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RESEARCH REPORT

HVAC SYSTEMS IN MULTI-UNIT HIGH RISE RESIDENTIAL BUILDINGS

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ACKNOWLEDGEMENT

Our thanks is extended to all those organizations and individuals who kindly donated their time to discuss their experiences with Multi-Family Buildings; over 150 organizations contributed in such a manner.

Thanks are also extended to Wayne Webster (CMHC) for his help in guiding the direction of this work and for reviewing draft documentation.

ABSTRACT

Prior to this study there was a sense that current heating ventilation and air conditioning (HVAC) systems for high-rise multi-family buildings were often failing to perform satisfactorily.

In order to identify the problem areas, and the extent to which such problems might exist, the Canada Mortgage & Housing Corporation commissioned this current work.

A review of literature and a nation wide field survey was carried out which has enabled a catalogue of popular system and equipment types, and typical problem areas, to be developed.

Based on this catalogue, suggestions for improving HVAC system performance are presented. These suggestions encompass training and technology transfer, demonstration, and research and development activities.

RESUME

Avant étude, il semblait que les systèmes de chauffage, de ventilation et de climatisation (CVC) présentement en usage dans les tours d'habitation multifamiliales ne fonctionnaient pas toujours de façon satisfaisante.

Afin d'identifier les problèmes et leur importance, la Société Canadienne d'Hypothèques et de Logement a commandé la présente étude.

A la suite d'une analyse de la documentation et d'un sondage mené à la grandeur du pays, un inventaire des systèmes et des genres d'installation les plus populaires ainsi que les problèmes typiques a été compilé.

En se basant sur cet inventaire, des suggestions en vue d'améliorer le rendement des systèmes CVC sont présentées. Ces suggestions couvrent le transert de la Technologie et de la formation, les démonstrations ainsi que les activités de recherche et de développement.

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

EXECUTIVE SUMMARY

MECHANICAL SYSTEMS IN HIGH-RISE RESIDENTIAL BUILDINGS

Introduction

A literature review and field survey of 150 organizations representing 25,000 dwelling units in 260 buildings was undertaken to determine typical practice, as well as state-of-the-art, of the mechanical (plumbing, heating, ventilating and air conditioning) systems in high-rise residential buildings.

Research Program

The 1981 Canadian Census indicates that apartments having less than 5 stories constitute 16.3% of occupied private dwellings, while those having 5 or more stories (high-rise) constitute 9%. The multi-storey high-rise segment ranges from low cost rental apartments to luxury condominiums. They frequently consume a higher density of energy, provide a lower standard of comfort, and demonstrate a disproportionate share of physical defects, when compared to low-rise housing. Further, the ultimate owner and user generally have little or no involvement in the construction process.

Findings

- electric baseboard is the most popular form of heating and has the fewest operational complaints. Central gas boiler(s) with hydronic perimeter (baseboard) units are next in popularity. In Montreal virtually all installations are electric but through the Prairies it is unusual if gas is not used. Oil heating systems are limited to the Maritimes and the North;
- virtually all buildings (95%) have a central make-up air system supplying into the corridor where it passes through door undercuts and cracks into the individual suites. Two respondents reported that air was ducted into the suites in at least one instance and two other buildings used a transfer grill between the corridor and suites. The make-up air systems typically run continuously, although they may be turned off via timeclocks to conserve energy;
- 48% of the buildings had simple central exhaust systems, 14% had a variation on a central arrangement, and 38% had individual kitchen and bathroom exhaust fans. Central exhaust systems frequently are controlled in the same manner as the make-up air system while local (manual or humidity) switches control the individual fans;
- ventilation system performance and/or air leakage, or movement, were responsible for the largest number of complaints;
- system commissioning was frequently reported to be less than satisfactory;
- approximately one-third of the units were air conditioned by permanent (non-window) equipment (condominiums accounted for 38% of these units). Common areas and lobbies are normally air conditioned if the suites are, however, the corridor make-up air system generally is not;

- approximately 75% have domestic water heated at a central location (most of the remainder have electrical units in each suite, while there are some high efficiency gas installations in South-western Ontario). The current approach in B.C. is to electrically "heat trace" mains rather than provide a recirculation loop and pump. Approximately 10% of the installations are heated by the space heating boiler. 80% of the central systems have insulated piping;
- 53% of the buildings had heated garages, 24% had unheated, and the remainder either had On Grade or Open parking structures. Parking in colder climates tended to be in enclosed heated areas. 61% of the heated garages used electric unit heaters (in Montreal there were 84%).
- garage ventilation was normally unheated (72%). Heat recovery was not incorporated in any installation. 78% of the systems were controlled by carbon monoxide detectors. The remainder were either operated continuously, via a timeclock, or had manual intervention;
- services in unheated garages are protected from freezing via trace heating, insulation, constructing a heated ceiling space, or using dry (standpipe and sprinkler) systems.
- routine Operating & Maintenance (O & M) tasks are normally performed by the building janitor/superintendent. Larger organizations may have skilled resources in-house but most (78% of total) also utilize outside contractors.
- problems associated with O & M skill requirements are baised to the perceptions of owners, operators, developers, and property managers as 74% of the survey respondents were from this group.

Implications for the Housing Industry

A number of recommendations for Research, Development, and Demonstration activities are defined. They include:

- creation of a multi-disciplinary review panel to balance functional priorities (eg. lower energy consumption, improved comfort, energy source, etc) and budget constraints for activities to be undertaken;
- development of practical economical systems to control infiltration and odour transfer while providing quality, economical ventilation;
- preparation of manuals of good practice reflecting current knowledge. It was found that problems were most frequently due to personal, rather than collective, lack of knowledge;
- enhancement of education and skills training/upgrading activities via courses at community colleges, videos defining operating, servicing and maintenance functions for systems, enhancing commissioning activities, etc;
- development of innovative electric baseboard controls;
- demonstration of control strategies and heat usage metering for hydronic systems; and
- development and adoption of Building Codes which provide clearer definitions of system performance requirements. Current references such as "in accordance with good engineering practice" is a problem for many practitioners.

INSTALLATIONS MÉCANIQUES DANS LES TOURS D'HABITATION

Introduction

On a effectué une étude documentaire et une enquête auprès de 150 organismes représentant 25 000 logements répartis dans 260 bâtiments en vue de déterminer le genre, de même que le degré d'avancement technologique, des installations mécaniques (plomberie, chauffage, ventilation et climatisation) utilisées dans les tours d'habitation.

Programme de recherche

Le recensement effectué au Canada en 1981 indique que les immeubles d'appartements de moins de cinq étages constituent 16,3 p. 100 des habitations privées occupées, et ceux de cinq étages ou plus (tours d'habitation), 9 p. 100. Les bâtiments de grande hauteur vont des appartements à loyer modique aux luxueux logements en copropriété. Ces tours consomment fréquemment une plus grande densité d'énergie, procurent un niveau moins élevé de confort et présentent proportionnellement plus de défauts matériels que les immeubles de faible hauteur. En outre, le propriétaire et l'occupant n'ont généralement pas de droit de regard sur le processus de construction.

Résultats de l'enquête

- Le chauffage par plinthes électriques est le dispositif le plus populaire et celui qui suscite le moins de plaintes quant à son fonctionnement. Les chaudières à gaz centrales dotées de radiateurs périmétriques à eau chaude suivent en popularité. À Montréal, presque toutes les installations sont électriques. Dans les Prairies, par ailleurs, les systèmes au gaz sont privilégiés. Les installations de chauffage au mazout ne sont utilisées que dans les Maritimes et dans le Nord.
- Pratiquement toutes les tours (95 p. 100) sont munies d'un système central d'air de compensation donnant sur les corridors. L'air arrive aux logements individuels en passant sous les portes et par les fissures. Deux répondants ont signalé que, dans un cas, l'air parvient aux logements par un conduit, et que dans au moins deux autres bâtiments, on a recours à une grille de transfert entre les corridors et les logements. En général, les installations d'air de compensation fonctionnent continuellement, bien qu'elles puissent être mises hors tension périodiquement au moyen d'un interrupteur à minuterie pour économiser l'énergie.
- Quarante-huit pour cent des tours disposent d'un simple système central d'extraction d'air, 14 p. 100 comptent sur une installation centrale modifiée et 38 p. 100 sont dotées de ventilateurs d'extraction individuels pour salles de bains et cuisines. Les installations centrales d'extraction sont fréquemment commandées de la même manière que les systèmes d'air de compensation tandis que des interrupteurs locaux (manuels ou hygroréglables) contrôlent les ventilateurs individuels.

- Les plaintes ont surtout trait à la performance de l'installation de ventilation, aux infiltrations d'air ou au mouvement d'air.
- Le fonctionnement des installations est souvent considéré comme moins que satisfaisant.
- Le tiers environ des logements est climatisé au moyen d'un équipement permanent (non installé dans une fenêtre) (les copropriétés constituant 38 p. 100 de ces logements). Les aires communes et les halls sont habituellement climatisés si les logements le sont aussi. Cependant, les corridors munis d'un système d'air de compensation ne le sont généralement pas.
- Approximativement 75 p. 100 des tours ont des chauffe-eau centraux. Pour ce qui est des autres tours, on fournit des chauffe-eau électriques dans chaque logement ou, comme dans le sud-ouest de l'Ontario, on dispose d'installations au gaz à haute efficacité. Actuellement, il est pratique courante en Colombie-Britannique de réchauffer les conduites principales par dispositifs électriques au lieu d'avoir recours à une boucle et à une pompe de recirculation. Environ 10 p. 100 des installations sont chauffées par le générateur de chaleur affecté aux locaux. Quatre-vingt pour cent des systèmes centraux sont dotés de conduites isolées.
- Cinquante-trois pour cent des tours d'habitation offrent des garages chauffés, 24 p. 100 des tours fournissent des garages non chauffés et les autres ont soit des espaces extérieurs de stationnement, soit des structures de stationnement ouvertes. Les places de stationnement en climat froid sont plus souvent situées à l'intérieur et chauffées. Soixante-et-un pour cent des garages chauffés le sont au moyen de générateurs d'air chaud électriques (à Montréal, cette proportion atteint 84 p. 100).
- La plupart des garages ne sont pas chauffés (72 p. 100). La récupération de chaleur n'est incluse dans aucune des installations ayant fait l'objet de l'enquête. Soixante-dix-huit pour cent des installations sont asservues à des détecteurs de monoxyde de carbone. Les autres fonctionnent continuellement, sont réglées par une minuterie ou dépendent de l'intervention humaine.
- Les services utilitaires dans les garages non chauffés sont protégés du gel grâce au réchauffage des conduites, à l'isolation ou à la présence d'un vide de plafond chauffé; dans le cas des canalisations d'incendie et des extincteurs automatiques, on a recours à l'air comprimé.
- Le travail relié au fonctionnement et à l'entretien est habituellement confié au concierge de l'immeuble. Les grandes sociétés peuvent employer des travailleurs spécialisés, mais la plupart des organisations (78 p. 100 au total) ont recours à des entrepreneurs.
- Les problèmes associés aux connaissances qu'exigent les tâches de fonctionnement et d'entretien sont étroitement liés à la perception qu'en ont les propriétaires, les exploitants, les promoteurs et les gestionnaires immobiliers puisque 74 p. 100 des personnes interrogées lors de l'enquête faisaient partie de ce groupe.

Conséquences pour l'industrie du logement

Cette enquête a donné lieu à un certain nombre de recommandations en ce qui a trait aux activités de recherche, de développement et de démonstration :

- créer un groupe d'examen multidisciplinaire chargé d'équilibrer les priorités fonctionnelles (réduction de la consommation énergétique, amélioration du confort, source d'énergie utilisée, etc.) et les contraintes budgétaires selon les activités à entreprendre;
- mettre sur pied des systèmes économiques pragmatiques visant à contrer les infiltrations d'air et la transmission des odeurs tout en procurant une ventilation économique de qualité;
- rédiger des manuels des règles de l'art fondées sur les connaissances actuelles (on s'est en effet aperçu que les problèmes découlaient souvent d'un manque de connaissances sur le plan personnel plutôt que collectif);
- parfaire l'éducation, perfectionner les activités de formation au moyen de cours dans les collèges communautaires et de vidéos expliquant le fonctionnement et l'entretien des installations, améliorer la mise en service de ces systèmes;
- mettre au point des commandes novatrices de plinthes électriques;
- organiser des démonstrations de stratégies de contrôle et de comptage de l'utilisation de la chaleur concernant les installations de chauffage à eau chaude;
- élaborer et adopter des codes du bâtiment qui définissent plus clairement les exigences de performance de ces installations. Des énoncés comme «... doivent être conformes aux règles de l'art...» causent des problèmes à bien des entrepreneurs.

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1. INTRODUCTION

1.1 Background

The changing economic forces precipitated by the energy crisis in the 1970's forced the building industry to review how it builds and manages buildings. Since that time there have been significant improvements in energy efficiency although this improvement has been by no means uniform across the various building types.

Single family homes have attracted the lions share of the research and development effort, perhaps because they are more numerous, by comparison to commercial and institutional buildings; are simple to understand; and because retrofits and changes of construction practices are relatively inexpensive to undertake.

Larger buildings, on the other hand, have not fared as well as the single family home and of these the multi-unit dwellings has received a disproportionately meagre share of the research interest. A possible reason for this lack of attention may be that large commercial, institutional and industrial projects may provide a greater engineering challenge than do apartment buildings.

It is somewhat of an anomaly today that a dwelling unit in a multi-storey project with only a single exposed exterior wall can often have an "equivalent energy consumption"1 higher than a single family dwelling with several times the exposed area. For example, Hancherow reports consumption for apartments in Calgary between 0.92 GJ/sq.m. and 1.46 GJ/sq.m. whilst for townhouses and row housing between 0.86 and 1.37 GJ/sq.m. Whilst using energy at a higher density multi-unit buildings often provide lower standards of comfort and have a disproportionate share of physical defects.

