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HVAC CONSULTANT

# FINAL REPORT

# FOR

# CANADA MORTGAGE & HOUSING CORPORATION

# ON

# MAIN SQUARE
# TORONTO

August 31, 1994

# DISCLAIMER

ABSTRACT

The objective of this work was to improve our understanding of how high-rise HVAC systems operate in a 20 year old building. This work should support better quality heating and ventilating systems in high-rise residential structures. The work involved evaluating the existing designs (system condition, performance and suitability), determining actual ventilation system airflows for both summer and winter conditions, identifying inefficiencies in the space and domestic water heating systems, evaluating the performance of electrical equipment serving the mechanical systems, and recording benchmark air quality readings. The results were obtained in 4 tower, 1080 apartment social housing complex, with commercial space, in Toronto.

The bathroom and kitchen exhausts were dirty and unbalanced. The unheated make-up air supplied to the corridors is a problem. Individual unit temperature controls have recently been added, but occupants, particularly in the lower apartments, suffer from lack of heat due to the single glazed windows. The electrical and fuel energy used is 30% more than comparable sized structures in Toronto. Domestic water consumption is considerably higher than apartments which have undergone a water conservation program. A reduction target of 22% with a 2 year payback is noted. The indoor air quality is within international threshold levels for Total Volatile Organic Compounds. The energy consumed by the relatively new refrigerators is almost double current Energuide published recommendations.

Modifications are proposed for the plumbing, space heating, ventilation and garage ramp heater control systems. The changes recommended will not only improve occupant comfort and system performance, and but will reduce energy and environmental waste. Payback periods are as low as 1.5 years.

Some of the work could be performed using energy service contractors (ESCO's). ESCO's are normally paid from operating cost savings and therefore guarantee performance.

Wayne Webster
Research Division
September 1994

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# 1.0 EXECUTIVE SUMMARY

## 1.1 The Site

Main Square is a 23 year old apartment complex with four residential towers varying from 9 to 28 storeys. The 1080 suites have a gross area of 90,000 $m^2$, while an office, retail and community centre comprise another 15,000 $m^2$.

The population is estimated at 2500. It consists of 45% seniors, 20% single parent families and 35% singles.

## 1.2 Ventilation

Bathrooms and kitchens are ventilated with 23 roof mounted exhaust fans. A portion of the exhaust air is made up with unheated outside air which is delivered to the corridors. The lack of heat in the corridors together with the dirt and unbalanced airflow in the exhaust systems constitutes a problem at present.

## 1.3 Heating

Gas-fired boilers and wallfin radiation provide heating for eight months a year. A measure of individual temperature control of the suites has been added with Danfoss type self-contained radiator valves but the single glazed window sash is now so poorly fitting that the lower apartments suffer badly from underheating in cold weather. Residents have tried to overcome this by operating electric ovens, even to the extent of blowing circuit breakers during the January 1993 cold snap.

## 1.4 Energy Consumption

The use of gas and electric energy in 1992 can be compared with an average of 40 other Toronto apartments taken from the Engineering Interface Limited database and shown in the following table:

| | ENERGY USE | | | COST/YR FOR 104,400m² | | |
|---|---|---|---|---|---|---|
| | Fuel ekWh/yr/m² | Electricity kWh/yr/m² | Total | Fuel @ 13.5¢/m³ | Electricity @ 6¢/kWh | Total |
| Main Square | 366 | 98 | 464 | $500,000 | $614,000 | $1,114,000 |
| Toronto Data-base | 299 | 71 | 370 | $410,000 | $445,00 | $ 855,000 |
| Main Square overrun | 67<br>(22%) | 27<br>(38%) | 94<br>(30%) | $ 90,000<br>(22%) | $169,000<br>(38%) | $ 259,000<br>(30%) |

It is estimated that about half of the gas heating cost could be eliminated with a combination of new well-fitted double glazed sash and a heat exchanger applied between exhaust and outside air. The payback for the heat exchanger would be within 10 years while the payback for the new sash is judged by the local CMHC office to fall between 15 and 25 years depending upon the quality of sash used.

## 1.5 Domestic Water

Domestic water consumption in 1992 was 281 m³/suite. About 8% of this is heated for use in washrooms and kitchens.

It is estimated, from results in CityHome and Metro Toronto apartments, that a water conservation exercise would save 22% worth $55,000/yr. This could be carried out through a tender process with an estimated 1 1/2 year payback or through an energy service contract with an estimated two year payback.

## 1.6 Indoor Air Quality

Measurements were made on exhaust air streams between 1700 and 1900 hours. Mar/94

These indicated a Total Volatile Organic Compound level of 380 $\mu g/m^3$ and $CO_2$ at 475 ppm. These levels compare with international safe thresholds of 600 $\mu/m^3$ and 1000 ppm respectively. It is thought that the suites are being adequately ventilated at present, in part, through the leaky window sash.

## 1.7 Appliances

There has been a recent purchase of new refrigerators with Energuide labels of 1056 kWh/yr. This energy level for 12 cubic foot refrigerators can be compared with current Energuide recommendations of 540 kWh/yr.

The difference in cost with the new models could be related to a saving of $39,000/yr.

## 1.8 Recommendations

- Clean and rebalance the exhaust air grilles

- Conduct a detailed review of the economics of a ventilation heat exchanger for the make up air system

- Add radiation drain valves at the base of the heating circuits so that 22 years of sludge can be flushed out and circuits fully cleaned. This will help to overcome shutdowns to clear intermittent blockages at the Danfoss valves

- Clear the problem with the radiation check valve in Building A and then operate each of the four buildings with one pump instead of two. The second pump can be used as a spare. This will save $10,000/yr.

- Add a sensor in the ramp so that the electric heating cable will only operate when the ramp surface temperature falls below 5°C.

  This may reduce the electric energy used at present by 50% and save $3,000/yr.

- Call for ESCO proposals on water conservation with the prospect of reducing water usage and saving up to $55,000/yr.

- Prepare a detailed analysis of domestic water booster pumping. Energy costs can be reduced if the first five floors could be fed directly by City pressure. Arrangements might also be made to add a small booster pump capable of handling small night time loads.

