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RESEARCH REPORT

IDENTIFYING AND REMOVING POLLUTANTS FROM HEAT RECOVERY VENTILATORS

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IDENTIFYING AND REMOVING POLLUTANTS FROM HEAT RECOVERY VENTILATORS

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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 conditions in Canada. Under Part IX of the 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 publish and distribute the results of this research.

ABSTRACT

This study investigated the presence of allergens such as dust and molds in heat recovery ventilation systems and the duct work. It also looks at two different types of cleaning equipment and their ability to clean these pollutants from the rigid and flexible ductwork and heat recovery ventilator (HRV) cores in dedicated balanced supply and exhaust ventilation systems. Samples from the ductwork and cores of ten ventilation systems were tested for levels of dust and mold. The ductwork and cores were then cleaned using standard ductwork cleaning apparatus, then tested again to indicate the success of the cleaning process. All houses were tested for air and surface mold counts using an RCS air sampler and typical swab collection systems. Two of the ten houses were retested over a period of fifteen months. There were high mold counts on the surfaces of the supply air ducts. However, there was no correlation to house air mold counts, which were found to be inconclusive. It could not be determined whether airborne molds were considered a health risk in the houses as tested. It was also found that conventional equipment was not effective in cleaning the ductwork systems.

revealed that the cleaning was hit and miss. Cleaning was also affected by the size of the duct and location of ductwork. Exposed ducts should have been easier to clean but were often missed due to placement of the compressed air hose.

Time to clean the system varied depending on the number of ducts and the size of the crew cleaning the system. Three of the four companies used only one individual to perform the cleaning. Cost to clean the duct work was generally around $150.00 per house and the time to setup, clean the ductwork and tear down the equipment was from 3 to to 5 hrs. While the cleaning company crew was working on the ductwork, the consultants cleaned the filters and core of the HRV, instructing the homeowner on the procedure (if homeowner was not available, information on procedure was left at the house or forwarded at a later date).

The results of the study indicate that mold counts were high in the ductwork and cores, with consistently higher counts found in the fresh air supply duct to the HRV (typically, a length of flex duct). However, there was no correlation between the levels of the surface counts in the systems and the air samples taken in the house, which were found to be inconclusive. It could not be determined whether airborne molds were considered a health risk in the houses as tested.

The field work for this study did show that homeowners generally are not well informed on: a) what the HRV does and how to use the controls (other than on and off) and b) how to maintain the machine to optimize its performance. There were no filters on exhaust grilles in kitchens and bathrooms in most of the conventional houses. The R2000 houses had filters on exhaust grilles in kitchens, but only one house had filters in the bathroom. In general, the HRV air flows were out of balance. The air flows were balanced by the consultants at the time of site visit, after cleaning.

In recent years, the practice of recirculating exhaust air from the the house back through the HRV and into the house through the supply ductwork has become more prominent (one system with this recirculation mode (NSERP06C) was included in this study — this system also included a 'heat wheel' instead of a conventional solid core). Further study of recirculating mode HRV systems may show that these systems have a greater impact on the indoor air quality, especially if the kitchen and bathroom exhaust grilles have not been filtered.

Recommendations from the results of this study include the following points:

- HRV exterior fresh air hoods should contain a pre-filter and be accessible for cleaning

- Ductwork from the exterior fresh air hood to the HRV should be solid rather than flex duct, and should be installed in a way that the duct can be easily cleaned

- HRV ducting attachments would be easier to clean if there were a 'quick release' or other detachment method

- Pre-filtering of all exhaust grilles should be considered

- Exterior fresh air hoods should be required to be installed at a height of 120 mm (48 inches) above finished grade to ensure the intake air is above the height of outside mold spore dispersal from sources such as garden beds, lawns, bare soil under decks, etc..

- More promotion of information available to homeowners on maintaining HRV systems (NRCan's and CMHC's publications available through HRV supplier/installer operations, local CHBA offices, CMHC offices and provincial departments/agencies dealing with housing and/or energy use).

- Current duct cleaning methods are not adequate for cleaning duct work in central ventilation systems.

- Further testing of airborn mold levels in houses with central ventilation systems is indicated to ascertain that the systems are not adding to the health risk or exaberating health problems for occupants.

EXECUTIVE SUMMARY

Poor indoor air quality can support allergic reactions, viral and bacterial infections and asthma or asthma-like symptoms due to sensitization. Some factors that increase exposure to poor indoor air quality include: more airtight construction and renovation techniques (less 'natural' ventilation), a higher number (and complexity) of chemicals used in or kept in houses, and the larger amount of time which people spend indoors (up to 90% of a lifetime may be indoors) and are thus exposed to more potential sensitizers. Dedicated balanced supply and exhaust ventilation systems are now being installed to increase the quality of the indoor air. The components of these systems should be investigated for the presence of possible allergens and sensitizers and consequent production of poor indoor air quality.

The Atlantic Region has the highest number of installed balanced supply and exhaust ventilation systems per capita in Canada. In fact, Nova Scotia is one of the few provinces in which there are several firms whose only product/service delivery is the design and installation of dedicated balanced supply and exhaust ventilation systems. The equipment commonly used in these types of systems are known as heat recovery ventilators (HRVs). In most houses, little or no attention is paid to the maintenance or overall condition of the ductwork or cores in these systems. It was felt that there was potential for unhealthy levels of dust and mold growth due to warm, humid air in ductwork as well as unhealthy levels of dust and other particulate matter due to inefficient or poorly maintained filters in HRV cores.

The objectives of this study were to determine whether dedicated ventilation systems harbour unhealthy levels of dust and mold; whether existing duct cleaning methods are successful at lowering those levels; and to develop further recommendations and guidelines for builders and homeowners for the maintenance of dedicated residential ventilation systems. Any viable recommendations and guidelines will be passed on to be added to NRCan's or CMHC's publications on HRVs.

Ten single family homes in the Province of Nova Scotia built within the last 10 years were included in this study (four R2000 program houses and six conventionally built houses). Four houses were tested in the fall of 1996 and the remaining six were tested in March 1997. All of these homes were owned or occupied by the same household for at least the previous 12 months. Homes were identified and selected from a variety of housing types, requests from consumers and HRV types. Homes in which major renovations or significant changes to the homes that could affect its energy performance or ventilation regime were undertaken in the past 12 months were excluded from the study. A variety of housing types and styles were tested including two-storey homes, split entry homes, bungalows and one and one half storey homes. One semi-detached unit was also included.

Samples from the ductwork and HRV cores in the conventional installed HRV systems of these houses were tested for dust and mold levels. Testing Included air and surface mold counts using RCS 'spinner' air sampler and typical swab collection systems. The ductwork and cores were then vacuum cleaned using standard ductwork cleaning apparatus, then the systems were tested again to give an indication of the success of the cleaning process. A video camera was also used to visually inspect the ductwork before and after cleaning. Two houses were retested three times more at intervals over the fifteen months following the cleaning.

Two types of cleaning equipment from four different companies were used in the study:

- Truck Mounted System: The supply and exhaust ducting was disconnected at the house side of the HRV and a flexible duct was attached to each side of the ducting as it was being cleaned. This duct was run outdoors to the truck that contained a fan that removed air from the duct and a series of collection bags to catch the debris.
- Portable Power Vacuum: The supply and exhaust ducting was disconnected at the house side of the HRV and a flexible duct was attached to each side of the ducting as it was being cleaned. This duct was run to a portable high power vacuum located in the same room as the HRV. A series of filters which included a bulk catcher, a bag filter and a HEPA filter collect any debris and contaminates before the exhausted air is returned to the room.

Both of these systems were design to be used in forced air heating and air conditioning systems. However, over the past several years they have started being used for cleaning the smaller duct work of central ventilation systems. Equipment adaptation has been duct work connections and pressure modulation. The operation was similar to standard forced air duct cleaning in that compressed air was sent through the duct work while the duct system was put under a negative pressure. No brushes were used due to the small size, inaccessibility and type of ductwork found with HRV's. Since none of the companies had viewed the duct before and after cleaning they really did not know how effective the cleaning had been. The effectiveness of the cleaning is only judged by what was collected by the vacuum system. Video results

SOMMAIRE

Une qualité médiocre de l'air intérieur peut entretenir des réactions allergiques, des infections virales et bactériennes, ainsi que des symptômes d'asthme ou apparentés à l'asthme causés par la sensibilisation. Parmi les facteurs qui augmentent l'exposition à une qualité médiocre de l'air intérieur, notons : les techniques de construction et de rénovation plus étanches à l'air (moins de ventilation « naturelle »), un plus grand nombre (et une plus grande complexité) de produits chimiques gardés ou utilisés à l'intérieur des habitations et la majeure partie du temps que les occupants passent à l'intérieur des habitations (parfois jusqu'à 90 % d'une vie entière), s'exposant ainsi à davantage de sensibilisants potentiels. On installe actuellement des systèmes spécialisés de ventilation par aspiration et air fourni équilibrés dans le but d'améliorer la qualité de l'air intérieur. On devrait examiner la présence possible d'allergènes et de sensibilisants dans les composants de tels systèmes et la production conséquente d'un air intérieur de qualité médiocre.

La région de l'Atlantique compte le plus grand nombre de systèmes spécialisés de ventilation par aspiration et air fourni équilibrés par habitant de tout le Canada. En fait, la Nouvelle-Écosse est l'une des rares provinces où l'on trouve plusieurs entreprises dont les seuls produits/services fournis ou assurés sont les installations et la conception de systèmes spécialisés de ventilation par aspiration et air fourni équilibrés. Les équipements couramment utilisés dans ces types de systèmes sont désignés sous l'appellation de ventilateurs-récupérateurs thermiques (VRT). Dans la plupart des habitations, on ne consacre que peu ou pas du tout d'attention à l'entretien ou à l'état général du réseau de gaines ou du coeur de ces systèmes. Il nous a semblé qu'il existait un potentiel de niveaux insalubres de poussière et de croissance de moisissures causés par l'air chaud et humide à l'intérieur du réseau de gaines et de niveaux insalubres de poussière et autres matières particulaires attribuables à des filtres inefficaces ou mal entretenus dans les coeurs des ventilateurs-récupérateurs thermiques.

La présente étude avait pour objectifs de déterminer si les systèmes de ventilation spécialisés pouvaient ou non être le foyer de niveaux insalubres de poussière et de moisissures; si les méthodes existantes de nettoyage des gaines parviennent ou non à abaisser ces niveaux; et de mettre au point, à l'intention des constructeurs et des propriétaires de maisons, des lignes directrices et des recommandations plus poussées concernant l'entretien des systèmes de ventilation spécialisés résidentiels. Toute recommandation et ligne directrice viable sera transmise aux fins d'ajout aux publications de RNCan ou de la SCHL portant sur les ventilateurs-récupérateurs thermiques.

Dix maisons unifamiliales de la province de la Nouvelle-Écosse construites ces dix dernières années ont été incluses dans la présente étude (quatre maisons du programme R2000 et six constructions classiques). Quatre maisons ont été mises à l'essai à l'automne de 1996, et les six autres, en mars 1997. Toutes ces maisons appartenaient aux mêmes occupants ou étaient occupés par les mêmes occupants depuis au moins 12 mois. Ces maisons ont été préparées et sélectionnées parmi une grande variété de types d'habitations, de demandes de la part de consommateurs et de types de ventilateurs-récupérateurs thermiques existants. Ont été exclues de l'étude les maisons dans lesquelles on avait apporté au cours des 12 mois précédents des rénovations majeures ou des changements considérables pouvant influer sur les performances énergétiques ou le régime de ventilation. On a mis à l'essai divers types et styles d'habitations, dont les maisons à étage, les maisons avec entrée à mi-étage, les bungalows, ainsi que les maisons à étage mansardé. Une unité d'habitation jumelée a également été incluse.