Another influence that has led to this unfortunate situation might well be the unique relationship between the developer or building owner and the tenant. Unlike commercial, institution or industrial ventures, and single family house construction, the building will most often, not be occupied, and often not be owned by the builder nor is it likely that the ultimate user will have any input on the

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1 "Equivalent energy consumption" expressed on a per unit floor area basis would include common areas consumption.

design and construction process. Further, the ultimate user will have very little influence to force the building owner to correct building and operating deficiencies, being only one of a large number of small tenants.

This kind of situation is most in evidence in low rental accommodation. At the other end of the market place, in luxury condominium developments for instance, we are seeing however, the emergence of a strong litigious owner, the condominium corporation, who are starting to make building designers and developers think a little more cautiously about the product they are offering. It is interesting to note that some consultants have one scale of design fees for rental apartment buildings and another, higher scale, for condominium buildings.

To give a sense of relative importance for addressing apartment buildings data from the 1981 Canada Census provides the following statistics for apartment building of four storeys or more.

* apartments constitute 25.3% of occupied private dwellings
* 16.3% are in less than 5 storey buildings
* 9% are in buildings of more than 5 storeys

It is against this background that Canada Mortgage and Housing Corporation (CMHC) have commissioned this present study which is aimed at establishing an understanding of current practice; its weaknesses; and opportunities for improvement through the encouragement and support of further research and demonstration projects.

1.2 Methodology

The task, which was essentially one of information collection, sorting, review and analysis was carried out for two types of data. The first being existing 'data' in the form of published papers and technical literature; the second being new information collected primarily for the purposes of this study.

The literature review (existing data) was commenced with a key word search of IBSEDEX, ICONDA and Engineering Index data bases at the Canadian Institute for Scientific and Technical Information (CISTI) and the use of our own technical library; efforts were concentrated on literature not greater than fifteen years old and primarily of continental North American origin and English language papers from Europe and Scandinavia. References considered of interest and taken from material obtained in this initial effort provided a second wave of information.

'New data' was collected by carrying out interviews with individuals and organizations associated with the design, construction and operation of multi-unit dwellings. 74% of those interviewed represented building developers, owners, managers and operators. Approximately 150 interviews were carried out representing in excess of 260 buildings and 25,000 dwelling units across Canada.

Interviews were structured through the use of a questionnaire. A very detailed questionnaire was originally developed following the literature search. Simpler 'field survey' questionnaires were developed from this detailed questionnaire (see Appendix III) and used during the actual interviews. The more detailed questionnaire was used to summarize the data on a regional basis and is available in the detailed survey responses.

Interviews were co-ordinated or carried out primarily by three organizations; by Leslie Jones & Associates Inc. for Ottawa and SW Ontario; by Chalifour Marcotte et Associes for the Outaouis, Quebec and the maritimes; and by SMB Consultants for British Columbia and the prairie provinces.

The reader is cautioned against placing too much statistical significance to the information (specifically numerical information) presented in this report. The interviews were not specifically organized to provide a statistically meaningful sample; nor was it the intent of the work to develop such statistical information. The reader is also cautioned that there may be lack of objectiveness in some of the responses received. For instance, in certain sets of data concerning the level of satisfaction with designers and contractors there was some suggestion that individuals rated their own profession more highly than others.

The work should be understood as a first and very broad brush attempt to describe in general terms typical construction practices and weaknesses. It is considered the first step towards giving focus and a sense of urgency and importance to the development of a suitable program of research and development.

2. REVIEW OF CURRENT PRACTICE

2.1 Apartment Suites Heating

Based on the results of our survey, averaged across Canada, electric baseboards are the predominant means of heating. Usage is placed at between 53 and 81% and increasing; ie. electric baseboard is increasing in popularity as a means of heating. There are, of course, strong regional variations which would appear to be driven by fuel availability and economics, ie. electric baseboards are seldom used in the Prairie Provinces whilst they are used almost exclusively in the province of Quebec.

The primary reason for selecting baseboard heating tends to be its low initial cost. Electric heating also offers the benefit of being able to be individually and accurately metered with only a relatively small incremental cost to the electrical distribution.

Electric baseboard appears to get displaced by gas fired systems where such systems are felt to offer significantly lower operating (and presumably life cycle) costs. A number of respondents in the Prairies claimed their choice of hydronic systems was based on this form of heating having the lowest first cost which would appear to contradict the common opinion that electric baseboard offers the lowest first cost.

Other reasons for the choice of the electric baseboard is its general reliability, low cost of individual room control, low operating and maintenance costs, low space requirements and for the designer, ease of design. Of those buildings utilising this form of heating, control is overwhelmingly by remote (wall mounted thermostats); almost 90% of which are line voltage (as opposed to low voltage) type. As with other forms of heating, with only two exceptions, we did not find any use of setback type thermostats (the exceptions were not for baseboard installations).

The second most widespread form of heating is the central boiler with hydronic baseboards. Based on our survey we would place usage at between 13 and 35% of the market. As previously mentioned these systems are most used in the Prairie provinces. Unlike electric systems there are a mix of control strategies used including both electric and pneumatic control valves, either one per apartment (most common) or one per room (luxury accommodations); thermostatic radiator valves; and inside/outside control (ie varying the temperature of water delivered to the suites with variations in outdoor air temperature). Inside/outside control might be used on its own or with control valves. We are not able, from our survey results, to place any range of use on the various types of control strategies used except to say that in most situations some form of individual apartment control is provided. In only one of the buildings was this control a night setback type. Further the survey results did not suggest that "advanced" control techniques for indoor/outdoor control such as solar radiation, wind speed/-direction, night setback and morning boost compensations were being utilised.

Other occasionally used heating types include:

* water loop heat pump
* hydronic fan coils
* incremental units
* electric furnace
* radiant electric ceiling heating
* in-floor electric heating
* gas furnace

The first four of these heating types are typically only used where the building is air conditioned and a combined heat/cool system can be used. The actual choice of heating is more likely to be made as a result of the choice of air conditioning rather than on the relative merits of the heating system. Often these systems may be used with supplementary, often electric, perimeter heating. The incremental units and electric furnace system may utilise direct electric heating and/or air source heat pumps. The gas furnaces were only seen in SW Ontario where Union Gas have a technology development program and are promoting "vertical gas distribution" with separate (gas) metering and through the wall package heating and heat/cool units.

The combined total percent usage of these "secondary" systems based on the survey results lies between 8% and 13%.

None of those interviewed reported any experience with radiant hydronic systems or combination heating domestic hot water systems. Only in one building were passive solar features utilised.

2.2 Apartment Suites Air Conditioning

Based on the survey results around one third of multi-unit dwellings are air conditioned by permanent equipment (i.e. excluding those buildings where window units are used). This may well be an inflated figure given the relatively high proportion of condominium projects in our sample (38%); or inaccurate sampling method.

Of the reported buildings a little over a third were incremental units,a little less than a quarter were split systems, whilst a little over a quarter were central chilled water. The remainder, which can be classified as systems only occasionally used included water loop heat pump and individual water cooled units (cooling water coming from a central cooling tower).

Whilst the data is somewhat less than complete on the reasons for selection of system types some general principals are apparent.

* Incremental units are selected primarily on the basis of low first cost and can more often than not be found in the low end of the market.
* Central chilled water systems are normally chosen for the high end of the market and for those buildings that because of their height, cannot be served by split systems. Typically central chilled water systems will be the most expensive of the three main systems types.
* Split systems will often be on medium rise projects (up to 4 or 5 storeys), medium to high end of the market. Typically costs would likely lie in between incremental and central chilled water system costs.

2.3 Apartment Suites Ventilation

Ventilation systems reported all rely on a combination of supply and exhaust systems. With very few exceptions, heated, and occasionally cooled air, is delivered to public corridors and/or lobbies from where it passes, in over 95% of the cases, through door undercuts and cracks into the individual suites. In only two buildings were transfer grilles provided between the corridor and suites. In only three buildings, and by one engineer in B.C. who reported it in "several" buildings, was the make-up air actually ducted into the suites.

Canada-wide electrically heated systems predominated through gas is usually the popular choice where gas was available or already used in the building for space heating. Gas systems predominantly are indirect gas fired; few hydronic heated installations were reported presumably since such systems are extremely vulnerable to freezing unless glycol is used. (There appear to be few oil fired installations; three hydronic/oil systems were reported in Halifax)

With only four exceptions, humidification was not provided on the make-up air systems meaning that the air delivered to the corridor would have a very low moisture content during cold weather.

Typically the systems would run continuously although it is not uncommon for time clocks to be provided to schedule the operation; systems might for instance be shut off during the evening hours. No systems were reported as having variable supply air delivery. Where central exhaust were provided the most common make-up air volume quoted was 100% of the exhaust volume; the range reported, however, was between 100 & 140%. Where individual exhausts were used the reported make-up air percentage varied between 25 and 70% of the sum of the individual exhaust rates; between 40 and 50% however was more common.

Central exhaust systems were reported as most widely used; 48% of the buildings in the sample had simple central exhaust systems whilst another 14% had variations of central systems. These variations included:

* central bathroom exhaust with recirculating charcoal range hood
* "hybrid system" with individual exhaust fans dis charging into a common mechanically exhausted shaft
* combination of central and individual, eg. central system for the upper floors with individual fans for the lower floors

The remaining 38% of cases had individual bathroom and kitchen exhaust fans. Suites with laundry facilities may also have a booster fan for the clothes dryer where the dryer is located a long distance from the exterior wall. Very occasionally one fan may be used to exhaust two bathrooms or a kitchen and a bathroom or a bathroom and clothes dryer.

The method of controlling exhaust systems was not consistently well reported but information provided suggests that central systems would be controlled in the same manner as the make-up air system, whilst bathroom exhausts would be controlled by local switches and kitchen exhaust by switches or speed controller on the hood. In B.C. the control of bathroom fans by means of a (de)humidistat (a means of control suggested in the BC Building Code2), is not uncommon (25% of the sample buildings had this form of control), this method of control was not reported elsewhere. Individual exhaust systems would not run continuously.

In all but one case (in Ottawa) exhaust ducts were reported as discharging directly to the outside of the building as is required by at least the Ontario Building Code. In the Ottawa building exhausts for the lower suites exhausted in the basement garage. Typically exhaust ducts would run in bulkheads dropped below the structural floor, to an exterior wall; ducts might also be cast into the structural floor - we have no data to quantify in what ratio these two methods of ducting occur.

Finally 11% of those situations where central systems were used utilised some form of heat recovery; run around, heat wheel and heat pump types were reported. Heat recovery was not reported in any of the individual exhaust systems (heat recovery is not considered practical for a central supply individual exhaust situation).

2.4 Garages Heating & Ventilation

Heated garages were provided in 53% of the buildings in our sample; a further 24% had unheated garages, the remaining 21% having either on grade or open parking structures. Colder climates tend to have a higher percentage of enclosed heated garages whilst milder locations like Vancouver have few. From a standpoint of construction cost, longevity and low operating costs, remote open parking structures are favoured although such an approach to providing parking spaces is generally severely restricted by planning and land economics.

The preferred choice of heating garages is by electric unit heaters, 61% being heated in this manner. An even higher percentage is heated this way in those areas where electric space heating is predominant (eg. 84% in Montreal). Conversely, if central gas fired hydronic heating is provided in the building it would appear likely that hydronic or gas unit heaters would be used.

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2 It is suggested that RH is a reasonable practical indicator of the overall level of normal "pollutants" that can be expected in the dwelling.

Typically garages would be heated to prevent freeze up of services rather than to normal comfort temperatures. We do not have much data concerning actual temperatures maintained; of the few reported cases or on our own experience the range lies between 5 and 10 deg.C.

The predominant means of (enclosed) garage ventilation (72%) is reported as exhaust only drawing unheated air through louvres or ducts from outside. In the remaining 28% of cases a heated make-up air system is provided; this might be electric or direct fired gas. (Direct fired gas where the products of combustion pass with the outside air into the garage are permitted in garages when operated in sequence with exhaust systems). None of the survey results indicated any use of heat recovery ventilation systems although as an office we have used such systems on two multi-unit residential garages.

The minimum ventilation rate given in the National Building Code for parking garages (3.9 L/s/sq.m.) would appear to be universally adopted as a design value (in the Ontario Building Code this is the minimum value for constantly operating sys-tems). By far the largest percentage (78%) of systems were reported as being controlled by carbon monoxide detectors. The others being on time clocks or constant operation with manual intervention.

In order to protect services from freezing in unheated garages the following techniques are commonly employed.

* trace heating
* insulation
* enclosing vulnerable services in a heated ceiling space
* use of dry systems (standpipe and sprinklers)

In garages with unheated make-up air, where the temperature typically might dip during periods of ventilating, insulation might be considered a sufficient protection against possible freeze damage.

The lower the maintained temperature in the garage the more need there is for the slab to be insulated to prevent discomfort to the occupants above. (A dropped ceiling space with heating is sometimes used for a similar effect).

Whilst we were not able to collect reliable information on these aspects of protecting services, our own experience suggests to us that there is no commonly accepted best solution.

2.5 Common Areas HVAC

For the most part common rooms and lobbies will be air conditioned when the suites are air conditioned and in most cases by the same means used for the suites. Out of our sample around 10% of the buildings without air conditioning provide air conditioning to common areas. City water cooled packaged air conditioners are often used for isolated air conditioning needs along with split systems and incremental units. Data on air conditioning for corridors is somewhat less well reported, indications are, however, that in most cases, even in air conditioned buildings, cooling is not provided.

2.6 Domestic Hot Water Heating

Around three quarters of the water heating systems in the sample are central systems, primarily with pumped recirculation. B.C. was the only province reporting the use of electrically trace heated mains in lieu of recirculation loops to maintain delivery temperature (50% were reported as having trace heated mains3 - this percentage would be for recent designs and the system is reportedly gaining in popularity). Of these central systems the majority, around three quarters, would be gas fired, a further 20% electric and the remaining oil fired. Typically these central systems would be separate from the space heating (ie. self-contained), only around 10% were reported as being heated by the space heating boiler.