### 1.9 Terms of Reference for Study

Please refer to Appendix B.

# 1.0 RÉSUMÉ


## 1.1 L'emplacement

Main Square est un ensemble de logements datant de 23 ans et comportant quatre tours résidentielles de 9 à 28 étages. Les 1 080 appartements occupent une superficie brute de 90 000 m² alors qu'un bureau, un centre communautaire auquel s'ajoutent quelques commerces se partagent une superficie brute de 15 000 m².

Les résidents, 2 500 personnes environ, se composent d'aînés à 45 %, de familles mono-parentales à 20 % et de célibataires 35 %.

## 1.2 Ventilation

La ventilation des salles de bains et des cuisines se fait au moyen de 23 ventilateurs d'extraction installés sur le toit. Une partie de l'air évacué, mêlé à de l'air extérieur, alimente les corridors sans être réchauffé. L'absence de chauffage dans les corridors auquel s'ajoutent la poussière et le déséquilibre du débit d'air du système d'évacuation posent présentement un problème.

## 1.3 Chauffage

Le chauffage est assuré, 8 mois par année, par des chaudières à gaz et des radiateurs à ailettes. Depuis l'addition de robinets de radiateur "Danfoss", la température peut être réglée individuellement dans les appartements, mais les fenêtres à simple vitrage sont tellement mal ajustées que le chauffage devient problématique par grand froid dans les appartements des étages inférieurs. Pour pallier à ce manque de chauffage, les résidents ont fait fonctionner leur four électrique durant la vague de froid du mois de janvier 1993 au point que les disjoncteurs coupaient le courant.

## 1.4 Consommation d'énergie

Le tableau qui suit établit la comparaison de la consommation de gaz et d'électricité à Main Square par rapport à celle de 40 autres complexes immobiliers situés à Toronto, les données étant tirées de la base de données «Engineering Interface Limited»

| | CONSOMMATION D'ÉNERGIE | | | COÛT ANNUEL/104 000 m² | | |
|---|---|---|---|---|---|---|
| | Combustible | Électricité | Total | Combustible | Électricité | Total |
| | ekWh/an/m² | kWh/an/m² | | 13,5 c/m³ | 6c/kWh | |
| Main Square | 366 | 98 | 464 | 500 000 $ | 614 000 $ | 1 114 000 $ |
| Base de données de Toronto | 299 | 71 | 370 | 410 000 $ | 445 000 $ | 855 000 $ |
| Coûts additionnels à Main Square | 67 (22 %) | 27 (38 %) | 94 (30 %) | 90 000 $ (22 %) | 169 000 $ (38 %) | 259 000 $ (30 %) |

Nous sommes d'avis que l'ajout de nouveaux châssis de fenêtres à double vitrage et d'un échangeur de chaleur à la prise d'air pourrait réduire les dépenses de gaz de moitié environ. Il faudrait un peu moins de 10 ans pour récupérer l'investissement requis pour installer l'échangeur de chaleur, et, d'après le bureau local de la SCHL, entre 15 et 25 ans pour récupérer celui lié à la pose des nouveaux châssis de fenêtres selon leur qualité.

1.5 Consommation d'eau

La consommation d'eau fut de 281 m³ par appartement en 1992, dont 8 % est chauffée pour les cuisines et les salles de bains.

Nous estimons, tel que démontré dans les appartements de CityHome et du Grand-Toronto qu'un exercice d'économie de l'eau pourrait réduire la consommation de 22 % et ainsi permettre de réaliser des économies de 55 000 $ par année. Il faudrait 1 1/2 an pour récupérer l'investissement si l'on procède par appel d'offres ou environ 2 ans si une entente est conclue avec un membre de l'association «Energy Service Company».

## 1.6 Qualité de l'air intérieur

Les débits d'air évacué ont été soumis à un contrôle entre 1 500 heures et 1 700 heures en mars 1994.

Les résultats obtenus indiquent un niveau total de composés organiques volatils de 380 $\mu g/m^3$ et un niveau de gaz carbonique de 475 ppm. Les niveaux internationaux reconnus sécuritaires sont respectivement de 600 $\mu g/m^3$ et de 1 000 ppm. Il semble donc que la ventilation dans les appartements soit adéquate, ce qui s'explique, en partie, par la faible étanchéité à l'air des châssis de fenêtres.

## 1.7 Appareils ménagers

Des réfrigérateurs neufs consommant 1 056 kWh/par année selon l'étiquette Energuide ont été récemment achetés. Selon le répertoire Énerguide courant, les réfrigérateurs de 12 $pi^3$ les plus efficaces ne consomment que 540 kWh/par année. De tel appareils auraient coûté 39 000 $ par année de moins en frais de fonctionnement, mais le coût d'achat moins élevé des nouveaux modèles représente une économie à peu près identique.

## 1.8 Recommandations

- Nettoyer et rééquilibrer les grilles des ventilateurs d'extraction

- Effectuer une revue minutieuse des répercussions financières de l'installation d'un échangeur de chaleur en ce qui concerne le système d'air de compensation

- Ajouter des robinets de purge à la base des circuits de chauffage afin de pouvoir nettoyer à fond les dépôts accumulés depuis 22 ans. Cela évitera de mettre hors service le système de chauffage par suite de l'obstruction intermittente des robinets Danfoss.

- Régler le problème avec le clapet de retenue dans l'immeuble A et, par la suite, faire fonctionner chaque bâtiment avec une pompe au lieu de deux, l'autre pompe étant mise en réserve. Cette mesure ferait épargner 10 000 $ par année.

- Ajouter un détecteur dans la rampe pour que le câble électrique chauffant ne fonctionne que lorsque la température de la surface de la rampe est inférieure à 5 °C

Cela pourrait réduire de 50 % la quantité d'électricité utilisée et faire économiser 3 000 $ par année

- Lancer des appels de propositions portant sur l'économie de l'eau aux membres de l'association Energy Service Companies dans le but de réduire la consommation d'eau et d'économiser jusqu'à 55 000 $ par année.

- Effectuer une analyse minutieuse du pompage en surpression de l'eau domestique. Les coûts en énergie seraient réduits si les cinq premiers étages pouvaient être alimentés par le système municipal. L'ajout d'une petite pompe à surpression pourrait suffire à la faible demande durant la nuit.

