RESEARCH REPORT

ASSESSMENT OF SUITE COMPARTMENTALIZATION AND DEPRESSURIZATION IN NEW HIGH RISE RESIDENTIAL BUILDINGS

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ASSESSMENT OF SUITE COMPARTMENTALIZATION AND DEPRESSURIZATION IN NEW HIGH RISE RESIDENTIAL BUILDINGS

FINAL REPORT

September 2005

Prepared for

Canada Mortgage and Housing Corporation
and
Tridel Group of Companies

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ABSTRACT

Air leakage testing and pressure measurements were measured in 8 suites in 3 newly constructed apartment buildings in Toronto, Ontario, Canada. The objectives of the study were to characterize the extent to which suites are sealed from one another, common areas and the exterior, the performance of in-suite exhaust fans, resultant in-suite air pressure and the performance of corridor air ventilation systems. The testing found that the suites tested were relatively airtight although undesirable leakage area persists between adjacent suites and common areas. The research also found that in-suite bathroom fans, range hoods and clothes dryers did not exhaust as much air as intended by design due to installation problems as well as in-suite depressurization due to the operation of other competing exhaust fans. Indoor-outdoor temperature conditions (stack effect) and wind conditions also impact on the ventilation capacity of in-suite exhaust systems. The corridor air ventilation system tested was unable to positively pressurize the corridor on lower floors against the forces of mid-winter stack and wind effects. The testing indicates that the airtightness of suites and the combined capacity of installed exhaust fans are sufficient to cause suites to become significantly depressurized relative to outdoors. This should be considered when exhaust appliances are being specified and consideration is given to the venting of in-suite combustion appliances.

Key Words

Multi-unit residential buildings, air leakage, ventilation, exhaust fans, compartmentalization, depressurization

Disclaimer

This project was conducted for Canada Mortgage and Housing Corporation (CMHC) under Part IX of the National Housing Act. The analysis, interpretations, and recommendations are those of the consultant and do not necessarily reflect the views of CMHC or those divisions of CMHC that assisted in the study and its publication.

Executive Summary

There is growing interest on the part of developers of high-rise residential buildings to review aspects of conventional building design with regards to air management systems. This review would require investigation of the degree to which individual apartments are isolated from one another (otherwise known as compartmentalization) and the current ventilation strategy of supplying make up air to corridors to replace exhaust air from fans and appliances in individual suites. There are a number of potential benefits to better compartmentalization of apartments. It would reduce overall air movement through the building and limit natural air exchange thus reducing space heating costs, increasing comfort and better enabling control of indoor temperature and humidity conditions. Isolated apartments would also reinforce the integrity of individual apartment spaces for fire and smoke control and reduce the potential for odour and noise transfer between apartments. Compartmentalized suites might however impact the ability of corridor ventilation systems to effectively “make up” the air exhausted from the suites.

The field testing reported on in this study was designed to:

1. Characterize the degree to which apartments are compartmentalized in new residential high-rise buildings.
2. Determine the extent to which the air leakage areas between adjacent suites, between suites and hallways and between suites and outside can be reduced.
3. Evaluate the impact of apartment compartmentalization on the performance of in-suite exhaust appliances, and,
4. Assess the need, and potential design parameters, of make-up air systems.

Tridel Corporation, one of Canada’s leading developers of high-rise residential buildings presented an opportunity to do suite air tightness, exhaust fan performance and depressurization testing in three different high rise buildings. Specifically, the following tests were conducted:

- Air tightness tests were done on a total of 8 suites in the three buildings
- One air tightness test was done on a suite before and after the suite to hallway door was weather-stripped
- The exhaust flow rates of bath fans, range hoods and dryers were measured in six suites
- The relative pressure between suites and the exterior and between suites and the hallway were measured with the exhaust appliances operating in six suites.
- The relative pressure difference between the hallway and suite and between the hallway and the exterior was measured before and after the corridor make up air system was operating in one building.

Highlights of the test results include:

- New high rise suites are already relatively air tight, in many cases as tight as R-2000 single family homes and tighter than the tightest of suites tested in a CMHC study of 11 high rise apartment buildings across Canada.

- The largest air leakage location is around and under the suite doors to the hallway. With very simple weather-stripping of the suite door, the overall leakage area of a suite was reduced by 40%.

- The exhaust appliances within suites do not move as much air as they are designed to exhaust and yet still have the capacity to induce significant negative pressures within the suite with respect to the exterior, adjacent units and the hallways. Bath fans, range hoods and dryers, with their booster fans exhaust as little as half of what the design air flow would indicate. However, even at this, with all the appliances operating the suites can be depressurized by more than 20.

- The corridor ventilation system in a building tested was able to induce a hallway to suite pressure of approximately 5 –10 Pa. This was enough to stop odour migration from suites to the hallway on the lower floor of the building, even though this floor was under negative pressure due to stack pressures. Sealing suite doors to the hallway allowed the induced pressure to rise to 10-15 Pa.

The findings of testing indicate some important opportunities. First, even though suites are already air tight, very simple and inexpensive weather-stripping of suite doorways and supplementing current air sealing details with caulking of the top and bottom plates of interior walls would greatly enhance the compartmentalization of suites. Second, the design capacity for make up air systems could be reduced to reflect the actual installed capacity of the exhaust appliances and the lower air flow required to pressurize hallways once suite doors are air sealed.

The testing also demonstrated that exhaust appliances, along with wind and stack pressures, are currently depressurizing suites and the level of depressurization would be increased if the suites were air sealed more effectively. The level of acceptable depressurization needs to be determined with consideration given to the impact on exhaust appliance performance and the potential for negative pressures to induce water entry into exterior wall assemblies. Exhaust fan performance is affected by the negative pressure induced in the suites when the fans are operated. This impact can be minimized by reducing exhaust fan capacities, specifying fans with higher static pressure capabilities – static in the order of 75 Pa. must be overcome in addition to the resistance inherent in the vent ducts. Another alternative would be to install balanced ventilation devices in suites or provide direct make up air ducts to individual suites.

While this study indicates some interesting opportunities, further testing to validate results across a wider range of builders, building types and geographic locations would be useful. An important variable in this type of testing is clearly wind pressures. Future testing should include provisions for factoring out or quantifying wind effects on blower door testing, pressure readings and exhaust airflow readings.

Résumé

Les promoteurs des tours d'habitation sont de plus en plus intéressés à revoir les aspects de la conception classique touchant les systèmes de gestion de l'air des bâtiments. Pour ce faire, il faut étudier le degré d'isolement des appartements les uns des autres (autrement connu sous le nom de compartimentation) et la technique courante d'alimenter les corridors en air de compensation pour remplacer l'air extrait par les ventilateurs et les appareils des logements. Une meilleure compartimentation des logements procure certains avantages. En effet, elle permet de réduire le mouvement d'air général dans tout le bâtiment et limite le renouvellement d'air naturel, contribuant ainsi à abaisser les frais de chauffage, à accroître le confort et à mieux contrôler le degré intérieur de température et d'humidité. L'isolement des logements renforce aussi l'intégrité de chaque logement sur le plan de la sécurité incendie et de la propagation de la fumée, en plus de réduire les risques de transmission des odeurs et du bruit d'un logement à l'autre. La compartimentation des logements pourrait, par contre, compromettre la capacité des systèmes de ventilation des corridors de compenser avec efficacité l'air extrait des logements.

Voici les objectifs des essais menés sur le terrain dont fait état la présente étude :

5. Établir le degré de compartimentation des logements des nouvelles tours d'habitation.
6. Déterminer dans quelle mesure il s'avère possible de réduire les fuites d'air entre les logements voisins, entre les logements et les corridors, de même qu'entre les logements et l'extérieur.
7. Évaluer l'incidence de la compartimentation sur la performance des appareils d'extraction des logements.
8. Évaluer la nécessité, et les paramètres de conception, des systèmes d'air de compensation.

Tridel Corporation, l'un des plus importants promoteurs canadiens de tours d'habitation, a fourni l'occasion de mener des essais d'étanchéité à l'air des logements, de performance des ventilateurs d'extraction et de dépressurisation dans trois tours d'habitation. Les essais suivants ont été effectués :

- des essais d'étanchéité à l'air ont été effectués sur un total de 8 logements des trois tours;
- un essai d'étanchéité à l'air a été effectué à l'égard d'un logement avant et après que la porte du logement donnant sur le corridor ait été pourvue de coupe-froid;
- les débits d'extraction des ventilateurs de la salle de bains, de la hotte de cuisinière et de la sécheuse ont été mesurés dans six logements;
- la pression entre les logements et l'extérieur, de même qu'entre les logements et le corridor, a été mesurée alors avoir mis en marche les appareils d'extraction dans six logements;
- la pression entre le corridor et le logement, de même qu'entre le corridor et l'extérieur, a été mesurée avant et après avoir mis en marche le système d'approvisionnement en air de compensation d'un bâtiment.

Faits saillants des résultats d'essais

- Les logements des nouvelles tours d'habitation sont déjà plutôt étanches à l'air, l'étant dans bien des cas autant que les maisons R 2000 et davantage que les logements les plus étanches qui ont été testés lors d'une étude de la SCHL portant sur 11 tours d'habitation répartis dans tout le pays.

- Les plus importantes fuites d'air se font autour et en dessous des portes des logements donnant sur le corridor. La simple pose de coupe-froid a permis de réduire les fuites d'air générales de 40 %.

- Les appareils d'extraction des logements ne déplacent pas autant d'air qu'ils sont censés et pourtant ils ont la capacité de susciter des pressions négatives assez importantes par rapport à l'extérieur, aux logements voisins et aux corridors. Les ventilateurs de salle de bains, les hottes de cuisinière et les sécheuses n'extraient pas plus de la moitié de leur débit de calcul indiqué. Malgré cela, lorsque tous les appareils fonctionnent, les logements peuvent subir une dépressurisation supérieure à 20 Pa.

- Le système de ventilation de corridor d'un bâtiment testé pouvait susciter une pression corridor-logement de 5 à 10 Pa. C'était suffisant pour éviter que les odeurs des appartements se propagent jusque dans les corridors de l'étage inférieur du bâtiment, même si cet étage subissait une pression négative en raison de l'effet de tirage. Rendre étanches les portes des appartements donnant sur le corridor a permis de faire passer la pression induite à 10 – 15 Pa.

Les résultats des essais laissent entrevoir d'importantes possibilités. D'abord, même si les logements sont déjà étanches à l'air, l'adoption de mesures vraiment simples et peu coûteuses, comme poser des coupe-froid aux portes des logements et calfeutrer les lisses et sablières des murs intérieurs, augmenteraient grandement la compartimentation des logements. Puis, la capacité de calcul des systèmes d'approvisionnement en air de compensation pourrait être réduite en fonction de la capacité des systèmes installés et du moindre mouvement d'air requis pour pressuriser les corridors, une fois les portes des logements rendues étanches à l'air.

Les essais ont également indiqué que les appareils d'extraction, de même que les pressions du vent et l'effet de tirage, contribuent à dépressuriser les logements et que le niveau de dépressurisation serait accru si l'étanchéité à l'air des logements était réalisée avec plus d'efficacité. Le niveau de dépressurisation acceptable doit être déterminé en prenant en considération son incidence sur la performance des appareils d'extraction et les risques que les pressions négatives entraînent des infiltrations d'eau dans les murs extérieurs. La performance des ventilateurs d'extraction subit les effets de la pression négative suscitée dans les logements. On peut certes en atténuer les effets en réduisant la capacité des ventilateurs d'extraction, en spécifiant des ventilateurs davantage efficaces en présence de pressions statiques élevées, puisqu'ils doivent surmonter des pressions statiques de l'ordre de 75 Pa, ainsi que la résistance des conduits de ventilation. Une autre option consisterait à installer des dispositifs de ventilation équilibrée dans les logements ou un conduit d'admission d'air de compensation dans chacun des logements. .

La présente étude laisse présager d'intéressantes possibilités, mais d'autres tests s'imposent pour valider les résultats parmi une plus vaste gamme de constructeurs, de types de bâtiments et de régions géographiques. Les pressions du vent constituent de toute évidence une importante variable dans ce genre de tests. Les futurs essais devront inclure des dispositions pour tenir compte ou quantifier les effets du vent sur les essais au moyen d'un ventilateur à débit contrôlé, les relevés des pressions et des débits d'air extrait.

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1. Introduction

As a means of meeting growing concerns regarding energy efficiency, occupant health, comfort and security while responding to evolving market trends, many developers of high-rise residential buildings have begun questioning various aspects of conventional building design. One aspect of building design that has a significant contribution to energy performance and mechanical system capital cost is ventilation. Over the past few decades the most common ventilation strategy has been to provide individual point source exhaust fans, such as bath fans and range hoods in individual suites and deliver fresh air into the corridors. Corridor ventilation is considered by designers to have as many as four functions:

- Meet code ventilation requirements of the corridor space itself
- Provide fresh air to individual suites. The corridors are presumed to be pressurized and the suite door is often designed to have an undercut or other leakage paths to allow air into the suites
- Provide for odour and smoke control between suites by pressurizing the common areas
- Provide "make up" air for the exhaust appliances – bath fans, range hoods and dryers in each suite.

However, there is a growing interest in isolating individual suites from one another. The degree of compartmentalization can affect many aspects of the total building performance and occupant satisfaction. Compartmentalized apartments reduce air movement through the building, limiting indoor-outdoor air exchange thus reducing space heating costs, increasing comfort and better enabling control of indoor temperature and humidity conditions. Isolated apartments also reinforce the integrity of individual apartment spaces for fire and smoke control. Isolated apartments also have appeal to consumers in that the opportunity for odour (tobacco smoke and cooking) and noise transfer between apartments is significantly reduced. Clearly, however, compartmentalized suites will affect the design objectives of the common ventilation strategy listed above.

The degree to which individual apartments can be isolated from one another has not been fully tested to any significant degree. There is a common perception in the construction industry that the fire and sound separations provided between apartments are sufficient, but air leakage testing has routinely shown that many air leakage points still exist. Building managers continue to report that occupants complain of cooking odours in apartment buildings, new and old, and this demonstrates the relative permeability of interior partitions in multi-unit residential buildings.

Furthermore, should it be possible to seal apartments from one another (vertically and horizontally), questions have been raised about the performance of exhaust appliances and the conventional ventilation strategies in small, relatively airtight, spaces. For instance, the ability of range hoods and clothes dryers to exhaust air from well-sealed apartments has not been explored. The need for make-up air will have to be determined and how it will be supplied, given the construction and operating regimes of high-rise residential buildings, is also not well understood.

An opportunity arose with one of Canada's leading developers of high-rise residential buildings to explore such issues. Tridel Corporation is actively exploring ways to build buildings that respond to evolving regulatory, consumer and environmental concerns. Tridel had several buildings under construction where the degree to which apartments are compartmentalized could be explored and the subsequent impact on in-suite exhaust appliance airflow capacities determined.

Air Solutions was contracted to perform field tests in three different Tridel buildings to assess various aspects of air tightness, exhaust fan performance and depressurization in individual suites.

The three buildings were:

- Building 1: 29 story building with condominium suites ranging in size from 120 m^2 to 300 m^2

- Building 2: A 16 story building with condominium suites ranging in size from 64 m^2 to 100 m^2.

- Building 3: 19 story building with condominium suites approximately 100 m^2 in size.

2. Test Goals, Objectives and Methodology

Testing was done at three different high rise buildings in the Greater Toronto area. One building was fully finished and occupied. The other two were substantially complete, with some of the upper level suites still requiring final trim and painting. The testing was done on four different test days and weather conditions on those days have been recorded. The objectives and test methodology are described below.