Most of the systems were reported to have at least part of their pipework system insulated, usually the recirculation loop or mains. In 20% of the cases it was reported that insulation was not provided on any pipework.

The primary reason for selecting central systems appear to be reduced operating cost - by virtue of the lower cost of gas or oil, although some reported these systems as being lower in first costs than individual heaters.

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3 An argument in favour of these systems in BC is the low life expectancy of recirculation loop pipework resulting from the combined effects of high and continuous water velocities, high water acidity and entrained air. (Typical life expectancy 14-18 years).

Around one quarter of the installation were reported as being individual electric; ie. each suite would have its own water heater. In these situations pipework would typically not be insulated. The most popular reason for installing individual electric was reported as low first costs. Another advantage, though not raised frequently in the survey, is that where individual metering is provided, the tenant or condominium owner pays only for what hot water he or she personally uses.

Individual gas fired units have been installed on a demonstration project basis by Union Gas (these installations have not been accounted for in the above projected percentages). High efficiency gas fired water heaters vented to exterior walls by PVC piping are being used, as are, on another project, gas fired water heaters venting into a common vertical vent, on the top of which is provided a powered inducer.

Finally just a single solar (assisted) domestic hot water heating system was reported.

3. REVIEW OF CURRENT SYSTEMS WEAKNESSES

3.1 General Issues

In addition to specific technical items, which are discussed in the following sections, a number or more general issues were targeted for investigation during the surveys and the results of these are presented below.

Degree of satisfaction with the design and construction team was one of the items we were interested in obtaining some information on. Based on the paper by Foss, if practice here is similar to that in Norway, we can expect design and construction professions to be responsible for 80% of projected building defects amounting to 2-1/2% of the total value of construction. (The remaining 20% resulting from material deficiencies). Whilst our survey could not address such a level of detail we did ask those interviewed to express their degree of satisfaction with designers and contractors and highlight those cases where the correction of defects represented a "significant part of their maintenance budget". Percentage figures for level of satisfaction are presented in the table below. The figures are overall averages based on responses from a sample predominantly representing building "users" (74% were owners, operators, developers or managers). We have not tried to remove any natural biases from the results, ie. for instance, we have not removed engineers' ratings of engineers from the figures. Few respondents, however, did give self-evaluations and we would not expect this to change the percentages to any significant degree. Removing the design teams evaluations of themselves from the calculation, for example, only reduced the level of satisfaction by two percentage points. Out of 83 responses to the question regarding required remedial work, 28 (34%) reported significant expenditures to correct design deficiencies. In reality the actual figure may be higher since for the older building the person interviewed may not be familiar with earlier problems or may have long since forgotten the 'teething problems' of the building.

	Very Satis-fied	Satis-fied	Neutral	Dis-Satis-fied	Very Dis-satis-fied
Architects	28%	47%	19%	5%	1%
Engineers	26%	55%	10%	8%	1%
Contractors	35%	42%	12%	10%	1%
Commissioning	15%	44%	18%	16%	7%
Maintenance	21%	62%	12%	3%	2%
OVERALL	27%	49%	14%	8%	2%

If we aim to provide a "satisfactory" level of service to our clients we can see that, as in industry overall we miss this goal once out of every four attempts. Commissioning organisations stand out as missing this goal almost twice as frequently.

Unprompted responses that were suggested as leading to substandard products included:

* Construction not being carried out in accordance with the contract documents
* Equipment substitutions (made by contractors) often resulting in inferior equipment to that specified
* Inadequate supervision during construction
* Selection of sub-standard equipment to meet tight construction budgets
* Poor workmanship
* Low design fees
* Inadequate feedback to designers of successes or failures of their designs
* Compliance with Codes not uniformly and rigorously enforced

These problems are not, however, unique to multi-family buildings. On this point the following excerpts from the 1990 presidential address to the Chartered Institute of Building Services (UK) summarises the problems quite aptly.

> "What the traditional system does is to select designers who seek to create quality, which then has to be realised by contractors selected on a basis of lowest price, who thus pursue a policy of minimising costs. The two

> aims are in conflict, for differentiated quality and lowest costs are opposing strategies."
>
> "It is widely understood that the building industry generally has a poor image, and this acts as a disincentive to recruitment. The whole industry is not seen to offer a career structure comparable with that of many competing industries. Within the overall scene, building services engineering is a poorly understood occupation, the word 'services' in the title seems not to aid understanding."

Maintenance practices were also of interest and results collected in the surveys indicated by far the majority of maintenance (78%) gets carried out by a mix of in-house staff and outside contractors. The actual ratio would depend on the level of expertise of in-house people; for most in-house maintenance situations the task of day to day simple O&M tasks would fall on the janitor/superintendent who might well be inadequately suited to the task. Whilst the preceding table does not indicate an unusually high level of dissatisfaction with maintenance perse we must acknowledge that a significant percentage of the organisations contacted were in fact responsible for overseeing maintenance and might well be expected to give biased opinions about its success.

Other factors contributing to lack of maintenance and/or the implementation of desirable improvements included:

* Rent control legislation
* High levels of vandalism and abuse of common facilities
* Lack of competent staff

3.2 Heating

Whilst it is not possible to give numerical significant data from the survey there are a number of general comments and trends that have been identified and these are presented below.

Perhaps one of the more significant items is that hydronic systems tend to give rise to more complaints than do electric baseboard systems. The most commonly reported complaints associated with the performance of hydronic systems being poor temperature control, operating and maintenance problems, noise, and high initial costs. Poor temperature control is commonly attributed to one or more of the following factors.

* poor pipework design
* poor balancing
* lack of individual controls
* control valve reliability
* control valve performance (particularly thermostatic radiator valves)
* frozen pipework (often attributed to air infiltration)

Operating and maintenance problems can be considered a consequence of the items listed above and often result in what users consider to be excessively high operating costs. It is also reported that janitors, who are often the first to attempt to solve day to day operating problems, very often do not understand the complexities of the more advanced control systems and can often negate any benefits they might otherwise offer. Another drawback of these central systems commonly reported in the survey is that they do not lend themselves to individual metering and that consequently costs cannot be passed onto tenants or individual condominium owners.

In contrast, relatively few complaints about electric heating were expressed by those interviewed, the only significant and recurring problem being that of their high operating costs. For developers building rental accommodation this is clearly not a disincentive to use such systems if individual metering is provided. Other complaints included:

* lack of robustness
* unattractive appearance
* poor temperature regulation when integral thermostats are used

Of the "secondary" (not so popular) types of heating system there is not a large amount of information on which to draw conclusions. Reported, however, were the following:

* temperature control problems during spring and fall seasons where two pipe heat and cool hydronic fan coil systems are utilised
* consequences of premature failure of in-floor electric heating systems (for one housing authority before 20 years and because of the difficulty of replacement, their substitution with electric baseboard)
* susceptibility of electric radiant ceiling systems to physical damage and a tendency of overheating in spring and fall

In addition there were a number of problems raised that are common, in varying degrees, to a number of systems. These include:

* poor envelope integrity
* condensation on windows
* under and oversizing of equipment
* drapes covering baseboards and adversely affecting the heating
* cold drafts particularly at (large) windows
* cold floors, particularly above overhangs
* overheating, particularly where individual controls or meters are not provided
* complexity of controls, and
* reliability of controls

Whilst not directly a heating systems component, poor envelope integrity, particularly with regards to air and water tightness is a commonly reported problem impacting upon the operation and success of the heating system. Poor envelope also has implications on the ventilation systems and is discussed more fully in that section.

Condensation is not purely a heating related problem but can be minimised by correct placement of heating elements below windows and/or ensuring air is blown uniformly over the window surface.

Undersizing and oversizing of equipment appeared on a disturbingly high number of completed questionnaires; other than design error or over-cautiousness there is, for most situations, no justified explanation for this.

Cold drafts will in the first instance be created by the amount and quality of the glazing but placement of the heater below glazing will minimise complaints. Modulating systems provide a more reliable means of preventing drafts in that the amount of heat will be in proportion to the potential down-draft. Electric heat, which typically is either on or off, is thus not consistently effective against down-drafts, especially so when the equipment is oversized. During the off cycle which can occur even in extreme cold weather, cold down-drafts can be a problem.

In seniors projects, where suites are often small and furniture placement options limited, and, where the occupants are particularly sensitive to drafts and spend a lot of time sitting, this intermittent heating can result in much discomfort.

Overheating can result from unbalanced or poorly zoned or controlled common (hydronic) systems or by tenants setting their thermostats above normally accepted comfort settings. Overheating typically leads to the opening of windows for ventilation (and cooling) even in extreme weather conditions.

Whilst there are few people who would admit to not understanding how a simple thermostat works a recent study in the UK suggests that even such a simple device is widely misunderstood. The introduction of electronic setback thermostats has added an order of magnitude into the complexity of this simple device and because of lack of user understanding or reliability, there are many contractors who will not install such equipment to avoid call backs because the system is "not working". Whilst these devices appear to have made little inroads to individual suites, devices of similar or greater complexity such as indoor-outdoor controls were reported to be beyond the understanding of the typical on-site operator (usually the janitor).

3.3 Ventilation

From our initial review of literature on apartment buildings we were expecting ventilation issues to be of significant, if not predominant, importance. This was substantiated by the survey results - ventilation in its widest sense of the overall air movement into, out of and through the building proved to be the item causing most concern.

Within the overall context of "ventilation" those issues that appeared with most regular repetition included:

* noise
* ventilation performance (environmental quality)
* envelope leakage

those that appeared with somewhat less repetition included:

* lack of reliability of equipment
* high energy costs[4]
* condensation on windows

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4 According to Railio, between 30 & 50% of total energy use can be attributed to ventilation & infiltration (Finnish data).

and those that appeared occasionally included:

* high capital cost of the make-up air system
* condensation causing fabric or structural deterioration
* loss of fire integrity5
* windows opened to control winter overheating

The lack of ventilation to all habitable rooms6 is voiced as a concern in the literature but was not specifically raised in the survey. This is not to say it is not a problem. Lundquist (Denmark) measured ventilation rates as low as 1 L/s per person in bedrooms; 5 L/s per person per bedroom is recommended in the CSA (preliminary) standard on residential ventilation requirements. As envelope gets tighter we foresee this as becoming a more important issue.

Noise problems manifest themselves in a number of ways. Noise is created by the fans, by high velocity air in ducts and at supply and exhaust outlets. Small exhausters (ceiling fans) are notably noisy to the extent that they simply will often not get used which ultimately affects air quality. The BC Building Code requires that ceiling fans be selected below 2.5 sones or 60 dBA in an effort to limit noise from ventilators. Even central systems are not devoid of noise though more often than not it is associated with those apartments located in close proximity to central ventilation equipment or is a problem in the corridors. Air noise (whistling) created by the corridor make-up air flowing around the suite/corridor door into the apartment is not an uncommon complaint; that is when draft strips have not been fitted to eliminate objectionable drafts, the transmission of noise from the corridor or the whistling noise itself.

Noise transfer is also a problem and the ventilation system can provide a low resistance path for noise transfer. Central systems are more susceptible to this than are individual systems.

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5 Marchant places the risk of fire in multi-family housing 10 times higher than in single family dwellings (UK statistic).

6 Bedrooms and living areas are typically not provided with any forced ventilation unless ducted A/C systems are provided.

The most noticeable and common form of lack of ventilation system performance is the movement of odours, more often than not the transfer of cooking odours into the corridors. Other transfers do occur and reported in our survey and/or in the literature are the movement of garage, laundry and garbage room odours, and the contamination of make-up air with smoke from wood burning fireplaces or exhaust air. Other problems include the transfer of tobacco smoke from public corridors and lobbies (from people collecting there to smoke to avoid doing so in their own apartments)7 and the complete lack of any form of ventilation when central systems are scheduled off. Lack of proper ventilation can also manifest itself in the form of condensation on windows which would be aggravated by poor window performance. Avoiding the use of exhaust fans during bathing or cooking will often lead to such conditions.

Conditions in the corridor itself were sometimes criticized as being too cold in winter and too hot and "stuffy" in summer - a number of those interviewed expressed a desire for the air to be cooled to improve summertime conditions.

Shutting off corridor make-up air systems, which is often done to reduce energy consumption; and sometimes to minimise evening noise or because the system is inadequate in very cold weather; often precipitates complaints. When systems are turned off during winter hours air infiltration through the system can also give rise to cold corridors.

Duct leakage can also reduce ventilation efficiency, since air will not be delivered or exhausted from where it would be of most benefit; standards of duct construction are not considered to be particularly high in residential construction. Joints are often not sealed; sheet metal held by self-tapping screws is often substituted for proper gasketted access doors.

Lack of proper balancing can also create localized air quality problems, as can undersized ventilation systems and inadequate exhaust performance.

Envelope leakage, in addition to the direct adverse effects it can have on fabric integrity and heating performance can, under the action of wind or stack effect, have a

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7 This was not a widely reported occurrence and was raised only during a Montreal area survey.

significant impact on the ventilation system by affecting or modifying air flow patterns to the extent that designed air flow patterns can be completely reversed. This is discussed further in Section 4.3.

A significant source of infiltration is considered to be through the ventilation systems themselves. Outdoor air dampers seldom close to provide a reasonable air tight seal even when fully functional; often they are found in a non-functional condition.

Central duct systems are also considered as potential compromises of fire integrity in that they provide a possible path for the movement of fire and smoke through the building. This path is usually required by Code to be protected by thermally activated fire dampers and/or fire rated construction but missing fire dampers, dampers installed upside down or out of the plane of fire separation or dampers that are not maintained or fail to stop smoke transfer can be considered inherent weaknesses in this approach. Lack of appropriate packing between ductwork and the structure also reduces the fire and smoke integrity of the partition.8

Finally, lint collection in ducts from laundry facilities can ultimately lead to reduced dryer efficiency whilst the collection of lint around the exhaust outlet can result in an unsightly appearance.