## 1.9 Cadre de référence de l'étude

Voir Annexe B.

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## 2.0 DESCRIPTION OF THE SITE

The site is known as Main Square. It is situated at the south east corner of Danforth and Main Streets in the City of Scarborough. It consists of four high-rise residential towers incorporating 1080 suites, day care, recreation centre, shops and medical office space. See Figure 8.

The project was built in 1973.

### 2.1 Area Suite Definition and Demographics

| | | | NUMBER OF SUITES | | | | |
|---|---|---|---|---|---|---|---|
| Building | Number* Storeys | Gross Area** $m^2$ | Bachelor | One Bedroom | Two Bedroom | Three Bedroom | Total |
| A | 30 | 23,721 | 108 | 216 | - | - | 324 |
| B | 23 | 26,644 | 84 | 84 | 167 | - | 335 |
| C | 25 | 27,200 | 8 | 132 | 103 | 50 | 293 |
| D | 11 | 13,365 | 19 | 45 | 64 | - | 128 |
| Retail/ Office | 2 | 13,570 | - | - | - | - | - |
| **Total** | 91 | 104,400 | 219 | 477 | 334 | 50 | 1,080 |

### 2.2 Ventilation Systems

The four major towers are served by roof mounted fans, 11 washroom exhaust and 12 kitchen exhaust. See Figures 9, 10, 11 & 12. Outside air is filtered but unheated, supplied by seven supply air fans. The three tall buildings have outside air supplied from above and below while the nine storey tower is supplied from the penthouse only. All fans operate continuously. Each suite has been designed with one 15 l/s washroom exhaust grille and one 30 l/s kitchen exhaust grille. This provides an air change of from a half to one air change per hour depending upon the area of the suite.

2.3 Heating System

Each tower has two or more natural draft gas-fired boilers mounted in its respective penthouse.

Each tower has two circulating pumps which operate continuously to serve wallfin type radiation in each suite. The radiation elements are piped in a reverse-return type circuit in order to assist a balance in water flow.

The boilers are staged in operation by an outdoor-indoor type of automatic control thermostat.

The systems operate from 15th September to 15th May approximately, and are shut down in summer.

Chemical corrosion control of the radiation water has been scheduled only for the last seven years.

2.4 Building Enclosure

The building incorporates windows for approximately 35% of the wall area. The windows and balcony doors are single-glazed with steel factory type sash. The sash is not weatherstripped and has become poorly fitted in many cases.

The walls are masonry with strapping and dry wall interior finish. The insulation value of the walls is approximately R-1.0. SI

2.5 Changes since Original Construction

Self-contained Danfoss radiation valves were added three years ago to each radiation element. This was done in all likelihood to save fuel.

In the past the temperature control in the suites has been poor because of leaky windows, unsophisticated radiation schedule and lack of vertical zoning (e.g. discriminating the radiation schedule for the upper and lower halves of the buildings.

Temperature control in the suites has been improved since the addition of the automatic valves although this expense might not have been necessary if the windows had been of good quality and the radiation temperatures better controlled.

2.6 Operating Staff

Building operation is subcontracted and the staff changes from time to time. The operating superintendent has been reemployed by each agency, however, and has been steadily involved for over eight years. He and his small staff are knowledgeable and are operating the building systems as well as their design allows.

## 3.0 ENERGY CONSUMPTION

It might seem unfair to compare Main Square with an average of other multi-storey residential buildings because of its greater age. Yet, the higher energy required for single glazed windows common to high-rise units in the 1970's are counterbalanced by the higher ventilation rates practised in later construction. Double glazing would save approximately 17 $kWh/m^2/yr$ (for conduction losses alone) at Main Square. The same energy increment would be required for the additional exhaust rates, 15 up to 25 l/s for washrooms and 30 up to 35 l/s for kitchens, commonly used in recent apartments.

Thus, the comparison is more legitimate than it might have seemed.

### 3.1 Gas and Electricity Comparison with other Similar Buildings

Energy has been summarized from the 12 monthly gas and electricity invoices for 1992 using FASER, the energy analysis program prescribed for Ontario Hydro incentive calculations. The invoices and FASER output are shown in Appendix C.

The area of the premises has been measured from the drawings for buildings A, B, C and D. Garage space has not been included in the area since it is unheated. The electric energy for garage lighting and pipe tracing is included, however, since there were no means to meter it separately.

Building B includes 13,600$m^2$ of shops and office space. This cannot be divorced from the balance of Building B area since the heating bill is common to both.

Buildings C and D must also be included together since they have a common boiler plant. These problems make it more difficult to compare the four towers with each other and the total complex with other apartments which lack the commercial space.

The 1992 energy, with these understandings, is presented as follows:

| Apartment | Area m² | Fuel ekWh/yr/m² | Electricity kWh/yr/m² | Total ekWh/yr/m² |
|---|---|---|---|---|
| A | 23,721 | 326 | 94 | 420 |
| B | 40,214 | 430 | 86 | 516 |
| C/D | 40,465 | 325 | 111 | 436 |
| **Total** | **104,400** | **366** | **98** | **464** |

The average of 40 other Toronto apartment complexes taken from the Engineering Interface database and shown on Figure 1 is:

| | |
|---|---|
| Fuel | 299 ekWh/yr/m² |
| Electricity | 71 kWh/yr/m² |
| Total | 370 ekWh/yr/m² |

Main Square would compare with this average as follows:

| | ENERGY USE | | | COST/YR FOR 104,400m² | | |
|---|---|---|---|---|---|---|
| | Fuel ekWh/yr/m² | Electricity kWh/yr/m² | Total | Fuel @ 13.5¢/m³ | Electricity @ 6¢/kWh | Total |
| Main Square | 366 | 98 | 464 | $500,000 | $614,000 | $1,114,000 |
| Toronto Data-base | 299 | 71 | 370 | $410,000 | $445,00 | $ 855,000 |
| Main Square overrun | 67 (22%) | 27 (38%) | 94 (30%) | $ 90,000 (22%) | $169,000 (38%) | $ 259,000 (30%) |

### 3.2 Breakdown of Gas Consumption

Natural gas provides the heating for four building requirements:

- fabric losses
- make up air caused by exhaust ventilation
- domestic hot water
- infiltration

An estimate can be made of fabric losses because the building insulation values are known. Make up air heating can be calculated because the exhaust air volumes were measured. Building A domestic hot water consumption was measured for 24 hours, June 24/25, 1993.