On a vérifié les niveaux de poussière et de moisissures d'échantillons provenant du réseau de gaines et des coeurs de ventilateurs-récupérateurs thermiques d'installation de type courant de ces maisons. Les essais comprenaient le dénombrement des moisissures dans l'air et sur les surfaces, au moyen de l'échantillonneur d'air centrique SVF et de systèmes classiques d'écouvillonnage. Le réseau de gaines et les coeurs ont ensuite été nettoyés à l'aspirateur, au moyen d'appareils de nettoyage de gaines standard, puis l'on a échantillonné à nouveau les systèmes pour obtenir une indication de l'efficacité du nettoyage. Une caméra vidéo a également été utilisée dans l'inspection du réseau de gaines avant et après l'intervention de nettoyage. À intervalles réguliers, deux de ces maisons ont été mises à l'essai trois fois de plus au cours de la période de quinze mois suivant le nettoyage des gaines.

Deux types d'équipements de nettoyage provenant de quatre entreprises différentes ont été utilisés dans le cadre de cette étude :

- Système embarqué à bord d'un camion : Les conduits d'amenée et d'évacuation ont été déconnectés côté maison du ventilateur-récupérateur thermique, et un conduit flexible a été monté de chaque côté du réseau de gaines pendant qu'il était nettoyé. Ce conduit allait à l'extérieur jusqu'au camion qui contenait un ventilateur aspirant l'air des gaines et une série de sacs pour la récupération des débris.

- Aspirateur haute puissance de type portable : Les conduits d'amenée et d'évacuation ont été déconnectés côté maison du ventilateur-récupérateur thermique, et un conduit flexible a été monté de chaque côté du réseau de gaines pendant qu'il était nettoyé. Ce conduit allait jusqu'à un aspirateur haute puissance de type portable situé dans la même pièce que le ventilateur-récupérateur thermique Une série de filtres, dont un capteur en vrac, un filtre à poches et un filtre à particules à haute efficacité (HEPA), recueillaient les débris et les agents contaminants de l'air d'extraction retoumant dans la pièce.

Ces deux systèmes ont été conçus pour utilisation sur des installations de climatisation et de chauffage à air chaud pulsé. Toutefois, ces demières années, on a commencé à les utiliser pour le nettoyage des réseaux de gaines de plus petite taille dans les installations de ventilation centrale. L'adaptation des équipements s'est produit au niveau des connexions de gaines et de la régulation de pression. Le fonctionnement était semblable à celui du nettoyage des gaines par air pulsé standard : l'air comprimé est pulsé à l'intérieur des gaines alors que le réseau est mis en pression négative. Aucune brosse n'a été utilisée en raison de la taille, de l'inaccessibilité et du type des gaines de ces ventilateurs-récupérateurs thermiques. Comme aucune des entreprises en cause n'a vu le réseau de gaines avant et après le nettoyage, elles n'ont vraiment pu savoir à quel point l'intervention s'est révélée efficace. L'efficacité du nettoyage n'est jugée que par la nature de ce qui a été recueilli par l'aspirateur. Les résultats indiqués par les caméras vidéo ont révélé que l'efficacité de l'intervention de nettoyage était aléatoire. La grosseur de la gaine et l'emplacement du réseau de gaines influaient également sur l'efficacité du nettoyage. Les gaines apparentes auraient dû être plus faciles à nettoyer, mais ont souvent été mal nettoyées en raison de la mise en place du conduit d'air comprimé.

Le temps de nettoyage du réseau variait selon le nombre de gaines et le nombre de personnes affectées au nettoyage. Trois des quatre entreprises n'affectaient qu'une personne à l'opération. Le coût du nettoyage des réseaux de gaines s'élevait à environ 150 $ par maison, et le temps consacré à la mise en place des équipements, au nettoyage proprement dit et au démontage des équipements variait entre 3 et 5 heures. Pendant l'intervention de l'équipe de l'entreprise de nettoyage, les consultants nettoyaient les filtres et le coeur du ventilateur-récupérateur thermique et expliquaient au propriétaire de la maison les différentes étapes de l'intervention. (En l'absence du propriétaire de la maison, l'information sur l'intervention effectuée était laissée sur les lieux ou devait y être expédiée ultérieurement.)

Les résultats de l'étude ont révélé un dénombrement élevé de moisissures dans le réseau de gaines et dans les coeurs, de même que des dénombrements plus élevés de façon constante dans le conduit d'amenée d'air frais au ventilateur-récupérateur thermique (généralement, un tronçon de conduit flexible). Cependant, on n'a trouvé aucune corrélation entre les niveaux des dénombrements en surface dans le réseau de gaines et les échantillons d'air prélevés dans la maison qui se sont révélés non concluants. On n'a pu déterminer si les moisissures en suspension dans l'air étaient considérées ou non comme un risque pour la santé dans les maisons mises à l'essai.

Le travail sur le terrain de cette étude a effectivement révélé toutefois que les propriétaires de maison ne sont généralement pas bien informés : a) sur le fonctionnement du ventilateur-récupérateur thermique et sur la façon d'utiliser ses commandes (outre la mise en marche/à l'arrêt); et b) sur la façon d'entretenir l'appareil de manière à en optimiser les performances. Dans la plupart des maisons de construction classique, il n'y avait aucun filtre sur les hottes aspirantes de la cuisine et de la salle de bain. Les maisons R2000 comportaient des filtres sur la hotte aspirante de la cuisine, mais seulement une maison en comportait dans la salle de bain. De façon générale, le débit d'air du ventilateur-récupérateur thermique était en déséquilibre. Le débit d'air était équilibré par les consultants, à l'occasion de la visite des lieux, après le nettoyage.

Ces dernières années, il est devenu plus courant de recirculer l'air extrait de la maison, à travers le ventilateur-récupérateur thermique, puis de nouveau à l'intérieur de la maison, par le réseau de gaines d'alimentation. (Un système fonctionnant sur ce mode de recirculation [NSERP06C] est inclus dans la présente étude - ce système comporte également une roue thermique au lieu d'un coeur massif de type classique.) Des études ultérieures des systèmes de ventilateur-récupérateur thermique à mode de recirculation pourraient révéler que ceux-ci influent davantage sur la qualité de l'air intérieur des habitations, plus particulièrement dans les cas où les hottes aspirantes de la cuisine et de la salle de bain ne sont pas munies de filtres.

Les recommandations émanant des résultats de la présente étude englobent les points suivants :

- Les hottes d'air extérieur des ventilateurs-récupérateurs thermique devraient comporter un préfiltre et être accessibles aux fins de nettoyage.
- Les réseaux de gaines de la hotte d'air extérieur au ventilateur-récupérateur thermique devraient être formés de conduits solides plutôt que flexibles et devraient être installés de manière à pouvoir être nettoyés facilement.
- Les fixations des gaines du ventilateur-récupérateur thermique seraient plus faciles à nettoyer si elles comportaient un dispositif de dégagement rapide quelconque.
- On devrait envisager de munir de préfiltres toutes les hottes d'extraction.
- Les hottes d'air extérieur devraient être installées à une hauteur de 120 mm (48 po) au-dessus du niveau fini du terrain afin d'assurer que le niveau de l'air d'alimentation soit supérieur à celui des sources de dispersion de spores de moisissures à l'extérieur de la maison (plates-bandes, pelouses, sol nu sous les terrasses, etc.).
- Les propriétaires de maison devraient avoir accès à plus d'information au sujet de l'entretien des systèmes de ventilateur-récupérateur thermique (publications de RNCan et de la SCHL offertes chez le fournisseur/l'installateur des ventilateurs-récupérateurs thermiques, aux bureaux locaux de l'ACCH, aux bureaux de la SCHL et aux agences/ministères provinciaux s'intéressant à l'habitation et/ou à l'utilisation de l'énergie).
- Les méthodes courantes de nettoyage des gaines ne conviennent pas au nettoyage des installations de ventilation centrale.
- Des essais plus approfondis des niveaux de moisissures en suspension dans l'air véhiculés par les installations de ventilation centrale sont indiqués dans le but de confirmer que ces installations ne contribuent pas aux risques pour la santé ou n'exacerbent pas les problèmes de santé existants des occupants.

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SECTION I — GENERAL HOUSE CHARACTERISTICS

1.0 INTRODUCTION

Ten houses in Nova Scotia were selected to participate in this study of dedicated ventilation systems in newer conventional energy efficient and R-2000 houses built after 1989. A number of tasks were undertaken.

- Door fan depressurization tests were conducted as per the current accepted protocols (CGSB and 'As Operated').
- Air leakage sites were identified, as were opportunities for improvement in air barrier techniques and details.
- The performance of mechanical ventilation systems and their compliance with current standards was assessed.
- Air and surface samples were taken before and after the cleaning process
- Video was taken of the ductwork before and after the cleaning process
- The ductwork and the HRV core were cleaned
- Ventilation rates were measured before and after the cleaning process They were also balanced (where possible) following the current F-326 ventilation standards.

2.0 DESCRIPTION

The consultant located ten single family homes in the Province of Nova Scotia built within the last 10 years. All of these homes were owned or occupied by the same household for at least the previous 12 months. Homes were identified and selected from a variety of housing types, HRV types, and requests from homeowners for investigations into IAQ. Homes in which major renovations or significant changes that could affect their energy performance or ventilation regime were undertaken in the past 12 months were excluded from the study.

A variety of housing types and styles were tested including two-storey homes, split entry homes bungalows and one and one half storey homes. We also included one semi-detached unit. The average exterior surface area of the homes tested was 423.6 m^2 with the largest exterior surface area measured at 59.7 m^2 and the smallest at 239.6 m^2. The average house volume of the tested houses was 547.2 m^3 with the largest volume 920 m^3 and the smallest 332.7 m^3.

TABLE I.A: Age of tested houses

CONVENTIONAL		
HOUSE ID	AGE	STYLE
NSERP01C	1993	two storey
NSERP02C	1991	split entry
NSERP03C	1992	two storey
NSERP04C	1989	one storey
NSERP05C	1992	one & half storey
NSERP06C	1995	one storey
R2000		
NSERP01R	1989	split level
NSERP02R	1992	two storey, semi-detached
NSERP03R	1992	two storey, semi-detached
NSERP04R	1994	two storey

NB: Throughout this report, the houses tested will be listed In this manner in tables and charts: conventional — 01C through 06C, then R2000 — 01R through 04R, with a shaded area between the two groups

3.0 GENERAL HOUSE ANALYSIS

3.1 AIR TIGHTNESS TESTS

Door fan depressurization tests were performed using Minneapolis Door Model Three. The sealing protocol followed for all air tightness tests was that set out in the CGSB 149.10M86 standard.

The average air tightness (CGSB) for all ten houses measured was 2.98 ACH@50 PA. The tightest house tested at 2.2 ACH@50 PA **(NSERP04R)** while the leakiest house tested at 3.99 ACH@50 PA **(NSERP04C)**. Seven of the ten houses tested at between 2.20 and 3.13 ACH@50 PA. The average Equivalent Leakage Area (ELA this value is approximately the total leakage area of all the leakage openings in the envelope of the house. at 10 PA) of the homes tested was 698.63 cm^2. The largest ELA was recorded in **NSERP03C** at 986.97 cm^2. **NSERP02R** had the smallest ELA at 260.61 cm^2. The standard deviation was equivalent to 240.34 cm^2. The average Normalized Leakage Area (NLA is the normalized leakage area in square centimetres per square metre) for the all ten houses was 1.4, with an overall range from .94 to 2.21.

The average air tightness (CGSB) of the six conventionally built houses was 3.25 ACH@50 Pa. The tightest conventionally built house tested at 2.43 ACH@50 PA **(NSERP05C)** while the leakiest conventionally built house tested at 3.99 **(NSERP02C & NSERP04C)**. The average Equivalent Leakage Area (ELA) of the conventionally built homes tested was 698.63 cm^2. The largest ELA was recorded in **NSERP03C** at 986.97 cm^2. **NSERP02C** had the smallest ELA at 388.39 cm^2. The standard deviation was equivalent to 240.34 cm^2. The average NLA for the conventionally built houses was 1.24, with an overall range from .94 to 2.21.