3.4 Air Conditioning

There were very few concerns expressed about weaknesses in air conditioning systems, much less by comparison for instance than for ventilation, heating and domestic water heating. Perhaps the most commonly recurring complaints, however, concerned noise.

Complaints of noise in suites located directly under rooftop mounted central chillers appears synonymous with this kind of installation. Incremental units have a reputation for the noise they produce. Noise from fan coils and the evaporator of split systems can be troublesome if sufficient care is not taken to follow simple noise reduction techniques. Noise from condensing units can also be an

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8 This applies equally well to penetrations by pipes and electrical cables and conduits.

irritant if they are not located away from normally used spaces. For this reason commonly used equipment would not be appropriate, for instance, for location on an exterior balcony even though this might be considered an otherwise suitable spot.

Other complaints and problems reported include:

* Poor air distribution. Usually ductwork is restricted to bulkheads or dropped ceiling in the core area of the apartment; trying to minimise the extent of these dropped ceiling areas can compromise air diffusion systems. For similar reasons arranging return air can be problematic and it is not unusual for fan coils and the evaporators in split systems to be installed without a ducted return drawing air via a series of transfer grilles, from the room (typically a storage or laundry area) in which they are located. Incremental units also have limited air distribution capabilities.
* Rapid deterioration of elastomeric piping insulation on refrigerant piping to condensing units, ie. where it is exposed to outside conditions without adequate PVC or metal covering.
* Inadequate flushing of chilled water pipework systems leading to blockages in pipes and coils.
* Improper balancing of chilled water pipework systems. * Higher than necessary operating (energy) costs in central systems because there is no individual accountability for usage.
* Lack of reliability and high maintenance costs; failure of a single component in a central system can often have unfortunate consequences for the whole of the building.
* The need for air conditioning for seniors projects.

3.5 Garages Heating & Ventilation

Structural and maintenance problems caused by ice and salt, which lie outside our scope of work, appear to be the overriding concern to owners and operators. Never-the-less mechanical problems and concerns were raised and these include:

* high cost of operating garage heating and ventilation systems (Ottawa Hydro reports that common meter consumption can be as high as one half of the total building consumption)
* high cost and low reliability of ramp snow melting systems

* ventilation systems/controls tampered with (to increase the garage temperature and/or reduce operating costs) preventing proper ventilation
* uneven ventilation, ie. some areas of garage not properly vented
* high temperatures and humidities (by melting and evaporating ice and snow) accelerates rusting and cause/aggravate structural problems (typically the garage walls will not have a vapour barrier)
* movement of contaminated air from the garage to occupied areas by leakage within the building or outside the building from the exhaust discharge
* noise: the major problems appear to be associated with suites located near to ventilation equipment or supply and exhaust louvres
* tenants leave cars running in the garage to warm up (we would presume that this is more likely in unheated garages)
* pipe freeze-ups
* water and ice build-up in dry pipe systems requiring systems to be drained (this may be a consequence of leakage past the alarm valve or not using an adequate air dryer for the system air compressor)
* difficulty of locating leaks in pipework when it has been covered by drywall (typically all horizontal distribution of piped services is carried out in the garage)
* pipe insulation vulnerable to damage/abuse
* exposed services passing between floors vulnerable to vehicular damage
* high cost and poor appearance of slab finish. Extensive services running through and below the slab make drywall finish (required over insulation) difficult to install
* leakage and condensation damage around the bases of drains and electrical services to exterior landscaped areas
* residual low levels of carbon monoxide during those periods when the exaust fan is not operating. This is typical in those situations with a single fan controlled by a CO monitor
* difficult to keep clean; where air is drawn from the garage for the purposes of make-up air for locker and equipment room ventilation these rooms also tend to become very dirty very quickly
* low light levels, sombre appearance and perception of lack of (personal) security. (Close circuit TV surveillance systems are common in up-market projects)

* lack of fail-safe features in ventilation systems, eg. reliance is placed on the operation of single pieces of equipment (ie. run and standby systems are not provided)

3.6 Domestic Hot Water Heating

Incorrect sizing, ie. undersized equipment, appear to be the most frequently raised problem. There is some suggestion that this in part may be due to the insensitivity of current sizing procedures to varying lifestyles. One can, for instance, see professional, childless working couples with a busy social life and a fondness for jacuzzi tubs having a significantly different hot water usage pattern than retired seniors. For projects with mixed occupancy central systems may offer some safety through diversity of use, there is no safety factor, however, when individual water heaters are used.

Other concerns and issues raised included:

* Plumbing noise. We have no field collected information concerning the common types of noise.
* Leakage. The lack of sufficient and/or accessible shut off valves often compounds the effects of leakage from hot and cold water systems.
* High operating cost. Lack of individual accountability for hot water usage may contribute to higher than necessary costs for central based systems and apartments without individual metering.
* Heavy peak demand charges incurred by electric water heating.
* Low reliability. Duplication of equipment to avoid a complete lack of delivery capability does not appear to be a common practice.
* Unacceptable shower performance when pressure balancing type valves are not used.
* Cost of guarding against water damage from leaking (individual) hot water tanks adds significantly to the cost of this type of system (individual drains are required).

4. DISCUSSION

4.1 General Issues

Somewhat surprisingly to us, at least initially, was the relatively frequently expressed desire for more rigorous Codes, Standards and guidelines. Specific comments and suggestions included:

* Less ambiguous, easier to read, illustrated Codes[9]
* Good practice guides[10]
* Mandatory ventilation standards. The current "Preliminary Standard CSAF326.1" on ventilation for single family dwellings might be expanded to cover multi-unit dwellings and made mandatory
* Quicker response to new technology
* Higher insulation standards
* Better window quality standards
* "Energy Audit" of proposed new designs
* Mandatory individual metering
* Sensitivity to the environment
* Greater sensitivity to user needs
* Define various levels of quality

It is quite clear from years in practice that Codes and standards typically define both minimum and maximum standards except where there is a tangible marketing benefit for doing otherwise. For instance, for the developer, choices between high standards of pipe insulation and marble in the entrance lobby are easy for him to make; clearly he will choose the marble unless he is mandated or convincingly persuaded to do otherwise. Even if the developer can see the benefit of pipe insulation he is operating in a competitive market and potential purchaser or renter likely will not. As one respondent stated, a condominium owner purchases a lot more than what he sees in his own individual unit. Even if he did see more, the complexities of the engineering involved would likely be beyond personal experience or understanding.

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9 The recently issued Ontario Code & Construction Guide for Housing might be considered an appropriate type of approach for promoting better design solutions.

10 same as above

For condominiums, therefore, there is an even stronger argument for defining better and more comprehensive standards in order to protect the interest of the purchaser.

Likewise, there is a very strong argument for mandatory energy performance since the average purchaser or mortgage holder will not be able to determine or evaluate the potential energy efficiency of this type of building. The City of Vancouver has adopted an Energy Code effective July 1991, but there appears to be little other legislation controlling energy efficiency.

Other suggestions for ultimately improving the end product suggested by those interviewed included:

* Demonstration projects (of suitable technologies)
* Reliable life cycle costing information to aid better equipment and systems selection
* Task force and Technology Centre for developing, cataloguing and disseminating information. Such a suggestion is seen as an important one given the fragmentation of the building industry into small organisations that are not capable of individually supporting research and development
* Better education. This would include various levels from the education and training of new engineers with skills and knowledge specifically suited to the industry; ongoing training and skills upgrading of tradesmen; and the training of operation and maintenance personnel.
* Changing energy pricing policies and/or offering incentive to influence or promote energy conserving practices.
* Change depreciation (taxation) rules to favour better maintenance practices (longer write-off periods)
* Since it is not uncommon for developers and contractors to go into bankruptcy leaving building owners with little protection (after the warranty period) it is suggested that lending institutions be forced to take a greater responsibility for ensuring quality

4.2 Space Heating

From the perspective of the building developer, engineer and ultimate end user, electric heating appears to offer a close to ideal technical solution for multi-unit housing. Its main weakness is not technical in nature, but its perceived high operating cost.

When electric heating is viewed in the wider context of energy supply and demand and their impact on the environment the issues become far more involved and lie outside of the scope of this current work. It is clear, however, that reliance should not be placed on a single fuel and that technical developments for both gas and electric fuels should be pursued. Given the current disproportionate share of the market held by electric heating and the problems that some utilities are having or are projecting meeting current demands without expanding controversial hydro or nuclear projects, there is some justification for placing emphasis on addressing the weakness of gas heated systems.

Whatever kind of fuel is adopted, however, universal benefit will be obtained by improving the thermal integrity of the envelope. Given the not uncommon complaint of structural and air leakage problems with current and recent past designs it is considered appropriate that some effort be made toward the development of better envelope systems. Air and moisture control is considered a key issue and is discussed further in the following section (4.3 Ventilation).

For electric heating systems the main issue is reducing usage and cost. If time of day rates or some other incentive for minimising peak demand become common for this type of building, then controlling the time of usage by utilising storage techniques would become appropriate.

In terms of reducing electric usage for heating the following are considered appropriate:

* restricting the use of common metering
* improved control

Common metering is generally agreed to result in higher energy usage. Typical of many reported statistics is Ottawa Hydro's own data which indicates 37 to 41% higher consumption where common meters are used; the lower figure is for non-electric heated suites, the higher where electric space heating is utilised.

Ottawa Hydro also reported that in individually metered buildings up to 50% of the electrical consumption can be on the building's common meter which is a significant amount. On a similar note one property management company reported that electricity can form up to 1/3 of the condominium's fees as compared with around 1/10 for gas charges.

Improved control would come from the ability to modulate heat from the baseboard, as opposed to an on/off type of control, and the ability to schedule temperatures on an hourly and daily basis. Modulating the output would also eliminate the problem of cold drafts down windows during the baseboard off-cycle. We feel that closer control of temperature and the elimination of cold drafts will result in comfort at a lower overall average temperature; the argument being that thermostats will not need to be set artificially high to offset the effect of cold drafts and low swing temperatures. The technology for providing such control is readily available but is simply not used because of its high cost. We see the development of, and incentives to use, a simple to operate and reliable low cost programmable thermostat combined with a baseboard with modulating output control as the most logical and significant next step for electric space heating.

For gas based systems, the issue is not merely one of reducing energy usage but in lowering first cost, improving systems performance and minimising operation and maintenance costs.

In terms of reducing energy usage a significant saving should be achievable if individual metering were provided (literature suggest savings of between 20 and 40% for individual metering in the case of electricity, this of course includes reductions associated with other non-heating activities). Two approaches are possible to providing metering. One is to provide a central heat source and monitor the heat delivered by the hydronic system to each dwelling unit. The other is to distribute gas around the building and provide individually metered gas connections to self-contained heating appliances in each dwelling unit.

The technology for hydronic heat metering is available and is considered a relatively "mature" technology; it is in common usage in Europe and Scandinavia but has not found favour in North America. Its relatively high capital cost, arguments about accuracy and reliability, and the ongoing cost of maintaining the equipment and the accounting system weighed against any perceived "benefit" are likely the reasons for its lack of popularity. (see also the previous discussion on "benefits" under section 3.1 General Issues). Given that this method of providing individual billing would, in particular, be applicable to the existing building stock, it is recommended some effort be made toward establishing and promoting suitable techniques. We would consider a project encompassing a review of available techniques, laboratory testing as felt necessary, and a demonstration project documenting costs, problems and benefits as being appropriate.

The alternative to individual heat metering, ie. gas distribution to in-suite appliances, is being actively pursued by some gas utilities. Union Gas have around 30 such "vertical subdivision" projects in and around the Chatham area in SW Ontario. Typically gas at 2 psig is distributed in steel gas mains to meter stations within the building and from these meter stations in copper tubing to individual suites. Packaged gas heat, electric cooling (Magic Pak) units have been used in these projects. These units which are quite bulky, take up valuable perimeter area (they are direct vented and must be installed on an exterior wall). BC Gas is also making a strong attempt to increase gas usage in multi-unit buildings; many apartment units in the Vancouver area are reported to have gas fireplaces with direct wall venting and fan recirculation for space heating.

Union views these experiments as encouraging and are looking towards an expanded appliance portfolio of equipment to suit the range and demands of developers. Fairly recent developments such as combination heat/domestic hot water system such as the "Integra" (see Appendix 5) and hybrid system such as the "kool-fire" baseboard heat pump system (see Appendix 5) have the potential to increase the appeal of gas vertical subdivisions. From our own experience with high efficiency units in small commercial buildings and single family dwelling we see venting as a potential problem area with wall vents producing visible smoke plumes and under certain conditions, considerable ice and frost build-up on the adjacent wall.

We see a proven technology of self-contained high efficiency and competitively priced gas fired systems as having a potentially significant impact on the future choice of heating systems and the ability to provide lower overall energy use than current conventional systems.

The introduction of a vertical gas distribution also raises the possibility of utilising gas cookers and clothes dryers. Development of suitable equipment and the successful implementation and dissemination of results of a range of demonstration projects are key technical issues to developing this technology. Equipment developments and demonstration projects at the moment appear to be driven by the gas utilities desire to win back a market share of the apartment and condominium projects from hydro companies. Such activities should, however, be supported as part of a properly planned and co-ordinated effort at improving multi-unit residential construction practice.

Besides electric heat and self-contained gas based systems, there are hydronic systems with central boilers. This is the oldest of the three forms of heating systems previously discussed and one would think the design and operation of such a long established system type would suffer few problems. As previously noted this is not the case, though it is difficult to say exactly how serious and widespread the problems are or to provide any firm answers how such installations can be consistently improved. Certainly the knowledge is available and is frequently demonstrated since clearly not all systems exhibit poor performance. If there is a move back to central water systems we suspect that designers not raised on these systems will commit errors that by rights should not occur.