2.1 Goals

i. To characterize the degree to which apartments are compartmentalized in new residential high-rise buildings.

ii. To determine the extent to which the air leakage areas between adjacent suites, between suites and hallways and between suites and outside can be reduced.

iii. To evaluate the impact of apartment compartmentalization on the performance of in-suite exhaust appliances, and,

iv. To assess the need, and potential design parameters, of make-up air systems.

2.2 Methodology

2.2.1 Air Leakage Characterization Testing

Objective: To characterize the equivalent leakage area at 10 Pa pressure (ELA at 10 Pa), normalized leakage area (NLA at 10 Pa), air change rate (ACH at 50 Pa) and normalized flow rate at 75 Pa. pressure of newly constructed apartments in high-rise buildings.

A "blower door" test was done on a total of 8 apartments in three different high-rise residential buildings selected by Tridel. Testing was conducted in accordance with CAN/CGSB 149.1 "*Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*", modified slightly for apartments. The apartments were all drywalled but at various stages of trim and finish. In all cases, the blower door was located in a balcony door or window to the exterior. Smoke penciling and subjective assessment of air leakage paths was done in each suite. In all cases the blower door tests were done without regard for the condition of the hallways. That is, some of the corridors were not fully finished and it was not possible to control the differential pressures between the test suites and the corridors. Nor were we able to control the operation of the corridor ventilation system. In most buildings there were too many people coming and going and construction stages varied too greatly to be able to apply any standard conditions to the corridors. *However, the test results did not appear to be affected by conditions in the hallway*. Deliberate openings in the suite exteriors (exhaust appliances etc.) were sealed or dampers closed where possible.

Scale drawings provided by Tridel were used to calculate the envelope areas and volume of the suites.

2.2.2 Performance Characterization of In-Suite Exhaust Appliances

Objective: To assess the exhaust airflow capacity of in-suite exhaust appliances and the relative pressure they induced on the suite with respect to outside and with respect to the adjacent hallway.

The airflow capacity of the kitchen range hood, bath fans and clothes dryer was measured within the test suites in the three buildings. The exhaust airflows were measured in various operating modes, individually, simultaneously and with doors open and closed. Again no attempt was made to try to control the corridor and this did not appear to affect performance. A variety of measurement techniques were employed to overcome access barriers, wind effects and validate accuracy.

- A hot wire anemometer air velocity traverse was used on all dryers. The traverse was taken in the straight section of ducting from the exhaust appliance. The average of velocities across the duct and the cross sectional area of the duct were used to calculate an airflow rate in the duct. This same traverse method was used on some of the range hoods. Measurements were compared with design specifications of the fans and appliances installed. For the bath fans and some range hoods an Exhaust Flow Hood developed by the Energy Conservatory Group was used. This method was checked against the duct traverse method and the results were within +/- 5% of one another.

- An attempt was made to do a hot wire anemometer traverse at the exhaust grilles of the bath fans, range hoods and dryer. In most buildings the grilles were not accessible from the balconies and where they were accessible the wind effects made accurate or repeatable measurements very difficult.

The pressure difference between the suite and the hallway and between the suite and outside were measured with various combinations of exhaust appliances operating using an Energy Conservatory digital pressure gauge with a wind averaging function.

2.2.3 Air Tightness and Exhaust Appliance Performance in a Suite with a Weather-stripped Hallway Door

Objective: To measure the impact on air tightness, exhaust appliance performance and depressurization in a suite when the air leakage pathway around the hallway door was reduced.

A blower door test was completed on a suite before and after weather-stripping was applied to the hallway door. The weather-stripping applied was the commonly available, inexpensive peel and stick, vinyl “V” seal.

The airflow performance of exhaust fans within the suite was measured both before and after the suite door was weather-stripped. The pressure difference between the suite and the hallway was also measured at various exhaust appliance-operating points.

Note: On the day of this testing it was 5 ^{0}C and raining outside with strong, gusting winds. The wind variance was so great that a full, accurate depressurization test in accordance with the CGSB standard was impossible. The air tightness results in Table 1 below were extrapolated from a “single point” depressurization test at 70 Pascals and assuming a flow exponent of 0.65.

2.2.4 Characterization of the Pressure Differences between Suites and Hallways Induced by a Corridor Ventilation System

Objective: To measure the impact of hallway ventilation systems on the pressure difference between suites and the hallway.

Measurements of the relative pressure between suites and the hallway and between outside and the hallway were taken in a finished building on the second floor and on the top (29^{th}) floor with the corridor ventilation systems on and off. On the 29^{th} floor the testing was repeated after all of the suite doors (4 in total) on that floor were taped off – simulating weather-stripped doors. No attempt was made to seal the elevator and fire escape doors. In this building there were two independent corridor ventilation systems, one serving the lower 11 floors, the other serving the upper 18 floors. The testing was done with all the combinations of operating conditions for these two systems.

Air velocity measurements were taken at the two large hallway ventilation supply grilles using a hot wire anemometer. The size of the grill was measured and a "free area" adjustment factor was used to estimate the airflow from the grill when the ventilation system was on. This estimate was compared against the HVAC commissioning balancing report supplied by the building management firm.

3. Findings

3.1 Test Conditions

Weather conditions varied considerably on the four test days. Specifically wind conditions affected the accuracy and repeatability of tests on two of the test days. Swirling wind effects on upper level suites made pressure measurements difficult and time consuming. Fortunately the digital pressure gauged used had a long term averaging function that allowed pressure readings to be averaged over any time period. When wind conditions were at the most variable an averaging time interval of 30 seconds was used. Provisions for averaging measurements or some other method to limit or reduce the impact of wind effects is clearly very important for any high rise pressure and airflow testing.

The three buildings were in various stages of construction. Building 3 was completely finished and essentially fully occupied. During the testing there was no attempt made to control access to the building or elevators. During the testing of hallway to suite pressures it appeared that elevator movement or the opening of exterior doors was affecting pressure readings. As much as possible the results reflect readings taken when conditions appeared to be stable.

Building 2 and Building 1 still had some suites under construction, although the overall building envelope was completed and the elevators were operational. Due to access and time limitations, testing was done in some suites where the exhaust fans were not operational or in one case where the range hood was clearly not working properly and could not be fixed.

In these buildings there was a lot of activity in the hallways and it was impossible to control access to adjacent suites or to the elevators. However, the activity did not appear to affect pressure or airflow readings in the suites tested.

3.2.1 Air Leakage Characterization Test Results:

Table 1 shows the air leakage test results for the 8 suites expressed in four different formats.

- ACH at 50 Pa — Air Changes per Hour at a differential pressure between inside the suite and the exterior of 50 Pascals. The result is calculated in accordance with CAN/CGSB 149.1 "*Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*" from a series of at least six pressure readings and includes correction for temperature and barometric pressure. Tectite Version 2.5 software was used to generate the results. The software is provided by The Energy Conservatory for the Minneapolis Duct Blaster Model B used in the testing. ACH at 50 Pa. is commonly used to evaluate the air tightness of detached single family dwellings. For comparison certified R-2000 homes would have air tightness at or below 1.5 ACH. It is worth noting that the small volume of apartments in comparison with houses doesn't really allow for a direct comparison of air leakage characteristics based on volume.

- ELA cm^2 @10 Pa — The Equivalent Leakage Area at a differential pressure of 10 Pa. Defined as the area of a sharp edged orifice that would leak the same amount of air as the building does at a pressure of 10 Pa. It is commonly thought of as being the collective size of all the holes in the building envelope. For example, in Building 3 Suite 1913, weather-stripping the hallway door reduced the ELA by 91.6 cm^2. Again, the Tectite software was used to calculate this number.

- NLA cm^2/m^2 @ 10 Pa — The normalized leakage area in cm^2/m^2 at a differential pressure of 10 Pa. It is calculated by dividing the ELA by the exterior surface area of the building envelope – walls, floors, ceilings. This allows for comparison of different sized suites or to a standard. For example, R-2000 houses would have an NLA of no more than 0.7 cm^2/m^2.

- Norm. Flow — This is an air leakage index defined as the airflow in liters per second (L/s) required to create a differential pressure between the suite and outside of 75 Pa., divided by the exterior surface of the suite. This index is commonly used in high rise buildings. For comparison, a CMHC study of 11 high rise apartment buildings across Canada found overall air flow indexes in the range of 0.9 to 10.3 L/s / m^2 @ 75 Pa. It should be noted that these are exterior-only whole building, whole floor or exterior wall measurements as opposed to measurements of the total interior and exterior leakage areas of a given apartment.

It should be noted that the air leakage results reflect the total interior and exterior surface areas of the walls, floors and ceilings that define the boundaries of the suites.

The air leakage results demonstrate the suites are air tight; some of them very airtight. All but two had air flow indexes at 75 Pa. that were below the lowest indexes found in the recent CMHC survey of apartment buildings. Moreover, the single largest leakage area is around the suite to hallway door as demonstrated by the over 40% reduction in ELA and Normalized Flow by weather-stripping the hallway door in Building 3 Suite 1913.

Table 1 Air Leakage Characterization Test Results

Suite No.	ACH @ 50 Pa	ELA cm^2 @10 Pa	NLA cm^2/m^2 @ 10 Pa	Airflow L/s @75 Pa.	Norm. Flow L/s / m^2 @ 75 Pa
Building 1 303	1.23 ACH	74.19	.26	136.4	0.47
Building 1 2402	2.52 ACH	456.8	1.03	346.4	0.78
Building 1 2401	3.12 ACH	407.1	1.01	369.1	0.92
Building 1 2502	1.19 ACH	272.3	.61	154.8	0.35
Building 2 114	3.16 ACH	318.7	1.19	270.9	1.01
Building 2 1006	2.62 ACH	138.7	0.77	130.3	0.72
Building 2 1506 (Door taped)*	2.13 ACH	144.5	0.80	99.6	0.55
Building 3 1913 (As Is)	2.46 ACH	221.3	0.82	203.4	0.76
Building 3 1913 (Sealed Door)	1.44 ACH	129.7	0.48	119.4	0.44

* *The hallway door threshold was not installed so the bottom of the doorway was taped*

The suites varied considerably in size. The characteristics of the individual suites and the test conditions on the day of testing are shown in Table 2.

Table 2 Summary of Test Conditions and Air Leakage Notes

Suite	Surface Area m^2	Conditions	Air Leakage Notes
Building 1		Calm, mild day approx., 15 ^{0}C	
303	289.9	Finished, range hood duct blocked	Suite door, elect. outlets to adjacent units
2402	443	9’ Ceilings, some trim and grilles missing	Suite door, around plumbing, elect. outlets to adjacent units
2401	403.1	Finished, 9’ ceilings	Suite door, balcony garden door, under sill in kitchen, adjacent suite elect. outlets, around toilet flange
2502	443	Trim not finished, fans not working	Suite door, plumbing access spots
Building 2		Gusty winds, approx. 8 ^{0}C	
114	268.1	Finished, 9’ ceilings	2 patio doors, suite door and elect. outlets to adjacent units
1006	180.6	8’ ceilings, finished suite	Suite door and one exterior elect. outlet
1506	180.6	Trim not complete, 8’ ceilings	Suite door, leakage at one large window frame and exterior elect. outlets
Building 3		Very windy, raining 5 ^{0}C	
1913	269	Finished suite	Sliding door leaking a lot

Note: Building 2 Suite 1506 did not have a completed threshold so it was taped to complete the testing.

Note: Surface area = sum of all interior and exterior surfaces separating the apartment from the outside and interior spaces

3.2.2 Subjective Air Leakage Assessment

- Without question and in all suites the single largest leakage area is around and under the door to the hallway. This was nicely demonstrated when the door to the suite at Building 3 was weather-stripped with inexpensive materials. While there was still some small leakage around the door detected with the application of a smoke pencil, the amount of leakage was dramatically reduced.

- In general it appeared there was as much leakage from the corridor and adjacent suites to the suite as there was from the outside to the suite.

- There was noticeable leakage around plumbing penetrations through partition walls between suites and corridors. There was an opportunity to look at construction details in an adjacent building under construction. From this inspection it is suspected the air leakage noted in partition walls is coming from under and over the top and bottom plates of the wall – all other aspects of the wall details and plumbing penetrations looked to be well sealed for fire separation.

- In Building 2 Suite 114 there was significant leakage around the 2 patio doors, primarily between the operable door and frame. This is a common deficiency of sliding patio doors. This was the only suite to have two patio doors and this may account for the high air leakage ratings for this suite.

- There was air leakage noted around electrical outlets installed in partition walls between suites, typically more air leakage at these “interior” outlets than those on exterior walls. This could again be the result of air leakage under and over bottom and top plates.

- It was difficult to assess the differences in air leakage for different types of interior walls – shear walls and double stud walls for example. This was because, even in the shear walls, the strapped walls in front of the concrete wall were still “connected” to hallway walls.

3.2.3 Performance Results of In-Suite Exhaust Appliances

To assess the airflow capacity of exhaust appliances in each suite measurements were taken with each appliance operating independently – that is, only one on at a time. In many suites there were two bathrooms and thus the airflow from both fans is shown.

To assess the potential depressurization impact of the appliances on the suites, all the appliances were turned on at the same time. The results of this testing are shown in Table 3.

Table 3 Exhaust Fan Performance and Suite Depressurization:

Suite No.	Bath L/s	Range L/s	Dryer L/s	Pressure to Outside All Fans On
Building 1 303	29, 29	18**	49	53 Pa
Building 1 2402	24, 33*	101	57	25 Pa
Building 1 2401	33*, 35*	92	47	21 Pa
Building 1 2502 ***	-	-	-	-
Building 2 114	31	113	61	25 Pa
Building 2 1006	35, 35	64	47	50 Pa
Building 2 1506 ***	-	-	-	-
Building 3 1913 (Door As is)	33, 38	49	52	35-40 Pa
Building 3 1913 (Door sealed)	33, 38	47	52	65-75 Pa

* *Fan grilles not on*
** *Range hood not working properly*
*** *Fans not operational on day of test*

Note: In all cases the pressure outside was higher relative to inside, that is, the suites were depressurized
The airflow of the dryers includes the operation of the booster fans

3.2.4 Air Tightness and Exhaust Appliance Performance in a Suite with a Weather-stripped Hallway Door

Table 4 shows the results of more detailed testing of exhaust fan performance and suite depressurization in one suite. The Building 3 suite was chosen because it was in a completed and occupied building. The door was weather-stripped and then exhaust appliances were operated first individually and then in combinations to see the impact on suite depressurization both to the hallway and to outside and the impact on the airflow of the fans themselves.

Of interest, on this day of testing, due primarily to wind pressures, the relative pressure between the exterior and the hallway varied from –15 to + 15 Pa. on the 19th floor. For comparison purposes the relative pressure between the exterior and the hallway was also measured on the third floor of the building. The range on this floor was –5 to +25 Pa. (exterior to hallway). Both of these readings were taken with the corridor ventilation system on and while it may be expected that the corridor ventilation system would always maintain a positive pressure with respect to the suites, this is not always the case.

Table 4 Exhaust Fan Performance at Building 3 Suite 1913 (Door weather-stripped) at Various Operating Points:

Operating Mode	Bath (L/s)	Range (L/s)	Dryer (L/s)	Pressure to Outside	Pressure to Hall
Everything on	7, 17	40	42	65-75 Pa.	80 Pa.
Bath Fans only	33, 38	-	-	20-25 Pa.	30-40 Pa.
Dryer only	-	-	52	15-25 Pa.	40 Pa.
Range Hood only	-	47	-	15-30 Pa.	20-25 Pa.
Dryer & Range on	-	42	45	50-60 Pa.	65-70 Pa.

Note: The range of pressures noted is due to gusting winds. It was very difficult to get steady pressure readings even with the time averaged function.
In all cases the suites were at a lower negative pressure with respect to the hallway and the outside.