The average air tightness (CGSB) of the four R2000 built houses was 2..58 ACH@50 PA. The tightest R2000 house tested at 2.2 ACH@50 PA **(NSERP02R & NSERP04R)** while the leakiest R2000 house tested at 2.41 ACH@50 PA **(NSERP03R)**.The average Equivalent Leakage Area (ELA) of the R2000 built homes tested was 491.67 cm^2. The largest ELA was recorded in **NSERP04R** at 713.48 cm^2. **NSERP02R** had the smallest ELA at 260.61 cm^2. The average NLA for the R2000 houses was 1.24, with an overall range from 1.09 to 1.38. These figures are well above the standard for R2000 construction (1.5 ACH, with an NLA of less than 1.0)

TABLE I.B: Air Tightness Test Results — CGSB 149.10M86

HOUSE TAG #	VOL (M3)	AREA (M2)	ACH@50 Pa	ELA (CM2)	NLA
NSERP01C	624.02	451.21	3.07	835.55	1.85
NSERP02C	332.72	295.05	3.99	388.39	1.32
NSERP03C	919.96	595.95	2.91	986.97	1.66
NSERP04C	477.34	400.20	3.99	882.39	2.21
NSFRP05C	725.00	577.46	2.43	627.61	1.08
NSERP06C	413.20	502.70	3.13	470.90	0.94
MEAN:	582.04	470.43	3.25	698.63	1.51
MAX:	919.96	595.95	3.99	986.97	2.21
MIN:	332.72	295.05	2.43	388.39	0.94
STD DEV:	218.18	113.41	0.62	240.34	0.48
NSERP01R	570.33	491.78	3.51	679.68	1.38
NSERP02R	353.60	239.60	2.20	260.51	1.09
NSERP03R	353.60	239.60	2.41	313.00	1.31
NSERP04R	879.82	596.70	2.20	713.48	1.20
MEAN:	539.34	391.92	2.58	491.67	1.24
MAX:	879.82	596.70	3.51	713.48	1.38
MIN:	353.60	239.60	2.20	260.51	1.09
STD DEV:	248.92	181.03	0.63	237.98	0.13
ALL HOUSES					
MEAN:	564.96	439.03	2.98	615.85	1.40
MAX:	919.96	596.70	3.99	986.97	2.21
MIN:	332.72	239.60	2.20	260.51	0.94
STD DEV:	218.14	140.40	0.68	249.78	0.39

The average air tightness (As Operated) for nine of the ten houses measured was 3.11 ACH@50 PA., an increase of 5% see Table 1.C for the results. The tightest house tested at 2.29 ACH@50 PA **(NSERP02R)** while the leakiest house tested at 4.34 ACH@50 PA **(NSERP04C)**. Seven of the nine houses tested at between 4.07 and 2.54 ACH@50 PA. The average Equivalent Leakage Area (ELA) of the homes tested was 580.02 cm^2. The largest ELA was recorded in **NSERP03C** at 1015.93 cm^2. **NSERP02R** had the smallest ELA at 265.35 cm^2. The standard deviation was equivalent to 258.19 cm^2.

The average air tightness (As Operated) of the six conventionally built houses was 3.38 ACH@50 Pa. The tightest conventionally built house tested at 2.54 ACH@50 PA **(NSERP05C)** while the leakiest conventionally built house tested at 4.34 ACH@50 PA **(NSERP04C)**. The average Equivalent Leakage Area (ELA) of the conventionally built homes tested was 643.84 cm^2. The largest ELA was recorded in **NSERP03C** at 1015.93 cm^2. **NSERP02C** had the smallest ELA at 402.84 cm^2. The standard deviation was equivalent to 246.12 cm^2.

The average air tightness (As Operated) of the four R2000 built houses was 2.69 ACH@50 PA. The tightest R2000 house tested at 2.29 ACH@50 PA **(NSERP02R)** while the leakiest R2000 house tested at 3.28 ACH@50 PA **(NSERP01R)**.The average Equivalent Leakage Area (ELA) of the R2000 built homes tested was 500.25 cm^2. The largest ELA was recorded in **NSERP04R** at 783.16 cm^2. **NSERP02R** had the smallest ELA at 265.35 cm^2. The average NLA for the R2000 houses was 1.25, with an overall range from 1.11 to 1.33 cm2/m2.

Note: NSERP01C was the pilot test house and was not tested in the as operated condition.

TABLE I.C: Air Tightness Test Results — As Operated

HOUSE TAG #	VOL (M3)	AREA (M2)	ACH@50 Pa	ELA (CM2)	NLA (cm2/m2)
NSERP01C	N/A	N/A	N/A	N/A	N/A
NSERP02C	332.72	295.05	4.07	402.84	1.36
NSERP03C	919.96	595.95	3.14	1015.93	1.71
NSERP04C	477.34	400.20	4.34	729.61	1.82
NSERP05C	724.88	577.46	2.54	621.74	1.07
NSERP06C	413.20	502.70	3.13	449.10	0.89
MEAN:	573.62	474.27	3.44	643.84	1.37
MAX:	919.96	595.95	4.34	1015.93	1.82
MIN:	332.72	295.05	2.54	402.84	0.89
STD DEV:	242.83	126.36	0.74	246.12	0.40
NSERP01R	570.33	491.78	3.23	654.58	1.33
NSERP02R	353.60	239.60	2.29	265.35	1.11
NSERP03R	353.60	239.60	2.54	297.90	1.24
NSERP04R	879.82	596.70	2.65	783.16	1.31
MEAN:	539.34	391.92	2.68	500.25	1.25
MAX:	879.82	596.70	3.23	783.16	1.33
MIN:	353.60	239.60	2.29	265.35	1.11
STD DEV:	248.92	181.03	0.40	258.19	0.10
ALL HOUSES					
MEAN:	558.38	437.67	3.10	580.02	1.32
MAX:	919.96	596.70	4.34	1015.93	1.82
MIN:	332.72	239.60	2.29	265.35	0.89
STD DEV:	230.32	148.85	0.71	247.01	0.30

TABLE I.D: Significant Leakage Areas

AIR LEAKAGE AREAS	01C	02C	03C	04C	05C	06C	01R	02R	03R	04R
window w/stripping	√	√								
electrical switches & outlets, ext. walls	√			√	√	√	√	√	√	
electrical switches & outlets, int. walls	√						√			
clg mounted light fixtures							√			
attic hatches	√	√		√	√		√	√	√	√
interior window trim	√	√		√			√			√
door weatherstripping	√	√		√	√	√		√	√	√
electrical entrance/panel	√					√	√	√	√	
dryer duct at header				√						
plumbing stack			√	√		√	√	√	√	√
chimney thimble							√			√
under door frame at sill	√									√
unfinished areas	√			√	√					
garage to house surface	√		√							√
exposed joist header area (bsmt)	√	√	√		√		√			
kneewall/main wall junction		√								
poorly seated/broken dampers			√							
entry door frames			√			√	√			√
window frames										√
slider windows		√	√				√			√
behind bathtub @ ext..wall										√
central vac @ o/side vent			√							
ventilation system duct @ ext wall	√	√	√					√		
ventilation system duct @ attic/clg			√							
overhang/cantilever	√									

REVIEW OF AIR TIGHTNESS TESTING RESULTS

A review of the R-2000 houses included in this study indicates that none of the four houses would pass the R-2000 standard of 1.5 ACH in their current state. This could be attributed to several causes, including damage to the air barrier system by homeowners and modifications by tradespeople (including the installation of additional exhaust equipment, moving or otherwise disturbing the air barrier, weatherstripping wearing out, etc.).

CGSB 149.10M86 versus As Operated Testing

There was not a large difference in the air tightness between the CGSB 149.10M86 standard and the as operated air tightness test. The range in the difference was 0% for NSERP06C and 20% for NSERP04R. The average for the conventional houses was 4% and the R-2000 was 10%.
CGSB follows a protocol were all intentional openings are sealed for the Air Tightness Test. In the As operated test condition there is no sealing of any openings. The smallest difference was in electrically heated houses as there are not as many openings as found with wood and oil heated houses. Combustion air ducts, flues and barometric dampers will allow a fair amount of air to enter a house when put under a negative pressure.

3.2 HOUSE DEPRESSURIZATION TESTING

House depressurization tests were performed in accordance with the test procedure set out in CSA F326-M91. A Dwyer block incline manometer was used to perform the test. Combustion heating device s were present in 6 of the 10 houses. They included oil-fired boilers, direct vent gas fireplaces or a wood-burning appliance or fireplace.

One of the six conventional houses (NSERP03C)was depressurized to 11.25 Pa. The downdraft cooktop caused the house to depressurize beyond the 5 Pa limit.

None of the R2000 homes depressurized beyond 5.0 Pa.

All houses tested as per standard protocol, starting from the 'at rest' mode, and then activating the HRV , the dryer, and adding appliances exhausting 75 L/s or greater.

Table I.E: House Depressurization Results

HOUSE TAG#	TESTED Pa	Pa LIMIT	HEATING SYSTEM	EXHAUST DEVICES
NSERP01C	[--]	5	OIL HYDRONIC	HRV, DRYER, OIL-FIRED HYDRONIC
NSERP02C	6	5	ELECTRIC BASEBOARD	AIR EXCH'R, DRYER, WOODSTOVE, CENTRAL VAC
NSERP03C*	11.25	5	OIL HYDRONIC	HRV, DRYER, OIL HYDR., DRAFT COOKTOP
NSERP04C	N/A	N/A	ELECTRIC BASEBOARD	HRV, DRYER, KITCHEN FAN
NSERP05C	1.9	5	ELECTRIC BASEBOARD	HRV. DRYER. CENTRAL VAC, EPA F'PLACE
NSERP06C	2.5	5	MASONRY HEATER	HRV, DRYER, MAS. HTR AIRTIGHT DOORS
MEAN:	5.4	5.0		
MAX:	11.2	5.0		
MIN:	1.9	5.0		
STD. DEV.	4.3	0.0		
NSERP01R	0.25	5	ELECTRIC BASEBOARD	HRV, DRYER, WOOD F'PLACE
NSERP02R	N/A	N/A	ELECTRIC BASEBOARD	HRV, DRYER
NSERP03R	N/A	N/A	ELECTRIC BASEBOARD	HRV, NO DRYER
NSERP04R	3.75	5	OIL HYDRONIC	HRV, DRYER, HUMIDEX, 2 BATH FANS
MEAN:	2.0	5.0		
MAX:	3.8	5.0		
MIN:	0.2	5.0		
STD. DEV.	2.5	0.0		
ALL HOUSES				
MEAN:	4.3	5.0		
MAX:	11.2	5.0		
MIN:	0.2	5.0		
STD. DEV.	3.9	0.0		

3.3 HEATING SYSTEMS

The homes relied on a mix of primary heating systems, with seven of the ten houses using electrical baseboards, two of the houses tested were oil-fired mid-efficiency boilers and one house used a masonry heater with tight fitting glass doors. Houses with forced air systems were intentionally avoided.

TABLE I.F: Primary and Supplemental Heating Sources

CONVENTIONAL		
HOUSE TAG #	PRIMARY SOURCE	SUPP. SOURCE
NSERP01C	electric baseboard	direct vent gas fireplace
NSERP02C	oil mid efficiency hydronic (bbd)	woodstove
NSERP03C	electric baseboard	fireplace w/glass doors
NSERP04C	electric baseboard	none
NSERP05C	electric baseboard	EPA approved fireplace
NSERP06C	masonry heater w/glass doors	electric baseboard
R2000		
NSERP01R	electric baseboard	none
NSERP02R	electric baseboard	none
NSERP03R	electric baseboard	none
NSERP04R	oil mid efficiency hydronic (bbd)	EPA approved fireplace

SECTION II —CLEANING AND VENTILATION WORK

1.0 OVERVIEW OF METHODOLOGY

Ductwork and cores of the dedicated ventilation systems in each of the ten houses in the study were cleaned using standard ductwork cleaning apparatus, then tested again to indicate the success of the cleaning process. Two of the houses (NSERP03C and NSERP03R) were tested at intervals over the fifteen month period after cleaning to determine the effectiveness of cleaning systems, and the length of time required between cleanings.

1.1 VENTILATION SYSTEM CHARACTERISTICS

Listed below are the components of each system cleaned and sampled in the study, including specific controls.

