	14	4.0	28		31.6	15	1978				50
GREATEST PRECIPITATION IN ONE DAY / PRÉCIPITATION MAXIMALE EN UNE JOURNÉE	21.2	24	24.0	17		91.7	11	1951				50
MAXIMUM RAINFALL RECORDED IN / HAUTEUR DE PLUIE MAXIMALE ENREGISTRÉE EN:												
5 MINUTES	M	M	M	M		2.3	20	1971				26
10 MINUTES	M	M	M	M		3.3	9	1964				26
15 MINUTES	M	M	M	M		4.1	9	1964				26
30 MINUTES	M	M	M	M		6.9	9	1964				26
60 MINUTES	M	M	M	M		11.7	20	1971				26
24 CONSECUTIVE HOURS / HEURES CONSÉCUTIVES	22.9	24	M	M		91.7	11	1951				50
MEAN WIND SPEED (km/h) / VITESSE MOYENNE DU VENT (km/h)	16.9		22.2		24.4	32.8		1945	20.5		1980	50
MAXIMUM SPEED (2 min mean) (km/h) / VITESSE MAXIMALE (moyenne sur 2 min.) (km/h)	NW 56	14	WSW 73	8		N 98	1	1943				50
MAXIMUM GUST SPEED (km/h) / POINTE DU VENT MAXIMALE (km/h)	NNW 80	14	SSW 93	12		SW 159	10	1960				43
TOTAL HOURS OF SUNSHINE / TOTAL DES HEURES INSOLATION	101.9		137.9		115.5	177.9		1989	66.3		1951	45
MEAN STATION PRESSURE (kPa) / PRESSION MOYENNE À LA STATION (kPa)	99.77		100.09		99.30	100.29		1987	98.43		1963	50
GREATEST STATION PRESSURE (kPa) / PRESSION MAXIMALE À LA STATION (kPa)	101.28	1	101.75	19		102.50	19	1949				50
LEAST STATION PRESSURE (kPa) / PRESSION MINIMALE À LA STATION (kPa)	97.05	14	98.00	8					94.97	6	1961	50

CLIMATOLOGICAL DATA THIS MONTH FOR THE PAST 10 YEARS
DONNÉES CLIMATOLOGIQUES CE MOIS-CI POUR LES DERNIÈRE ANNÉES

YEAR / ANNÉE	MAXIMUM TEMP / TEMP MAXIMALE	MINIMUM TEMP / TEMP MINIMALE	MEAN TEMP / TEMP MOYENNE	RAINFALL / HAUTEUR DE PLUIE	SNOWFALL / HAUTEUR DE NEIGE	TOTAL PRECIP / PRECIP TOTALE	MEAN WIND SPEED / VITESSE MOYENNE DES VENTS	MAXIMUM WIND SPEED / VITESSE MAXIMALE DES VENTS	SUNSHINE HOURS / HEURES INSOLATION	HEATING DEGREE-DAYS / DEGRÉS-JOURS DE CHAUFFE	GROWING DEGREE-DAYS / DEGRÉS-JOURS DE CROISSANCE	COOLING DEGREE-DAYS / DEGRÉS-JOURS DE RÉFRIGÉRATION
1982	20.0	-10.4	2.0	53.1	21.1	73.1	25.1	74	168.7	481.6	20.7	0.0
1983	19.6	-11.0	3.8	135.2	1.6	136.4	21.1	65	71.8	425.1	43.0	0.0
1984	9.9	-12.0	-0.2	205.8	17.7	235.2	23.6	63	83.2	547.6	0.0	0.0
1985	12.3	-8.9	-0.1	33.3	43.4	96.2	27.9	74	139.1	540.6	0.4	0.0
1986	24.1	-8.2	4.2	124.2	4.4	129.2	20.2	63	143.0	412.8	66.5	0.0
1987	15.7	-7.0	2.0	119.3	1.3	120.9	20.3	56	122.4	481.5	9.6	0.0
1988	11.2	-5.2	0.9	140.0	17.1	159.1	24.4	63	101.6	512.5	0.0	0.0
1989	17.7	-4.0	5.1	35.4	10.2	45.8	24.5	69	177.9	462.6	6.9	0.0
1990	14.6	-9.4	2.7	96.6	6.4	103.6	22.2	73	137.9	458.5	13.3	0.0
1991	12.9	-6.4	0.4	44.3	20.0	62.3	16.9	56	101.9	527.9	2.8	0.0

