REPORT FOR THE

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VENTILATION
STATE-OF-THE-ART REVIEW
ONTARIO HYDRO

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The "fresh" air requirements for human occupancy depend on a number of conditions which must be met.

(i) adequate oxygen and low enough carbon dioxide levels to support life

(ii) adequate humidity for comfort yet low enough for prevention of moisture damage to the building

(iii) sufficiently low odour level for acceptance

(iv) sufficiently low level of particulates (smoke, dust, trace metals and organics)

(v) safe levels of contaminants such as

    formaldehyde
    radon and radioactive daughter products
    ozone
    nitrogen oxides
    sulphur dioxide

(vi) acceptably low loss (gain) of energy during the heating (cooling) season when providing "fresh" air

Table 1 lists the maximum recommended levels of each of the above contaminants for 24 hour exposure.

TABLE 1 Common Contaminants in Household Air and Recommended Maximum Levels

Contaminant	Maximum Recommended Level for 24-hour Occupancy	Reference
Carbon Dioxide	9000 mg/m^3	1
Carbon Monoxide	25 mg/m^3	1
Total suspended particulates	0.1 mg/m^3	1
Humidity	about 50% relative humidity	2, p 208
Odour level	ppm to ppb depending on substance	1, p 26
Formaldehyde	0.15 mg/m^3	2, p 66
Radon and daughters	0.01 working level (about 2 picocuries/litre)	2, p 396
Ozone	0.05 ppm	3, p 21-6
Nitrogen oxide(NO_2)	0.2 to 0.4 ppm for 1 hour exposure	9

materials. The gas is radioactive and occurs in such minute amounts that it is imperceptible to humans. It decays through several stages to solid materials which are also radioactive. The real danger to health is the likelihood that these radioactive materials, when inhaled, will lodge in the respiratory tract, where subsequent radioactive decay can destroy tissue and initiate latent cancer of the lungs. The manner in which radon and daughter products build up in unventilated spaces is described in Appendix 1. The normal method of controlling the level of radon gas in occupied spaces is by ventilation with uncontaminated air. Some control of the daughter products may be possible by filtration. Houses built on materials enriched in radium can reach much higher levels of radioactivity than the presently recommended maximum safe levels. Examples of these have been reported/6/ in Port Hope, Elliot Lake, Bancroft and Uranium City. Mr. Roger Eaton, Technical Secretary of a Federal-Provincial task force on radioactivity recommends 0.5 air changes per hour/6/ to prevent the buildup of toxic gases including radon, carbon monoxide, nitrogen oxides and cleaning solvents in residences.

In Denmark, a considerable amount of work has been done in the field of radon detection and control/2, p 399/. During the winter in Denmark, radon levels above 1 pCi/ℓ (close to the present recommended maximum safe level) were found in unventilated basement rooms, and well below 1 pCi/ℓ in living rooms of brick houses. In concrete houses where mechanical ventilation was not used, levels considerably above 1 pCi/ℓ were found. During summer measurements, readings were much lower in all cases.

In Appendix 1, methods of estimating exhalation rates (rates at which radon gas is released by materials), radiation levels and ventilation requirements are given. A ventilation rate of 1 air change per hour will reduce the radiation level to 0.8% of the original level/2, p 396/. In certain locations in Sweden, 1/2 air change per hour is inadequate to maintain radon levels below 1 pCi/ℓ/2, p 413/. It appears that, depending on location, the level of radon may determine the minimum ventilation rate required for the building. The rate may be high enough to control all contaminants of concern, but may create other problems, such as dryness during the heating season, and high energy usage.

(iii) Ozone

Ozone is a colourless gas which occurs in nature as a result of ionization of oxygen gas during electrical storms, or the reaction between ultraviolet radiation and air in the upper atmosphere. In cities where hydrocarbon pollutants exist from car and industrial emissions, ozone is produced in a photochemical reaction during sunny periods. In concentrations of 0.015 parts of ozone per million parts of air, the odour is barely detectable/8/. Typical outdoor levels range between 0.015 to 0.03 ppm/3/ and in polluted cities levels have been observed to reach 0.15 ppm/9/. The odour level at 1 ppm is very disagreeable, and is similar to sulphur. At this concentration, it may cause headaches, and irritation in the upper respiratory tract.

Electronic air cleaners generate small amounts of ozone while ionizing air (5 to 20 x 10^{-6} ft^3 ozone/min)/3/. Simultaneously, ozone is consumed by materials in the house, and a balance is quickly reached. Ozone infiltrating from outdoors will also be consumed by the materials in the house, especially by wool and nylon carpeting/3/. For example, indoor and outdoor ozone levels were measured in a house with an electronic air cleaner and were as follows/3/:

outdoor ozone level:	0.025 ppm
indoor ozone level:	0.002 ppm
air change rate:	1/2 ach

Occasionally, ionization devices and ozonating purifiers appear in the market place for residential and commercial use, and the amount of ozone generated is not always specified. There should be cause for concern in the misuse or misapplication of these devices, particularly since the chronic local and systemic effects are not known/8/.