TABLE II.A: Description of Ventilation Equipment

HOUSE TAG #	YEAR	TYPE	MFGR	MODEL	CORE TYPE	REMOTE CONTROL	DEHUMIDI- STAT
NSERP01C	1993	HRV	VENMAR	FLAIR 3055 Standard	PLASTIC	NONE	YES
NSERP02C	1991	AIR to AIR	VENMAR	EA-109	N/A	NONE	YES
NSERP03C	1992	HRV	NUTECH	LIFEBREATH 200 MAX	METAL	AT MACHINE	YES
NSERP04C	1989	HRV	NUTECH	LIFEBREATH 200 MAX	METAL	AT MACHINE	YES
NSERP05C	1987	HRV	CES	VANEE 2000 PLUS	DOUBLE PLASTIC	PUSH BUTTON 20 MIN. (B/K)	YES
NSERP06C	1995	ERV	VENMAR	FLAIR 3055 DUO	PLASTIC HEAT WHEEL	PUSH BUTTON 20 MIN. (B)	YES
NSERPO1R	1989	HRV	AIR CHANGER	DPA 275	PLASTIC	WIND UP TIMER (B)	YES
NSERP02R	1992	HRV	VENMAR	FLAIR 3055 COMPACT H.E.	PLASTIC	NONE	YES
NSERP03R	1992	HRV	VENMAR	FLAIR 3055 COMPACT H.E.	PLASTIC	NONE	YES
NSERP04R	1994	HRV	VENMAR	FLAIR 85115 Compact H.E.	PLASTIC	NONE	YES

B = Bathroom, K = Kitchen

TABLE II.B: Condition & Location of Fresh Air Intake Hoods

HOUSE TAG #	PRE-FILTER YES	PRE-FILTER NO	HOOD LABEL Y/N	HT ABOVE GROUND MM (IN)	DISTANCE TO EXH. DEVICES MM (IN)	DESCRIPTION OF BLOCKAGE
NSERP01C		√	N	2500 [98]	1700 [67]	LEAVES, LOCATED UNDER DECK
NSERP02C		√	N	1380 [54]	1700 [67]	NO BLOCKAGE
NSERP03C		√	N	600 [23]	1820 [72]	DOG HAIR, LEAVES, DIRT, LINT
NSERP04C		√	N	2500[98]	1820 [72]	MINOR BLOCKAGE, LEAVES AND LINT
NSERPO5C		√	N	600 [23]	1900 [75]	LEAVES, DIRT, LINT
NSERP06C		√	N	2500 [98]	2150 [85]	NO BLOCKAGE
NSERP01R	√		Y	450 [18]	1750 [69]	PRE-FILTER HEAVILY LOADED
NSERP02R		√	N	2500 [98]	1820 [72]	NO BLOCKAGE
NSERP03R		√	N	2500 [98]	1820 [72]	NO BLOCKAGE
NSERP04R		√	Y	2440 [96]	2700 [106]	NO BLOCKAGE

TABLE II.C: Exhaust Devices Other than HRV Present in Houses & 'Bag Testing'[1] Results

HOUSE TAG #	BATH FAN #1	BATH FAN #2	RANGE HOOD	TOTAL
NSERP01C	[--]	[--]	N/A	
NSERP02C	14 [30]	11 [23]	N/A	25 [53]
NSERP03C	11 [23]	14 [30]	N/A	25 [53]
NSERP04C	N/A	N/A	28 [60]	28 [60]
NSERP05C	N/A	N/A	N/A	
NSERP06C	N/A	N/A	N/A	
NSERP01R	N/A	N/A	N/A	
NSERP02R	N/A	N/A	N/A	
NSERP03R	N/A	N/A	N/A	
NSERP04R	28 [60]	28 [60]	N/A	56 [120]

All flows estimated in L/s [CFM].

1.2 CLEANING OF SYSTEMS

Following are tables summarizing information on ventilation system cleaning history and the type and cost of cleaning as per this study.

The first table shows the frequency at which the components of individual ventilation systems have been maintained over the course of time, to the best of the homeowner's or contractor's knowledge. One system (NSERP01R) was maintained more completely than the others, with the exception of having the HRV core cleaned on a regular basis. Only three of the ten systems had exterior intake hood screens cleaned on a regular basis, however, of those three, only two had the intake filter at the HRV cleaned on a regular basis. In all, most attention was paid to the filters inside the HRV box (six of ten systems). Of all ten houses, only on had the ductwork cleaned previously.

Four of the ventilation systems in this study were cleaned using a Portable Vacuum System: a large, portable unit that sat inside the house and exhausted in to the room it was located after the air had passed through a series of filters. The other six were cleaned using a truck-mounted vacuum system. Assuming the vacuum system duct is tightly sealed, this system would reduce the amount of fine particulate matter disturbed and left in the house, like an exterior vented central vacuum system.

One house system (NSERP04C) was sprayed with an antimicrobial agent without the knowledge of the consultant. This spray didn't seem to be very effective in reducing mold counts in the air samples pre and post cleaning, nor did it alter the surface findings. This would indicate that spraying is only effective close to the immediate spray radius and does not permeate the whole ductwork system.

Crew size was one or two people, with the average time spent cleaning the ductwork was 3.5 hours. The minimum time spent cleaning was 2.5 hours and the maximum time spent was 6.5 hours. This house had the most numerous supply diffusers and exhaust grilles (12 diffusers and 5 grilles). The smallest system had one diffuser and one grille, while seven of the houses had 7 or 9 diffusers and 2 to 5 grilles. The cost of using these cleaning systems ranged from $165.90 for the Portable Vacuum System to $218.60 for the Truck Vacuum System, with an average cost of $192.25.

[1] 'Bag Testing' is a simple method of screening ventilation system performance that was devel ped by Don Fugler of CMHC's Research Division in Ottawa. When used in conjunction with calibration curves developed for use with the Duct Flow Test Apparatus described below, flow rates in exhaust and supply ducts can be determined to ± 10% accuracy in a range of 5 to 30 L/s (10 to 63cfm). The Duct Flow Test Apparatus consists of a plastic refuse bag ('GLAD brand 66x91 cm only), some means of allowing the bag to be placed, quickly over the outlet or inlet to be tested while minimizing air leakage,a and a stop or wrist watch with a second hand. Testing is run with the exterior doors and windows closed, and the ventilation system running in its usual mode. The bag is quickly placed over the fan opening and timed until it has reached 90% of its capacity (for supply duct) or until it is 90% empty (for exhaust duct). Each outlet is 'bagged' three or four times to obtain an average reading, then this time is looked up on the calibration curve and matched with the estimated flow rate.

TABLE II.D: Frequency of Cleaning of System Components

HOUSE TAG #	EXTERIOR HOOD SCREENS	KITCHEN EXHAUST FILTER	HRV INTAKE FILTER	HRV EXHAUST FILTER	HRV CORE	VENT'N DUCTWORK	BATH EXHAUST FILTER
NSERP01C	2 x Y/H	N/A	Q/H	Q/H	N	N	N/A
NSERP02C	N	N/A	N/A	N/A	N/A	N	N/A
NSERP03C	N	N/A	2 x Y	2 x Y	N	N	N/A
NSERP04C	N	N/A	N	N	N	N	N/A
NSERPO5C	N	M/H	2 x Y/H	2 x Y/H	Y/H	N	M/H
NSERP06C	N	M	LIGHT @ HRV (N)	LIGHT @ HRV (N)	N	N	M/H
NSERP01R	2 x Y/H	M/H	Y/C	Y/C	N	M/H	M/H
NSERP02R	N	M/H	Y/H	Y/H	Y/H	N	N/A
NSERP03R	N	N	N	N	N	N	N/A
NSERP04R	Y/H	N	2 x Y/H	2 x Y/H	N	N	N/A

W-weekly M-monthly Q-quarterly Y-yearly N-never H-homeowner C-contractor

TABLE II.E: Cleaning Systems used

HOUSE TAG #	CREW SIZE	TIME (HRS)	TYPE OF CLEANING SYSTEM	#SUPPLY DIFFUSERS	# EXHAUST GRILLES	COST OF CLEANING
NSERP01C	2	2.5	PORTABLE VACUUM	8	5	$160.50
NSERP02C*	1	4	PORTABLE VACUUM	1	1	$187.50
NSERP03C	1	4	TRUCK VAC	9	5	$160.50
NSERP04C	1	2.5	TRUCK VAC	2	3	$160.50
NSERPO5C	1	2.5	TRUCK VAC	7	3	$160.50
NSERP06C	1	3	TRUCK VAC	7	3	$160.50
NSERP01R	2	4	PORTABLE VACUUM	9	5	$160.50
NSERP02R	2	3	PORTABLE VACUUM	7	2	$160.50
NSERP03R	2	3	PORTABLE VACUUM	7	2	$160.50
NSERP04R	1	6.5	PORTABLE VACUUM	12	5	$451.00
			AVERAGE COST PER HOUSE			$192.25
			AVE. $/HOUSE –PORTABLE			$213.42
			AVE. $/HOUSE – TRUCK VAC			$160.50

*** Sanitizing was included in this cleaning. The material safety data sheet (MSDS) supplied by the cleaning company indicates that the product, BBJ Air Conditioner MicroBiocide is an antimicrobial spray with health hazards at the concentrated form ("toxic by ingestion; irritation to eyes and skin, but not a sensitizer"). There are no listed health hazards at the diluted form.**

2.0 VENTILATION SYSTEM PERFORMANCE

Following are comments on individual ventilation systems, listed by HRV make and model, installation details, pre and post cleaning air flows (balanced or unbalanced), and ease of cleaning. Also noted is whether or not the system as installed meets the current Minimum Ventilation Capacity (MVC) as required by the F-326 Ventilation Standard.

None of the conventional houses met F-326 requirements for Minimum Ventilation Capacity (MVC) and only a few would meet the installation requirements, with undersizing the kitchen exhaust ductwork and no filtering being the consistent deficiency. R-2000 Homes had been installed following F326 and had been inspected . Airflows in some cases did not meet the current F326 requirements.

Conventional Houses

NSERP01C HRV: Flair 3055 Standard

- Duct work Installation was poorly done even though the installation was carried out by a trained certified HRAI installer. Two thirds of the ductwork was ridged round duct and the other third was insulated flex duct. The flex duct supplied and exhausted the 2nd floor.
- Rooms were supplied by 100mm (4") diffusers and 100mm (4") round exhaust grilles.
- Runs appeared to be complicated, as it was difficult to run the video camera and the duct cleaning equipment through the ductwork.
- The maximum exhaust air flow rate that the HRV could achieve was 38 L/s (80 CFM). We believe this is due to the size and installation of the duct work.
- Ventilation rates were not adequate nor were the flows balanced. There were no air flow dampers to indicate that the system may have been balanced when installed. After cleaning duct work and removing debris from the 6.35mm (.25 in) screen in the exterior fresh air hood, the supply rate increased by 100% on high speed and 50% on low. Exhaust rate remained the same.
- We were unable to increase exhaust air flows 38 L/s or (80 CFM) on low and high speed operation. A damper was installed to reduce supply air flows. Air flows were balanced on low speed but could not be balanced on high speed or meet the Minimum Ventilation Capacity (66 L/s or 140 CFM) required by the F326 standard.
- There were no filters on exhaust grilles in bathrooms or kitchen.
- The 100mm (4") exhaust duct to the kitchen was undersized and should have been a minimum of a 125mm (5") duct .

NSERP02C Venmar : Air Exchanger

- This was an air exchange system which we believed was installed by the builder.
- System had one exhaust grille located in the upper floor main hallway and one supply diffuser located in a bedroom located at the bottom of the stairway.
- Duct work consisted of 200mm(8") flex for both supply and exhaust ducting.
- Duct work was difficult to clean due to the nature of the flex duct.
- Air Exchanger was really inaccessible for cleaning without disassembling the the unit. Unit was very dirty although did not harbour any visible mold.
- Duct cleaner spent considerably more time cleaning even though there were only the two duct runs.
- Unknown to us, during the cleaning process the technician sprayed a biocide into the duct work before we acquired our post cleaning swabs. As expected post cleaning swab counts were very low.
- Supply air from outside mixes with a percentage of the exhaust air before being delivered to the lower level diffuser.
- Due to installation we were unable to install equipment to obtain accurate air flow rates.
- Even though the system had been operating there were numerous signs of mold on windows and cold closet walls.