Note/Avis
1 Climatological Day/Journée climatologique 0231 NST - 0230 NST
2 Normal/Normale 1951-1980
3 Extremes for period of record/Extrêmes pour la période de registre
4 Maximum rainfall recorded in: may overlap calendar days/Hauteur de pluie maximale enregistrée en: peut-être pour plus d'une journée du calendrier

DRY BULB TEMPERATURES AT/TEMPERATURES DU THERMOMETRE SEC A: ST. JOHN'S NFLD.

APR. AVR. 1991

HEURE/ HOUR	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
DATE 1	-39	-43	-46	-48	-52	-56	-50	-41	-27	-18	-10	5	2	14	6	8	-10	-13	-19	-22	-25	-43	-50	-50
2	-47	-47	-43	-42	-40	-39	-33	-29	-21	-13	7	29	19	16	11	4	1	-1	-9	-12	-14	-15	-20	-26
3	-30	-32	-30	-32	-32	-32	-28	-18	-15	-6	10	24	32	42	48	47	47	35	17	11	7	6	4	1
4	-2	-5	-8	-13	-18	-18	-18	-15	-12	-7	10	8	24	31	22	24	16	12	1	-5	-7	-11	-13	-14
5	-15	-13	-11	-13	-10	-13	-7	14	36	57	73	83	103	106	108	107	98	83	62	41	44	51	32	26
6	29	32	37	32	19	13	14	17	29	41	52	64	65	57	56	55	48	10	-4	-12	-16	-21	-23	-26
7	-29	-31	-33	-37	-38	-36	-35	-32	-30	-25	-29	-26	-25	-21	-26	-25	-27	-31	-32	-32	-33	-32	-29	-30
8	-35	-37	-38	-39	-40	-41	-39	-36	-31	-28	-27	-23	-26	-27	-27	-26	-24	-24	-24	-25	-26	-25	-28	-28
9	-27	-27	-28	-29	-32	-28	-23	-20	-14	-9	-5	-3	-8	-1	-9	-14	-18	-19	-20	-21	-21	-22	-27	-28
10	-28	-26	-26	-27	-28	-30	-31	-26	-24	-24	-16	-9	-8	-10	-11	-18	-20	-21	-26	-30	-29	-27	-26	-25
11	-24	-21	-20	-19	-17	-14	-11	-10	-8	-7	-5	-1	4	12	32	65	76	64	38	24	16	11	6	8
12	-8	5	5	4	4	2	-1	1	6	6	4	1	-5	-10	-14	-21	-25	-34	-42	-48	-50	-54	-55	-53
13	-57	-61	-62	-62	-60	-63	-62	-60	-58	-54	-48	-41	-29	-30	-28	-29	-33	-43	-49	-54	-56	-54	-54	-51
14	-49	-46	-47	-47	-50	-52	-53	-52	-50	-47	-45	-42	-40	-39	-39	-40	-41	-39	-39	-39	-37	-36	-35	-38
15	-31	-33	-36	-32	-33	-29	-21	-11	-2	8	15	22	26	32	38	40	35	27	15	3	-13	-16	-15	-22
16	-24	-27	-32	-42	-36	-42	-39	-27	-11	19	8	1	8	22	23	19	16	9	-10	-26	-35	-35	-38	-35
17	-36	-37	-40	-40	-43	-42	-43	-44	-40	-37	-35	-35	-33	-32	-32	-32	-31	-32	-31	-34	-32	-32	-32	-33
18	-34	-36	-35	-34	-36	-33	-34	-30	-17	-12	-8	-1	5	-5	-7	-10	-11	-14	-19	-20	-19	-14	-11	-7
19	-5	-6	-4	-2	-1	0	1	2	4	5	10	13	22	26	24	25	25	25	22	19	20	19	17	19
20	18	18	24	18	17	18	18	27	25	29	34	56	49	44	54	64	55	56	54	20	30	27	32	37
21	34	35	32	31	29	33	36	38	39	43	43	47	43	26	17	5	-3	-5	-9	-13	-13	-14	-14	-14
22	-14	-14	-14	-13	-13	-11	-5	-6	-3	1	7	8	8	6	3	3	2	2	1	4	2	1	1	1
23	1	0	-1	-1	0	2	8	14	28	29	29	33	39	60	62	70	80	75	72	69	73	66	66	70
24	77	103	103	97	95	84	95	63	61	57	60	91	99	121	117	121	113	97	82	66	61	52	38	46
25	38	34	37	28	24	41	55	59	63	60	59	48	56	63	66	62	41	35	34	13	5	11	19	12
26	11	8	12	23	25	8	-1	-5	-5	8	15	15	17	21	28	22	26	11	3	-15	-25	-29	-31	-35
27	-38	-37	-30	-20	-3	19	22	36	28	101	117	126	109	98	94	84	80	64	47	26	27	15	-10	-5
28	-12	-14	-17	-19	-14	-15	-6	1	3	18	19	31	43	51	55	27	11	4	-9	-15	-14	-14	-15	-17
29	-16	-17	-17	-32	-45	-36	-18	-14	-11	3	3	10	12	31	17	22	13	-9	-10	-11	-13	-17	-14	-12
30	-11	-15	-16	-23	-25	-24	-22	-22	-26	-23	-15	-10	2	7	4	5	2	1	-4	-7	-7	-5	-5	-4