Whilst these systems have been around for many years there are recent equipment developments which could be integrated into such systems. Such developments would include small low volume/low mass, high efficiency and condensing boilers, microprocessor controls, variable speed drives (for variable speed pumping), flow metering devices to aid balancing and new materials such as plastic piping, including that suitable for radiant heating.

As part of an integrated approach to improving heating performance the preparation of a manual of good design, balancing, commissioning and operating practices along with a review of and appropriate use of new technologies might be considered. In preparing such a publication one might look to Europe and Scandinavia communities where, because they have not had the "benefit" of low cost electricity, fossil fired hydronic heating system design have tended to progress more rapidly than here in Canada.

Finally there are heat pump systems which to date have had little impact on the multi-unit housing market. We suspect that heat pumps are rarely, if ever, selected on the basis of a preferred heating system; rather they are provided as a consequence of a requirement to provide air conditioning. Even where heat pumps could be provided, as opposed to a straight air conditioning unit, we have found that most often they are <u>not</u>. One could conclude that the air to air heat pump is <u>not</u> an appropriate technology for this application given, for the example of an incremental unit that:

* the heat pump option increases the typical cost of a 1-1/2 ton unit by around 50%,
* still requires a full design capacity back-up electrical heater,
* operates somewhat noisily,
* will noticeably reduce the expected life of a unit that is often less than robust to start with,
* is a potential source of air and water leakage
* can be considered visually obtrusive

On the other hand, there is a lot of expressed interest in closed loop systems utilising central heating and heat rejection equipment with individual water to air reversible heat pumps provided in the suites. Whilst again the technology is not new there are few examples of such systems uncovered by our survey. Whilst we share this enthusiasm we have found it difficult to get such systems accepted having designed only two such systems in the last five years; only one of which was an apartment building and which unfortunately did not proceed to construction. These systems are generally more difficult and time consuming to design than conventional central systems and the sizing of the central elements and control of the ideal loop temperature is not considered an exact science. They do, however, have the potential to provide an extremely energy efficient means of heating and cooling and can, for instance, capitalise on the benefits of passive solar heating by moving excess heat from southerly exposures to northerly ones where it can be utilised.

The cost of these systems, which typically are not the lowest first cost option, could be improved if it were not necessary to carry heating ductwork to the perimeter to offset cold drafts and radiation from windows. Improved thermal performance of the envelope could eliminate the need to do this but there is some justified nervousness in the design profession towards eliminating perimeter heating. Thermal comfort studies aimed at establishing when it is safe to do so would, we feel, make the water loop heat pump a more attractive choice. Design guides and case studies for such systems in the context of the Canadian climate might also encourage a wider use of this potentially attractive system.

4.3 Ventilation

Fundamental to providing satisfactory ventilation and maintaining fire (smoke) safety is the ability to control the flow of air into and out of and through the building. It is clear from the survey results, literature and our own personal experience that this control is not consistently being achieved.

The movement of air will be influenced by the air leakage of the envelope and internal partitions, and on the pressures created throughout the building by stack and wind action and the operation of fans. If we could build and maintain perfectly tight construction then controlling air pressures would not be important. Conversely, if we could control internal air pressure we would need not be so concerned about air tightness. In practice both strategies will be required; there are strong arguments, however, for doing as much as we can to provide air tight construction.

Given that the intent of the ventilation system is to provide ventilation of the suite and prevent air transfer from the suite to adjacent suites, or to the corridor, we see that the typical arrangement of supply to the corridor has an inherent weakness, ie. we are introducing a leaky element, the corridor door, into the system and trying to prevent reverse air flow through it by the use of fans. This becomes very difficult if not impossible to achieve fully and consistently for the following reasons:

* Stack and wind effects, (particularly in high buildings) can create pressures considerably in excess of those that can practically and economically be maintained by so called corridor pressurisation systems. Constantly varying outdoor temperatures, wind speed and direction means that pressures inside the building are also constantly varying which, in turn, affects the performance of these systems. We have observed strong air flow under doors and into the corridors in high buildings on moderately cold days in Ottawa despite operation of the corridor supply and central exhaust systems.
* For economy reasons systems are often shut down overnight, or sometimes even during the quiet daytime hours, leaving only the natural forces of wind and stack action to determine air transfer patterns.
* Individual tenants often take steps to seal off their doors to the corridor. If this is particularly well done, make-up air for their exhaust system will be either from outside, through envelope leakage; or from adjacent suites. Air flow from adjacent suites is quite possible for instance if adjacent suite exhaust fans are not operating, their doors are not sealed and there are leaks in the partition walls.

Loss of air movement control also occurs in the following situations:

* In common laundry facilities where make-up air, usually from the corridor system, is supplied to offset that exhausted by the dryers or by a combination of the dryers and a separate exhaust fan. When the dryers are not all operating there is a tendency for the room to be under positive pressure and force laundry air to adjacent areas.

* In common rooms with individual exhaust fans that are supplied with make-up air but in which the fans may not be operated.

As a priority we see that this aspect of controlling air movement, which has implications on envelope integrity, air quality, comfort and energy conservation requires a significant research effort. Efforts should be co-ordinated with the Canadian Building Envelope Council.

Integral to this effort would be a review and recommendations on types of ventilation systems and the issues surrounding the choice of either central or individual systems. Some of these issues are presented below.

Central Exhaust Systems Advantages: Ability to utilise heat recovery techniques; potentially quieter (no noisy exhausters); air quality maintained, ie. ventilation maintained through all cooking and bathroom use, if systems run continuously.

Individual Exhaust Systems Advantages: Lower overall air flow rates because of diversity (typically 40 to 50% lower make-up air than central systems with intermittent use of exhausters. Luoma quotes average kitchen exhaust as 50 minutes per day); balancing is not required; less compromise of building fire integrity; less floor space requirements (for shafts); and equipment failure has less of an impact on total building performance.

The use of individual exhausts is consistent with an overall design approach of constructing each suite as a separate unit that is as far as possible isolated from adjacent suites in terms of noise, air transfer and fire integrity. Such a tighter internal subdivision would reduce stack effect in the building and could conceivably ameliorate some envelope problems.

Other specific issues and ideas raised which may be an integral part of the above or related issues include:

* Provision of clothes dryers with more powerful fans to avoid having to install booster fans (control of the booster fan is typically problematic). All dryers might, for instance, be made with a two-speed fan and the appropriate fan speed selected on site to match the ductwork resistance. High water extraction rate dryers might also be an area of product development. (Small versions are available and used in public pools for spin-drying swimming costumes.)

* The use of passive wall intakes or individual suite heat recovery ventilators in lieu of a central make-up air. These devices would be used in conjunction with a philosophy of building individual suites as self-contained air-tight modules with as little linkage as possible to adjacent spaces or common areas.
* Improving the quality of ventilation products specifically with regards to longevity and low noise.
* Better controls for make-up air systems.
* Improving the air tightness of windows and mandating their use.
* Mandate tighter wall construction including on-site quality control.
* Provide design guidance and life cycle cost data for heat recovery products.
* Develop a low cost reliable (de)humidistat for controlling ventilation operation.
* Mandate ventilation rates and minimum system efficiencies (ventilation is considered to be a major energy user).
* Mandate full suite ventilation (ie. supply air to all habitable spaces). Often the fresh air supplied by the corridor system will not benefit the occupants if it just short circuits directly to the kitchen and bathroom.
* Review the ventilation needs for parking garages. Currently the Code sets a rate that is the same for all building types that have clearly very different usage patterns.
* Interlock individual suite exhaust fans with bathing and cooking activities to minimise condensation damage.

4.4 Air Conditioning

Given the relatively low number of complaints, relative low energy usage, and arguably that air conditioning for the most part is a luxury item, it is considered difficult to make a strong case for an extensive and concerted research effort being carried with government funds aimed purely at air conditioning.

It might, however, be reasonable to give some considerations to its integration and co-ordination with other mechanical systems, in particular with concerns for improved ventilation, in providing air conditioning for seniors projects, and in combined heat/cool systems such as the water loop heat pump.

From a purely equipment development aspect one can also see a need for more compact, quieter, more energy efficient, reliable and economically priced air conditioning equipment. Recent years have seen the introduction of such visibly acceptable equipment; unfortunately, with the all qualities expressed except for the "economical price" which is a major disincentive to their widespread use.

4.5 Garages

As with the other topics, a significant number of the problems reported could be avoidable if correct design procedures are followed. For these items more detailed Codes and/or a good practice guide would be considered appropriate.

The remaining problems for the most part are associated with two main issues; one is the economics and practicality of heating; the second concerning ventilation and air quality. There is, of course, some interaction between these two issues.

The question of heating is a multi-disciplinary problem. The benefits of a fully heated garage are that there is no need for any special precautions against freezing, that insulation need not be applied to the ground floor slab, and that a comfortable environment is provided. The downside is that it is expensive to operate and can accelerate rusting and structural damage. Which of the two alternatives provide the overall lower capital and life cycle costs is debatable and will, of course, be highly dependent on location. Life cycle cost studies might be pursued in order to give better guidance to building designers.

The second issue of air quality concerns not only the issue of ventilation within the garage itself but also that of its linkage with the rest of the building. Even with the provision of pressurised vestibules between a garage and stair and elevator shafts it has been reported (Harrje) that products from vehicle exhausts can migrate into the suites above. Consequently, we feel that the research effort on ventilation recommended earlier should encompass the parking garage. Particular issues that we feel should be addressed include:

* Review of current recommended ventilation rates. The Codes do not currently distinguish between types of occupancy; thus a theatre car park with a very peaky profile of use requires the same ventilation system capacity as would a residential garage with a significantly flatter usage pattern.

* The possible need and desirability of a continuous lower ventilation rate to lower background CO levels and perhaps limit leakage to the apartment suites.
* The desirability of guarding against system failure the consequences of which could in theory be fatal.
* Running exhaust fans to control humidity.
* Providing guidelines for ensuring uniform ventilation efficiency, ie. avoiding unventilated pockets. The use of transfer fans might be appropriate, for instance, where it is not practical to provide intakes and exhaust in all the requisite locations.
* Development of heat recovery equipment and systems aimed specifically at garage ventilation.

Two problems not included in the above for which we have yet to see satisfactorily handled concerns service penetrations through exterior slabs. These are:

* making the service penetrations watertight, and
* the provision of an insulation system that has longevity and can continue to prevent condensation damage to the bases of catchbasins and storm drains.

4.6 Domestic Hot Water Heating

We feel that the biggest single issue is that of the choice of system, ie. where and when and for what reasons is it better to chose a central system or individual systems. One can review the various advantages and disadvantages to these two basic systems but the most illusive questions to answer will be which has the lowest energy use and/or lowest life cycle cost. Associated with this are secondary issues such as the need to develop an improved understanding of water usage patterns, the cost effectiveness of pipe insulation and electric trace heating (as opposed to pumped recirculation). Responses in the survey, for instance, included on one hand claims that insulation is not at all cost effective and will do nothing to maintain delivery temperature if pumped recirculation is provided, to the other extreme where it is considered desirable to insulate all pipework. The issue of water usage patterns would, out of necessity of determining accurate relative life cycle costs, have to address the issue of possible usage variation between central and individual (cost accountable) systems.

A research effort and the issuing of up to date design guidance and life cycle costing information is thus considered appropriate to carry out at this time.

Other issues raised which might also be considered for research and development activities include:

* The use of individual high efficiency gas fired water heaters for use in buildings with individual gas metering. Heaters might be standalone or combination space heat/water heating units. Equipment developments are still required as are a wider experience with "vertical (gas) subdivisions".
* The cost/benefit of providing duplication of key components to improve the reliability of common systems.
* Possible relaxations in the Plumbing Code to reduce the cost of providing leak protection (drains) for individual water heaters whilst still providing leak protection.

4.7 Electrical Power

The intent of the study was to address HVAC systems and as such electrical power issues were not directly researched or specifically raised in our field survey.

One might conclude, however, that since there were no problems raised of an electrical nature in the field survey that electrical power systems are reliably doing the job they were designed to do. Certainly our own experience indicates that generally electrical problems are far fewer; and seldom of the nature of "basic design flaws" than are mechanical systems. Of course electrical equipment does fail; eg. motors burn out, and this in turn does have implications on the system or equipment being served by the motor.

Mechanical systems and equipment changes and development, and substitutions of electricity as a direct form of heating have the potential, however, to significantly affect the overall pattern of demand for electricity and perhaps also to affect individual building consumption patterns. Such potential influences on electrical demand and usage should be considered when pursuing mechanical system changes. To ignore interdisciplinary considerations is to run the risk of just moving problems around. A typical example of this is the potential of increasing electricity bills when set back strategies are applied to buildings with demand meters - the early morning demand charge (as electric heating operating at 100% capacity to pull the building back up to comfort conditions) exceeding the unit electricity cost savings achieved during the set back period.

4.8 Development of an R & D Program

Given a limited budget to spend on improving multi-unit construction, one ideally would like to arrange the ideas discussed above into some form of priority which could in turn define a course of action.

Ideally in order to do this one needs to define what the priorities and budget limitations are. For instance, a list of priorities for providing optimum creature comfort might look very different from one compiled on the basis of minimising life cycle costing.

Other "priorities" include:

* time frame (to effect changes)
* minimising first costs
* minimising energy costs
* fuel substitution
* improving longevity
* building type, ie. retrofit or new construction
* specific regional needs
* sensitivity to the environment
* optimising cost benefit

Budget constraints will also dictate the choice of any particular plan of action. Some issues are raised below.

* Distribution of benefits (ie. to whom are the benefits directed)

* Funding, ie. if funds are limited in total amount or time period more fundamental research would obviously not be a viable option.

* Risk; Some strategies that look promising may be more risky in terms of ultimately providing a return on the research dollar invested.

* Time frame; There may be a requirement to effect changes rapidly.

* Return; It might be considered necessary to obtain a direct monetary benefit from the invested research dollar as opposed to say solely improving quality.

* Source of funding; eg. direct sponsored research, special levies, tax concessions to assist private R&D efforts are alternative forms of funding.