3.2.5 Discussion of Findings from Exhaust Appliance Performance Testing:

- The bath fans in all of the suites had a design airflow of 48 L/s. It is presumed engineers have been specifying 48 L/s per bathroom in accordance with Section 6. 2.3.9(12) of the Ontario Building Code – 24 L/s per sanitary fixture (in the case of these suites this would include toilets and shower/ bath tubs). The actual air flow performance of the bath fans was always less than the design flow as the result of pressure losses in the duct and the outside terminations.

- When all fans (range hood, dryer, and bath fans) are on it creates a significant negative pressure in the suites relative to outdoors and the common corridors (regardless of whether the suite doors are weather-stripped) and this reduces the net exhaust flow from individual fans. The range of depressurization was from 21 Pa. in Building 1 Suite 2401 (one of the larger and “leakier” suites) to approximately 75 Pa. in Building 3 1913 after the door was sealed.

- Specifically, the airflow performance of the bath fans drop quickly as the negative pressure in the suites increases due to wind or operation of other exhaust appliances. This is inherent in the type of fans used (low static capabilities), but is not necessarily a problem (although it will reduce the capacity to deal with humidity and odours on an intermittent basis). In fact, it helps minimize the overall negative pressure in the suite when other intermittent exhaust appliances are operating.

- The design air flow of the range hoods in suites varied from building to building and in some cases from suite to suite. The incremental increase in flow from a “high capacity” range hood is limited by the static pressure induced by the duct and grilles used and the depressurization of the suite (from running the range hood fan and other fans). For example, in the most dramatic case Building 2 Suite 1006 had a Sakura Model 727 Range Hood that has a design capacity of 180 L/s at 25 Pa. The tested performance of this fan installed was only 64 L/s.

- All the range hoods were ducted with 150 mm (6”) diameter duct. The practical limitation of airflow in a 150 mm (6”) diameter duct is typically 100 L/s unless fans with very high static capabilities are used.

- The clothes dryers used in the suites have a manufacturers design airflow of approximately 50 L/s. The dryers in all suites had a “booster fan” installed inline in the exhaust vent. This booster fan is interlocked with the operation of the clothes dryer. It appears the booster fans do not increase the flow from the dryer dramatically. They do, however, appear to be able to help overcome the static pressure losses of the exhaust vent pipe and static pressure changes due to wind and the operation of other exhaust appliances and therefore keep air flows constant. The design flow of the booster fans is 65 L/s at 150 Pa. static pressure. This is an indicator that the dryer vent pipe and outside termination vent induces a very high static pressure of over 150 Pa.

- The make up air for exhaust appliances, in the suites without a sealed door, is coming from around the suite door, other leakage points in interior walls and through leakage paths in exterior walls – despite the best efforts of construction crews to minimize air leakage. Roughly 60% of the ELA is within building components other than the suite door.

- When the suite door was sealed, the exhaust appliances created a greater negative pressure between both the suite and the exterior and between the suite and the hallway. In all cases the negative pressure was greater in the suite to exterior than in the suite to hallway.

3.2.6 Characterization of the Pressure Differences Between a Suite and the Hallway Induced by a Corridor Ventilation System

Table 5 shows the results of pressure testing done at the Building 1 building on an upper and lower floor hallway. The testing was designed to show the impact of the corridor ventilation system on the relative pressures between the hallway and the exterior and the hallway to a suite.

The testing was done with the corridor ventilation systems in various operating modes. The building is served by two separate corridor systems, one for the lower floors and one for the upper floors. It appears the two corridor systems impact pressures on the 29th floor independently, however, there did not appear to be any impact on the second floor by the operation of the upper corridor ventilation system.

The Building Operating Manual includes a balancing report for the two air make up units. The balancing report shows a measured air volume of 195 L/s and 200 L/s respectively from the two corridor ventilation grilles on the second floor. A hot wire traverse of the grilles on this day of testing indicated airflows of 150 L/s and 160 L/s.

The 29th floor has four larger suites. To simulate weather-stripping of the doors, masking tape was applied to all four suite doors to see if there was any impact on the pressures created by the corridor ventilation systems. In addition, the exhaust appliances in one suite were turned on when the door was taped and the relative pressures were recorded. The suites on the second floor of the building were fully occupied and therefore the suite doors could not be sealed off for additional testing.

On the day of this testing there were high gusting winds that made pressure measurements difficult to stabilize, even when using a time averaging function on the pressure gauge. Thus a range of pressures has been reported. As well, it is important to note that the outdoor temperature on this day was 0 ^{0}C and the inside temperature was 22 ^{0}C.

Table 5 Pressures Induced by Corridor Ventilation Systems

Condition	Hallway to Outside	Hallway to Suite
29th Floor – Both Corridor Systems On	35 to 45 Pa	30 to 35 Pa
29th Floor – Upper Corridor System OFF	25 to 30 Pa	20 to 25 Pa
29th Floor – Both Corridor Systems Off	10 to 20 Pa	10 to 15 Pa
29th Floor – Doors Taped, All Systems Off	5 to 10 Pa	15 to 20 Pa
29th Floor – Doors Taped, Lower Fans On	15 to 25 Pa	25 to 30 Pa
29th Floor – Doors Taped, Both Fans On	30 to 35 Pa	40 to 50 Pa
29th Floor – Doors Taped, Hall Fans On, Exhaust Fans in One Suite On	30 to 45 Pa	75 Pa
2nd Floor – Both Corridor Systems On	5 to 10 Pa	3 to –5 Pa
2nd Floor – Lower Corridor System On	5 to 10 Pa	3 to –5 Pa
2nd Floor – Corridor Systems Off	-30 to – 40 Pa	- 3 to -5 Pa

Note: A positive pressure sign indicates the hallway was a greater relative pressure than the exterior or the suite.

3.2.7 Discussion of Findings from the Impact of Operating Corridor Ventilation Systems on the Pressure Differences between a Suite and the Hallway and between the Hallway and the Exterior

- With the corridor ventilation systems off, the lower floor suite and hallway were under a negative pressure with respect to outside and the upper floor suite and hallway were at a higher pressure. This would be due to stack pressures in the order of -30 Pa. on the second floor to as high as 20 Pa. on the 29th floor. It was impossible on this gusty day to isolate the stack pressure from wind pressures.

- With the corridor ventilation system off, there was noticeable air movement from the suites into the hallway on the lower floor. There was an almost immediate and dramatic increase in odours in the hallway as the corridor ventilation system was turned off on the second floor.

- The odour transmission was effectively stopped when the hallway pressure relative to the suite was as little as 3 to 5 Pa.

- Taping the suite doors (simulating weather-stripping) increased the pressure difference across the suite door to hallway by 10 to15 Pa. This demonstrates that lower corridor ventilation rates would be required to maintain a positive pressure in the hallways if the suite doors were air sealed.

- On the upper floor on this day, stack pressure created a positive pressure in the hallway even when the corridor ventilation systems were off.

- The corridor ventilation system intended to serve the lower floors was capable of increasing the pressure on the 29th floor by as much as 5 to 10 Pa. when the suite doors were not taped and 10 to 15 Pa. when the suite doors were taped. This would indicate an airflow path from lower floors to upper flows; presumably connections such as the elevator shaft, stairwells, garbage chutes etc

- The operation of exhaust appliances in one suite did not appear to affect the pressure difference between the hallway and the exterior.

4. Conclusions and Recommendations

Although the testing represented a small sample of building and suites, there were a number of interesting findings that were consistent with other industry testing and demonstrate opportunities for changing the design characteristics of high rise residential buildings.

Specifically, the testing indicates that:

- **New high rise suites are relatively air tight**
  Requirements for fire separation integrity and exterior envelope details that discourage water entry, serve to create tight envelopes.

- **The exhaust appliances within suites have the capacity to induce significant negative pressures within the suite with respect to the exterior, adjacent units and the hallways.**
  The current design premise is that make up air for exhaust appliances comes from the hallway around the suite door. While this is a significant leakage pathway, it is not the only one. The air tightness testing showed that there is leakage directly from adjacent suites and through the exterior envelope. Air leakage from adjacent suites can certainly result in odour complaints. Air leakage through the exterior envelope may induce water entry, increase energy use, cause drafts and may lead to comfort problems.

- **The largest air leakage location is around and under the suite doors to the hallway.**
  As much as 40% of the total leakage area of the suites is around the door. This has been an intentional part of building ventilation design. It is assumed the air leakage area allows make up air for the exhaust appliances to enter the suite. The testing shows that even with this leakage, exhaust appliances can induce negative pressures of up to 75 Pa.

- **Exhaust appliances perform well below their design airflow rates.**
  Washroom exhaust fans designed at 48 L/s exhaust between 24 and 38 L/s. Large capacity range hood exhaust capacities are effectively limited by the static pressure of 150 mm diameter ducts (and outside vents) to approximately half of their design capacity. Dryers that have design capacities of 50 L/s are interlocked with booster fans that have a design capacity of approximately 65 L/s at 150 Pa static pressure and yet still only exhaust between 47 and 61 L/s. The performance shortfall is the result of long restrictive duct runs, wind pressures on exterior hoods, building stack effects and the pressure induced by other exhaust appliances.

- **Applying simple weather-stripping to the suite door changes significantly the leakage characteristics of the suite.**
  As noted above, the ELA of the suite was reduced by 40% when a suite door was weather-stripped. Similarly taping the suite doors in a hallway increased the relative pressure the corridor ventilation system could induce across the suite doors. Exhaust appliance flows were reduced when the suite door was sealed.

- **Weather-stripping the suite door and adding to the air sealing details during construction could effectively create compartmentalized suites.**
  Adding caulking to the top and bottom plates of interior walls, increasing air tightness around electrical outlets and weather-stripping the suite doors would create very tight envelopes. Specifications and inspections of windows and doors – specifically sliding patio doors – to optimize air tightness would also be worthwhile.

Following are implications of these findings with respect to the design of make up air systems:

The design capacity for make up air systems could be reduced to reflect the actual installed capacity of the exhaust appliances. For example, it may seem appropriate to consider the design capacity of large range hoods for factoring make up air sizes. In practice the size of the vent duct and grille and not the airflow capacity of the fan, determines the installed capacity. Additional kitchen fan capacity may be attractive from a marketing perspective or from a perceived odour control benefit. However, it would be more effective to investigate hoods with lower total airflow capacities but higher static pressure capabilities or better yet, find hoods that have improved pollutant capture effectiveness at lower air flows.

Similarly, bath fans are being selected for a capacity of 24 L/s per sanitary fixture as per a section of the building code that applies to commercial, industrial and institutional washrooms with projected occupancy by a number of people at the same time. It would be more appropriate to design washroom ventilation rates based on residential occupancy. In this case a design flow of 25 L/s per washroom (or half of the existing design rate) would be most appropriate. Fortunately the average actual installed capacity of washroom exhaust fans is in the order of 30 L/s, so in practice it would not be a big change, but would allow for the downsizing of make up air capacity. Clearly the design capacity of exhaust fans must include provisions for the fans to overcome pressures of upwards of 75 Pa., in addition to the static losses of the duct work and grilles, in order for them to overcome the effects of other exhaust appliances in the same suite.

Furthermore, the testing demonstrated that even with loose fitting suite doors, not all of the make-up air came from the hallways. If an acceptable limit for suite depressurization could be determined, then make-up air design could include allowance for a portion of the air to come directly into individual suites through the exterior envelope. This is an acceptable design practice in single family buildings as well as commercial and industrial buildings. The key elements for the basis of design would be:

- To ensure combustion appliance venting would not be affected. In the buildings tested there were no spillage susceptible appliances. In buildings where fuel fired combustion appliances were considered, it would be very important to consider only those appliances that were able to vent properly under high negative pressures.

- Negative pressures in suites can induce odour transmission from adjacent spaces. Air sealing is recommended as the most reliable way of managing odours from adjacent areas.

- Negative pressures may induce the entry of water into the exterior building envelope – there are a number of considerations in this regard:

  - The exterior building envelope is already subjected to variable pressures due to stack and wind affects. The bottom floors are under constant negative pressures in winter months in the order of 30 – 50 Pa. and the upper floors have wind pressures that can easily exceed 50 Pa.

  - The largest exhaust appliances in suites, range hoods and dryers can be expected to be of intermittent use. Even though a dryer may be on for a few hours at a time, it is unlikely that usage would exceed more than 30% of a day.

  - Building envelope design already includes air sealing and water management principles to limit the potential for water entry and to promote drying of walls that may be intermittently wetted.

  - Air sealing is a more reliable alternative to mitigating the effects of negative pressure than trying to manage pressures with air make-up air systems.

- Negative pressures can result in drafts from outside that occupants would find uncomfortable. Again air sealing is the most reliable strategy in this regard

An important and practical function of the corridor air ventilation systems is to pressurize the hallways with respect to the suites to minimize odour transmission into the hallways. Fortunately a very small positive pressure is required to accomplish this task – in the order of 5 Pa. However, maintaining even a slight positive pressure is difficult in the face of occupants opening doors, elevators opening and closing and wind and stack pressures acting in varying ways simultaneously on different parts of the building. The task of managing pressures and flows in a building is made much easier when the suites are compartmentalized and when the hallways are as air tight as possible. The flows required to maintain pressures are lower when the building and the suites within the building are tighter.

Finally, ventilation strategies within suites that are balanced – exhaust flows balanced by equal supply air flows – would assist in pressure management and reduce make-up air design capacities. Even a passive hole with a free area of approximately 90 cm^2 (roughly the size of a common dryer vent) would replace the leakage area around the suite door. Unfortunately the pressure regimes in high rise building are such that passive holes react differently on lower floors than they do on upper floors, due to stack and variable wind effects. However, investigation into technologies that help balance exhaust flows from individual suites is very worthwhile in the effort to rationalize the overall ventilation strategy.

The small sample size of suites in this study pointed to some important opportunities. To validate and expand on these, further testing across a wider range of builders, building types and geographic locations would be useful. Future testing should include provisions for factoring out or quantifying wind effects on blower door testing, pressure readings and exhaust airflow readings.

Appendix

A. Building Profiles

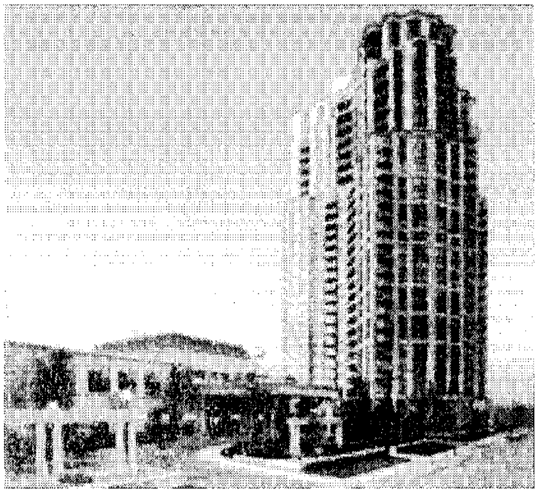
B. Floor Plans of Suites

C. Air Tightness Test Reports

D. Specifications of Exhaust Equipment

E. Balancing Report for Corridor Make-up Air System at Building 1

A : Building Profiles

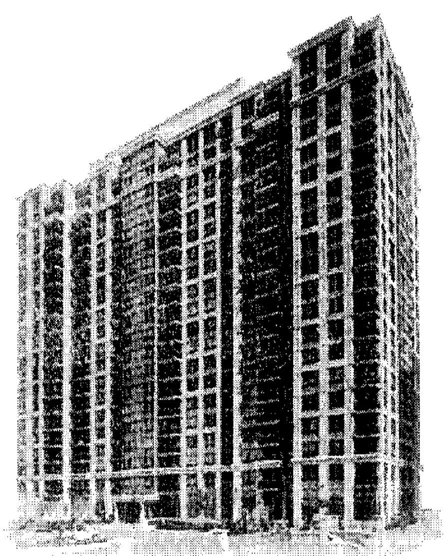


Building 1

- Phase I of two buildings
- 29 story building
- Luxury condominiums ranging from $400,000 to +$1 Million suites
- 1280 sq.ft. to 3200 sq,ft.