NSERP03C* HRV: Nutech Lifebreath 150 Max *House tested over 15 Months

- House was constructed to address asthmatic conditions of one of the children. There were no carpets and home owner had specified HRV to provide better indoor air quality.
- Installation was carried out by the builder with assistance from the HRV representative.
- Two thirds of the ductwork was ridged 100mm (4") round duct and the other third was insulated flex ducting that supplied and exhausted the 2nd floor. Duct work main trunk was 150mm (6") rigid metal duct.
- Rooms were supplied by 100mm (4") diffusers and 100mm (4") round exhaust grilles.

- There were no filters at bathroom or kitchen exhaust grilles.
- There were airflow measuring stations and dampers located in the duct work but they were incorrectly placed, resulting in inaccurate readings.
- Measured pre cleaning air flows revealed extremely low supply air flows. This was due to blockage found at the fresh air intake hood screen which was covered by a heavy mat of leaves, dog hair and other debris that had formed over the past years. Supply air flows at high speed went from 14 L/s (30 CFM) to 105 L/s (223 CFM) after the blockage had been removed and the system cleaned. Exhaust air flows at high speed went from 45 L/s (95 CFM) to 56.5 L/s (120 CFM). Blockage was not significant enough to effect the air flow rates when the HRV was running on low speed.
- Air flows were not balanced nor did they meet the Minimum Ventilation Capacity of 75.5 L/s (160 CFM) required by the F-326 standard.
- An electronic filter had been placed in the HRV but was located on the exhaust side of the core where air exits the HRV to the outside.
- After 15 months,retesting showed that 25% of the fresh air intake hood screen had become blocked.

NSERP04C HRV: Lifebreath 200 Max

- Attached bungalow located in small town. House owned by Housing Cooperative.
- Has had several tenants since being constructed. Current people have been living in house for past year.
- Previous tenant had requested a ventilation system to deal with recurring condensation on windows and mold on drywall. Even though the system had been running, condensation was found on windows of bedrooms and mold on drywall in front entry and closet on the day we conducted the testing.
- Current homeowner was not familiar with the operation or maintenance of the system.
- System was installed by some one who knew someone but was not an HRAI ventilation installer.
- HRV produced a noise that indicated a fan bearing was worn.
- Ductwork consisted of 150mm (6") round rigid metal. Supply and exhaust runs are 100mm (4") round rigid metal.
- There were only two supply diffusers, one located in the main hallway (low on the wall) and the other located in the floor of the dining room. Exhausts were located in the hallway of the kitchen and the bathroom.
- Before cleaning ventilation air flows on low speed were about 30% higher then the low speed requirement of F326 which is 40-60% of the MVC. High speed was adequate and both low and high speed air flows were balanced even though air flow dampers had not been installed.
- The fresh air duct from the outside hood to the HRV was an insulated 150mm (6") round rigid duct which ran a distance of about 6 Metres (20 feet) from the hood to the HRV. Water was found in the insulated sleeve of the duct as the outer vapour barrier had not been adequately sealed.
- Dining room supply duct located on the floor had a considerable amount of dirt, dust and objects that had fallen in the duct in the first couple of feet.
- Kitchen exhaust was not filtered and was very dirty from dust, lint and grease.

NSERP05C HRV: VanEE 2000 Plus

- Raised one and half storey house located in the country with wood floors and no carpets.
- Installation was done by homeowner who was familiar with the F326 Ventilation standard
- 150mm (6") round rigid duct work was run throughout the entire house.
- Kitchen and bathrooms exhaust grilles had filters.
- Ductwork was very clean on both the supply and exhaust ductwork. Only visible dust found in ductwork was from the sanding of hardwood floors.
- HRV interior had rust due to condensation that had formed along the metal plate that separated the exhaust air leaving the HRV and the fresh air entering. The exhaust run from the machine to the outside hood was 1 metre (3') and the fresh air run was 2 metres (6').
- 150mm (6") insulated flex duct from the fresh air intake hood to the HRV was heavily soiled with dust, bugs and lint.
- Air flows were sufficient and balanced on low speed operation but due to blockage on the intake hood screen high speed produced only 44 L/s (88 CFM) on the Supply airflow and the exhaust was 64 L/s (136 CFM). After removing the blockage the supply air flow came up to 54 L/s (115 CFM). which represented a 30% increase in air flow. Homeowner indicated that he operated the system continuously on low speed for 99% of the time.
- The system contained dampers and air flow measuring stations.
- This house had some of the lowest mold and bacteria counts and had the cleanest duct work of all the systems that were tested.
- Lower level of this home was finished, so cleaning of the main trunk was a little more difficult although the 100mm (6") supply and exhaust runs were easier to get cleaning equipment into.

NSERP06C HRV: Venmar Flair 3055 Duo

- Straw bale house built on a slab located in the country .
- System has a rotary wheel for heat recovery. Fins of the fans were heavily loaded with a build up of dirt and dust
- Wheel caused the unit to vibrate and was replaced after the testing. Air flow dampers are housed in the unit as are the air flow measuring devices.
- Air flows were on the high side but were balanced.
- Controls allowed for the system to recirculate inside air.
- Ductwork was fairly clean, bathroom ductwork showed sign of a water stain in one section of duct length.
- Installation was carried out by a trained certified HRAI Ventilation Contractor
- 100mm & 150mm (4&6") round rigid duct work was run in the attic and supplied and exhausted from the ceiling. Ductwork seams and joints had been taped and ductwork was covered with insulation.
- Supply was delivered using 100mm (4") ducting and 100mm (4") round diffusers that were found to be closed off in most of the rooms. Homeowner did not know they had been closed down.
- Kitchen 150mm (6") round exhaust grille was filtered, bathroom was unfiltered 100mm (4") .
- Intake and exhaust hoods were located at the soffit.
- There was water found in the outer layer of the insulated flex duct that brings fresh air from outside to the HRV. This was due to air from the interior leaking into the plastic outer layer vapour barrier due to poor connection at the HRV collar.

R-2000 Houses

All the R-2000 Ventilation systems were installed by a certified HRV ventilation installer. Duct work would have been inspected at the rough in stage and the HRV and air flows would have been tested before the home was occupied.

NSERP01R HRV: Air Exchanger: DPA 275

- Located in Halifax this four level split is located in area were development has been on going since 1989. One of the oldest R-2000 houses tested. The majority of the flooring was eight year old carpeting. Homeowner was concerned as his children seemed to have the flu on a regular basis.
- A black substance was found on the core but did not show high results for mold or bacteria.
- Standing water was found in the bottom pan of the intake side; there was no way for the water to drain except through the seams of the HRV cabinet which exhibited rust stains.
- HRV core was not removable and the HRV had to be dissembled into three parts and centre core was sent out for steam cleaning. Pre cleaning mold count was very high at 500,000. After steam cleaning the count was 2.
- Unlined stud wall cavity was used to supply air. Exhaust duct work throughout house was rigid metal. 175mm (7") round rigid metal duct was used for the main trunk of the supply and exhaust.
- Small amounts of construction debris were found in the supply duct cavities but there was no significant amount. Debris was found at the bottom of the wall cavity.
- Duct work was fairly accessible but cleaning only had a 50/50 result.
- All exhaust grilles in kitchen and bathrooms were filtered.
- Fresh air intake hood contained a foam filter placed in front of the screen. This foam filter was heavily loaded with dust and dirt. Measured pre cleaning air flows were within F-326 requirements. The system was then tested with foam filter removed from the intake hood. With the HRV running on low speed, the supply air flows went from 54 L/s (115 CFM) to 67 L/s (145 CFM) and 72 L/s (154 CFM) to 140 L/s (299 CFM) on high speed. After the system and pre-filter had been cleaned and replaced the air flows on the supply side were 42 L/s (88 CFM) on low speed and 87 L/s (185 CFM) on high. Low speed air flows dropped because the air flow damper had been disturbed during cleaning.
- Note: Post cleaning results had been destroyed and are not shown except for HRV core post steam cleaning. Pre cleaning counts were fairiy iow.

The next two houses are each side of a two storey semi-detached .Houses were built exactly the same and contained the same type of mechanical and heating equipment. It was chosen to see what effect occupants may have on the ventilation system when the homes and ventilation systems are identical and the environment and surrounding conditions are similar.

NSERP02R HRV: Flair 3055 Compact HE

- Left side of a Two storey semi-detached house located in an urban area and owned by a Housing Authority. Present occupant has been in the home since it was constructed.
- HRV and system has been maintained by occupant. (vacuumed and washed filters)
- Exterior intake and exhaust hoods were located 2700 mm above ground.
- Rooms were supplied by 100mm (4") diffusers , a 100mm (4") round exhaust grille was located in the bathroom and a 150mm (6") filtered exhaust grille in the kitchen.
- Exhaust grille and duct work in bathroom were extremely dirty.
- Duct work is 150mm (6") and 100mm (4") rigid metal.
- Pre cleaning the air flows were a little high on low speed and a little low on high speed but were balanced. After cleaning high speed came up to were it should be and low speed remained about the same.
- Duct work of the House was fairly dirty and swab results from pre and post were high although in most cases the post cleaning results were lower by 10 to 50%. In some cases counts increased which may have been due to disturbing material during the cleaning.
- The lower level was finished so the main trunks of the system were not very accessible. Cleaning only had a 50/50 result as the video revealed areas of the duct work still contained dust and lint.

NSERP03R* HRV: Flair 3055 Compact HE *House tested over 15 months

- Right side of a two storey semi-detached house located in an urban area and owned by a Housing Authority. Present occupant has been in the home for only 10 months.
- Occupants smoke as did the last occupant.
- System has not been maintained or serviced since being installed.
- Exterior intake and exhaust hoods were located 2440mm (8') above ground.
- Rooms were supplied by 100mm (4") diffusers, a 100mm (4") round exhaust grille was located in the bathroom and a 150mm (6") filtered exhaust grille in the kitchen.
- Exhaust grille and duct work in bathroom were extremely dirty.
- The kitchen filter was heavily loaded with a 6.25 mm (1/4") mat of dirt,lint and grease. When washed the filter revealed heavy staining from cigarette smoke.
- Metal filters located in the HRV crumbled when being cleaned with soap and water. New filters were installed.
- HRV was heavily stained by the cigarette smoke as was the Interior of the HRV cabinet.
- Duct work is 150mm (6") and 100mm (4") rigid metal.
- Pre cleaning the air flows were high on low speed and sufficient on high speed but were balanced.. After cleaning air flow rates remained the same.
- Duct work of the House was fairly dirty and swab results from pre and post were high although in most cases the post cleaning results were lower by 10 to 50%. In some cases counts increased which may have been due to disturbing material during the cleaning.
- The lower level was finished so the main trunks of the system were not very accessible. Cleaning only had a 50/50 result as the video revealed areas of the duct work that still contained dust and lint.

NSERP04R HRV: Flair 85115

- This two storey house was the largest R-2000 house tested in the study. House was located in the Halifax area and was exposed to winds off the ocean in the Halifax Harbour.
- Hardwood flooring was throughout the main floors with carpet and exposed concrete floors in the lower level.
- An in-law suite located in the lower level is part of the main house.
- Main trunk was a combination of 175mm (7") & 200mm (8") round ridged ducting.
- This system was ducted using 75mm (3") metal duct to supply rooms. This practise was used in the Metro area of Halifax /Dartmouth for a period of about two years . Duct work for the bathrooms consisted of 100mm (4") round metal and 81.25mm x 250mm (31/4" x 10") metal duct was used to exhausted the main kitchen. A 150mm (6") round metal duct exhausted the kitchen of the in-law suite.
- Kitchen exhaust grilles were filtered but bathrooms exhaust grilles were not.