An attempt was made to approximate infiltration heating, the component most difficult to calculate, by deducting the three assessed values from the total gas consumption. This was done for Building A using a 365 day extrapolation on DHW heating. The result is shown in Figure 2 where infiltration was found to be 75 kWh/m$^2$/yr or 27% of the total heating requirement.

Since infiltration worked out to require over three times the energy that a designer would ascribe for a new building, it was decided to obtain a building stack pressure profile. Figure 3 illustrates the result of the pressure testing which was carried out at the top and bottom of Building A with a magnehelic gauge. "Fans on" created a net (exhaust air minus outside air supply) extraction of 7500 l/s (16,000 CFM). This raised the neutral pressure plane by about three floors and created a shift of 0.5 mm (0.02 inches) water gauge at the entrance doors and in the penthouse.

It is important to know what the air leakage of the building walls would be at the ASTM test pressure of 7.6 mm (or 0.3 inches) of water gauge. This is the pressure at which leakage values are rated and compared. Figure 4 illustrates how a leakage of 7500 l/s (16,000 CFM) @ 0.5 mm (0.02 in.) can be extrapolated to 39,000 l/s (89,000 CFM) at 7.6 mm (0.3 in.) using an equation developed through NRC testing, e.g., leakage varies as the pressure difference to the power of 1.6.

The leakage rate for Building A walls at reference pressure is

$$\frac{39{,}000\ l/s}{10{,}140\ m^2} \text{ or } 3.8\ l/s/m^2$$

(1.3 $CFM/ft^2$). This can be compared with previous NRC testing with walls classified as tight at 0.44 $l/s/m^2$ (0.15 $CFM/ft^2$), average at 1.02 $l/s/m^2$ (0.35 $CFM/ft^2$ and loose at 2.0 $l/s/m^2$ (0.7 $CFM/ft^2$),

This degree of looseness in the building fabric is well known to the building occupants who live on the lower floors of the building and who were unable to obtain normal room temperatures last January because of the leaky steel window sash. This looseness ratio is also above the NRC ratings for very leaky buildings.

### 3.3 Breakdown of Electrical Consumption

Electrical consumption includes components of energy for tenant use, fans and pumps, elevators and general house use such as lights and ramp heat.

The energy for the fans and pumps was measured and is known. The total energy for 1992 was metered at 9.1 $kWh/m^2/yr$. A breakdown is shown graphically in Figure 5. The values of the unknown components are estimated from measurements on other buildings.

Some reasons for energy use, which is 2.1 $kWh/m^2/yr$. higher than averages noted on Figure 1, may include:

- ovens used on cold days to compensate for excessive infiltration on lower floors
- garage ramp heat not too well controlled
- retail use, not normally associated with apartment energy
- refrigerators using 75% more energy than the best listed in the Energuide series

### 3.4 Potential for Energy Conservation

Reductions in natural gas consumption could be made with an improved wall and with heat reclaim on the exhaust ventilation.

The improved wall would involve double glazing with better window frames and insulation applied to the brick exterior wall. These modifications would reduce both fabric heat loss and infiltration.

The heat exchanger would draw up to 80% of the heat in exhaust air to preheat fresh air supply.

The potential extent of these conservation actions is shown graphically in Figure 6. There could be a possible reduction of gas energy, as measured in Building A, of 60% from 283 kWh/ft$^2$/yr. to 108 kWh/m$^2$/yr.

Heat reclamation of exhaust air is more difficult in this complex since the exhaust and fresh air supply streams must be brought together to simplify heat exchange.

In the three major buildings most of the outside air is introduced from the bottom of the risers while the exhaust fans are all on the roofs.

Using Building A as an example it may be possible to withdraw the outside air duct riser and use the enclosing masonry shaft as a supply duct. In this case all the outside air could be supplied from a new 8200 l/s air unit mounted on the roof in the same location as the existing smaller unit.

The new unit would incorporate a supply and exhaust fan together with a rotary heat exchanger capable of up to 80% heat transfer from exhaust air. See Figure 7 for a general layout.

The saving in fuel could be approximated at:

$$\frac{17{,}500\mathit{CFM} \times 1.08 \times 24 \times 7000\ \mathit{D/D}}{35{,}120\mathit{Btu/m3} \times 0.7} \times \$0.143/\mathit{m3} = \$18{,}500$$

The cost is estimated as follows:-

| | |
|---|---|
| Air Unit 8200 l/s @ $5.50 | $ 45,000 |
| Ductwork 1636 Kg @ $11/Kg | 18,000 |
| Weatherproof insulation 195m$^2$ @ $54/m$^2$ | 10,500 |
| Remove existing duct trunk and air unit | 5,000 |
| Rigging to 75 m high roof | 2,500 |
| Electrical 20 HP x $125/HP | 2,500 |
| Air balance | 1,000 |
| Engineering & Commissioning | 10,000 |
| | 94,500 |
| 7% G.S.T. | 6,600 |
| **TOTAL** | **$101,100** |

The simple payback would be $\frac{\$101,100}{18,500}$ or 5.45 yrs.

Savings for new windows would be less attractive financially. John Hussiman has given estimates of from $215/m$^2$ to $365/m$^2$ for new windows with good air seals and a third the existing heat transmission rate. The range in cost denotes quality, maintenance and longevity from 15 to 25 years.

Savings in fuel are estimated at $5.60/m$^2$/yr for heat loss and $3.55/m$^2$/yr for reduced infiltration. The simple payback would be over 20 years for the cheapest glazing.

Savings for external metal cladding with R-4 (SI) would be less at $1.50/m$^2$/yr while application would run $215/m$^2$. This is even less cost effective than the window refit.