Building 2

- Phase I of two buildings
- 16 story building
- Condominiums starting at $170,000
- 685 sq.ft. to 1065 sq.ft.

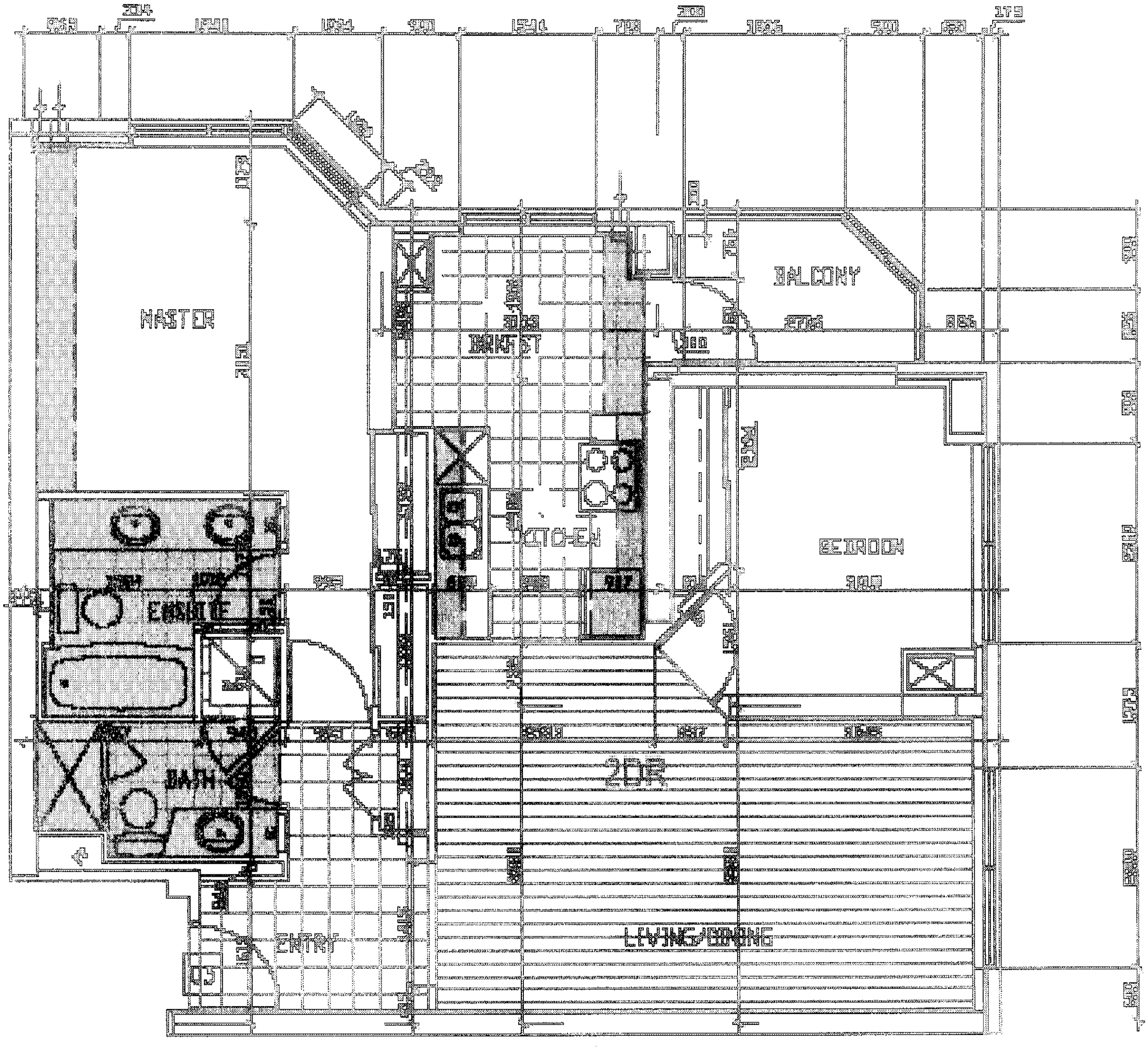


Building 3

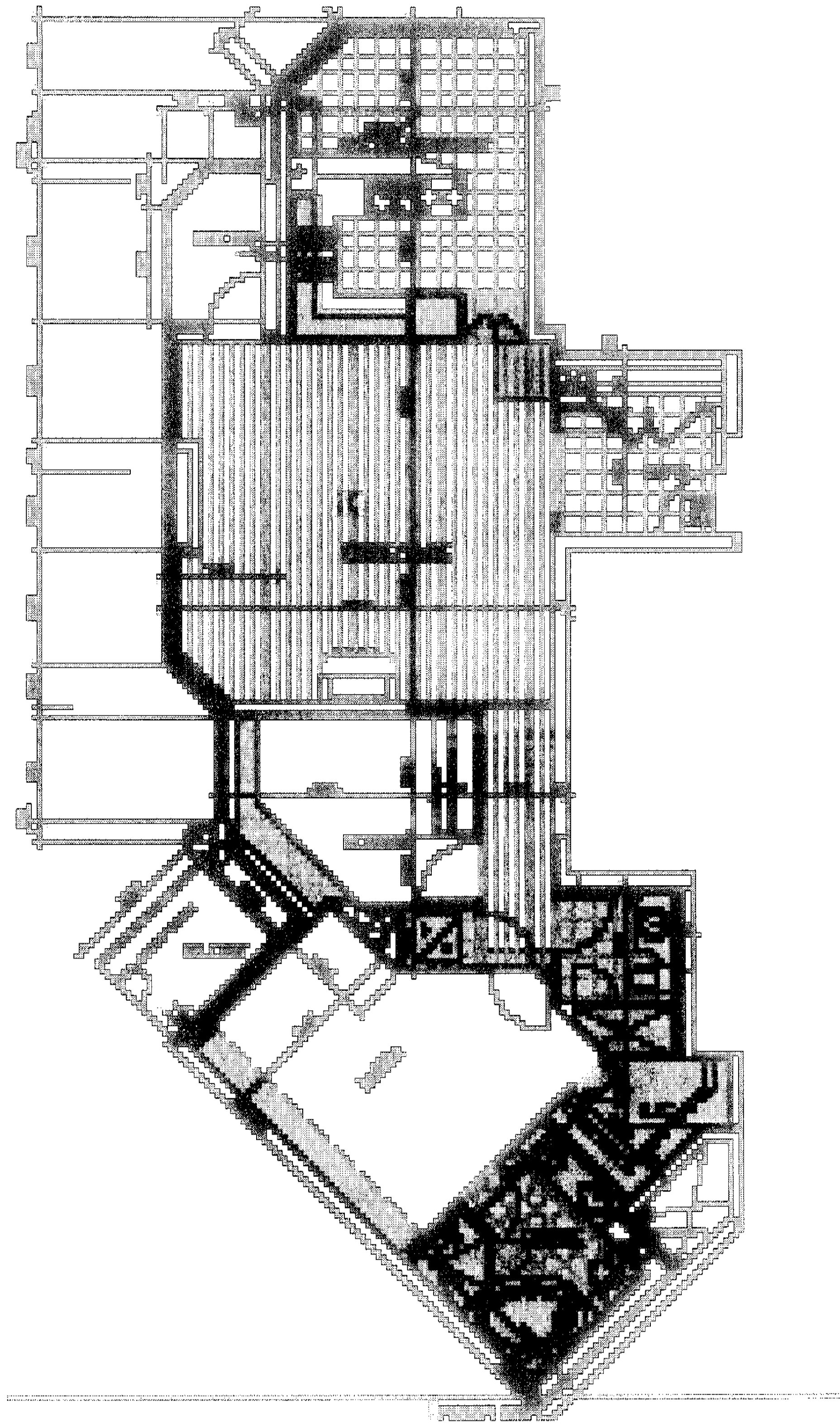
- 19 story building
- Condominiums starting at $230,000
- Approximately 1000 to 1200 sq.ft.