Note/Avis 1. Climatological Day/Journee climatologique 0231 N.S.T.- 0230 N.S.T.
2. Hours are L.S.T./Les heures sont a l'heure normale de la localite
3. Unit/Unite = 0.1 C

WIND SUMMARY / SOMMAIRE DES VENTS

ST. JOHN'S "A", NFLD. / T.N. APRIL/AVRIL, 1991

HOUR/ HEURE DATE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	RAFALE MAX GUST	HOUR/ HEURE
1	C	C	WNW	NNW	WNW	W	W	WNW	WNW	NW	NW	NNW	W	S	SE	SE	SE	SSE	SSE	SSE	SSE	SE	ESE	ESE		
			9	11	20	6	11	17	22	20	11	11	6	4	9	9	9	11	15	13	15	17	19	17		
2	ESE	ESE	ESE	ESE	ESE	ESE	SE	ESE	ESE	ESE	SW	WSW	W	W	W	W	W	W	W	W	W	W	W	W	W	1452
	11	28	26	26	33	22	20	20	19	19	11	30	43	48	50	46	41	37	33	31	33	35	30	35	67	
3	W	W	W	WNW	W	W	W	W	WSW	WSW	W	W	W	W	W	W	W	W	W	WSW	WSW	W	W	W		
	33	28	19	20	15	11	4	19	15	15	22	20	24	24	20	22	22	17	9	7	11	15	17	15		
4	W	W	WNW	W	W	W	W	W	WNW	WNW	WNW	WNW	W	W	W	W	W	W	W	W	W	W	W	W	W	1731
	11	11	11	19	20	22	19	22	26	22	19	22	17	22	22	17	20	24	26	20	26	26	28	26	47	
5	W	W	W	WSW	SSW	W	W	W	W	WSW	WSW	WSW	W	WSW	WSW	W	W	W	W	W	W	W	W	W	WSW	1332
	26	22	22	15	11	13	15	20	22	20	26	26	26	33	44	33	33	33	26	26	33	30	31	24	60	
6	W	W	W	WSW	W	W	W	W	W	WSW	W	W	WSW	W	W	WNW	WNW	NE	NNE	NNE	NE	W	NE	NE	WSW	0328
	22	22	19	26	24	24	19	24	19	19	20	19	13	15	15	11	9	11	13	17	15	15	15	19	37	
7	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	N	NNE	NE	NE	NE	NE	NNE	NE	NNE	N	N	NNW	N	NE		
	22	17	15	17	11	17	17	19	17	15	17	17	15	15	15	9	13	13	7	6	6	6	4	13		
8	NE	ENE	ENE	ENE	ENE	ENE	ENE	E	E	ESE	SE	SSE	SSE	SSE	SSE	SSE	SSE	SSE	SSE	S	S	SSW	C	C		
	9	9	9	9	7	9	9	7	9	9	6	13	15	13	13	13	13	7	4	9	7	2				
9	SSW	C	C	SE	E	SE	E	ESE	SE	SE	C	ESE	ENE	NE	NE	NE	ENE	NE	NE	ENE	NE	ENE	E	ENE		
	2			2	2	4	4	4	7	6		4	4	2	9	7	9	9	9	9	13	11	9	7		
10	E	E	E	E	ENE	E	E	ESE	E	ESE	E	E	ESE	E	ESE	E	E	E	E	ESE	SE	ESE	ESE	SE		