- Homeowner cleaned HRV filters twice a year, but kitchen filters were never cleaned and were found to be heavily loaded.
- Unknown to us, due to of a manufacturers defect, the HRV Core had been replaced a week before field testing . Pre and Post cleaning airflows were within F-326 limits and were probably set by the ventilation contractor at the time of core replacement.
- Even though the core was brand new it showed some very high mold counts before cleaning and went down to zero after cleaning. There may have been something that contaminated it before being installed.
- Because the duct work was only 75mm (3") it was difficult to access for video taping and cleaning. What we were able to see revealed that the cleaning was only 50 to 60 % effective.

2.2 MEASURED AIR FLOWS

Notes on following tables: figures are listed in litres per second followed by cubic feet per minute in square brackets. Where an asterisk (*) follows a figure under MVC (Minimum Ventilation Capacity), the house was built before the current standard was enacted.

TABLE II.F: Air Flows, Prior to Cleaning

HOUSE TAG #	SUPPLY LOW SPEED L/s [CFM]	EXHAUST LOW SPEED L/s [CFM]	F-326 Minimum Ventilation Capacity (MVC) @ 40 - 60% L/s [CFM]	SUPPLY HIGH SPEED L/s [CFM]	EXHAUST HIGH SPEED L/s [CFM]	F-326 Minimum Ventilation Capacity (MVC) L/s [CFM]
NSERP01C	42 [88]	38 [80]	26-40 [56-84]	42 [88]	38 [80]	66 [140]
NSERP02C	N/A	N/A	24-37 [52-78]*	N/A	N/A	61 [130]
NSERP03C	14 [30]	45 [95]	30-45 [64-96]*	14 [30]	45 [95]	75 [160]
NSERP04C	45 [95]	45 [95]	21-31 [44-66]*	54 [114]	58 [122]	52 [110]
NSERPO5C	34 [73]	34 [73]	21-31 [44-66]*	42 [88]	64 [136]	52 [110]
NSERP06C	46 [98]	46 [98]	21-31 [44-66]	54 [144]	67 [142]	52 [110]
NSERP01R	54 [115]	42 [88]	23-34 [48-72]*	72 [154]	72 [154]	61 [130]
NSERP02R	42 [88]	42 [88]	21-31 [44-66]*	45 [95]	45 [95]	52 [110]
NSERP03R	50 [107]	50 [107]	21-31 [44-66]*	61 [130]	58 [122]	52 [110]
NSERP04R	37 [78]	39 [83]	34-51 [72-108]	98 [208]	101 [214]	85 [180]

* Installed prior to current ventilation standards

TABLE II.G: Air Flows, Post Cleaning & Adjusted

HOUSE TAG #	SUPPLY LOW SPEED L/s [CFM]	EXH. LOW SPEED L/s [CFM]	F-326 Minimum Ventilation Capacity (MVC) @ 40 - 60% L/s [CFM]	SUPPLY HIGH SPEED L/s [CFM]	EXH. HIGH SPEED L/s [CFM]	F-326 Minimum Ventilation Capacity (MVC) L/s [CFM]	ADJUSTED SUPPLY LOW SPEED L/s [CFM]	ADJUSTED EXHAUST LOW SPEED L/s [CFM]	ADJUSTED SUPPLY HIGH SPEED L/s [CFM]	ADJUSTED EXHAUST HIGH SPEED L/s [CFM]
NSERP01C	59 [126]	38 [80]	26-40[56-84]	76 [162]	38 [80]	66 [140]	42 [88]	38 [80]	48 [103]	38 [80]
NSERP02C	[--]	[--]	24-37[52-76]	[--]	[--]	61[130]	[--]	[--]	[--]	[--]
NSERP03C	99 [210]	56 [120]	30-45 [64-96]	105 [223]	56.5 [120]	75 [160]	48 [102]	48 [102]	56 [120]	56 [120]
NSERP04C	43 [92]	45 [95]	21-31[44-66]*	54 [114]	57 [122]	52 [110]	35 [76]	35 [76]	42 [88]	42 [88]
NSERPO5C	34 [73]	34 [73]	21-31 [44-66]	54 [115]	64 [136]	52 [110]	34 [73]	34 [73]	60 [126]	60 [126]
NSERP06C	38 [80]	38 [80]	21-31 [44-66]	63 [134]	69 [147]	52 [110]	31 [66]	32 [68]	54 [115]	60 [126]
NSERP01R	68 [145]	49 [103]	24-37 [52-78]*	141[299]	80 [170]	61[130]	54 [115]	42 [89]	67 [135]	67 [135]
NSERP02R	42 [88]	42 [88]	21-31 [44-66]	92 [195]	92 [195]	52 [110]	38 [80]	38 [80]	45 [114]	45 [114]
NSERP03R	50 [107]	50 [107]	21-31 [44-66]	60 [130]	57 [122]	52 [110]	38 [80]	38 [80]	45 [114]	45 [114]
NSERP04R	37 [78]	39 [83]	34-51 [72-108]	98 [208]	101 [214]	85 [180]	37 [78]	39 [83]	98 [208]	101 [214]

SECTION III -- AIR & SURFACE SAMPLING

1.0 AIR SAMPLING

1.1 AIR SAMPLING PROCEDURE

Reuter Centrifugal Sampler (RCS) air sampler results indicate a wide range of colony forming units per cubic metre (CFU/m3), both within houses and between the different houses. Taking four common sites from all houses (some were tested in other areas by request of homeowner or by consultant), the results are as shown in the table below. The exterior samples (first column) were used as a control. These exterior samples were taken close to the intake hood of the ventilation system, 120mm (4 ft.) above grade.

1.2 AIR SAMPLING RESULTS

The current guidelines for health concerns due to microbials in indoor environments are as follows:

500 CFU/m_3 are acceptable in summer if the species are primarily Cladosporium or other tree or leaf fungi
Up to 150 CFU/m_3 are acceptible if there is a mixture of species largely from outdoors
More than 50 CFU/m_3 of any one species (other than Cladosporium or Alternaria spp) should be further investigated, especially if it is established that it is an indoor source.[2]

The analysis of RCS strips was done through InnovaCorp, Dartmouth, NS. Total colony forming units per cubic metre (CFU/m_3) for each sample were supplied, along with a percentage breakdown of the mold genera present. The genera noted were: Alternaria/Ulocladium; Aspergillus; Cladosporium; Penicillium; Scopulariopsis; yeast; and non-sporing isolates. The tables in Section V, Appendix, show the RCS strip results by house with the above mold genera identified by percentage. Table III.A indicates overall CFU/m_3 per sample, with levels of ^{3}150 CFU/m_3 in shaded areas. Table III.B shows a synopsis of the samples where individual genera counts were ^{3}50 CFU/m_3. In all other cases <50 CFU/m_3 of any given genera were present.

The difference between the exterior sample and the averaged interior samples for all houses tested was 57 CFU/m_3. The maximum difference between indoor and exterior samples was **NSERP03R** at 272 CFU/m_3, while the minimum difference (ie, more CFU/m_3 outside than inside) was **NSERP06C**, at -424 CFU/m_3. The standard deviation was 193 CFU/m_3.

As seen in Table III.B, the high concentrations of mold in post-cleaning samples generally (see appendix for detailed information), is probably due to the fact that the post-cleaning air samples were taken within two hours of the cleaning process. When NSERP01R was re-tested three days after cleaning, only a minimal amount of Alternaria/Ulocladium (<6 CFU/m_3) was detectable.

However, the immediate post-cleaning samples show a high level of Cladosporium and Penicillium immediately after cleaning in two thirds of the houses where there were no discernible levels in the exterior sample of all but one house (NSERP06C). It is notable that where NSERP06C had exterior and living room pre-cleaning levels of Cladosporium below the 50 CFU/m_3 mark, the post cleaning level of Cladosporium went up significantly (making up 58% of the total mold count for the post-cleaning sample). Yet, Cladosporium was not present in the exterior sample, indicating the possible presence of an interior source. This is also true for the other houses showing Cladosporium in the post-cleaning samples (NSERP01C, NSERP02C, NSERP04C, NSERP01R and NSERP04R). Only NSERP01C had Cladosporium levels of note before cleaning. Aspergillus was present only in the exterior sample of NSERP06C, but was not present in the post-cleaning sample. In NSERP04C, Aspergillus was present in the main bedroom pre-clean and in the living room post-clean samples in significant quantities. Penicillium in levels above 50 CFU/m_3 was present in NSERP01C, NSERP04C and NSERP01R before and after cleaning. However, levels decreased after cleaning in NSERP06C but increased after cleaning in NSERP02C.

In general, the R2000 houses had lower airborne mold counts than the conventionally built houses tested. However, this sample is too small to be of significant importance. Much of the overall differences in airborne mold counts can be attributed to occupant lifestyle differences. The data presented here is deemed to be inconclusive as to whether or not the airborne mold counts as tested and measured are a health concern.

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[2] Indoor Air Quality in Office Buildings: A Technical Guide (1993); Health Canada

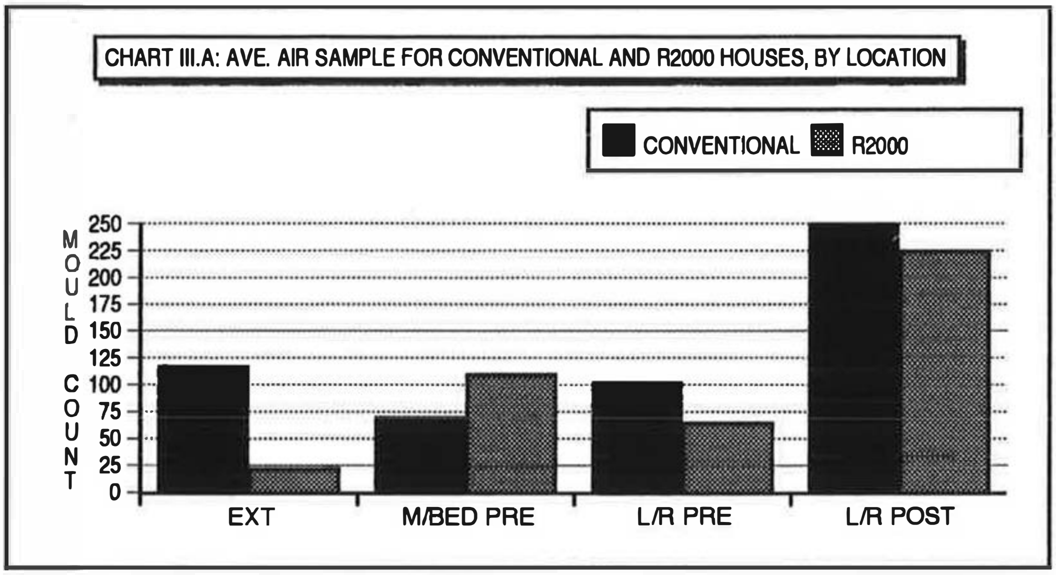
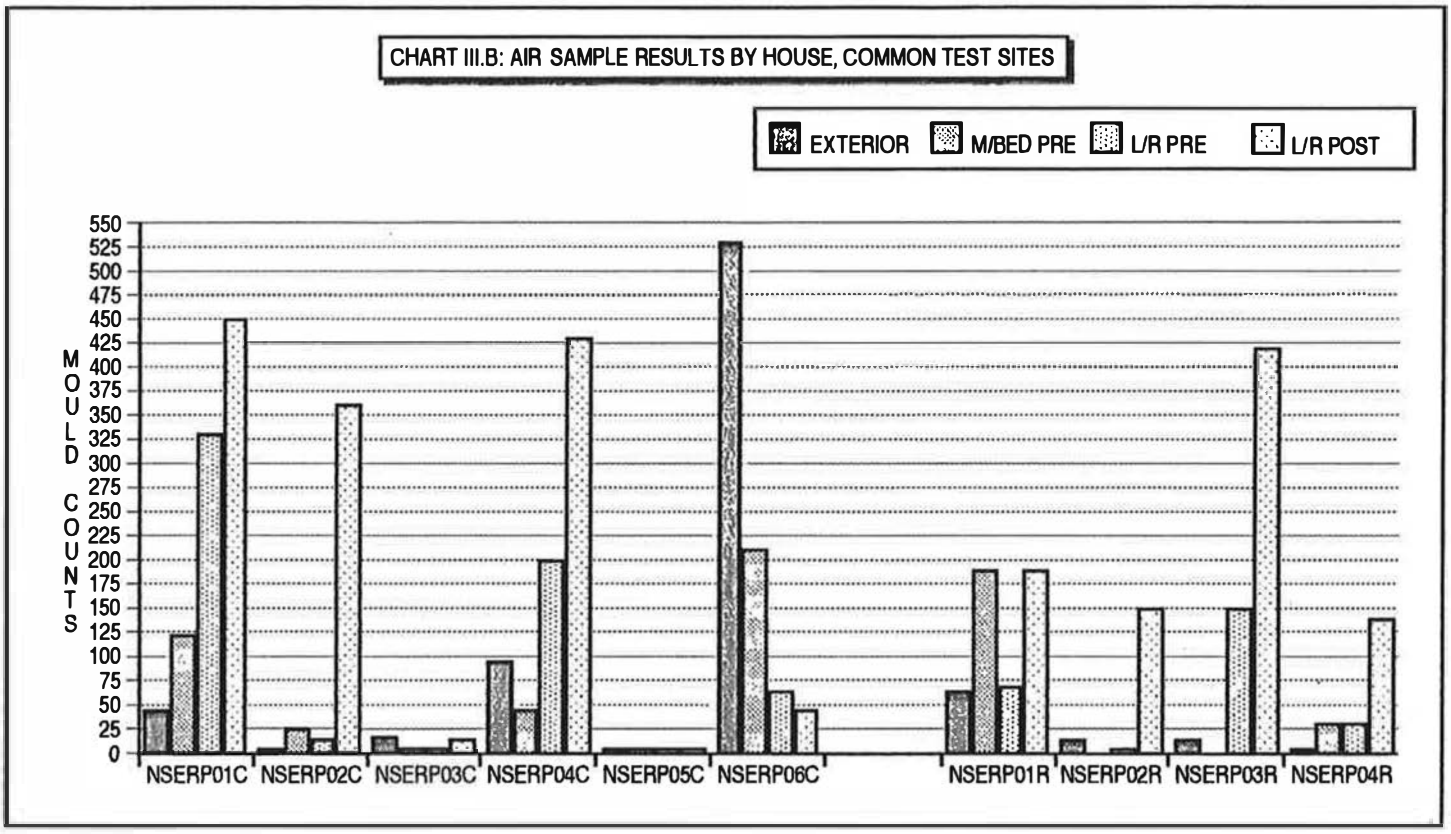