B: Floor Plans of Suites

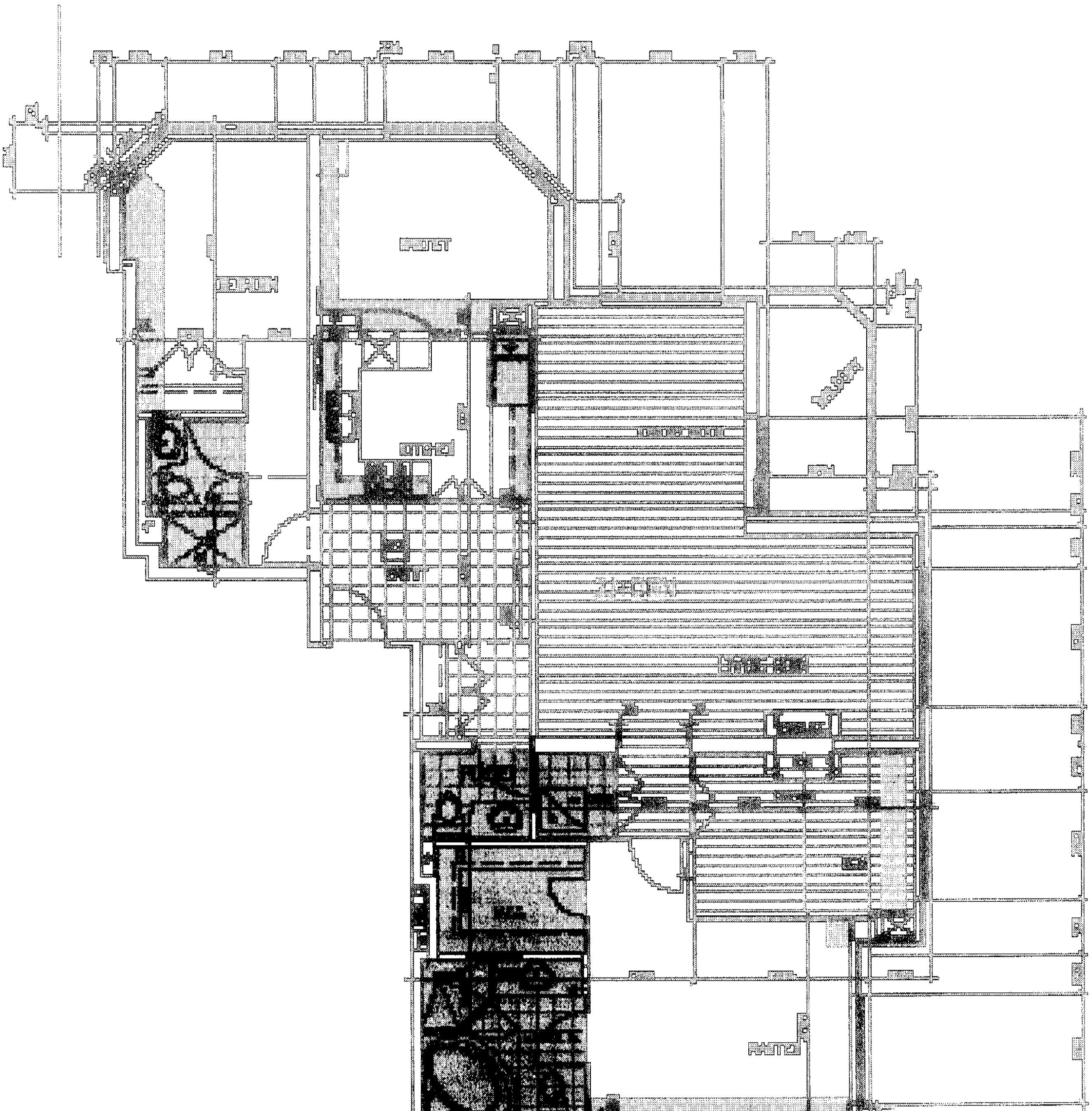
Building 1
Suite 303



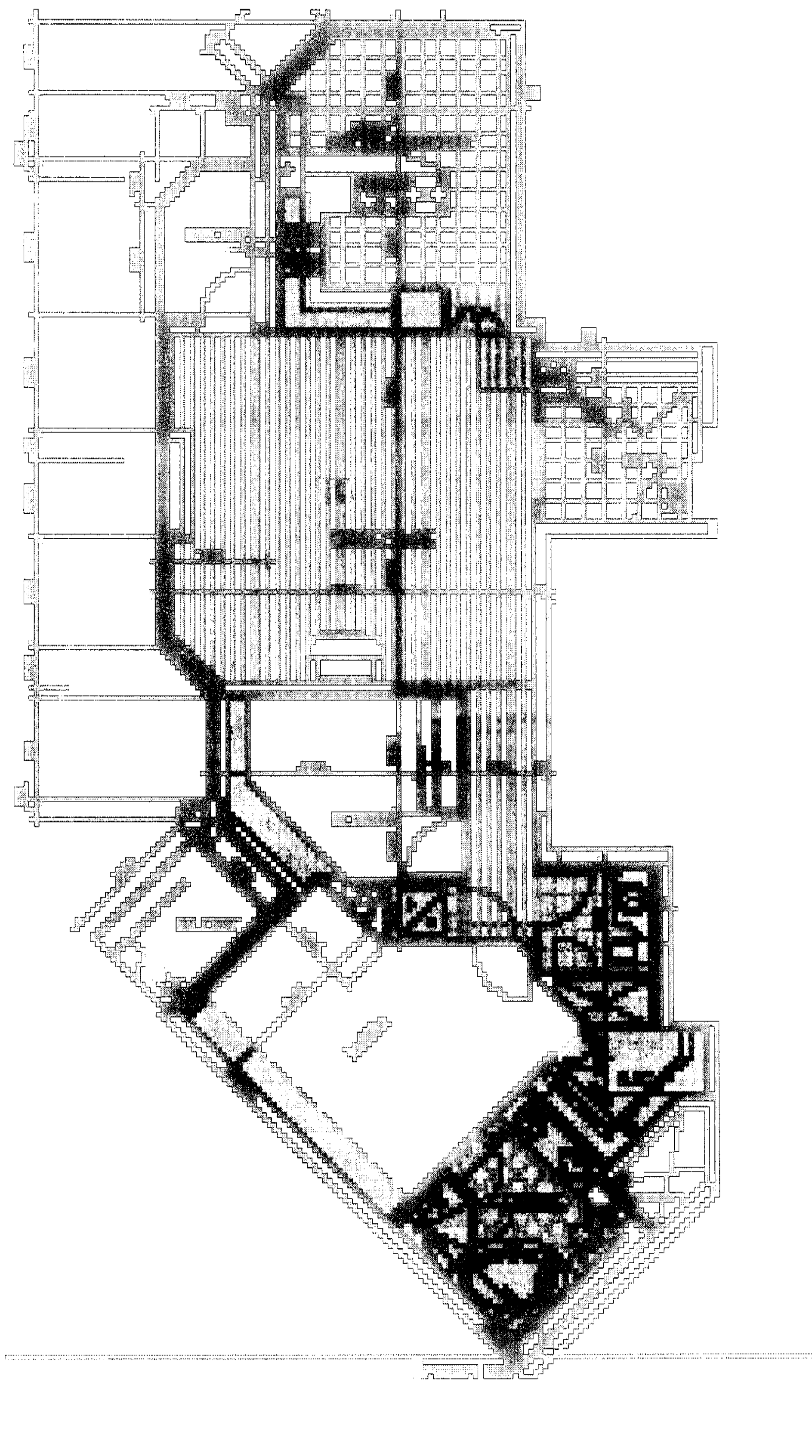
Building 1
Suite 2401



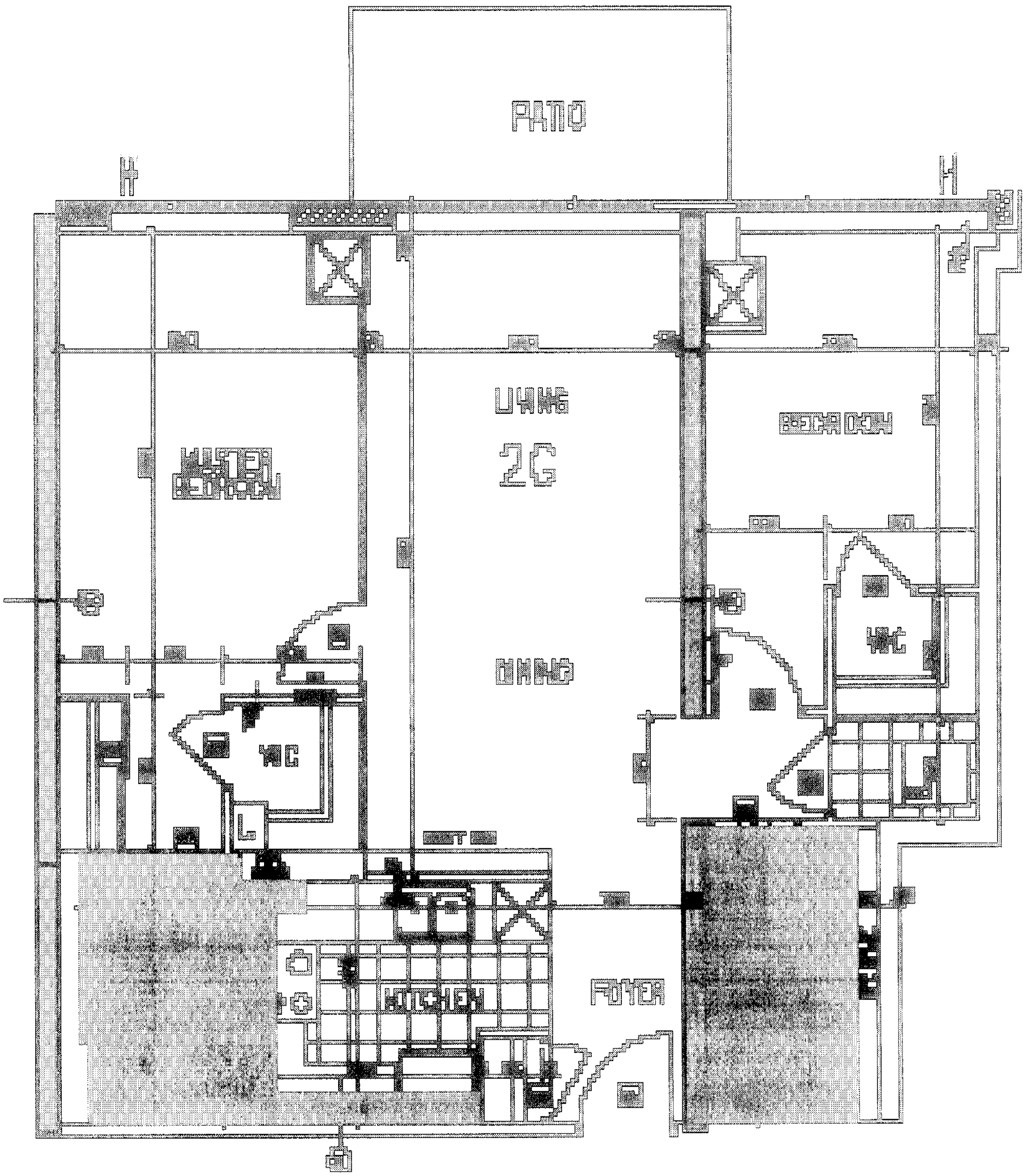
Building 1
Suite 2402



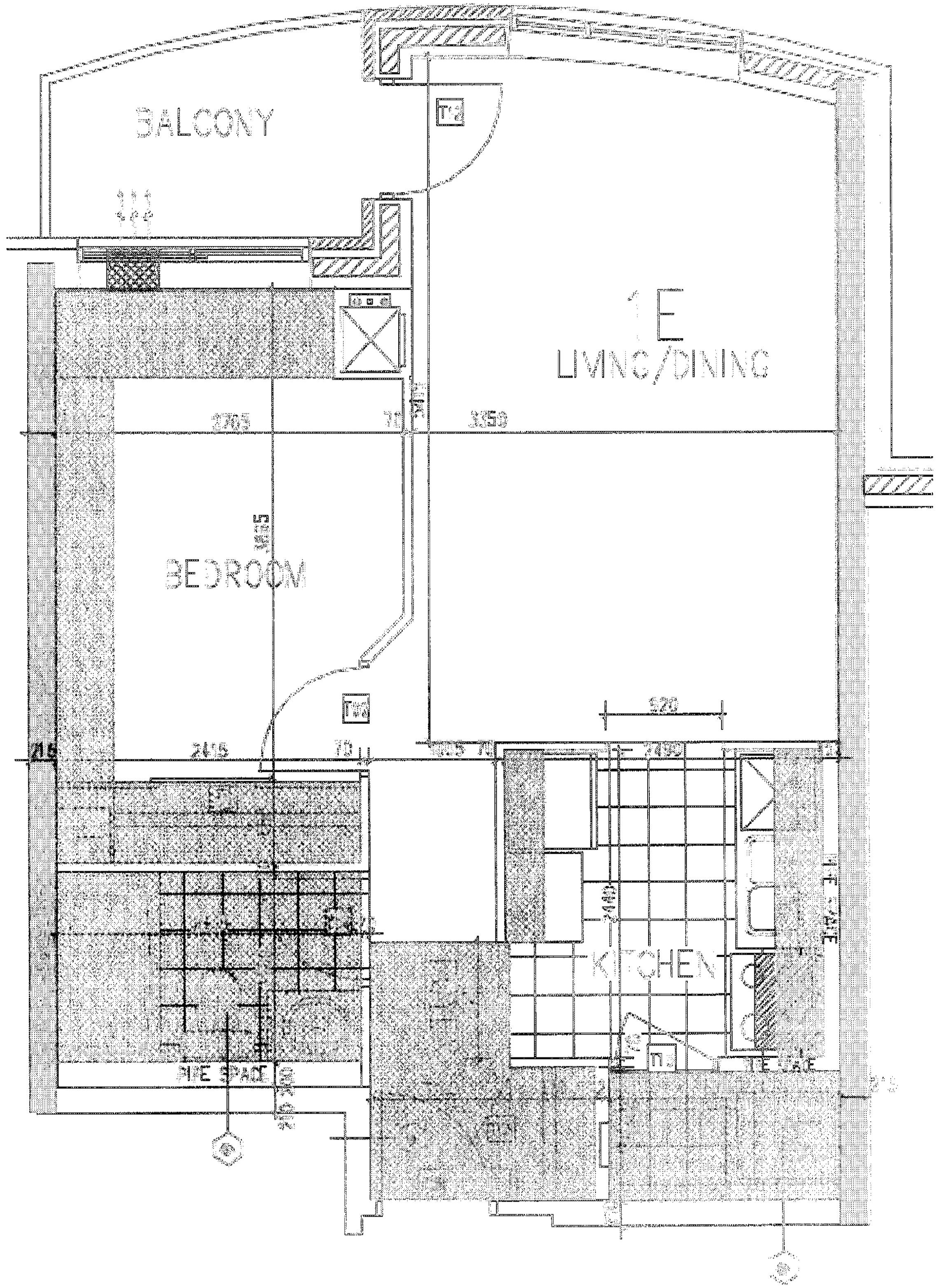
Building 1
Suite 2502



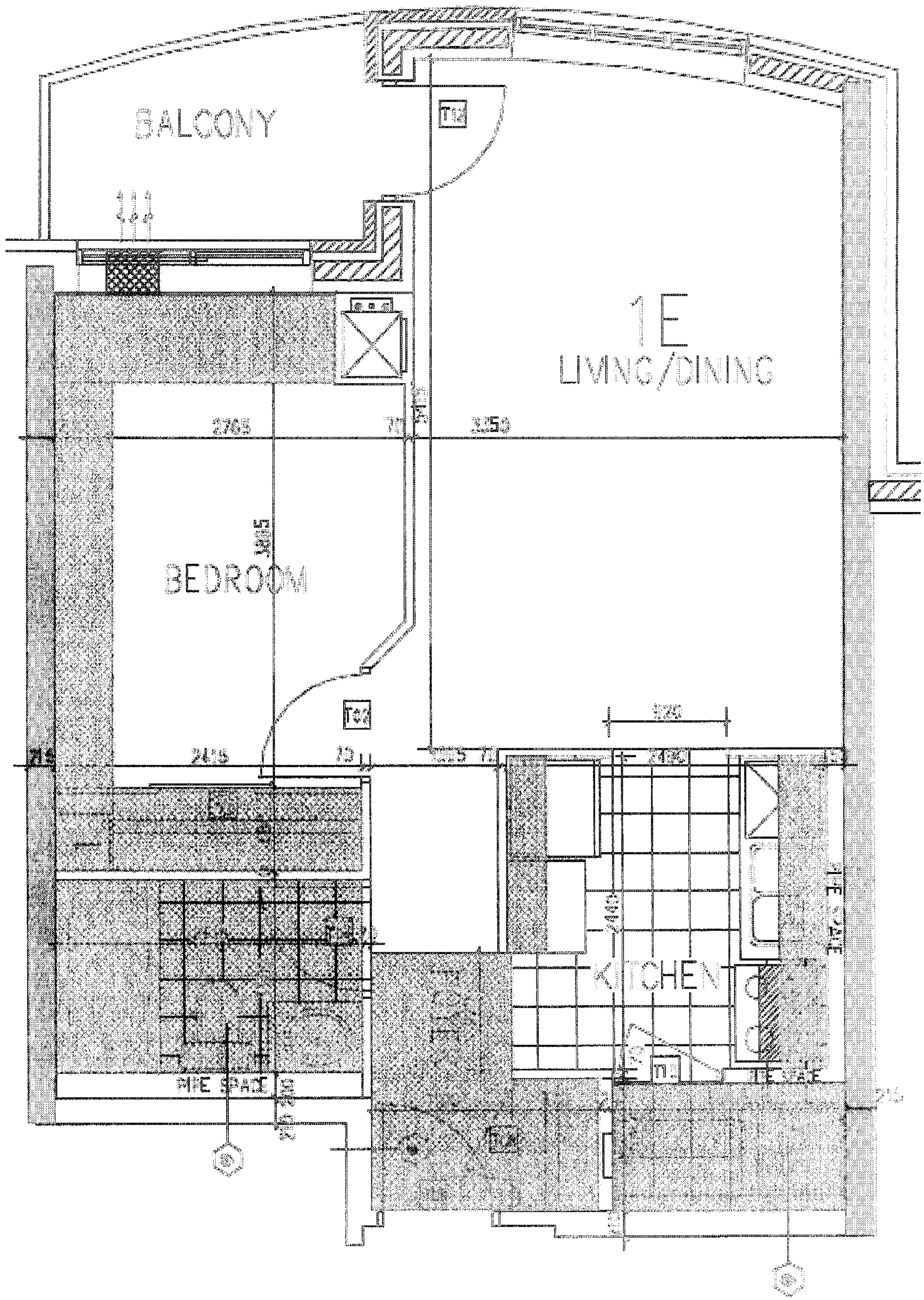
Building 2
Suite 114



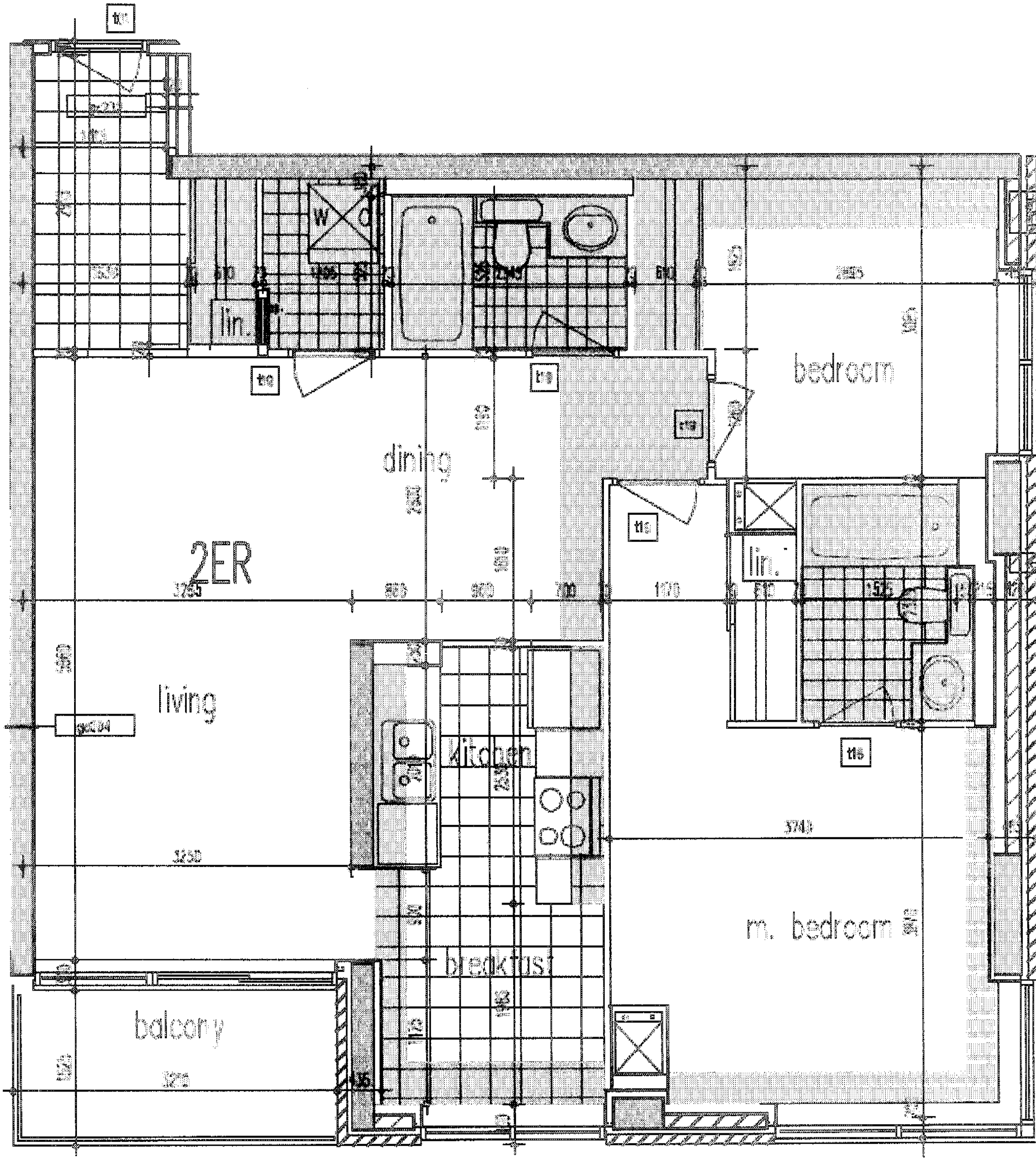
Building 2
Suite 1006



Building 2
Suite 1506



Building 3
Suite 1913



C : Air Tightness Test Reports

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Oct. 27 / 03
Test File: Tridel Avondale Suite 303

Technician: Gord Cooke

Customer: Tridel

Toronto,
Phone

Building Address: Avondale Towers
Suite 303
North York, Ontario

Test Results

1. Airflow at 50 Pascals: (50 Pa = 0.2 w.c.)
   169 CFM (+/- 1.7 %)
   1.23 ACH

2. Leakage Areas:
   11.5 in2 (+/- 6.4 %) Canadian EqLA @ 10 Pa
   4.8 in2 (+/- 9.1 %) LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve:
   Flow Coefficient (C) = 4.8 (+/- 13.2 %)
   Exponent (n) = 0.912 (+/- 0.030)
   Correlation Coefficient = 0.99635