In order to formulate a plan of action it is considered desirable that the above constraints and priorities be properly assessed and balanced against one another in order that an optimum program of research, development and training might be formulated. It is suggested that such an activity might best be pursued by a multi-disciplinary body reviewing the various options and constraints in much the same way that energy research dollars were allocated by the Panel on Energy Research & Development (PERD) during the flurry of research activity in the late seventies and early eighties.11

As a step to assist discussion we have collected the previously raised suggestions for activity into the following groups.

* Short term (& ongoing); essentially synonymous with lower costs and typically being related to technology transfer or legislative changes.

* Medium term; can be considered medium costs encompassing some form of demonstration of "recent" technology changes.

* Long term, typically high cost, research activities.

The order of presentation of individual suggestions presented below is purely arbitrary, ie. for reasons discussed above they are not arranged in any particular order or priority. (A list of selected projects for recommended action based on our own preliminary assessment is presented in Section 4.9)

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11 A study on energy conservation carried out in 1981 by the Bureau of Management Consulting (DSS) recommended as a major conclusion that EMR needs to make policy direction decisions on how it intends to influence energy conservation in apartment buildings.

Short term in the context of these suggestions relates to the speed at which some results of the program can be expected; not on the total length of the program since technology transfer is considered an ongoing activity.

"Short term" strategies raised include:

* More comprehensive, requirement specific, rigorous, better illustrated and up to date, Building Codes.

* More rigorous component standards, particularly for windows and wall systems.

* More uniform and thorough application of Codes and Standards.

* Improved education and training for all those involved in the industry including owners and operators, developers, contractors, engineers and architects. Both ongoing training (skills upgrading and updating on new technologies) and pre-work force education and training need to be considered.

* Legislative changes to favour a particular technology or fuel source or accountability (eg. mandate individual metering)12. Reducing electrical demand through gas (or oil?) substitutions is also a possibility.

* Design guidelines and good practice guides. Particular discipline areas raised included hydronic heating, water loop heat pump systems and commissioning. Reliable life cycle costing information is considered highly desirable in such publications.

* Technology (Transfer) Centre. It has been suggested that such a centre, linked with or operated by a task group, could be an appropriate vehicle for technology transfer. Such a centre might also make recommendations on further research, development and demon strations. Arguably the centre could be ex-

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12 There is a conversed argument presented to this (in Sweden) that having common metering and utilities paid by the Landlord puts pressure on the Landlord to build and create an energy efficient building.

tended to co-ordinate or carry out demonstrations and R & D activities.

Medium term strategies, which are listed below, would result in a flow of new information for dissemination ("Short Term Strategies") and may well indicate additional research needs ("Long Term Strategies").

Demonstration projects are considered a key element to moving untried technology into the market place since builders and developers, and to a lesser extent Architects and Engineers, are generally very cautious about using "new" systems and equipment.

* Evaluation and demonstration of electric and electric heat storage systems for reducing electrical demand.

* Review and demonstration of technologies for metering hydronic heating systems.

* Life cycle costing studies; particular areas raised in the study include water loop heat pumps, ventilation system options, heating system options, domestic water heating options, pipe insulation, garage heating and ventilation options.

* Review advances in hydronic heating system designs materials and equipment and implement further research, development or technology transfer projects.

* Demonstration and enhancement of vertical gas subdivision technology.

* Demonstration of water loop heat pump system and enhancement of design guidelines.

* Review and demonstration of alternative ventilation systems currently in use or under study in other countries[13] as well as here in Canada.

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13 Review of European and Scandinavian practice is recommended since these countries have a much higher percentage of their population housed in multi-unit buildings (about twice the percentage than here in Canada) and have relatively high fuel costs.

The results of R & D efforts ("Long-term strategies") would typically be followed by a demonstration phase. Areas of required R & D raised or prompted by the study include:

* Development of better envelope systems.
* Development of low cost, individual, modulating, simple programmable controls for electric baseboard heaters
* Gas heating appliance development for vertical subdivisions. System venting is considered a key area of development. Cogeneration may be another.
* Thermal comfort studies aimed at establishing minimum envelope criteria necessary to eliminate the need for perimeter located heating (work will be very location dependent).
* Research into improving ventilation and controlling air flow into, out of, and through the building.

4.9 Specific Recommendations

Based on the information presented in technical papers and that obtained from our own field survey we have prepared below a number of suggested activities for public funding.[14]

These suggestions are the ones we would choose without the benefit of the kind of wide input recommended in the previous section. The reasons for their selection are also discussed - not all the possible activities presented in the earlier sections of this report have been included in this list.

Wider technical discussions on the topics can be found in earlier text and are not repeated her to avoid duplication.

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14 Some activities like equipment developments for use in vertical gas distribution systems (eg. condensing furnaces and water heaters) are also considered important but for the moment development appears to be progressing satisfactorily under normal market forces with gas utilities encouraging development and use in order to regain market share of the multi-unit industry.

* <u>Ventilation R&D</u>. This is considered ultimately <u>a long term multi</u>-disciplinary activity. We would recommend, however, that an initial technical review paper be presented discussing in detail the current situation and presenting R&D activities and perhaps preliminary design practice recommendations.

  By ventilation we refer to all those aspects relating to air movement into, out of, and through the building by means both natural and mechanical.

  This activity is considered to be the most pressing on the basis that this area is quite clearly the area that is causing most problems and concerns.

  The aim of this research activity would ultimately lead to practical systems and techniques for controlling unwanted air leakage and transfer of odours, and the provision of quality, economical ventilation.

* <u>Manual of Good Practice</u>. It is quite clear that <u>there is the collective</u> knowledge to produce very good designs but it is also equally clear that this knowledge is not universally shared or readily available. On the basis that this activity potentially offers the best value for money spent we would recommend that a document be prepared describing problems and design solutions for multi-unit housing design, installation, commissioning and operation. Reliable life cycle costing information is considered an important aspect of this work since quality designs will not be adopted unless there is some overall economic justification for doing so.

* <u>Education & Training</u>. Whilst a somewhat general <u>type of recommendation</u>, improved education and training is offered as a recommended action item on the basis that this is perhaps the most important key item to improving and subsequently maintaining a high standard of design and construction. It is clear to us that because of the fragmented nature of the industry - there are no truly large organizations or employers - education and training has not followed a structured path. (This is true of the building industry in general). Better education and training is considered desirable at all levels and skills throughout the industry.

* <u>Evaluation & Demonstration of Control Strategies & Heat Metering for Hydronic Systems</u>. This activity is presented as an important one on the basis that there is a significant potential energy benefit from making users responsible for their own fuel bills (for individual electrical metering the benefit is placed between 20 and 40%). Improving temperature control, which also is a widely reported problem, also offers potential energy savings as well as improved comfort.

* <u>Development & Demonstration of Improved Electric Baseboard Control</u>. Since electric baseboard heating is the most popular form of heating we see justification for encouraging the development of advanced controls that could be used for both existing and future projects. Our initial suggestion is for a modulating control, for closer control of space temperature and increased comfort (theoretically allowing an overall lower average air temperature to be maintained) combined with a low cost set-back type thermostat. The cost of a modulating output/set-back thermostat could, we feel, be significantly reduced if perhaps schedule options were simplified (at a nominal loss of flexibility) and units were widely used allowing mass production. The effect of such a control on electric utility peak demand would, however, need to be evaluated before embarking on such a development.

* <u>Improve Building Codes</u>. From the survey it is clear there is a lot of frustration with current building codes. If we had to summarise the complaints and comments received with a single statement we would have to say that it is that the current codes do not adequately address "performance". (Historically codes have addressed safety issues). We feel that statements such as "HVAC systems should be designed, constructed, and installed to conform to good engineering practice", referring also to other documents such as ASHRAE Handbooks, do <u>not</u> clearly define minimum acceptable standards and is open to wide (mis)interpretation by developers, engineers, architects, contractors and code officials.

To reduce this weakness we would recommend that a critical review be undertaken of the current (model) National Building Code aimed at identifying all those areas where the code is ambiguous or lacking in adequately defining or ensuring satisfactory performance in multi-unit housing. (Some areas have already been identified in our survey).

APPENDICES

APPENDIX I

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APPENDIX II

ABRIDGED SUMMARY OF SURVEY RESULTS

ABRIDGED SUMMARY OF RESULTS FOR TORONTO

Number of Organizations/Individuals Interviewed 13
Number of Buildings 11+ }see note 1
Number of Dwelling Units 2567+ }see note 1
% with Suites Air Conditioned 70%
% with Common Rooms Air Conditioned 100%
% with Heated Enclosed Garage 55%
% with Unheated Enclosed Garage 18%
% Condominium 40%
% Common Electricity Meter 91%

Heating Types (Apartments)	1. Incremental	36%	
	2. Hydronic Fan Coil	27%	
	3. Hydronic Baseboard	18%	
	4. Electric Baseboard	9%	
	5. Water Loop Heat Pump	9%	
Cooling Types (Apartments)	1. Incremental	34%	
	2. Central	50%	
	3. Water Loop Heat Pump	16%	{2}
Exhaust Type (Apartments)	1. Central	60%	
	2. Individual	30%	
	3. Mixed	10%	
Make-Up Arrangement (Apartments)	1. Electric	50%	
	2. Gas	50%	
Heat Recovery		10%	
D.H.W. Heating	1. Central Gas	90%	
	2. Individual Electric	10%	
Garage Heating	1. See Note {3}		
Garage Ventilation Operation	1. Heated Make-Up Air		{3}
	2. Time Clock Control	38%	
	3. Continuous	38%	
	4. CO Control	12%	
	5. Manual	12%	

NOTES:

{1} Numerical data presented are based on this reduced sample, supplementary non-numerical information was obtained covering a larger sample of buildings.
{2} This is very likely an inflated figure since non of the other interviewees discussing general experience talked about these systems.
{3} No reliable information.

ABRIDGED SUMMARY OF RESULTS FOR HALIFAX

Number of Organizations/Individuals Interviewed 8
Number of Buildings 8
Number of Dwelling Units 1201
% with Suites Air Conditioned 0%
% with Common Rooms Air Conditioned 0%
% with Heated Enclosed Garage 0%
% with Unheated Enclosed Garage 25%
% Condominium 50%
% Common Electricity Meter 25%

Heating Types (Apartments)	1. Electric Baseboard	63%
	2. Hydronic Baseboard	37%
Cooling Types (Apartments)	1. No Air Conditioning	
Exhaust Type (Apartments)	1. Central Bathroom with Charcoal Kitchen Hood	50%
	2. Central	37%
	3. Individual	13%
Make-Up Arrangement (Apartments)	1. Gas	62%
	2. Oil/Hydronic	38%
Heat Recovery		13%
D.H.W. Heating	1. Central Oil	50%
	2. Central Electric	25%
	3. Individual Electric	25%
Garage Heating	1. None	
Garage Ventilation and Operation	1. See Note {2}	

NOTES:

{1} Gas is not available.
{2} Insufficient information.

ABRIDGED SUMMARY OF RESULTS FOR QUEBEC (EXCLUDING MONTREAL & THE OUTOUAIS)

Number of Organizations/Individuals Interviewed 16
Number of Buildings 13+ }see note {1}
Number of Dwelling Units 4214+ }see note {1}
% with Suites Air Conditioned 27%
% with Common Rooms Air Conditioned 53%
% with Heated Enclosed Garage 69%
% with Unheated Enclosed Garage15%
% Condominium 20%
% Common Electricity Meter 85%

Heating Types (Apartments)	1. Electric Baseboard	100%
Cooling Types (Apartments)	1. Incremental	100%
Exhaust Type (Apartments)	1. Central	62%
	2. Mixed	30%
	3. Central Bathroom & Charcoal Kitchen Hood	8%
Heat Recovery		0%
Make-Up Arrangement (Apartments)	1. Electric	100%
D.H.W. Heating	1. Central Electric	58%
	2. Individual Electric	26%
	3. Central Oil	8%
	4. Central Gas	8%
Garage Heating	1. Electric Unit Heater	89%
	2. Hydronic Unit Heater	11%
Garage Ventilation and Operation	1. Heated Make-Up Air	67%
	2. CO Control	87%
	3. Constant Operation	13%

NOTES:

{1} Numerical data presented are based on this reduced sample, supplementary non-numerical information was obtained covering a larger sample of buildings.

ABRIDGED SUMMARY OF RESULTS FOR OUTOUAIS

Number of Organizations/Individuals Interviewed 11
Number of Buildings 11
Number of Dwelling Units 1501
% with Suites Air Conditioned 27%
% with Common Rooms Air Conditioned 45%
% with Heated Enclosed Garage 27%
% with Unheated Enclosed Garage 18%
% Condominium 27%
% Common Electricity Meter 73%

Heating Types (Apartments)	1. Electric Baseboard	82%
	2. Incremental Heat Pump	9%
	3. Hydronic Fan Coil	9%
Cooling Types (Apartments)	1. Central Chilled Water	66%
	2. Incremental	34%
Exhaust Type (Apartments)	1. Individual	42%
	2. Central	33%
	3. Hybrid	17%
	4. Central Bathroom & Charcoal Kitchen Hood	8%
Make-Up Arrangement (Apartments)	1. Electric	100%
Heat Recovery		0%
D.H.W. Heating	1. Central Electric	54%
	2. Individual Electric	27%
	3. Central Gas	19%
Garage Heating	1. Electric Unit Heater	66%
	2. Hydronic Unit Heater	33%
Garage Ventilation and Operation	1. See Note {1}	

NOTES:

{1} Incomplete information, CO sensors for ventilation control reported.