TABLE III.A: Air samples by house, common test sites (CFU/m3, 4 minute sample time)

	EXTERIOR	M/BED PRE	L/R PRE	L/R POST	TEMP ext. °C	TEMP Int. °C	R.H. Int.	AVE. DIFF. (Ex/In)
NSERP01C	44	123	330	450	6	18	62	257
NSERP02C	6	25	13	360	6	16	56	127
NSERP03C	18	6	6	13	-1	18	45	-10
NSERP04C	94	44	200	430	-1	18	64	131
NSERP05C	6	6	6	6	1	18	51	0
NSERP06C	530	210	63	44	13	22	52	-424
NSERP01R	63	190	69	190	1	18	52	87
NSERP02R	13		6	150	4	20	48	65
NSERP03R	13		150	420	4	21	48	272
NSERP04R	6	31	31	140	3	18	44	61
MEAN:	79	79	87	220	4	19	52	57
MAX:	530	210	330	450	13	22	64	272
MIN:	6	6	6	6	-1	16	44	-424
STD DEV:	161	83	108	179	4	2	7	193

TABLE III.B: Air Samples having ≥50 CFU/m3 of specified mold genera present

	EXTERIOR	M/BED PRE	L/R PRE	L/R POST
Alternaria/Ucladium				
Aspergillus	06C	04C		04C
Cladosporium		01C		01C, 02C, 04C, 06C, 01R, 04R
Penicillium	06C	01C, 06C	01C, 04C, 01R	01C, 02C, 04C, 01R, 04R
Scopulariopsis				
Yeast	06C			
Non-sporing Isolates				04C



2.0 SURFACE SWAB SAMPLING

2.1 SURFACE SWAB SAMPLING PROCEDURES

Samples were taken in all houses at the following locations before and after cleaning. Some houses had more samples taken where there were obvious signs of mold/mildew growth, or in bedrooms where the occupant had respiratory problems. Two of the houses (NSERP03C and NSERP03R) were retested at intervals over a 12 month period. Full tables of all samples taken are found in the appendix. For the purpose of comparison, only the seven common sites are listed here. Comparison tables & charts are shown for mold counts (CFU/swab = approx.. 4 cm^2 sample area) at each site, before and after cleaning. Common Swab Sample Sites:

A: DUCTWORK AT SUPPLY, MAIN BEDROOM
B: DUCTWORK AT SUPPLY, MAIN LIVING AREA
C: DUCTWORK AT EXHAUST, KITCHEN
D: DUCTWORK AT EXHAUST, MAIN BATHROOM
E: HRV CORE
F: INSULATED FLEX DUCT AT FRESH AIR TO HRV
G: SUPPLY DUCTWORK AT HRV TO HOUSE

2.2 SURFACE SWAB SAMPLING RESULTS

Precleaning testing indicated that, on average, the highest surface mold counts at common sites were at the HRV core (30959 CFU/area swabbed) and at the fresh air intake to the HRV (9322 CFU/area swabbed). Prior to cleaning, on average, the lowest counts were found in the main bedroom supply duct (3411 CFU/area swabbed), although the living room supply, kitchen exhaust and supply air to house were within 3% of the main bedroom supply. Post cleaning results indicated that, on average, the highest surface mold counts were at supply air to house (11309 CFU/area swabbed), and the lowest counts were at the living room supply (188 CFU/area swabbed). The average overall reduction of discernible mold counts was 29189 CFU/area swabbed. All swab sites showed a reduction in CFU/area swabbed after cleaning except the main bedroom supply and the supply air to house. Post cleaning swabs showed a redistribution of mold counts (see charts III.D and III.E).

TABLE III.C:
Average swab samples at common test sites (CFU/area swabbed)

COMMON SWAB SITES – MEAN	CFU/Aswab
PRE CLEANING	
SUPPLY: MAIN BEDROOM	3411
SUPPLY: LIVING ROOM	4711
EXHAUST: KITCHEN	5675
EXHAUST: MAIN BATHROOM	8152
HRV CORE	30959
FRESH AIR TO HRV	9322
SUPPLY AIR TO HOUSE	5371
AVERAGE TOTAL CFU/Aswab	67602
POST CLEANING	
SUPPLY: MAIN BEDROOM	4342
SUPPLY: LIVING ROOM	188
EXHAUST: KITCHEN	4894
EXHAUST: MAIN BATHROOM	5543
HRV CORE	6980
FRESH AIR TO HRV	5157
SUPPLY AIR TO HOUSE	11309
AVERAGE TOTAL CFU/Aswab	38413
DIFFERENCE	
SUPPLY: MAIN BEDROOM	931 (UP)
SUPPLY: LIVING ROOM	4523.5 (DN)
EXHAUST: KITCHEN	781.4 (DN)
EXHAUST: MAIN BATHROOM	2609.2 (DN)
HRV CORE	23978.7 (DN)
FRESH AIR TO HRV	4165.4 (DN)
SUPPLY AIR TO HOUSE	5938.1 (UP)
AVERAGE TOTAL REDUCTION	29189

CHART III.C: PRE CLEANING AVERAGE SWAB MOULD COUNTS BY LOCATION

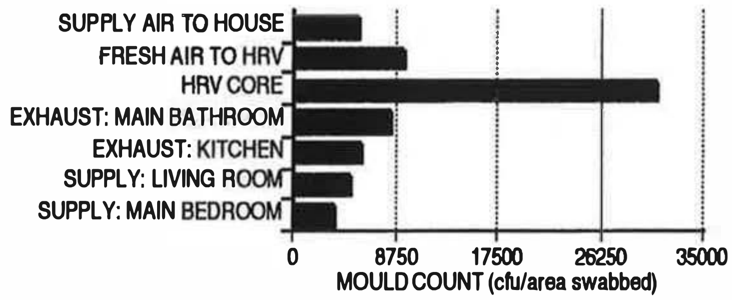


CHART III.D POST CLEANING AVERAGE MOULD COUNTS BY LOCATION

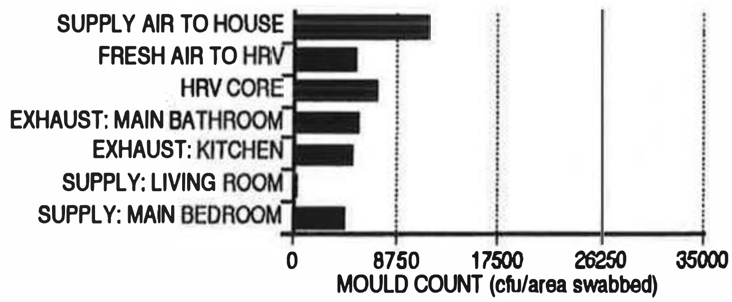


CHART III.E: PRE CLEANING DISTRIBUTION (CFU/area swabbed)

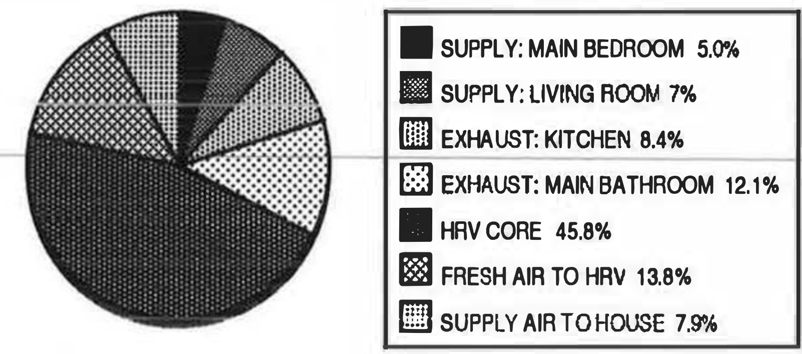
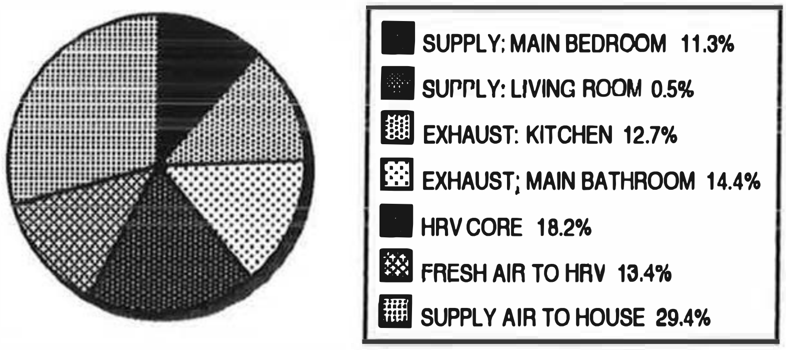


CHART III.F: POST CLEANING DISTRIBUTION (CXFU/area swabbed)



2.3 LONG TERM TESTING RESULTS

Two houses, NSERP03C and NSERP03R were revisited over a period of 15 months from the initial site visit, at the intervals listed in the table below. Following is a summary of the differences between pre and post clean results; post clean and subsequent visit results; and pre clean and final visit results (increases from initial preclean readings or from visit to visit are shown as positive numbers, decreases are shown as negative numbers).