5. Test Settings:
   Test Standard = CGSB
   Test Mode = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

Date of Test: Oct. 27 / 03 Test File: Tridel Avondale Suite 303

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
14.0	n/a					+/- 0.00
-90.0	62.0	326	323	-1.6	Ring 1	
-85.0	58.5	317	314	-0.0	Ring 1	
-80.0	54.0	304	301	0.7	Ring 1	
-75.0	49.5	291	289	1.4	Ring 1	
-70.0	44.2	275	273	1.0	Ring 1	
-65.0	39.3	260	257	0.8	Ring 1	
-60.0	33.2	239	236	-1.6	Ring 1	
-55.0	30.5	229	227	0.5	Ring 1	
-50.0	25.4	209	207	-1.7	Ring 1	
13.0	n/a					+/- 0.00

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Oct. 27 / 03
Test File: Tridel Avondale Suite 2401

Technician: Gord Cooke

Customer: Tridel

Toronto;
Phone

Building Address: Avondale Towers
Suite 2401
North York, Ontario

Test Results

1. Airflow at 50 Pascals: 603 CFM (+/- 0.4 %)
   (50 Pa = 0.2 w.c.) 3.12 ACH

2. Leakage Areas: 63.1 in2 (+/- 2.9 %) Canadian EqLA @ 10 Pa
   33.8 in2 (+/- 4.3 %) LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve: Flow Coefficient (C) = 49.0 (+/- 6.5 %)
   Exponent (n) = 0.641 (+/- 0.016)
   Correlation Coefficient = 0.99881

5. Test Settings: Test Standard = CGSB
   Test Mode = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

Date of Test: Oct. 27 / 03 Test File: Tridel Avondale Suite 2401

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
0.5	n/a					+/- 0.00
-75.0	53.0	790	782	0.1	Open	
-70.0	48.0	752	745	-0.4	Open	
-65.0	44.0	720	713	-0.0	Open	
-60.0	40.0	686	680	0.3	Open	
-55.0	36.0	651	645	0.7	Open	
-50.0	31.0	604	598	-0.7	Open	
-0.5	n/a					+/- 0.00

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Oct. 27 / 03
Test File: Tridel Avondale Suite 2402

Technician: Gord Cooke

Customer: Tridel

Toronto,
Phone

Building Address: Avondale Towers
Suite 2402
North York, Ontario

Test Results

1. Airflow at 50 Pascals: (50 Pa = 0.2 w.c.)
   598 CFM (+/- 0.7 %)
   2.52 ACH

2. Leakage Areas:
   70.8 in2 (+/- 5.3 %) Canadian EqLA @ 10 Pa
   40.7 in2 (+/- 8.0 %) LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve:
   Flow Coefficient (C) = 65.6 (+/- 12.1 %)
   Exponent (n) = 0.565 (+/- 0.030)
   Correlation Coefficient = 0.99455

5. Test Settings:
   Test Standard = CGSB
   Test Mode = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

Date of Test: Oct. 27 / 03 Test File: Tridel Avondale Suite 2402

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
-3.3	n/a					+/-.0.00
-75.0	46.6	741	734	0.0	Open	
-70.0	43.8	718	711	1.0	Open	
-65.0	38.8	676	669	-0.7	Open	
-60.0	34.7	639	633	-1.5	Open	
-55.0	32.7	620	615	0.7	Open	
-50.0	29.0	584	579	0.4	Open	
-3.0	n/a					+/- 0.00

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Oct. 27 / 03
Test File: Tridel Avondale Suite 2502

Technician: Gord Cooke

Customer: Tridel

Toronto,
Phone

Building Address: Avondale Towers
Suite 2502
North York, Ontario

Test Results

1. Airflow at 50 Pascals: (50 Pa = 0.2 w.c.) — 282 CFM (+/- 0.5 %)
   1.19 ACH

2. Leakage Areas: — 42.2 in2 (+/- 3.7 %) Canadian EqLA @ 10 Pa
   27.7 in2 (+/- 5.6 %) LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve: — Flow Coefficient (C) = 54.7 (+/- 8.4 %)
   Exponent (n) = 0.419 (+/- 0.021)
   Correlation Coefficient = 0.99522

5. Test Settings: — Test Standard = CGSB
   Test Mode = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

BUILDING LEAKAGE TEST   Page 3

Date of Test: Oct. 27 / 03 Test File: Tridel Avondale Suite 2502

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
-3.0	n/a					+/- 0.00
-75.0	64.0	331	328	0.2	Ring 1	
-70.0	60.0	321	318	0.0	Ring 1	
-65.0	55.0	307	304	-1.0	Ring 1	
-60.0	53.0	302	299	0.7	Ring 1	
-55.0	49.0	290	287	0.6	Ring 1	
-50.0	44.0	275	272	-0.5	Ring 1	
-4.0	n/a					+/- 0.00

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Oct. 28 / 03
Test File: Tridel Mondeo Suite 114

Technician: Gord Cooke

Customer: Tridel

Toronto,
Phone

Building Address: Mondeo
Suite 114
Scarborough, Ontario

Test Results

1. Airflow at 50 Pascals: (50 Pa = 0.2 w.c.) — 444 CFM (+/- 1.0 %)
   3.16 ACH

2. Leakage Areas: — 49.4 in2 (+/- 6.8 %) Canadian EqLA @ 10 Pa
   27.5 in2 (+/- 10.2 %) LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve: — Flow Coefficient (C) = 42.0 (+/- 15.2 %)
   Exponent (n) = 0.603 (+/- 0.037)
   Correlation Coefficient = 0.99274

5. Test Settings: — Test Standard = CGSB
   Test Mode = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

BUILDING LEAKAGE TEST Page 3

Date of Test: Oct. 28 / 03 Test File: Tridel Mondeo Suite 114

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
1.0	n/a					+/- 0.00
-75.0	196.0	580	574	0.6	Ring 1	
-70.0	174.0	546	541	-1.3	Ring 1	
-65.0	167.0	535	530	1.1	Ring 1	
-61.0	148.0	504	499	-1.2	Ring 1	
-55.0	137.0	485	480	1.1	Ring 1	
-49.0	116.0	446	442	-0.4	Ring 1	
1.0	n/a					+/- 0.00

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Oct. 28 / 03
Test File: Tridel Mondeo Suite 1006

Technician: Gord Cooke

Customer: Tridel
Toronto,
Phone

Building Address: Mondeo
Suite 1006
Scarborough, Ontario

Test Results

1. Airflow at 50 Pascals: (50 Pa = 0.2 w.c.)
   207 CFM (+/- 1.2 %)
   2.62 ACH

2. Leakage Areas:
   21.5 in2 (+/- 7.8 %) Canadian EqLA @ 10 Pa
   11.5 in2 (+/- 11.6 %) LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve:
   Flow Coefficient (C) = 16.6 (+/- 17.4 %)
   Exponent (n) = 0.644 (+/- 0.042)
   Correlation Coefficient = 0.98774

5. Test Settings:
   Test Standard = CGSB
   Test Mode = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

Date of Test: Oct. 28 / 03 Test File: Tridel Mondeo Suite 1006

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
3.0	n/a					+/- 0.00
-75.0	310.0	278	276	0.6	Ring 2	
-70.0	283.0	266	263	0.3	Ring 2	
-68.0	260.0	255	252	-2.1	Ring 2	
-65.0	255.0	252	250	-0.3	Ring 2	
-60.0	244.0	247	244	2.5	Ring 2	
-57.0	215.0	232	229	-0.7	Ring 2	
-55.0	207.0	227	225	-0.4	Ring 2	
-50.0	185.0	215	213	-0.1	Ring 2	
2.0	n/a					+/- 0.00

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Oct. 28 / 03
Test File: Tridel Mondeo Suite 1506 Door taped

Technician: Gord Cooke

Customer: Tridel

Toronto,
Phone

Building Address: Mondeo
Suite 1506 Door Taped
Scarborough, Ontario

Test Results

1. Airflow at 50 Pascals: (50 Pa = 0.2 w.c.) — 168 CFM (+/- 1.4 %) 2.13 ACH

2. Leakage Areas: 22.4 in2 (+/- 7.7 %) Canadian EqLA @ 10 Pa
   13.8 in2 (+/- 11.3 %) LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve: Flow Coefficient (C) = 24.6 (+/- 16.7 %)
   Exponent (n) = 0.491 (+/- 0.039)
   Correlation Coefficient = 0.99054

5. Test Settings: Test Standard = CGSB
   Test Mode = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

BUILDING LEAKAGE TEST   Page 3

Date of Test: Oct. 28 / 03 Test File: Tridel Mondeo Suite 1506 Door taped

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
5.0	n/a					+/- 0.00
-75.0	182.0	213	211	-0.2	Ring 2	
-70.0	170.0	206	204	-0.4	Ring 2	
-65.0	162.0	201	199	0.6	Ring 2	
-60.0	152.0	195	193	1.0	Ring 2	
-55.0	135.0	184	182	-1.0	Ring 2	
5.0	n/a					+/- 0.00

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Nov. 28 / 03
Test File: Tridel Strathaven Suite 1913

Technician: Gord Cooke

Customer: Tridel

Toronto,
Phone

Building Address: Strathaven
Suite 1913 - door not weatherstripped
Mississauga, Ontario

Test Results

1. Airflow at 50 Pascals: 332 CFM
   (50 Pa = 0.2 w.c.) 2.45 ACH

2. Leakage Areas: 34.3 in2 Canadian EqLA @ 10 Pa
   18.2 in2 LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve: Flow Coefficient (C) = 26.1
   Exponent (n) = 0.650 (Assumed)

5. Test Settings: Test Standard: = CGSB
   Test Mode: = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

BUILDING LEAKAGE TEST Page 3

Date of Test: Nov. 28 / 03 Test File: Tridel Strathaven Suite 1913

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
0.0	n/a					+/- 0.00
-70.0	105.0	424	413	0.0	Ring 1	

BUILDING LEAKAGE TEST

Air Solutions Inc.
44 Darren Cresent
Cambridge, Ontario N3C 3Y1
Phone: 519-658-6232
Fax: 519-658-6103

Date of Test: Nov. 28 / 03 Technician: Gord Cooke
Test File: Tridel Strathaven Suite 1913 Door Weatherstripped

Customer: Tridel

Toronto,
Phone

Building Address: Strathaven
Suite 1913 - weatherstripped
Mississauga, Ontario

Test Results

1. Airflow at 50 Pascals: 195 CFM
   (50 Pa = 0.2 w.c.) 1.44 ACH

2. Leakage Areas: 20.1 in2 Canadian EqLA @ 10 Pa
   10.7 in2 LBL ELA @ 4 Pa

3. Minneapolis Leakage Ratio:

4. Building Leakage Curve: Flow Coefficient (C) = 15.3
   Exponent (n) = 0.650 (Assumed)

5. Test Settings: Test Standard: = CGSB
   Test Mode: = Depressurization
   Equipment = Series B Minneapolis Duct Blaster

Infiltration Estimates

1. Estimated Average Annual Infiltration Rate:

2. Estimated Design Infiltration Rate:

3. Recommended Minimum Ventilation Guideline:

Cost Estimates

1. Estimated Cost of Air Leakage for Heating:

2. Estimated Cost of Air Leakage for Cooling:

BUILDING LEAKAGE TEST Page 3

Date of Test: Nov. 28 / 03 Test File: Tridel Strathaven Suite 1913 Door Weatherstripped

Data Points: Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow	Temperature Adjusted Flow	% Error	Fan Configuration	Baseline Std Dev (Pa)
0.0	n/a					+/- 0.00
-70.0	36.0	249	242	0.0	Ring 1	

D : Specifications for Exhaust Equipment

Tag: Fan type J Double Bathroom Exhaust Fan

XL SERIES

REVIEWED AS NOTED

REVISE & RESUBMIT

REJECTED

AS SPECIFIED

of the submitted data is for general performance only solely on the information provided by the manu ... Any variations from the Contract documents and field conditions such as dimensions, arrangements, locations, sizes ... levels, etc. to ensure conformance with allotted clearances, intended uses, other trades, etc the responsibility of the Trade.

A & G ENGINEERING LTD. Consulting Engineers
3601 Victoria Park Ave., Suite #
Scarborough, Ontario M1W 3Y3

SIGNED

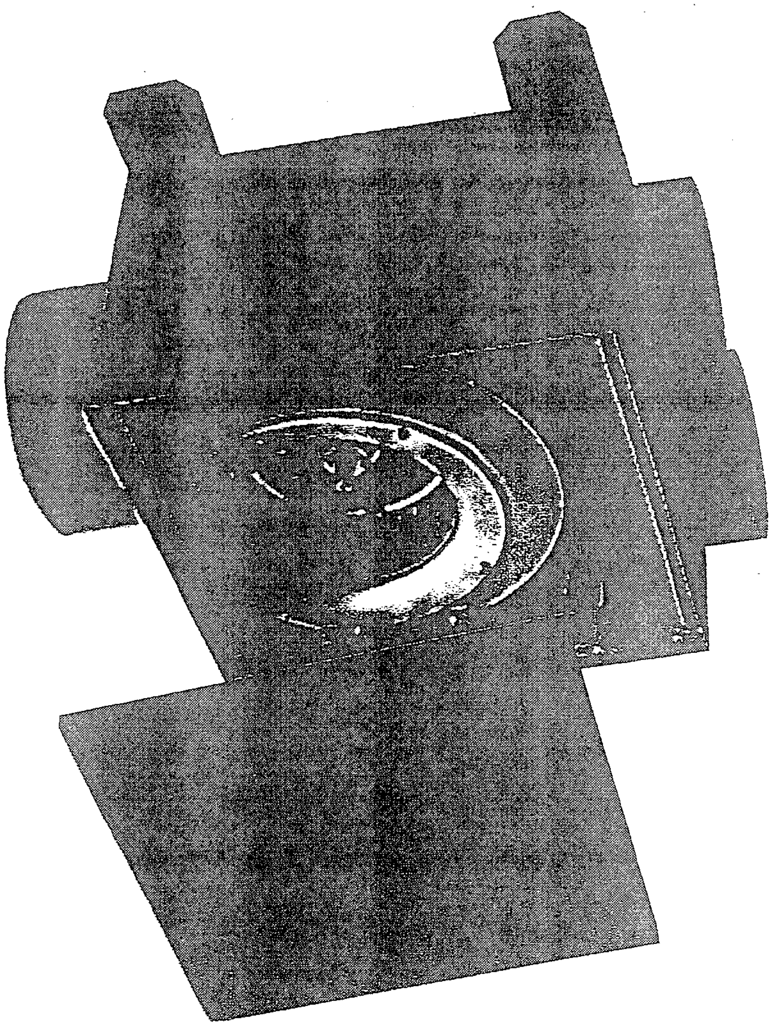
1/18/02

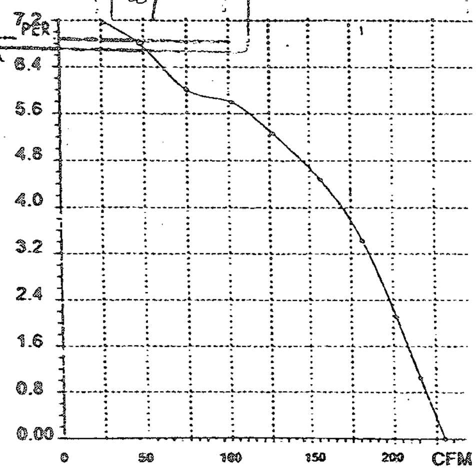
Models: SMP 260
SMP 350

TESTED / CERTIFIED

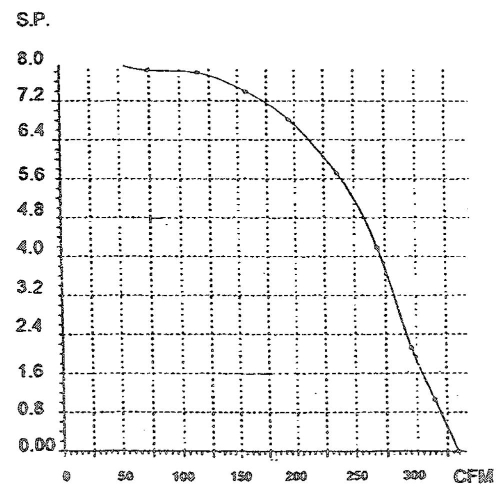
HOME VENTILATING INSTITUTE
DIVISION OF AMCA

SMP UNIVERSAL EXHAUST SYSTEM WAS DESIGNED TO MOVE LARGE VOLUMES OF AIR UNDER SEVERE STATIC PRESSURE CONDITIONS. ITS HOUSING CONSISTS OF HEAVY DUTY INSULATED SATIN COAT GALVANIZED STEEL FINISH, WHICH SUCCESSFULLY LOWERS SONE LEVELS. THIS FAN FEATURES A COMPACT HOUSING AND IS ONLY 8" HIGH (Model SMP 260) or 9" (Model SMP 350) WHICH SIMPLIFIES INSTALLATION IN THOSE TIGHT CEILING SPACES.