	7	7	6	9	9	11	13	13	15	17	17	22	17	17	17	19	15	9	13	15	15	17	13	17		
11	E	E	E	SE	SE	SE	SE	SE	SE	SE	SE	SE	SSE	S	WSW	SW	WSW	WSW	W	WSW	W	WSW	W	WSW		
	7	7	6	20	22	19	20	20	28	28	28	19	9	9	7	6	13	26	13	24	22	19	22	26		
12	SW	WSW	SW	WSW	WSW	WSW	WSW	WSW	WSW	W	WNW	WSW	NNW	NNW	N	N	N	N	N	N	NNW	NNW	NNW	NNW	NNW	1445
	15	31	24	28	22	26	30	26	30	22	26	30	30	31	35	28	30	35	33	26	26	26	24	22	38	
13	NNW	NNW	N	N	N	N	N	N	N	N	NNW	N	NE	NE	NE	NNE	NNE	NE	NE	NNE	NNE	NNE	N	N		
	20	26	20	19	19	26	19	20	24	20	19	11	20	19	19	19	19	17	17	19	17	17	20	20		
14	N	N	N	N	N	N	NNW	NNW	N	N	N	NNW	NNW	NNW	NNW	NNW	NW	NW	NW	NW	WNW	NW	NW	NW	NNW	1530
	20	17	22	20	28	26	22	30	33	37	33	37	37	44	44	46	52	56	52	44	44	46	44	46	80	
15	NW	WNW	NW	WNW	WNW	WNW	W	W	W	W	WSW	W	W	W	WSW	WSW	WSW	WSW	SSW	SW	WSW	W	WSW	WSW	WNW	0252
	44	41	46	37	41	41	31	26	28	28	31	33	28	30	20	26	22	17	15	6	9	11	13	9	67	
16	W	WSW	WSW	W	W	W	W	WSW	WNW	ESE	SE	SE	SE	SE	ESE	SE	E	SE	SE	NE	C	E	C	S		
	13	11	9	9	6	11	9	7	2	6	11	9	7	11	9	11	7	6	6	6		4		4		
17	C	C	E	C	E	ENE	E	E	E	E	E	E	E	ENE	NE	ENE	ENE	ENE	ENE	ENE	ENE	NE	ENE	NE		
			4		4	7	11	11	15	15	15	17	17	17	19	17	17	19	17	15	17	13	9	11		
18	NE	NNE	NE	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NE	NE	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	1214
	15	13	15	22	22	22	26	26	28	30	26	24	30	31	24	28	24	30	30	30	28	28	28	28	50	
19	NNE	NNE	NNE	NNE	NNE	NNE	NE	NNE	NNE	NE	NE	NNE	NNE	NNE	NNE	NNE	NE	NNE	NNE	NNE	NNE	NNE	NE	NE		
	28	28	24	22	22	19	22	19	11	15	15	17	17	19	17	15	15	15	15	13	13	15	15	15		
20	NE	N	NE	NE	NNE	NNE	NNE	ENE	N	NNE	NNE	NNE	NE	NNE	NE	N	NNE	N	N	NNE	NE	NNE	NNE	N		
	13	7	13	13	9	7	9	7	6	9	11	6	7	6	6	9	6	9	9	6	7	9	11	11		
21	NNE	N	N	N	N	NNE	NNE	NNE	NNE	N	NNE	NNE	ENE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE		