ABRIDGED SUMMARY OF RESULTS FOR MONTREAL

Number of Organizations/Individuals Interviewed 40
Number of Buildings 40+ see Note {1}
Number of Dwelling Units 6840 see Note {1}
% with Suites Air Conditioned 21%
% with Common Rooms Air Conditioned 29%
% with Heated Enclosed Garage 100%
% with Unheated Enclosed Garage 0%
% Condominium 16%
% Common Electricity Meter 59%

Heating Types (Apartments)	1. Electric Baseboard	85%
	2. Hydronic Baseboard	5%
	3. Electric Furnace or Heat Pump with Supplementary Baseboard	5%
	4. Radiant Electric	2.5%
	5. Water Loop Heat Pump	2.5%
Cooling Types (Apartments)	1. Incremental	50%
	2. Central Chilled Water	25%
	3. Water Loop Heat Pump	25%
Exhaust Type (Apartments)	1. Central	84%
	2. Central with Charcoal Kitchen Hood	11%
	3. Individual	5%
Make-Up Arrangement (Apartments)	1. Electric	88%
	2. Gas	12%
Heat Recovery		11%
D.H.W. Heating	1. Central Electric	39%
	2. Individual Electric	29%
	3. Central Gas	26%
	4. Central Oil	6%
Garage Heating	1. Electric Unit Heater	84%
	2. Hydronic Unit Heaters	10%
	3. Other	6%
Garage Ventilation and Operation	1. Heated Make-Up Air	52%
	2. CO Control	100%

Notes:

{1} One response addressed experience with several buildings containing approximately 1500 suites.

ABRIDGED SUMMARY OF RESULTS FOR VANCOUVER & VICTORIA

Number of Organizations/Individuals Interviewed 31
Number of Buildings 32+ }see note {1}
Number of Dwelling Units 4000+ }see note {1}
% with Suites Air Conditioned 10%
% with Common Rooms Air Conditioned "common" }see note {2}
% with Heated Enclosed Garage 3%
% with Unheated Enclosed Garage 72%
% Condominium 52%
% Common Electricity Meter 6%

Heating Types (Apartments)	1. Electric Baseboard	71%	
	2. Hydronic Baseboard	27%	
	3. Ceiling Radiant Electric	2%	
Cooling Types (Apartments)	1. Central Chilled Water "Most Common"		{2}
	2. Incremental "Common"		{2}
Exhaust Type (Apartments)	1. Individual	89%	
	2. Central	7%	
	3. Individual Bath & Charcoal Kitchen Hood	4%	
Make-Up Arrangement (Apartments)	1. Gas	77%	
	2. Electric	23%	
Heat Recovery		0%	
D.H.W. Heating	1. Central Gas	52%	
	2. Individual Electric	40%	
	3. Central Electric	6%	
	4. Central Oil	2%	
Garage Heating	1. See Note {3}		
Garage Ventilation and Operation	1. Heated Make-Up Air		{5}
	2. CO Control	56%	{4}
	3. Time Clock	6%	{4}
	4. Manual	9%	{4}

NOTES:

{1} Numerical data presented are based on this reduced sample supplementary non-numerical information was obtained covering a larger sample of buildings.
{2} Insufficient numerical data to give percentages.
{3} Heating is not common.
{4} Information not provided for all buildings, remaining 29% of cases may operate continuously.
{5} Insufficient information.

ABRIDGED SUMMARY OF RESULTS FOR CALGARY

Number of Organizations/Individuals Interviewed 5
Number of Buildings 5
Number of Dwelling Units 868
% with Suites Air Conditioned 40%
% with Common Rooms Air Conditioned 20%
% with Heated Enclosed Garage 100%
% with Unheated Enclosed Garage 0%
% Condominium 40%
% Common Electricity Meter 50%

Heating Types (Apartments)	1. Hydronic Baseboard	100%	
Cooling Types (Apartments)	1. Central Chilled Water "Most Common"		{1}
Exhaust Type (Apartments)	1. Central	100%	
Make-Up Arrangement (Apartments)	1. Gas	100%	
Heat Recovery		0%	
D.H.W. Heating	1. Central Gas	100%	
Garage Heating	1. Gas Unit Heater/Forced Air	100%	
Garage Ventilation and Operation	1. Heated Supply Air		{1}
	2. CO Control	100%	

NOTES:

{1} Insufficient information to give numerical data.

ABRIDGED SUMMARY OF RESULTS FOR EDMONTON

Number of Organizations/Individuals Interviewed 8
Number of Buildings 8
Number of Dwelling Units 686
% with Suites Air Conditioned 25%
% with Common Rooms Air Conditioned "Uncommon" see note {1}
% with Heated Enclosed Garage 86%
% with Unheated Enclosed Garage 14%
% Condominium 86%
% Common Electricity Meter 43%

Heating Types (Apartments)	1. Hydronic Baseboard	86%	
	2. Electric Radiant	14%	
Cooling Types (Apartments)	1. Splits		{1}
	2. Incremental Units		{1}
	3. Water Cooled (Central Tower)		{1}
Exhaust Type (Apartments)	1. Central	76%	
	2. Individual	12%	
	3. Hybrid	12%	
Make-Up Arrangement (Apartments)	1. Gas	100%	
Heat Recovery		0%	
D.H.W. Heating	1. Central Gas	100%	
Garage Heating	1. Gas Unit Heater/Forced Air	57%	
	2. Hydronic Radiators	29%	
	3. Hydronic Unit Heaters	14%	
Garage Ventilation and Operation	1. Heated Make-Up Air		{1}
	2. CO Control	87%	
	3. Time Clock Control	13%	

NOTES:

{1} Insufficient data to give numerical data.

ABRIDGED SUMMARY OF RESULTS FOR WINNIPEG

Number of Organizations/Individuals Interviewed 5
Number of Buildings 5 }see note {1}
Number of Dwelling Units not available
% with Suites Air Conditioned 66%
% with Common Rooms Air Conditioned 16%
% with Heated Enclosed Garage see note {2}
% with Unheated Enclosed Garage see note {2}
% Condominium 0%
% Common Electricity Meter 60%

Heating Types (Apartments)	1. Electric Baseboard	100%	{1}
Cooling Types (Apartments)	1. See Note {2}		
Exhaust Type (Apartments)	1. Central	100%	
Make-Up Arrangement (Apartments)	1. Gas	100%	
Heat Recovery		20%	
D.H.W. Heating	1. Central Gas	100%	
Garage Heating	1. See Note {2}		
Garage Ventilation and Operation	1. See Note {2}		

NOTES:

{1} Sample is not considered statistically representative. Eg. we understand that whilst electric baseboards are predominant, hydronic systems are common.

{2} Insufficient data.

ABRIDGED SUMMARY OF RESULTS FOR SASKATOON

Number of Organizations/Individuals Interviewed 4
Number of Buildings 3+ }see note {1}
Number of Dwelling Units see note {1,2}
% with Suites Air Conditioned see note {2}
% with Common Rooms Air Conditioned see note {2}
% with Heated Enclosed Garage see note {2}
% with Unheated Enclosed Garage see note {2}
% Condominium see note {2}
% Common Electricity Meter "most" }see note {2}

Heating Types (Apartments)	1. Mostly Hydronic Baseboard		{2}
Cooling Types (Apartments)	1. See Note {2}		
Exhaust Type (Apartments)	1. Individual	66%	
	2. Central & Charcoal Kitchen Hood	33%	
Make-Up Arrangement (Apartments)	1. Gas	100%	
Heat Recovery		0%	
D.H.W. Heating	1. Central Gas	100%	{2}
Garage Heating	1. See Note {2}		
Garage Ventilation and Operation	1. See Note {2} 2. 3.		

NOTES:

{1} 2 of 3 respondents' answers covered general experience covering more than a single building. Information may, however, not be typical.

{2} Insufficient data to give numerical data.

ABRIDGED SUMMARY OF RESULTS FOR OTTAWA

Number of Organizations/Individuals Interviewed 12
Number of Buildings 27+ }see note {1}
Number of Dwelling Units 2606 }see note {1}
% with Suites Air Conditioned 81% see note {3} & {4}
% with Common Rooms Air Conditioned
% with Heated Enclosed Garage 43%
% with Unheated Enclosed Garage 14%
% Condominium 71% }see note {3}
% Common Electricity Meter 5% }see note {2}

Heating Types (Apartments)	1. Electric Baseboard "most common"	(73%)	{3}
	2. Incremental "common"	(15%)	{3}
	3. Hydronic Baseboard "common"	(4%)	{3}
	4. Hydronic Fan Coil "occasional"	(8%)	{3}
	5. In-Floor Radiant Electric "occasional" (but not recently)		
Cooling Types (Apartments)	1. Splits	50%	
	2. Central Chilled Water	36%	
	3. Incremental	14%	
Exhaust Type (Apartments)	1. Individual	68%	
	2. Central	16%	
	3. Hybrid	8%	
	4. Mixed	8%	
Make-Up Arrangement (Apartments)	1. Gas	50%	
	2. Electric	50%	
Heat Recovery		0%	
D.H.W. Heating	1. Individual Electric "most common"	91%	{3}
	2. Central Gas "occasionally"	4%	{3}
	3. Central Electric "few"	4%	{3}
Garage Heating	1. Electric Unit Heaters	82%	
	2. Gas Fired Unit Heater/ Furnace	18%	
Garage Ventilation and Operation	1. Heated Make-Up Air	28%	{5}
	2. CO Control	100%	

NOTES:

{1} Some respondents cover significantly more buildings and units but some numerical information missing for those (8) organisations interviewed whose responses covered more than a single building.

{2} Ottawa Hydro statistic.

{3} % are based on only those interviews for which exact break down of heating is known.

{4} % is likely higher than average due to high proportional of condominiums in the sample.

{5} Ottawa Gas reports that heated make-up air systems are not frequently installed.

APPENDIX III

FIELD SURVEY QUESTIONNAIRES

GENERAL INFORMATION

Contact Person (Name/title)________________________
Name of the Organization__________________________
Name/address of Building__________________________

Type of Respondent: Consultant [ ] Contractor [ ]
Owner/Developer [ ] Operator [ ]
Building Manager [ ]

Building Height: from 4-7 floors [ ] from 8 & up [ ]

Building Type: Condo [ ] Rental [ ] Co-Ownership [ ]
Luxury [ ] Standard [ ] Low Income [ ]

Designed By: Consultant [ ] Contractor [ ]
Built for Sale [ ] Built for Holding [ ]

General Information

City:____________ Age of Building:__________
Electric Meter: Individual [ ] Common [ ]
Gas Meter: Individual [ ] Common [ ]
Type of Glass: Single [ ] Double [ ] Triple [ ]

Rate your satisfaction:

	Very Satisfied	Satisfied	Neutral	Not Satisfied	Very Dissatisfied
Architect	[ ]	[ ]	[ ]	[ ]	[ ]
Engineer	[ ]	[ ]	[ ]	[ ]	[ ]
Contractor	[ ]	[ ]	[ ]	[ ]	[ ]
Commission	[ ]	[ ]	[ ]	[ ]	[ ]
Maintenance	[ ]	[ ]	[ ]	[ ]	[ ]

Do designs differ from older (pre 1975/80) designs?

The O & M manuals prepared for you are:
Very Useful [ ] Useful [ ] Worthless [ ]

What incentives, research or demonstration projects or code changes do you feel might help improve the quality of multi-family dwellings?

Describe any specific and/or most common or urgent concerns.

How do you arrange for equipment maintenance?

Does the repair or replacement of design defects constitute a significant part of your maintenance budget?

Heating

Indicate the type of heating system in each location (specify, if other).

	Dwelling	Garage	Common Area	Circulation
Forced Air	[ ]	[ ]	[ ]	[ ]
Electric Baseboard	[ ]	[ ]	[ ]	[ ]
Hydronic Baseboard	[ ]	[ ]	[ ]	[ ]
Elec.Radiant Ceiling	[ ]	[ ]	[ ]	[ ]
Hot Water Radiant Floor	[ ]	[ ]	[ ]	[ ]
Electric Unit Heater	[ ]	[ ]	[ ]	[ ]
Hot Water Unit Heater	[ ]	[ ]	[ ]	[ ]
Heat Pump	[ ]	[ ]	[ ]	[ ]
Other	[ ]	[ ]	[ ]	[ ]
Other	[ ]	[ ]	[ ]	[ ]

Control System

	Dwelling	Garage	Common Area	Circulation
Integrated to Baseboard	[ ]	[ ]	[ ]	[ ]
Low Voltage Thermostat	[ ]	[ ]	[ ]	[ ]
Line Voltage Thermostat	[ ]	[ ]	[ ]	[ ]
Modulating Thermostat	[ ]	[ ]	[ ]	[ ]
Night Set-Back	[ ]	[ ]	[ ]	[ ]
Thermostatic Valve	[ ]	[ ]	[ ]	[ ]
Electric Valve	[ ]	[ ]	[ ]	[ ]
Other	[ ]	[ ]	[ ]	[ ]

In dwellings only:

If air system: Location of diffusers
Under the window [ ] Over the window [ ] Interior only [ ]
Through the exterior wall [ ]
Other (specify):

If not water system: Type of distribution
1 Pipe [ ] 2 Pipes [ ] 3 Pipes [ ] 4 Pipes [ ]
2 Pipes & elec. [ ]

Why did you choose this system?

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify)

Describe any problems with the design, installation, the occupants or the owner.

Cooling

Indicate the type of cooling system in each location:

	Dwelling	Common Area	Circulation
Is it air conditioned?(Y/N)	[ ]	[ ]	[ ]
Type			
Split	[ ]	[ ]	[ ]
Central with Fan Coil	[ ]	[ ]	[ ]
Through the Wall (DX)	[ ]	[ ]	[ ]
Through the Window (DX)	[ ]	[ ]	[ ]
Heat Pump Air/Air	[ ]	[ ]	[ ]
Heat Pump Water/Air	[ ]	[ ]	[ ]
Other	[ ]	[ ]	[ ]
Can this unit also heat? (Y/N)	[ ]	[ ]	[ ]
Does it provide fresh air?(Y/N)	[ ]	[ ]	[ ]

Control System

	Dwelling	Common Area	Circulation
In the unit	[ ]	[ ]	[ ]
On the wall	[ ]	[ ]	[ ]
Interlocked with cooling	[ ]	[ ]	[ ]

If central air
Type of distribution 2 Pipes [ ] 3 Pipes[ ] 4 Pipes [ ]
Air [ ]
Type of cooling Centrifugal[ ] Reciprocating [ ] Absorption[ ]

Why did you choose this system?