SMP 260 FAN



SMP 350 FAN

Reversomatic Htg. & Mfg. Ltd.
790 ROWNTREE DAIRY ROAD • WOODBRIDGE, ONTARIO, CANADA L4L 5V3 • PHONE (905) 851-6701 • FAX (905) 851-8376

SMP260, SMP 350

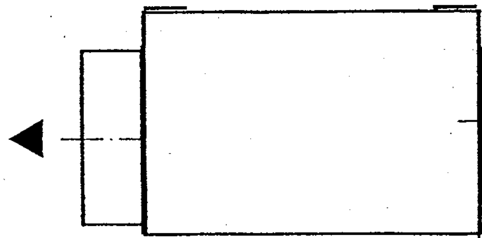
REVIEWED
REVIEWED AS NOTED
REVISE & RESUBMIT
REJECTED
SUBMIT AS SPECIFIED

Review of the submitted data is for general performance only and is based solely on the information provided by the manufacturer. Any variations from the Contract documents and site conditions such as dimensions, arrangements, locations, quantities, noise levels, etc. to ensure conformance with allotted spaces required clearances, intended uses, other trades etc. shall be the responsibility of the Trade.

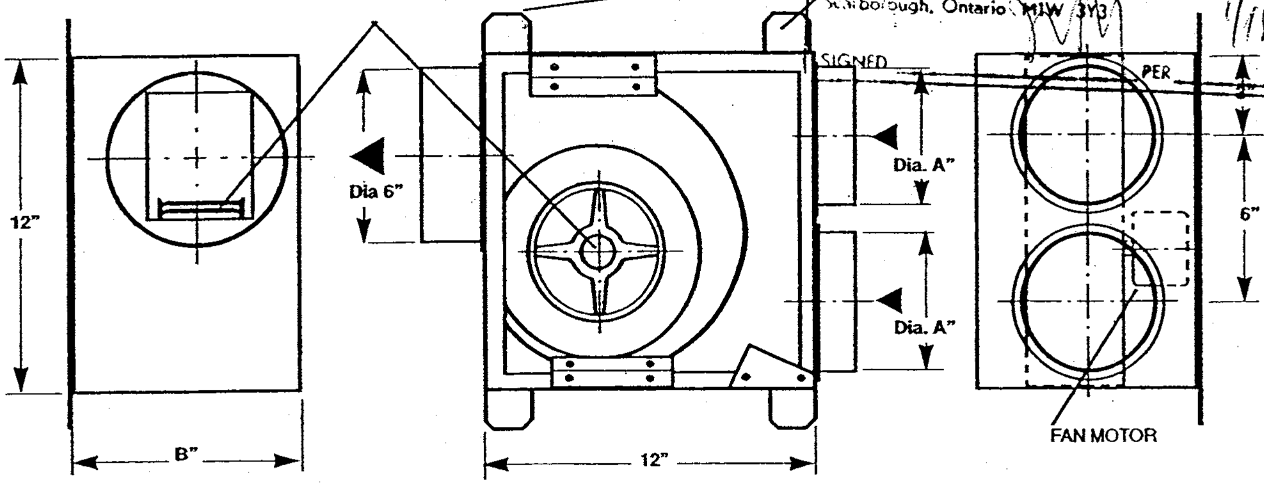
A & G ENGINEERING LTD. Consulting Engineers
3301 Victoria Park Ave., Suite # 406
Scarborough, Ontario M1W 3Y3

SIGNED PER

Model	A	B
SMP 260	5"	8"
SMP 350	6"	9"



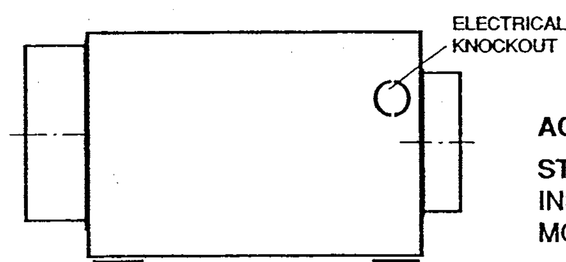
SIDE VIEW



SIDE VIEW

FRONT VIEW WITHOUT COVER PLATE

SIDE VIEW



SIDE VIEW

ACCESSORIES

STANDARD
INSULATED CABINET
MOUNTING BRACKETS

OPTIONAL
BALANCE BOX

FAN DATA

FAN MODEL	MOTOR 120 VAC 60 Hz			CUBIC FEET PER MINUTE											
	RPM	AMPS	HP	S.P.	.0	.05	.10	.15	.20	.30	.40	.50	.60	.70	.80
SMP 260	1550	1.3	1/25	CFM	230	220	215	210	205	190	170	140	100	40	
SMP 350	1550	2.7	1/10	CFM	335	325	315	305	295	280	270	255	230	210	45

RPM (Revolutions per minute) shown in nominal and performance is based on actual speed of test.
Unit was tested with inlet grille, backdraft damper and outlet duct.

Tag: Fan Type J Qty 156 Reversomatic Model SMP260 200 cfm @ .25" SP 1550 RPM 1.3 AMPS 120/1/60

CONTRACTOR Cooltech Air Systems		SMP 260, SMP350 FAN DETAIL	
ARCHITECT	JOB Skymark @ Avondale	DATE / SUPERSEDES / DRAWING NO.	
ENGINEER A&G Enginnering	DATE SUBMITTED January 7, 2002	REVERSOMATIC Heating & Mfg. Ltd Toronto, Ontario	

C US

Tag: Fan Type G Single Bathroom Fan

REVIEWED	✓
REVIEWED AS NOTED	
REVISE & RESUBMIT	
REJECTED	

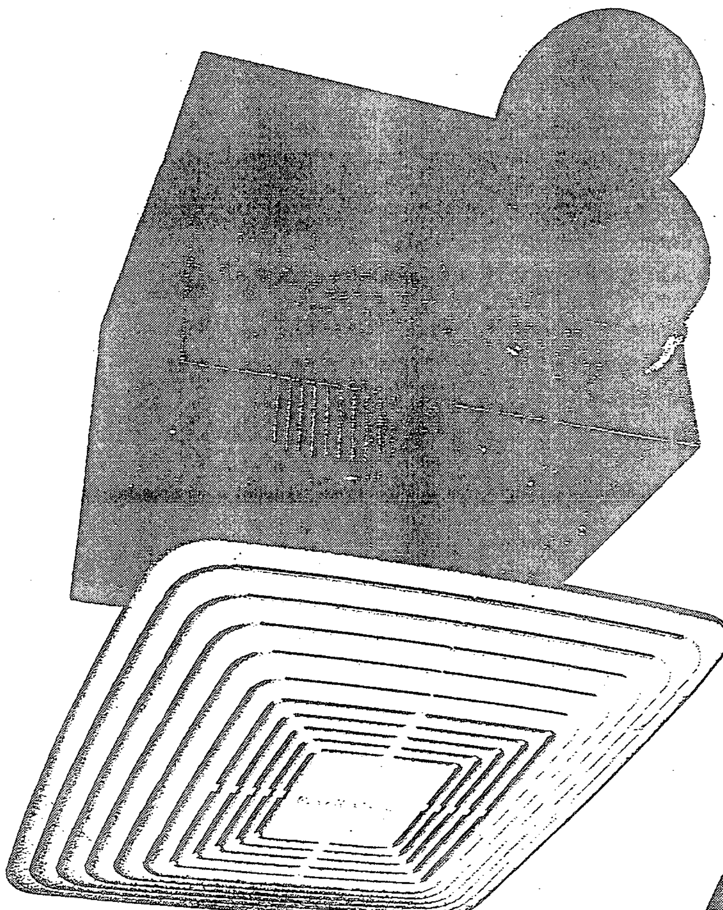
...only and is based solely on the information provided by the manufacturer. Any variations from the Contract documents and field conditions such as dimensions, arrangements, locations, sizes, quantities, noise levels, etc. to ensure conformance with allotted spaces required clearances, intended uses, other trades. etc shall be the responsibility of the Trade.

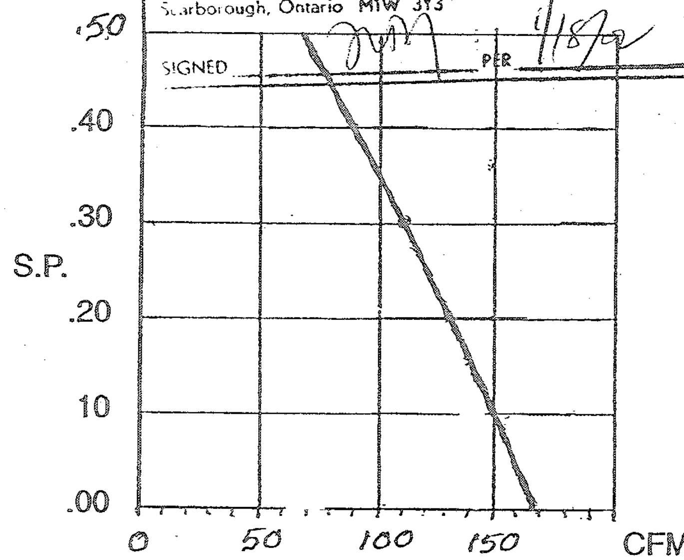
A & G ENGINEERING LTD. Consulting Engineers
3601 Victoria Park Ave., Suite # 406
Scarborough, Ontario M1W 3Y3

SIGNED ________ PER ________ 1/18/0?

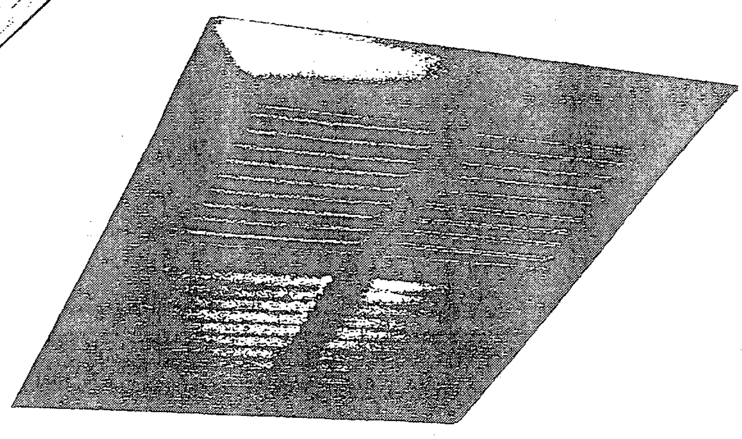
CF-170 ULTRA SUPER QUIET EXHAUST FAN 1.5 SONES

THE CF-170 FAN IS DESIGNED FOR HI PERFORMANCE AND QUIET OPERATION. THIS FAN IS EQUIPPED WITH ESPECIALLY DESIGNED MOUNTING SLOTS THAT ALLOW FOR EASY INSTALLATION ON CONCRETE CEILING OR WOODEN JOISTS. THE CF-170 IS CONSTRUCTED WITH CORROSION RESISTANT, HEAVY GAUGE SATIN COAT STEEL.





WHITE HIGH IMPACT STYRENE GRILLE



OFF WHITE ALUMINUM GRILLE

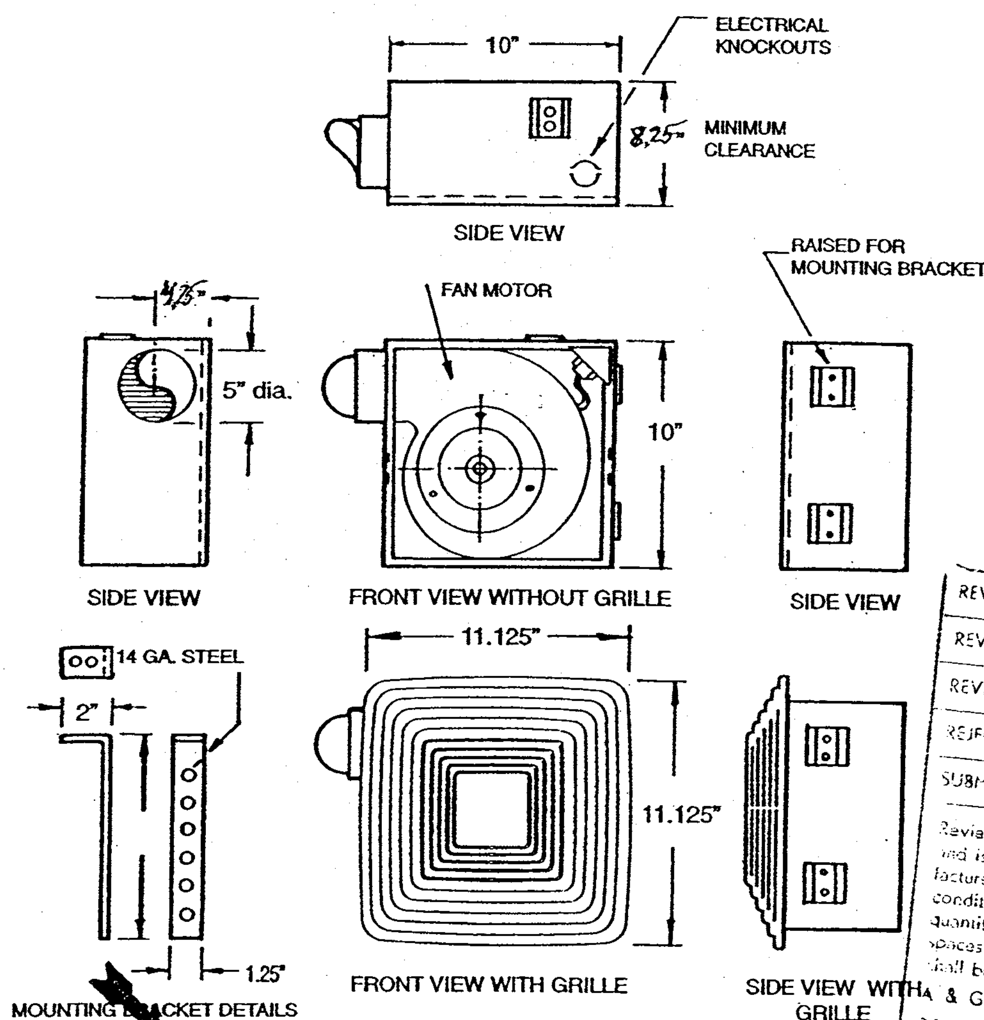
TESTED/CERTIFIED

HOME VENTILATING INSTITUTE
DIVISION OF AMCA

JULY 2001

Reversomatic Manufacturing Ltd.
790 ROWNTREE DAIRY ROAD ▪ WOODBRIDGE, ONTARIO, CANADA L4L 5V3 ▪ PHONE (905) 851-6701 ▪ FAX (905) 851-8376

CF-170 EXHAUST FAN



ACCESSORIES

STANDARD

INSULATED HOUSING
WHITE GRILLE
DAMPER
MOUNTING BRACKETS
ALUMINUM OR
STYRENE GRILLE

OPTIONAL

VARIABLE SPEED
CONTROL
ALUMINUM BACK
DRAFT DAMPER

REVIEWED

REVIEWED AS NOTED ✓

REVISE & RESUBMIT

REJECTED

SUBMIT AS SPECIFIED

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A & G ENGINEERING LTD. Consulting Engineers
3601 Victoria Park Ave., Suite # 406
Scarborough, Ontario M1W 3Y3

SIGNED JM PER 1/18/02

Tag: Fan Type G Qty 244 Reversomatic Model CF170 110 cfm @ .3" SP
1400 RPM .7 AMPS 120/1/60

FAN DATA

FAN MODEL	MOTOR 120 VAC 60 Hz			CUBIC FEET PER MINUTE								
	RPM	AMPS	HP	S.P.	.0	.05	.10	.15	.20	.25	.30	.40
CF 170	1400	0.7	1/75	CFM	167	158	150	142	132	120	110	90

RPM (Revolutions per minute) shown is nominal and performance is based on actual speed of test.
Unit was tested with inlet grille, backdraft damper and outlet duct.