3.5 Energy Consumption for Garage Ramp

The Main Square ramp measures 6 x 30 metres. It is equipped with 90 kW of Pyrotenax cable for snow melting. The cable is controlled by a "Melting Control System." The controller turns on the heat if the ambient temperature is below 40F (4.5°C) and moisture is present. The energy input to the cable was measured from 18 to 24 December 1993 as shown on Figure 32. This shows that power was on 55% of the time. This was required by the control protocol cited above because the weather was below 40F (4.5°C) 94% of the time and there was intermittent precipitation as shown on Figure 33.

If the controller was equipped with a thermostat buried in the asphalt and set for 40F (4.5°C), the power would have cycled for approximately 50% of the time it was on and there would have been a saving of

$$\frac{90kW \times \$.07/kWh \times 172\ hrs}{2} \times \frac{55}{100} \text{ or } \$296$$

for this seven day period. A 40F temperature is all that is required for snow melting according to Pyrotenax who recommend this control.

The cost of installing the additional sensor would be about $400. This would be a cost effective modification.

## 3.6 Kitchen Appliances

Each tenant has two electrical appliances, a stove and a refrigerator.

The Department of Supply & Services together with the Department of Natural Resources publish Energuide bulletins which define the range of energy required by different manufacturers for various sized appliances.

They also show the 20 year potential saving in electricity for using the most conserving appliance over the least conserving. See Figure 34.

As far as stoves are concerned there is little to show for a discriminating purchase. It might be worthwhile providing tenants with microwave ovens, however, since a 50% reduction in cooking energy may be worth as much as $35/yr.

Refrigerators provide the greatest opportunity to show a saving. Figure 35 indicates the typical Energuide use of a 12 cubic foot model (two compartment frost free) varying from 540 to 694 kWh/yr. The units purchased recently for Main Square, however, have an Energuide label for 88 kWh/month or 1056 kWh/yr. At 7¢/kWh the difference between these and the Energuide best would be (1056 - 540) x .07 or $36/yr. When all 1080 units are considered, this overrun becomes $39,000/yr. It is unfortunate that the refrigerators are only three years old. For any future purchase, energy should be an important consideration.

# 4.0 VENTILATION SYSTEMS

It was important to discover if, after 23 years, the ventilation systems were still operating with design intent.

A survey of the supply and exhaust fans was carried out in the summer of 1993.

## 4.1 Measured Performance of Fans

We measured and recorded the kilowatt input, airflow and operating static pressure of each of the 30 major fans. The locations of the fans are noted on Figure 8, Site Plan, Figure 9, Building A; Figure 10, Building B; Figure 11, Building C; and Figure 12, Building D. The operating measurements are shown on Figure 13.

The power factor of the fan motors is based on their size and the percent of nameplate energy requirement. These data enable the power factor to be drawn from Figure 14.

Actual watts are derived from measured amps x $\sqrt{3}$ x volts x power factor. Theoretical watts are based on CFM x Static Pressure ÷ 8.507. The fan efficiency is then

$$\frac{\text{Theoretical Watts}}{\text{Actual Watts}} \times 100$$

The fans were expected to be running in the 25% to 50% efficiency range but, with the exception of one, they actually varied between 1% and 41%. Reasons for the wide range may involve problems with site measurement, old motors with poor efficiency, "system effect" caused by poor fan inlet connection and dirt on the inner cup of the fan blades which changes the shape of the fan blade and reduces its efficiency. Considerations which affects fans and which must be taken into account for future design are shown in Figure 15.

The exhaust fans exceeded the design flow in some cases despite eroded efficiency. Exceptions to this occurred in Building D where both exhaust fans are operating against a 25 mm static pressure on their discharge because of extended ducts and dirty outlet screens.

The outside air supply units are all operating below the originally specified design volume. The systems supply unheated air to the apartment corridors. This has raised the discomfort index to the point that custodians have attempted to block airflow by closing the front deflection vanes of the air supply grilles.

All fans operate continuously. What is not supplied by the outside air units must be infiltrated to feed the exhaust fans. Since this infiltration air must be heated any way, it would seem preferable to preheat the supply air and place the supply-exhaust systems in better balance.

We noted that the elevator exhaust fans also ran continuously. In the penthouses for Buildings A, B and C it would not be expensive to direct the warm elevator exhaust into the outdoor fan intake. A less expensive option would be to revise the flow on the elevator fans and supply air to the penthouse. This would depress the neutral pressure plane by one or two floors and reduce infiltration at the entrance floor.

## 4.2 Exhaust Riser Measurements

It was noted that some of the exhaust fans were operating as much as 30% below design capacity. It was then found that some of the exhaust grilles in the suites were partially blocked, preventing the minimum air change of 0.3/hour as called for by ASHRAE guidelines and CSA Code #326.

A survey was undertaken on one of the risers for kitchen fan A5 and one of the risers for washroom fan A6 in Building A. The results as indicated on Figures 16 through 19 were that eight of the 28 kitchen exhaust grilles and six of the 28 washroom exhaust grilles were blocked completely. One grille was wallpapered over.

The air balance was so far from design that arrangements were made to rebalance these two risers. First, the grilles were removed and washed, then the duct stubs were vacuumed and finally the risers were rebalanced as well as possible. One bushel of dirt was removed from each riser. Figures 16 through 19 reveal the new air volumes as measured on a warm day and subsequently on a cold day.

There are approximately 110 risers and 2160 grilles which require similar attention. This could be attended to with school boy labour in the summer insofar as the cleaning is concerned. An estimate of time for cleaning is 50 man days. Air rebalance will require a similar amount of time but with more skilled manpower.

The changing pressure profiles in winter caused by stack effect will tend to unbalance airflows on the exhaust risers. See Figures 20a and 20b. This is particularly true, and has been known to cause the top grilles to actually supply polluted air from below, if the building wall is loose and the pressure drop between the grilles and exhaust fan is low. This tendency did not show up in our measurements as noted in Figures 16 through 19. The reason must be that the windows were well closed on the cold day and the negative pressure at the fans, at approximately 15 mm, was above the pressure differential caused by stack effect of approximately 10 mm.

## 4.3 Preferred Concepts

Future CMHC buildings in Toronto will be air conditioned if the present practice of City Home and the metro Housing Authority are followed. See Appendix H for a description of current system concepts and costs.