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify)

Describe any problem with the design, installation, the occupants or the owner.

Ventilation

Dwelling

Kitchen Exhaust: central [ ] indiv. [ ] charcoal [ ]
discharges to exterior [ ] garage [ ]
Operation: indiv. switch [ ] timer_____ hr.
continuous operation [ ]

Toilet Exhaust: central [ ] indiv. [ ]
discharges to exterior [ ] garage [ ]
Operation: indiv. switch [ ] sw/light [ ] timer_____ hr.
continuous operation [ ]

Bedroom Exhaust: central [ ] indiv. [ ]
discharges to exterior [ ] garage [ ]
Operation: indiv. switch [ ] sw/light [ ] timer_____ hr.
continuous operation [ ]

Livingroom Exhaust: central [ ] indiv. [ ]
discharges to exterior [ ] garage [ ]
Operation: indiv. switch [ ] sw/light [ ] timer_____ hr.
continuous operation [ ]

Dryer Exhaust: central [ ] indiv. [ ]
discharges to exterior [ ] garage [ ]
Operation: indiv. switch [ ] timer_____ hr.
continuous operation [ ]

Supply Air none [ ]
Coming From: corridor [ ] under the door [ ] transfer grille [ ]
separate system [ ] 1 per dwelling [ ]
in each room [ ] wall unit [ ]

Corridor pressurization: oil [ ] gas [ ] electric [ ]
operation__________ hr.
Heat recovery: wheel [ ] plate [ ] glycol [ ] heat pump [ ]

Indicate the % of compensation (supply air/exhaust air):_________

Humidification: central [ ] individual [ ] none [ ]

Why did you choose this system?

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify)

Describe any problem with the design, installation, the occupants or the owner.

<u>Garage Ventilation</u>

Garage: none [ ] heated [ ] unheated [ ] _____CFM/sq.ft
Operation: carbon monoxide [ ] manual [ ] timer ______hr.
Heating: oil [ ] gas [ ] electric [ ] heat recovery [ ]

Why did you choose this system?

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify)

Describe any problem with the design, installation, the occupants or the owner.

<u>Domestic Hot Water</u>

Tank: central [ ] indiv. [ ] combined heat/DHW [ ]
rented [ ] owned [ ]

Source: oil [ ] gas [ ] electricity [ ] Heat pump [ ]
Heat recovery: [ ] solar [ ] other (specify) ______________
Recirculation: no [ ] yes [ ]
Insulation: all pipework [ ] recirculation [ ]
in dwellings only [ ]

Why did you choose this system?

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify)

Describe any problem with the design, installation, the occupants or the owner.

FORM USED BY SMB CONSULTANTS

GENERAL INFORMATION

Person Interviewed (Name/Title): ______________________________
Name of Organization: ______________________________

Type of Respondent: Consultant [ ] Contractor [ ]
Owner/Developer [ ] Operator [ ]
Building Manager [ ]

Type of Evaluation: Complex (more than 1 building) [ ]
Simple (only 1 building) [ ]

Building:

Name/Address of Building: ______________________________
Year Built: ______
Height: 4-7 storeys [ ] 8 storeys & over [ ]
Type: Condominium [ ] Rental [ ] Co-operative [ ]
Luxury [ ] Standard [ ] Economy [ ]

Design By: Consultant [ ] Contractor [ ]
Reason Built: Built for sale [ ] Built for holding [ ]

GENERAL DESCRIPTION

Electric Metering: Individual [ ] Central [ ]
Gas Metering: Individual [ ] Central [ ]

Type of Glazing: Single [ ] Double [ ] Triple [ ]

Indicate
Satisfaction Level: - (Completed by Owner/Developer)

	Very Satisfied	Satisfied	Neutral	Not Satisfied	Very Dissatisfied
Architect	[ ]	[ ]	[ ]	[ ]	[ ]
Engineer	[ ]	[ ]	[ ]	[ ]	[ ]
Contractor	[ ]	[ ]	[ ]	[ ]	[ ]
Marketing Company	[ ]	[ ]	[ ]	[ ]	[ ]
Maintenance Company	[ ]	[ ]	[ ]	[ ]	[ ]

The O&M manuals drawings were: Very Useful [ ] Useful [ ]
Not Useful [ ]

What kind of research, pilot project, initiative or building code changes appear necessary to improve the quality of residential construction?

What are your most pressing concerns?

What schedule or program of equipment maintenance do you currently undertake?

Do replacement or the correction of design deficiencies constitute an important part of your maintenance budget?

Yes [ ] No [ ]

Comments: ____
____
____

Heating

Indicate the type of heating for each installation (specify if "other"). If complex evaluation use legend, if simple evaluation use checkmarks.

Legend: M - Most Common, C - Common, O - Occasional,
? - don't know

	Apartment	Garage	Common Area	Corridors
Electric Baseboard	[ ]	[ ]	[ ]	[ ]
Hot Water Baseboard	[ ]	[ ]	[ ]	[ ]
Ceiling and Radiant	[ ]	[ ]	[ ]	[ ]
Radiant Panel Electric	[ ]	[ ]	[ ]	[ ]
Floor Radiant, Hot Water	[ ]	[ ]	[ ]	[ ]
Forced Air, Gas-fired	[ ]	[ ]	[ ]	[ ]
Other:	[ ]	[ ]	[ ]	[ ]
Other:	[ ]	[ ]	[ ]	[ ]

	Apartment	Garage	Common Area	Corridors
Control System Type				
Integral Electric	[ ]	[ ]	[ ]	[ ]
Low Voltage Thermostat	[ ]	[ ]	[ ]	[ ]
Line Voltage Thermostat	[ ]	[ ]	[ ]	[ ]
Modulating Thermostat	[ ]	[ ]	[ ]	[ ]
Night Setback	[ ]	[ ]	[ ]	[ ]
Thermostat Subbase	[ ]	[ ]	[ ]	[ ]
Other:	[ ]	[ ]	[ ]	[ ]
Individual Room	[ ]	[ ]	[ ]	[ ]
Individual Suite	[ ]	[ ]	[ ]	[ ]

In the Apartments Only

If forced air system: The position of the outlets:

Under the windows [ ] Over the Windows [ ]
Across the exterior wall [ ] Other (specify) [ ]

If hot water system:

1 Pipe [ ] 2 Pipe [ ] 3 Pipe [ ] 4 Pipe [ ]
2 Pipe & Electric Heating [ ]

Why was this system chosen?

First Cost [ ] Energy Costs [ ] Low Maintenance [ ]
Fuel Availability [ ] Space Constraints [ ] Other [ ]
Individual Metering Possible [ ] Most Familiar With [ ]

Describe problems encountered in system design or installation, by Occupants or by Owners. (Use Legend; M, C, O, ?).

1. Poor temperature control
2. High installation cost
3. High running cost
4. Low reliability (frequent breakdowns)
5. High maintenance/operation cost (give some indication of the severity and frequency of the problem)
6. Inconvenient operation
7. Noise
8. Cold drafts and uneven temperatures (eg. by windows)
9. Cold floors
10. Systems not properly balanced
11. Inadequate O&M manuals
12. Other

No.	Design	Installation & Commissioning	Tenant/ Occupant	Owner/ Manager
1	[ ]	[ ]	[ ]	[ ]
2	[ ]	[ ]	[ ]	[ ]
3	[ ]	[ ]	[ ]	[ ]
4	[ ]	[ ]	[ ]	[ ]
5	[ ]	[ ]	[ ]	[ ]
6	[ ]	[ ]	[ ]	[ ]
7	[ ]	[ ]	[ ]	[ ]
8	[ ]	[ ]	[ ]	[ ]
9	[ ]	[ ]	[ ]	[ ]
10	[ ]	[ ]	[ ]	[ ]
11	[ ]	[ ]	[ ]	[ ]
12	[ ]	[ ]	[ ]	[ ]

Air Conditioning

Indicate the type of air conditioning for each installation:
(Use Legend; M, C, O, ?)

Type	Apartment	Garage	Common Area	Corridors
Central System w/Fan Coils	[ ]	[ ]	[ ]	[ ]
Wall mounted package unit	[ ]	[ ]	[ ]	[ ]
Window mounted package unit	[ ]	[ ]	[ ]	[ ]
Air source heat pumps	[ ]	[ ]	[ ]	[ ]
Water source heat pumps	[ ]	[ ]	[ ]	[ ]
Other	[ ]	[ ]	[ ]	[ ]
Does the system provide heating (Y/N)	[ ]	[ ]	[ ]	[ ]
Does the system provide fresh air make-up (Y/N)	[ ]	[ ]	[ ]	[ ]
Control System				
Integral to Package	[ ]	[ ]	[ ]	[ ]
Wall mounted	[ ]	[ ]	[ ]	[ ]

If Central Air Conditioning:

Type of distribution: 2 Pipe [ ] 3 Pipe [ ] 4 Pipe [ ]
Air [ ]

Type of cooling: Electric chiller ______
Absorption chiller ______

Why was this system chosen?

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify) [ ]

Describe any problems encountered in system design, or installation, by Occupants or Owners.

Ventilation (Use Legend: M, C, O, ?)

Apartment

Kitchen Exhaust: Central [ ] Individual [ ] Dehumidistat [ ]
Operation: Separate Switch ______ Timeclock ______ hrs.

Bathroom Exhaust: Central [ ] Individual [ ] Dehumidistat [ ]
Operation: Separate Switch ______ Timeclock ______ hrs.

Bedroom Exhaust: Central [ ] Individual [ ] Dehumidistat [ ]
Operation: Separate Switch ______ Timeclock ______ hrs.

Livingroom Exhaust: Central [ ] Individual [ ] Dehumidistat [ ]
Operation: Separate Switch ______ Timeclock ______ hrs.

Dryer Exhaust: Central [ ] Individual [ ] Dehumidistat [ ]
Operation: Separate Switch ______ Timeclock ______ hrs.

Make-Up Air: None [ ]
Corridor [ ] Undercut Doors [ ] Transfer Grille [ ]
Separate System [ ] One Per Space [ ] Forced Air [ ]
Wall Unit [ ]

Corridor Pressurization: Fuel Oil ___ Gas ___ Electric ___
Operation ___ hrs.
Recovery: None ____ Wheeled ____ Plate ____ Glycol ____
Heat Pump ____

Indicate % of make-up air (supply air/exhaust air): ______________

Humidification: Yes [ ] No [ ]

Why was this system chosen:

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify) [ ]

Describe problems encountered in system design, or installation, by Occupants or by Owners. (Use Legend: M, C, O, ?)

1. Adverse effect on fire safety
2. High installation cost
3. High running cost
4. Low reliability (frequent breakdowns)

5. High maintenance/operation cost (give some indication of the severity and frequency of the problem)
6. Inconvenient operation
7. Noise created by systems
8. Noise transfer to and from adjacent spaces
9. Poor air quality (low or high humidity, stuffiness)
10. Condensation on windows
11. Condensation causing structural degradation
12. Transfer of smells to and from adjacent spaces
13. Windows are opened in winter to control temperatures
14. Windows are opened in winter for fresh air/ventilation
15. Other

No.	Design	Installation & Commissioning	Tenant/ Occupant	Owner/ Manager
1	[ ]	[ ]	[ ]	[ ]
2	[ ]	[ ]	[ ]	[ ]
3	[ ]	[ ]	[ ]	[ ]
4	[ ]	[ ]	[ ]	[ ]
5	[ ]	[ ]	[ ]	[ ]
6	[ ]	[ ]	[ ]	[ ]
7	[ ]	[ ]	[ ]	[ ]
8	[ ]	[ ]	[ ]	[ ]
9	[ ]	[ ]	[ ]	[ ]
10	[ ]	[ ]	[ ]	[ ]
11	[ ]	[ ]	[ ]	[ ]
12	[ ]	[ ]	[ ]	[ ]
13	[ ]	[ ]	[ ]	[ ]
14	[ ]	[ ]	[ ]	[ ]
15	[ ]	[ ]	[ ]	[ ]

<u>Ventilation Garage</u> (Use Legend: M, C, O, ?)

Garage: None [ ] Heated [ ] Non-Heated [ ] _____ CFM/sq.ft.
Operation: Carbon Monoxide Sensor [ ] Manual Switch [ ]
Timeclock _____/hr.
Heating: Gas [ ] Electric [ ] Other [ ] Recovery [ ]

Why was this system chosen?

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify) [ ]

Describe any problems encountered in system design, or installation, by Occupants or Owners.

Domestic Hot Water (Use Legend: M, C, O, ?)

System: Central [ ] Individual [ ] Rented [ ] Purchased [ ]
Connected to hot water space heating system [ ]
Fuel: Gas [ ] Electricity [ ] Heat Pump [ ] Solar [ ]
Other ________________________
Recovery: No [ ] Yes [ ]
Recirculation: No [ ] Yes [ ]
Insulation: All Piping [ ] Recirculation Pipe Only [ ]
In the Apartments [ ]

Why was this system chosen:

First Cost [ ] Energy Cost [ ] Low Maintenance [ ]
Other (specify) [ ]

Describe any problems encountered in system design, or installation, by Occupants or Owners.

1. Insufficient hot water
2. High installation cost
3. High running cost
4. Low reliability (frequent breakdowns)
5. High maintenance/operation cost (give some indication of the severity and frequency of the problem)
6. Other

No.	Design	Installation & Commissioning	Tenant/ Occupant	Owner/ Manager
1	[ ]	[ ]	[ ]	[ ]
2	[ ]	[ ]	[ ]	[ ]
3	[ ]	[ ]	[ ]	[ ]
4	[ ]	[ ]	[ ]	[ ]
5	[ ]	[ ]	[ ]	[ ]
6	[ ]	[ ]	[ ]	[ ]