TABLE III.D: Long term testing results — surface swab sampling only (CFU/area swabbed)

NSERPO3C	PRECLEAN Mar 97	POSTCLEAN Mar 97	OCTOBER 97	FEBRUARY 1998	MAY 1998	15 MO AVE
MAIN BEDROOM	22	2	10	5	5	9
LIVING ROOM	2	2	10	5	5	5
KITCHEN	230	16	850	6,800	40	1,587
MAIN BATH	94	38	1,000	5	5	228
HRV CORE	2	2	280	5	130	84
Fresh Air Duct From Outside To HRV	9,100	7,400	50,000	5	N/A*	16,626
Supply Duct At HRV To House	12	6	110	3	330	92
MEAN:	1,352	1,067	7,466	975	86	2,189
MAX:	9,100	7,400	50,000	6,800	330	14,726
MIN:	2	2	10	3	5	4
STD DEV:	3,418	2,793	18,760	2,568	129	5,534
DIFFERENCES	PRE TO POST CLEAN	POST CLEAN TO 2ND VISIT	POST CLEAN TO 3rd VISIT	POST CLEAN TO 4TH VISIT	PRECLEAN TO 12 MONTHS LATER	
MAIN BEDROOM	-20	8	3	3	-17	
LIVING ROOM	0	8	3	3	3	
KITCHEN	-214	834	6,784	24	-190	
MAIN BATH	-56	962	-33	-33	-89	
HRV CORE	0	278	3	128	128	
Fresh Air Duct From Outside To HRV	-1,700	42,600	-7,395	N/A*	N/A*	
Supply Duct At HRV To House	-6	104	-3	324	318	
NSERPO3R	PRECLEAN Dec 96	POSTCLEAN Dec 96	October 1997	March 1998		15 MO AVE
MAIN BEDROOM	12,000	9,300	35	5		5,335
LIVING ROOM	21,000	0	5	5		5,252
KITCHEN	23,000	15,000	100	5		9,526
MAIN BATH	46,000	21,000	280	5		16,821
HRV CORE	30,000	8,900	1,200	5		10,026
Fresh Air Duct From Outside To HRV	44,000	13,000	180	5		14,296
Supply Duct At HRV To House	28,000	92,000	40	3,000		30,760
MEAN:	29,143	22,743	263	433		13,145
MAX:	46,000	92,000	1,200	3,000		35,550
MIN:	12,000	0	5	5		3,002
STD DEV:	12,280	31,209	424	1,132		11,261
DIFFERENCES	PRE CLEAN TO POST CLEAN	POST CLEAN TO 2ND VISIT	POST CLEAN TO 2ND VISIT	POST CLEAN TO 3RD VISIT	PRECLEAN TO 15 MONTHS LATER	
MAIN BEDROOM	-2,700	-9,265	-9,295	-9,300	-12,000	
LIVING ROOM	-21,000	5	5	0	-21,000	
KITCHEN	-8,000	-14,900	-14,995	-15,000	-23,000	
MAIN BATH	-25,000	-20,720	-20,995	-21,000	-46,000	
HRV CORE	-21,100	-7,700	-8,695	-8,900	-30,000	
Fresh Air Duct From Outside To HRV	-31,000	-12,820	-12,995			
Supply Duct At HRV To House	64,000	-91,960	-89,000	-92,000	-28,000	

***N/A = not available because of surface mold growth on sample**

SECTION IV - DISCUSSION OF FINDINGS

In all of the ventilation systems the insulated flex duct that runs from the HRV to the fresh air intake hood was heavily contaminated with bugs, dust, dirt, and lint. Systems where hoods were located 100-200 mm (4-8 inches) above grade were found to be dirty. Flex ducting was very difficult to clean, especially where duct runs were long and not accessible. An insulated rigid metal duct would be much easier to maintain. The connections of this duct to the port of the HRV and the exterior hood should be simple mechanical joints so that the duct could be easily detached for regular cleaning.

If the exterior fresh air hood contained a pre-filter it would prevent a great deal of dirt, bugs and dust from getting into the duct and reaching the interior of the HRV. Even though there is a filter located in the HRV to filter the incoming fresh air, it is usually inadequate for filtering fine dust and bugs that tend to be found through out the HRV interior cabinet and core. However, our testing did not include such pre-filters and there is no data on how this would affect airflows.

Blockage of the fresh air intake hood screen affected airflows differently when the HRV was operated on low and high speed. The air flows remained relatively the same on low speed before and after the blockage was removed. With the HRV running on high speed the air flow on the supply side was severely restricted. With partial blockage, the exhaust airflows were typically twice those of the supply side airflows. A system operating in this unbalanced mode will create a negative pressure in the house.

Dirty duct work did not have a significant impact on restricting air flows. Measurements taken prior to cleaning and post cleaning showed very little difference in air flow rates. The only rates that increased after cleaning were those systems that had blockage at the fresh air intake hood screen.

Current duct cleaning methods are not adequate for cleaning duct work in central ventilation systems. Viewing of the video tapes from the pre and post cleaning of the duct work revealed that both the portable and truck mounted units cleaned only 50-60 % of the visible duct dust. Cleaning relied on a compressed air wash placed upstream to dislodge contaminants and a high powered vacuum to collect it. The success of cleaning was dependent on were the air wash was placed and how accessible the duct work was. Ideally a brush would be used to dislodge the contaminates although this would be difficult due to the small diameter of the ventilation duct work and the limited accessibility. This is especially the case when the basement ceiling has been completed.

Consideration should be given to the installation of the exterior fresh air hood at a minimum height of 1200 mm (48 inches) above finished grade. Hoods located above this height in our study did not seem to be as heavilycontaminated at the fresh air intake hood screen.

To prevent contamination of the exhaust ductwork pre-filtering of all exhaust grilles should be considered. The duct work on the exhaust side of most of the systems tested were contaminated with dust and dirt due to the fact that there were no filters at the exhaust grilles. The result was that dirt, dust and lint ended up throughout the duct work. Only one of the of the conventional houses had a filter in the kitchen exhaust. All the R-2000 houses had a filter in the kitchen exhaust grille. NSERP05C and NSERP01R were the only two houses that had filters in the bathroom exhaust grilles. The duct work mold counts at these locations were some of the lowest which would imply that filtering had restricted the amount of contaminates entering the ductwork. In most systems this is not particularly a concern, as the air passing through the exhaust ductwork is vented to the outdoors. There may be a concern for systems that have a recirculation mode of operation were exhaust air is returned back through the supply duct work of the house and is not exhausted to the outside.

Although there are several federal and provincial publications and a manufacturer's manual dealing with the operation and maintenance of central ventilation systems, homeowners did not maintain their systems on a regular basis. Most were not aware of the need to clean the HRV core or filters. The operation of the dehumidistat and other speed controls were not well understood by a number of home owners.

SECTION V — CONCLUSIONS

The results of the study indicate that:

- Mold counts were high in the ductwork and cores, with consistently higher counts found in the fresh air supply duct to the HRV (typically, a length of flex duct).
- There was no correlation between the levels of the surface mold concentrations in the duct systems and the samples of airborne mold taken in the house. However, the airborne mold sampling results were inconclusive as to whether or not any of the houses had levels that could cause or exaberate health problems, based on current guidelines.
- Householders need to be instructed (or reminded) about maintenance requirements for their HRVs.
- HRV manufacturers and standards committees should consider means to keep HRV ductwork clean including: quick release duct to HRV connections, a restriction on the use of flex ducting, an outdoor filter on the fresh air supply, a higher ground clearance requirement for the fresh air supply, and pre-filters on HRV exhaust duct terminations in the house.
- Further testing of airborne mold levels in low-rise housing with central ventilation systems is indicated to determine whether airborne mold in ventilation systems is a health risk or concern for occupants.

SECTION VI — APPENDICES

RCS STRIP RESULTS, BY HOUSE WITH MOLD GENERA IDENTIFIED

All analysis of CFU/m3, mold genera present done by Austin Read, InnovaCorp. Dartmouth, Nova Scotia. Discrepancies in total percentages as per lab reports. Percentages which translate into ≥ 50 CFU/m3 for any one mold genera in any sample taken are indicated by shaded box, as are total mold counts per sample ≥ 150 CFU/m3. Cladosporium is indicated by bold text.

See page 20 for discussion of levels and current guidelines.

NSERP01C	LOCATION	EXT.	M/BED	L/R PRE	L/R POST
	molds (CFU/m3)	44	123	330	450
	mold GENERA PRESENT (%)				
	ALTERNARIA/ULOCLADIUM	15%		6%	6%
	ASPERGILLUS				3%
	CLADOSPORIUM	50%	40%	60%	58%
	PENICILLIUM		40%	17%	25%
	SCOPULARIOPSIS				
	YEAST	28%	5%	6%	6%
	NON-SPORING ISOLATES		15%	10%	3%
	UNKNOWN				
	TOTAL % IDENTIFIED GENERA	93%	100%	99%	101%

NSERP02C	LOCATION	EXT.	BABY RM PRE	M/BED PRE	FAM RM PRE	FAM RM POST
	molds (CFU/m3)	<6	69	25	13	360
	mold GENERA PRESENT (%)					
	ALTERNARIA/ULOCLADIUM		18%		50%	3%
	ASPERGILLUS					
	CLADOSPORIUM		9%			58%
	PENICILLIUM					25%
	SCOPULARIOPSIS					
	YEAST		55%	100%	50%	14%
	NON-SPORING ISOLATES		18%			
	UNKNOWN					
	TOTAL % OF IDENTIFIED GENERA		100%	100%	100%	100%

NSERP03C	LOCATION	EXT.	M/BED	L/R PRE	L/R POST
	molds (CFU/m3)	18	6	<6	13
	mold GENERA PRESENT (%)				
	ALTERNARIA/ULOCLADIUM				50%
	ASPERGILLUS	66%			
	CLADOSPORIUM		√		50%
	PENICILLIUM				
	SCOPULARIOPSIS	33%			
	YEAST				
	NON-SPORING ISOLATES				
	UNKNOWN				
	TOTAL % OF IDENTIFIED GENERA	99%			100%

NSERP04C	LOCATION	EXT.	M/BED	L/R PRE	L/R POST
	molds (CFU/m3)	94	44	200	430
	mold GENERA PRESENT (%)				
	ALTERNARIA/ULOCLADIUM				
	ASPERGILLUS	6%	29%	25%	12%
	CLADOSPORIUM	**20%**	**14%**	**19%**	**59%**
	PENICILLIUM	40%	43%	31%	26%
	SCOPULARIOPSIS				
	YEAST			19%	
	NON-SPORING ISOLATES	33%	14%	6%	15%
	UNKNOWN				
	TOTAL % OF IDENTIFIED GENERA	99%	100%	100%	112%

NSERP05C	LOCATION	EXT.	M/BED	L/R PRE	BED 2 PRE	L/R POST
	molds (CFU/m3)	<6	<6	<6	6	<6
	mold GENERA PRESENT (%)					
	ALTERNARIA/ULOCLADIUM					
	ASPERGILLUS					
	CLADOSPORIUM				√	
	PENICILLIUM		√	√		
	SCOPULARIOPSIS					
	YEAST					
	NON-SPORING ISOLATES					
	UNKNOWN					
	TOTAL % OF IDENTIFIED GENERA					

NSERP06C	LOCATION	EXT.	M/BED	L/R PRE	L/R POST
	molds (CFU/m3)	530	210	63	190
	mold GENERA PRESENT (%)				
	ALTERNARIA/ULOCLADIUM				
	ASPERGILLUS	12%	15%	30%	6%
	CLADOSPORIUM	**20%**	**18%**	**10%**	**58%**
	PENICILLIUM	16%	24%		16%
	SCOPULARIOPSIS				
	YEAST	47%	29%	20%	10%
	NON-SPORING ISOLATES		18%	30%	10%
	TRICHODERMA			10%	
	UNKNOWN				
	TOTAL % OF IDENTIFIED GENERA	95%	104%	100%	100%

NSERP01R	LOCATION	EXT.	BSMT PRE	MAIN PRE	UP. PRE	MN. POST	UP. POST	MN POST W/HRV	3 DAYS LATER
	molds (CFU/m3)	63	50	190	69	190	190	1100	6
	mold GENERA PRESENT (%)								
	ALTERNARIA/ULOCLADIUM	20%		3%					√
	ASPERGILLUS					23%	10%	2%	
	CLADOSPORIUM	**40%**	**22%**	**16%**		**20%**	**66%**	**81%**	
	PENICILLIUM		55%	77%	73%	63%	23%	21%	
	SCOPULARIOPSIS							2%	
	YEAST	40%		3%	9%				
	NON-SPORING ISOLATES	10%	22%	3%	18%			8%	
	UNKNOWN							5%	
	TOTAL % OF IDENTIFIED GENERA	110%	99%	102%	100%	106%	99%	99%	