A preferred concept would arrange the suite air handling units alongside the corridor where they can be serviced and metered easily from a corridor access door. This location also permits the direct supply of ventilation air from the corridor to the unit without invading the privacy of the suite. See Figure 7 in Appendix G.

Supply ventilation should be provided continuously from the roof to each suite by way of supply air shafts and the corridors. A similar amount should be exhausted from each suite through vertical risers back to the roof where the residual heating or cooling energy left in the exhaust air can be transferred to the supply air streams through rotary heat exchangers. See Figure 8 in Appendix G.

To ensure more positive evacuation of kitchen cooking odours and washroom dampness, these areas should be provided with 100 l/s and 50 l/s booster exhaust fans respectively. Heretofore, such booster fans have been exhausted directly to the outside through dampers which often get stuck open and increase the stack effect problem. Returning the exhaust air to the roof avoids this damper maintenance problem as well as allowing the recapture of ventilation energy.

## 5.0 HEATING SYSTEMS

In general the natural draft gas-fired boilers have operated efficiently over 23 years. Their heat exchangers were being replaced for the first time as this study was being done.

### 5.1 Measured Performance of Pumps

Nine major pumps were reviewed. The results are shown on Figure 22. Only one pump on pool recirculation for Building C showed up with a low efficiency. Perhaps this could be explained by the fact that the pool filter which is the major pressure drop in the system, had just been cleaned.

All pumps appear to be adequate in performing the job intended. A performance curve of the heating pump for Building A is shown in Figure 23B.

In Building A both pumps are operated for 6000 hrs/yr. They each supply 510 US GPM (32.2 l/s) vs the design of 490 US GPM (30.9 l/s).

On one day in February when the outdoor temperature was 13F (-10.5°C), the system was supplying water at 156F (69°C). The water was returning at 148F (64.5°C).

Most wallfin type heating systems are designed for a 20F (11°C) range while this system, even at full heating load, seems to operate at a 10.5F (5.8°C) range.

There is a rationale for operating this system on **<u>one</u>** pump. The other could then be used as a spare.

Suppose the hot water ranges from 88°C to 83°C heating a 21°C room. The temperature differential is then $\frac{88 + 83}{2} - 21$ or 64.5°C

With half the water the temperature differential would be: $\frac{88 + 78}{2} - 81$ or 62°C

The loss of heat could be overcome with a mere 2½°C increase in supply water temperature.

In reality, a single pump will pump more than 50% of the water owing to lower system resistance. In this case a single pump would pump about 650 US GPM (41 l/s) as shown in Figure 23.

Reexamining Figure 23B, it is clear that 650 US GPM lies beyond the pump curves. The manufacturer provided the information that the pump would, nevertheless, supply 650 GPM against 20 feet of head at a 38% efficiency. The "flow watts" would then be

$$\frac{650 \times 20 \times 8.33}{33{,}000 \times 0.38}\ 0.746 \text{ or } 6442$$

and the motor would draw

$$\frac{6442}{208 \times 1.73 \times 0.84} \text{ or } 21.3 \text{ amps}$$

The savings for operating one pump vs two would be taken from Figure 22 and the above as (6529)2 - 6442 or 6616 Watts. For a 6000 hr/yr operating schedule this saving would accrue 6.616 x 6000 x 0.07 or $2779/yr. If this procedure was followed for all four towers the annual saving could be as much as $10,000/yr.

This idea was taken up with the caretaker who countered that the Building A system cannot operate with one pump because of excessive noise and vibration. This turned out to be true although the reason seemed to be leaking check valves - something which can be corrected for less than $2500.

## 5.2 Radiation Schedules

Figure 24 indicates how the supply temperature for hot water radiation in Building A varied under the direction of a Johnson indoor/outdoor temperature controller. The correlation is not as good as it should be for a system in which this is the only control. However, the recent addition of Danfoss self-contained automatic valves on the radiation elements make the indoor/outdoor temperature control less important.

The data logger used on the radiation measurement indicated a temperature 10F less than actual owing to poor contact with the pipe but this error is not critical in the assessment of the performance of the controller.

The temperature in the suites suffered badly during the January 1994 cold spell in Toronto. This was not the fault of the boilers, since they were able to heat the radiation supply water to 190F (88°C), or the new Danfoss control valves. It could more easily be blamed on the single glazed sash where crack clearances have widened over the years.

## 5.3 Problems and Corrective Action

Features of the radiation circuits are shown in Figure 25. It will be apparent that a number of conventional features are missing or misplaced. For example, the check valves are located outside the pump isolating valves making the necessary servicing, noted earlier, more difficult to accomplish.

Three-way blending valves normally included to smooth out the radiation temperature are missing. Instead, the boilers are stopped and started on a less precise control as relayed from the indoor/outdoor thermostat.

Although the radiation elements are "reverse-returned" and fed from upper and lower circuits, the designers stopped short of feeding these circuits with separate pumps and different water supply temperatures as normally provided in tall buildings to accommodate the different levels of infiltration caused by stack effect.

Buildings of Main Square size are usually provided with primary and secondary pumping circuits with individual boiler circulators or automatic isolating valves. In this way boilers which are not required do not remain warm and lose heat through their stub stacks.

There are no isolating valves for radiation elements. This means that whole risers must be drained to clear occasional blockages from the new Danfoss self-contained rad valves.

Plugged rad valves are more prevalent since the radiation circuits for the basement have no drain valves. It is in these circuits where sludge tends to collect. When the upper circuits are flushed to remove sediment, the lower circuits re-supply the general system so that valve plugging continues.

Although it may not be cost effective to make any of the improvements noted above for better systems, the lower radiation circuits should be equipped with drain valves and the whole system flushed out again.

## 5.4 Metering

It is general knowledge that stack effect has more influence on infiltration than wind effect. In past studies, NRC has found stack effect to be responsible for up to 80% of infiltration in high-rise (over 12 storeys) residences.

In buildings over 15 storeys it has been common practice to divide the radiation circuits in two with the bottom storeys being supplied with hotter water than the upper storeys. In these buildings the radiation was piped with the top and bottom risers but both sets of piping are fed with the same temperature water by the same pumps.