	11	7	9	9	9	9	6	15	15	13	11	13	13	9	7	17	15	19	17	19	19	19	17	17		
22	NNE	NE	NE	NE	NE	ENE	ENE	NE	ENE	ENE	E	E	ENE	E	ENE	E	E	E	E	E	E	E	E	ESE		
	17	19	19	19	17	13	15	15	11	15	15	19	13	11	11	13	17	13	13	15	17	19	15	15		
23	ESE	ESE	SE	SSE	SSE	SSE	SSE	SSE	SSE	SSE	SE	SSE	SSE	S	S	S	S	S	S	S	S	SW	SSW	SW	S	1745
	11	9	17	11	19	15	13	11	15	15	7	19	15	19	19	22	31	30	26	30	30	17	13	11	45	
24	WSW	SW	SW	SW	WSW	SE	WNW	SSW	WNW	W	W	W	W	W	WSW	W	W	W	W	WSW	WSW	WSW	W	W		
	9	11	11	11	15	4	4	4	30	22	20	19	20	24	26	30	28	24	19	19	19	7	7	17		
25	WSW	W	W	W	W	W	W	C	C	SSE	S	SSE	SE	NNE	NNE	NE	ENE	C	C	C	C	NNW	NNW	NW		
	19	15	11	9	11	9	11			7	9	24	11	7	7	6	4					9	6	11		
26	NW	NNW	NNW	NNW	N	NNW	NNE	N	N	N	NNE	NNE	N	NNE	NNE	NNE	NNE	ENE	NNE	NNE	NE	NNE	W	WSW		
	9	7	6	9	9	9	17	17	24	19	22	20	19	17	19	20	15	9	9	4	4	2	7	4		
27	WSW	SW	S	S	S	SSW	SW	SSW	SW	SW	WSW	W	W	W	W	W	W	WNW	NW	WNW	NW	NNW	NNW	NNW	W	1330*
	6	4	4	6	13	9	6	15	15	26	22	22	22	30	26	33	28	28	30	19	9	9	6	24	48	
28	NW	NW	W	NNW	NW	NW	NW	NNW	NNW	NW	NW	WNW	WNW	NW	W	ESE	SSE	SE	ESE	SE	ESE	ESE	E	NNE	NW	0455
	15	19	17	22	17	19	11	20	20	19	19	19	19	19	11	13	11	9	11	9	9	6	4	4	35	
29	NE	C	C	NNW	NW	WNW	NW	NW	N	NW	NNW	NW	NW	NNW	NE	ENE	NNE	NE	NNE	N	N	NNW	NNW	NW		
	4			4	6	7	11	11	15	15	15	17	15	22	9	9	9	15	13	9	13	19	13	15		
30	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NW	NNW	N	N	NW	NW	NNW	0320
	20	15	22	20	24	22	22	20	22	19	22	20	19	19	17	13	17	15	15	13	11	11	7	13	37	

Note/Avis 1. Climatological day/Journee climatologique 0231 NST - 0230 NST
2. Hours are L.S.T./Les heures sont a l'heure normale de la localite
3. Unit/Unite = 1.0 km/h 4. C = Calm/Calm 5. M = Missing/Manquant
6. * Indicates more than one occurrence of same speed/