SOUND RATING

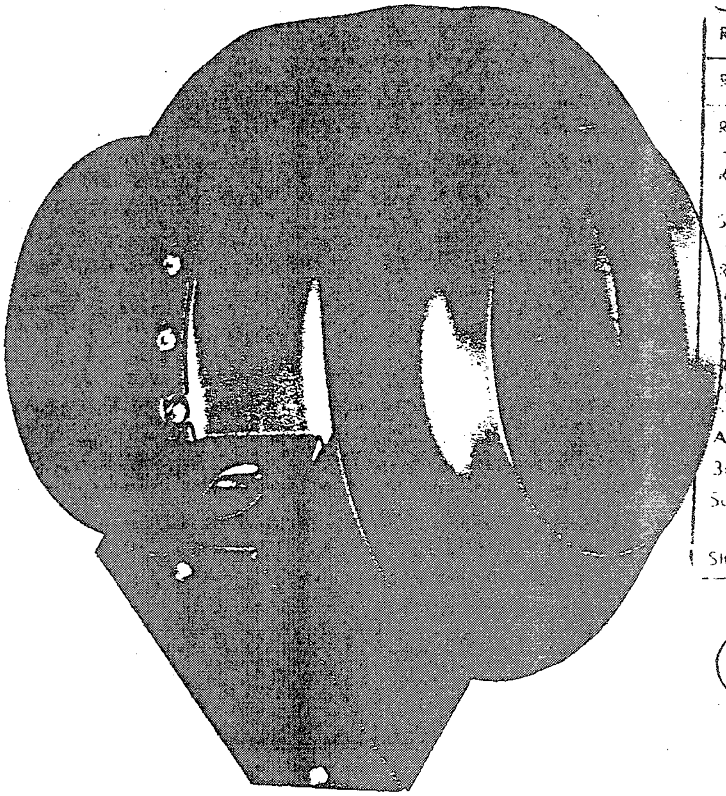
OCTAVE	1	2	3	4	5	6	7	8
CENTRE FREQUENCY Hz.	63	125	250	500	1000	2000	4000	8000
FULL-OCTAVE BAND SOUND PRESSURE LEVEL (dB)								

HVI CERTIFIED RATING 1.7 SONE

CONTRACTOR Cooltech Air Systems		CF-170 FAN DETAIL		
ARCHITECT	JOB Skymark @ Avondale	DATE	SUPERSEDES	DRAWING NO.
ENGINEER A&G Engineering	DATE SUBMITTED January 7, 2002	REVERSOMATIC Manufacturing Ltd Toronto, Ontario		

Tag: Fan Type H Dryer Exhaust Fan

RI SERIES
GENERAL PURPOSE EXHAUST FANS



REVIEWED
REVIEWED AS NOTED
REVISE & RESUBMIT
REJECTED
SUBMIT AS SPECIFIED

NRTL/C

Review of the ... performance only and is based sol... provided by the manufacturer. Any va... Co... documents and field conditions such as dimensions, arrangements, locations, sizes, quantities, noise levels, etc. to ensure conformance with allotted spaces required clearances, intended uses, other trades, etc. shall be the responsibility of the Trade.

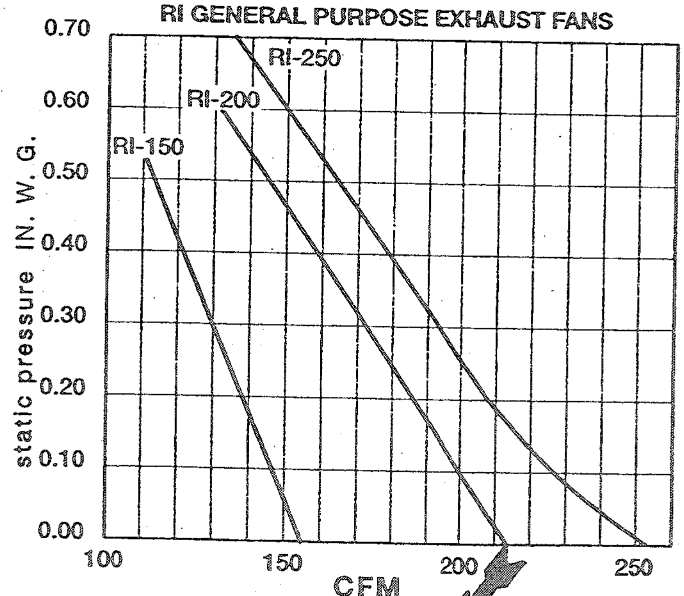
A & G ENGINEERING LTD. Consulting Engineers
3601 Victoria Park Ave., Suite # 406
Scarborough, Ontario M1W 3Y3

SIGNED ______ PER ______

SUBMIT
7LD 200

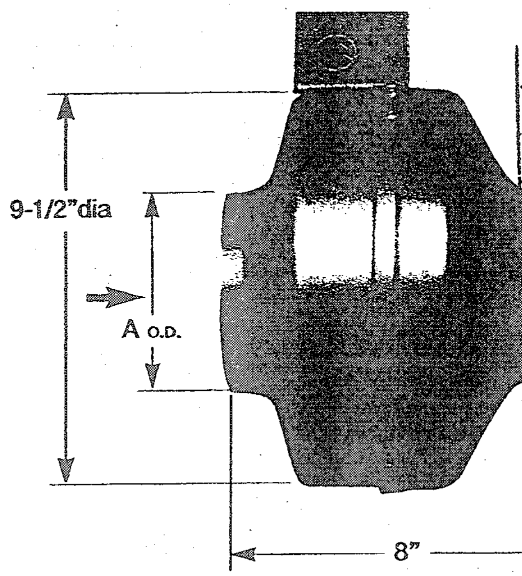
- Engineered to provide effective and reliable operation making it perfect for general purpose ventilation.
- Low profile construction for ease of installation in confined spaces.
- Built with a well balanced air over motor impeller assembly, and a backward inclined wheel for smooth quiet operation.
- High efficiency motor. Available for 4", 5" and 6" duct sizes.
- Fan housing constructed of heavy gauge satin coat steel with baked enemal finish.
- Suitable for use in Hi-rise condominium, office buildings, schools, boardrooms or where high volume quiet ventilation is required.

TECHNICAL DATA
RI GENERAL PURPOSE EXHAUST FANS



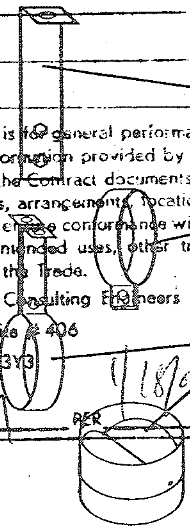
Model	RI-150	RI-200	RI-250
Sound level	2.2 sones	2.5 sones	2.7 sones

REVERSOMATIC HTG. & MFG. LTD
790 ROWNTREE DAIRY ROAD • WOODBRIDGE, ONTARIO, CANADA L4L 5V3 • PHONE (905) 851-6701 • FAX 905 (905) 851-8376



Model	RI-150	RI-200	RI-250
A	3-7/8"	4-7/8"	5-7/8"

REVIEWED
REVIEWED AS NOTED
REVISE & RESUBMIT
...ED
...T AS SPECIFIED
...w of the submitted data is for general performance only, ... based solely on the information provided by the manu...er. Any variations from the Contract documents ...tions such as dimensions, arrangements, locations, sizes, quantities, noise levels, etc. to ensure conformance with allotted spaces required clearances, intended uses, other trades, etc shall be the responsibility of the Trade.
A & G ENGINEERING LTD. Consulting Engineers
3501 Victoria Park Ave., Suite # 406
Scarborough, Ontario M1W 3Y3
SIGNED ______ PER ______ 1/18/02



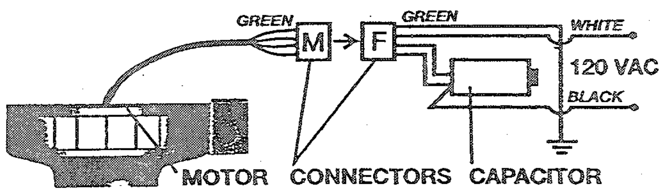
STANDARD ACCESSORIES:

1. Mounting Bracket, galvanized steel, for wall or truss mounting.

OPTIONAL ACCESSORIES:

2. Mounting Clamps for use with rigid duct, complete with foam rubber insulation
3. Suspension bracket
4. Backdraft Damper w/butterfly valve, to prevent cold air from entering when fan is not in use

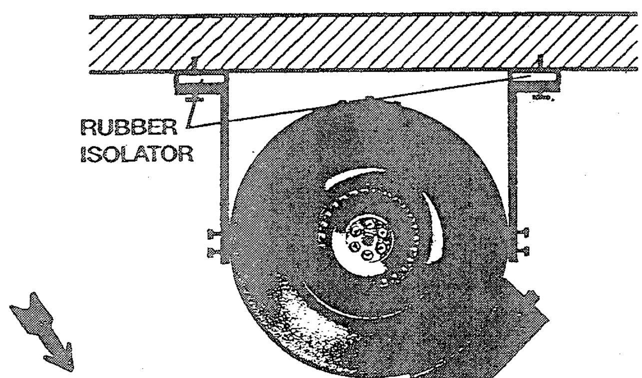
ELECTRICAL CONNECTION



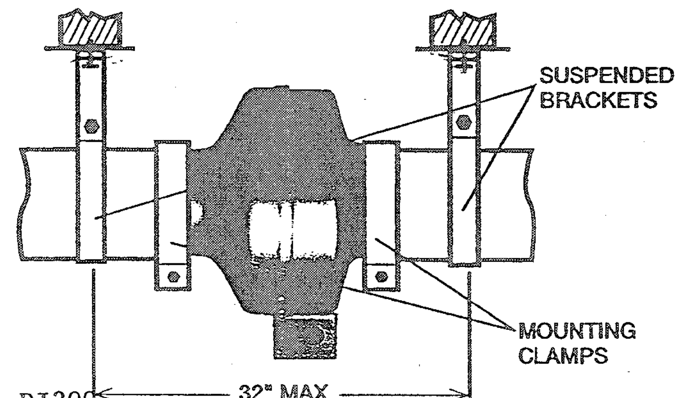
FAN MOTOR RATINGS (all models)
: 120V, 0.7A, 2500 RPM, 8µf

INSTALLATION INSTRUCTIONS

TRUSS OR CONCRETE SLAB



SUSPENDED INSTALLATION



Tag: Fan Type H Qty 333 Reversoamtic Model RI200
159 cfm @ .4" SP 2500 RPM .7 AMPS 120/1/60

PERFORMANCE CHART

MODEL	CUBIC FEET PER MINUTE (CFM) AT STATIC PRESSURE										
	0,00	0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.60	0.70
RI-150	156	152	148	144	140	136	132	125	-	-	-
R1-200	214	205	198	192	186	180	173	159	146	133	-
R1-250	252	239	227	216	208	201	194	180	165	150	133

CONTRACTOR Cooltech Air Systems		RI FAN DETAIL		
ARCHITECT	JOB Skymark @ Avondale	DATE	SUPERSEDES	DRAWING NO.
ENGINEER A&G Engineering	DATE SUBMITTED January 7, 2002	REVERSOMATIC Heating & Mfg. Ltd Toronto, Ontario		

E: Balancing Report for Corridor Make-Up Air System at Building

AIR DEFLECTION INC.

OUTLET CAPACITY READING SHEET

AB AIR BOOT
DT DUCT TRAVERSE
D DIFFUSER
G GRILLE

L LINEAR DIF.
O OPENING
R REGISTER
T TROFFER

DESIGNED DATA								CALCULATED DATA			TESTING DATA				FINAL	
FL.	ROOM No.	ROOM NAME	No.	SIZE		CAPACITY L/s	CAPACITY CFM	AREA SQ F.T.	FPM	V.P. or S.P. Pressure	V.P. Pressure	S.P. Pressure	L/s	m^3/s	FPM	CFM
29		CORRIDOR	1	18x18"	G		394	1.46							270	394
28			2	18x18"			394	1.46							280	408
27			3	22x22"			606	2.18							280	610
26			4												270	588
25			5												280	610
24			6												280	610
23			7												270	588
22			8	22x22"			606	2.18							280	610
21			9	30x30"			1000	4.06							240	974
20			10												250	1015
19			11												240	974
18			12												240	974
17			13												230	933
16			14												240	974
15			15												230	933
14			16												240	974
13			17				1000								230	933
12		CORRIDOR	18	30x30"	G		1064	4.06							270	1096
		RISER #1	1-18				14488									14198

Notes

VP VELOCITY SP STATIC PRESSURE

BLDG. SKYMARK PH.I.

SYSTEM "A" FRESH AIR UNIT

DATE NOV/03.

AIR DEFLECTION INC.

OUTLET CAPACITY READING SHEET

AB AIR BOOT
DT DUCT TRAVERSE
D DIFFUSER
G GRILLE

L LINEAR DIF.
O OPENING
R REGISTER
T TROFFER

		DESIGNED DATA					CALCULATED DATA			TESTING DATA				FINAL	
FL.	ROOM No.	ROOM NAME	No.	SIZE	CAPACITY L/s	CAPACITY CFM	AREA SQ F.T.	FPM	V.P. or S.P. Pressure	V.P. Pressure	S.P. Pressure	L/s	m^3/s	FPM	CFM
29		CORRIDOR	1	18x18" G		394	1.46							280	408
28			2	18x18"		394	1.46							290	423
27			3	22x22"		606	2.18							270	588
26			4											280	610
25			5											270	588
24			6											270	588
23			7											280	610
22			8	22x22"		606	2.18							270	588
21			9	30x30"		1000	4.06							250	1015
20			10											240	974
19			11											250	1015
18			12											230	933
17			13											240	974
16			14											230	933
15			15											250	1015
14			16											230	933
13			17			1000								240	974
12		CORRIDOR	18	30x30" G		1064	4.06							260	1055
		RISER #2	1-18			14488									14224
		RISER #1	1-18			14488									14198
		TOTAL:		RISER #1+2		28976									28422

Notes

VP VELOCITY   SP STATIC PRESSURE

BLDG. SKYMARK PH.I.

SYSTEM "A" FRESH AIR UNIT

DATE NOV/03.