To illustrate the difference in heating requirement, Clorius heat meters were installed in December 1993 on similar wallfin elements on the 2nd and 24th floors of Building A. After January and February the meters were read with the lower unit showing 835 units of heating and the upper unit showing 426 units. The lower reading on the 24th floor was despite the fact that the tenant was found to leave her window partly open on all but the coldest days.

Clorius manufacture heat meters of two types; one a simple graduated evaporation type, worth $10 and an electric type for $67 which, with a suitable multiplier, can be related to specific heating units. Either can be used to allocate heating cost to individual tenants. This is done routinely in Europe where 100,000's have been sold and where it is claimed that the meters reduce fuel consumption by up to 28%.

In the case of Main Square, to be fair to tenants who cannot control infiltration very well, a modifier would have to be applied for those tenants housed below the neutral pressure plane in the building if meters were installed. Further, the meter reading would have to be accomplished without the waste of time required to undo radiation covers to access the meter.

Heat meters would best apply in new buildings with tight wall enclosure and where the heat/cool apparatus can be accessed from the corridor so that the meters can be read at the time of equipment maintenance.

# 6.0 DOMESTIC WATER SYSTEM

## 6.1 Total Water Consumption

The Main Place operating record indicates an annual consumption of 66,670,000 Imperial gallons at an average cost of $3.78/1000 gallons.

The average use of water for the 1080 Main Place suites in 1992 was 281 $m^3$ per suite per year or 5140 Imp. Gal/month. See Appendix D for a monthly summary.

The total flow of domestic water for the complex for one day was measured at the booster pump in Building B. The flow rate was captured on a data logger using an ultrasound flow meter. The result is shown on Figure 26.

The 24-hour measurement of 208,000 Imperial gallons on June 23/24 was 14% higher than the average daily use of 183,000 Imperial gallons. Peak flow of 274 IGPM occurred at 0730 hrs., probably for morning showering. Minimum flow was 50 IGPM at 0250 hours. This may represent the requirement for water cooled condensing units in the supermarket plus leakage through water closets and taps.

## 6.2 Domestic Hot Water

The flow of domestic hot water was measured in Building A only. The results for a 24-hour review on June 24/25 are shown on Figure 27. The recirculation flow has been assumed at 25 IGPM. The total daily flow of DHW for Building A was 11630 I Gallons or 35.9 gal/day/suite. This is 21% of total daily water use in Building A and represents some 50 ekWh/$m^2$/yr or 15% of fuel use in Building A. This is lower than the 25% of fuel use expected for DHW in apartments but may be typical of the elder singles known to occupy Building A. The percentage heat for DWH must also be viewed in the context of heating required for the excess infiltration characterized by this building.

A temperature data logger was installed on the Tower A domestic hot water supply from 16 June to 27 June. Figure 28 shows the variation from setpoint of 60°C to a low of 51°C. The log for June 18/19 is shown with greater detail on Figure 29.

The thought of turning the set temperature down from 60°C to 51°C for energy conservation has now been defeated by the 8°C drift during maximum service.

In summary, the domestic hot and cold water is being supplied at adequate temperature and pressure. The total volume of DHW used and heat required to generate it is quite reasonable based on the survey of Building A.

## 6.3 Comparison with Other Buildings

Water consumption was measured in 10,000 suites owned by CityHome and the Metro Toronto Housing Authority. In all these buildings efforts were made to reduce water consumption by adding shower restrictors and changing hardware to reduce water closet consumption from 22 to 16 l/s per flush. The results are indicated in Figures 30 and 31. Figure 30 is derived from Figure 31.

## 6.4 Potential For Savings from Conservation

Since Main Square uses 5140 Imp. Gal/month it can be estimated that a similar contract would reduce water consumption by 22% or 61.5 $m^3$/suite/yr. At a cost of 83¢/$m^3$ the total saving for 1080 suites would be $55,000/yr. Water Matrix, a firm specializing in water conservation, estimates a cost of $90/suite or $93,000 to carry out revisions at Main Square. This offers an excellent 1.7 year payout.

## 6.5 Potential for Savings from Pumping Energy

Although there are two domestic water booster pumps, one is used only as a spare. The operating pump is handling from 50 to 225 GPM as shown on Figure 26. Between midnight and 5 a.m. the 50 GPM delivery is primarily a function of a spring loaded bypass.

If the pumping had been accomplished with three smaller pumps instead of one, the pumps could have operated at a more efficient point in their performance curves and the water bypass relief could have been reduced from 50 to 10 GPM.

The potential for a pumping substitution has been explored with Armstrong Ltd. Their proposal for a packaged assembly incorporating two - 50 GPM pumps and one 150 GPM pump is shown in Appendix E.

An attempt at costing energy for a single day provided the table in Figure 26B. At a rate of 7¢/kWh, the saving for the multiple pump setup was shown to be $10/day or $3650/yr. Against a quotation of $15,500 plus $3500 for installation, the simple payout would be 5.2 years. If a single 50 GPM pump was added to the existing pumping arrangement, the cost is viewed as $6,000 the saving $2,000/yr and the simple payout 3 years.

Further savings could be established if the lower floors of the complex could be disassociated from the booster pump and fed with City pressure. While this appears unlikely to be viable, it would be worthwhile, at least, to examine the possibility of feeding any water cooled condensers in the retail area directly from City pressure.

## 7.0 AIR QUALITY

In February 1994 a survey was undertaken in Building A by Healthy Buildings International Inc. This is included in Appendix F.

Total Volatile Organic Compounds, TVOC, were measured in both washroom and kitchen exhaust air discharges between 1700 and 1900 hours. Another reading was taken on a balcony on the 9th floor in order to get an average of the TVOC in ambient air as supplied to the building.

A listing of individual pollutants is shown in the report. The aggregate TVOC did not exceed 380 micrograms/$m^3$ however. This compares with the outdoor level at 54 $\mu g/m^3$ (and an international guideline of 600 $\mu g/m^3$)* cited as having no known association with health complaints.

Carbon dioxide levels at 475 ppm were also lower than the international guideline of 1000 ppm.

Unfortunately, the exhaust fans are drawing only from those suites in which the grilles are not blocked with dirt. Therefore, the readings do not constitute a universal clearance of good air in all suites.

* Cited from Danish guidelines reported in Environment International (Vol 13 pages 339-349 1987)

## 8.0 OPERATORS' WORKSHOP

In March 1994 a workshop was held at Main Square with attendance by Wayne Webster, P.Eng., and John Hussiman, P.Eng., of CMHC and various members of the building management and system operation staff.

The work done on the study was reviewed in detail and matters which could be improved were recorded. These included:-

- thermostat for ramp heater
- operation of fewer radiation pumps
- drain valves for lower radiation circuits
- water conservation tender

The present building staff is conscientious and performing as well as conditions permit. Some improvement in predicting and overcoming problems before they become severe could be made with an overall facilities management program.

Some of the overhead graphics used in the Workshop are included in Appendices G & H.

# 9.0 OPERATION AND MAINTENANCE INSTRUCTIONS

## 9.1 Fans and Air Handling Units

Building exhaust fans and outside air handling units will be operated continuously with shut downs only in case of emergency or maintenance. Garage exhaust fans are operated on timers.

Fan motors are sealed bearing and need no lubrication. See that motors are wiped clean during inspection.

Fans are all grease bearing types and are to be lubricated once a month in winter (November to April) and once every two months in summer.

Clean grilles and duct branches and shafts once every 10 years.

Check fan belt tightness during inspection and adjust as necessary.

Inspect for dirt in the cups of the fan blades and steam clean the fan wheels as necessary but not less than once every 5 years.

Instructions for maintenance of Brundidge fans are no longer available. Instructions for a similar make of fan are included as Appendix I.

## 9.2 Filters

Dustop filters used on outside air supply consist of a 25 mm white dry prefilter followed by a 25 mm coated blue secondary filter. Change the prefilters monthly and the secondary filters once every two months.

## 9.3 Pumps

The Aurora Model 344 pumps used for heating and domestic water boosting service require no maintenance except for periodic inspection and lubrication.

Electric motors have sealed bearings but the shaft bearings require greasing monthly during winter operation. Beware not to over lubricate.

Experience has shown that the pump seals will require replacement if the piping system is subjected to too much dirt or corrosive action. It is therefore important to continue with the chemical treatment contract and it would be wise to install the missing bottom circuit drain valves mentioned earlier in this report so that the system can be completely flushed for the first time.

A copy of the Aurora Pump Instruction Manual is included as Appendix J.

### 9.4 Boilers

The buildings are served with LAARS Type HB gas-fired natural draft boilers.

These units require semi-annual cleaning of line strainers and inspection of the condition of the tubes by removing the tube header covers. The units also require an annual check of combustion efficiency and safety controls by an experienced serviceman. Controls which must be checked include the high temperature limit switch, the pilot safety and relay and the automatic electric gas valve.

The boiler room should always be kept clean and free from the storage of combustibles.

The manufacturer's instructions for maintenance and troubleshooting are included in Appendix K.

### 9.5 Controls

Aside from the safety controls noted above, the only other heating system controls are the Johnson Outdoor-Indoor radiation temperature schedule devices in each boiler room.

These should be checked annually within a control service contract in the hope of improving their somewhat indifferent response. Operating instructions for this controller are contained in Appendix L along with a quotation by Johnson for a new superior substitute unit.

The only other controls in the building involve the dampers on the fan units but, since these are programmed for continuous operation it might reduce maintenance to wire the dampers open.

# 10.0 SUMMARY OF RECOMMENDATIONS

## 10.1 Maintenance of Exhaust Riser Air Balance

It was the intention of this report to demonstrate the tendency of stack effect to unbalance the flow of exhaust air from grilles on each floor to the exhaust risers. In the past this has been serious enough, on cold days, to cause the grilles on some upper floors to change from exhaust to supply of contaminated air.

The dirty condition of the exhaust systems and the need to adjust the dampers on the outside air supply grilles between the summer and winter measurements has thwarted this part of the study.

A description of stack effect followed with recommendations of how to overcome the associated problems can better be done in some future study with clean ducts and grille dampers which can be locked against occupant adjustment, and after changes made to make up air.

Meanwhile some effort should be expended to clean the supply and exhaust duct systems.

## 10.2 Water Conservation

There is an excellent opportunity for conservation of up to 30% of the water used today with a payout in less than two years. Tenders to do with work should be called. The tenders can be requested both with and without financing by the contractor.

## 10.3 Ventilation Heat Reclaim

The rotary heat exchanger provides the most efficient method of preheating ventilation air with exhaust air. This could be demonstrated in Building A, as a pilot, with a payback of less than six years and with a significant increase in the comfort of the occupants.

We recommend that requests for proposals be made to verify the economics and environmental improvement.

10.4 Garage Ramp Heating

A buried ramp thermostat scheduled to cycle the electric heaters when the ramp surface reaches 5°C may save up to $3,000/year but be installed for less than $500. We recommend that tenders be called for this measure.

10.5 Circulating Pumps

A significant saving can be made in the cost of heating by operating only one pump of the two provided for each radiation circuit. This involves diagnosing pump and check valve problems before proceeding.

An RFP could be made for engineering documents to allow multi-stage booster pumping for domestic water.

10.6 Radiation System Flushing

To avoid silt up causing failure of the DANFOSS radiation valves, we recommend installing drain valves at all low points of the basement circuits and a Filtrite model LMO-20 in the systems across each circulating pump.

Following the installation of the system drain valves and the filter:-

1. Flush out system using lower drain valves.

2. After flushing system add an iron chelating chemical cleaner at the recommended dosage to the system.

3. Circulate system water for at least 7 days and clean or change filter cartridges daily.

4. Flush system using lower drains until system water has no trace of cleaner.

5. Add a closed system corrosion inhibitor of the all organic type not a molybdate or chromate type.

### 10.7 Facilities Management

A study should be made to verify the economic potential of a computer program to manage inventory, equipment maintenance, system operating and preventive maintenance for the Main Square buildings.

### 10.8 Radiation Controller

A more reliable radiation controller is now available. Consideration could be given to spending $3,000 each for replacing three outdoor-indoor thermostats now serving the heating systems. See Appendix L for Johnson Controls quotation.