(iv) Nitrogen Oxide

Nitrogen oxide (NO_2) is produced outdoors by a photochemical reaction of hydrocarbon pollution in sunshine, and indoors by gas appliances such as stoves and unvented gas heaters. It has a red-brown colour, is highly toxic and irritating, and may cause death or permanent injury after very short exposure to small quantities. The maximum recommended allowable level for 1 hr exposure is 0.2 to 0.4 ppm/9/. In houses where gas cooking takes place, levels of nitrogen oxide as high as 0.8 ppm have been observed/7/. With a kitchen ventilation rate of 50 cfm (the ventilation rate given in ASHRAE Standard 62-73) and with the oven of a gas stove in operation, the nitrogen oxide concentration will be about 0.4 ppm/7/, which is higher than the recommended maximum.

A recent study in England reported a higher incidence of respiratory illness in children living in houses with gas stoves, compared to those in houses with electric stoves/7/. Ventilation requirements for houses where products of gas combustion are vented indoors may be higher than for other houses.

4. (a) METHODS OF MEASURING AIR LEAKAGE

During the early 1970's several groups of workers developed methods for estimating or measuring air leakage of buildings by pressurization techniques/10,11,12/. These methods involve installing a powerful exhaust fan temporarily through a doorway or window. Measurements of pressure drop and flow (or the pressure-flow characteristic of the fan) can be used to calculate the area of the opening which would permit the same air flow at the observed pressure difference. This area has been called the "equivalent leakage area", or "equivalent orifice area". Another method of expressing such observations is in terms of the air flow at a specific pressure difference. The advantage of these methods is that the observations describe the characteristic of the structure itself, independent of weather conditions. The actual air infiltration rate is variable and depends on wind velocity and direction, and on the temperature difference between the interior and exterior of the building.

Although the various methods of determining the air leakage characteristic are essentially the same, the ways of expressing the result are not. One answer is in terms of a leakage area, the other in terms of an air flow rate at one or more specific pressure differences. Adoption of a uniform method of expressing the measurement would permit direct comparison of results. Some results of both methods are presented in the following section.

4. (b) APPLICATIONS OF AIR LEAKAGE MEASUREMENT TECHNIQUES

Field measurements of the air leakage of 24 electrically heated houses in the Toronto area/11/ have indicated equivalent leakage areas ranging from 1.1 sq ft to 3.9 sq ft with a mean of 1.87 sq ft.

Most recently, the field measurement of equivalent leakage area of 36 houses in Toronto, Ottawa and Winnipeg has been reported/15/. The findings indicate that the equivalent leakage area of nominally identical pairs of houses, one of which is highly insulated and the other isn't, is not always smaller for the highly insulated house. The mean values of the equivalent leakage areas were as follows:

Toronto:	1.76 sq ft (single family detached)
Ottawa:	1.43 sq ft (mostly townhouses)
Winnipeg:	0.94 sq ft (single family detached)

In Sweden this pressurization method has been used to enforce air leakage standards as a control on the quality of construction/13/ since 1977. The air tightness values prescribed by law in Sweden are defined, at a given pressure difference (50 Pa), in terms of the rate of flow (m^3/h) divided by the area acting as an air barrier above grade (m^2). The prescribed levels are as shown in the following table/13/. There is also a requirement that the ventilation rate be close to 0.5 ach, to be achieved by controlled ventilation/13, p 79/.

Prescribed Tightness Levels in Sweden

Building		Tightness Required at 50 Pa
Detached houses and row houses		3.0 m^3/m^2-h
Apartment houses	2 floors	2.0 m^3/m^2-h
Apartment houses	3 floors	1.0 m^3/m^2-h

If a house relies on natural infiltration for the supply of fresh air, it is not possible at this time to specify the leakage area required to provide a given rate of air flow. The Swedish approach appears to be practical, as long as a suitable exhaust system is installed, and an adequate method or device to control the operation of the system is used.

Factory pre-assembly of building components generally leads to higher levels of air tightness than site construction. The mobile home industry in the US and factory built house systems in Denmark are prime examples where excessive air-tightness and insufficient ventilation have led to problems with high humidity and high levels of air contaminants/7, p 21/.

Leakage measurements on 63 houses in the Ottawa area have also been reported/14/ where the air flow at various pressure differences were presented, and the "relative tightness" was calculated by dividing the flow rate at <u>10 Pa</u> by the area of the air-barrier of the building above grade. The relative tightness ranged from 1.55 m^3/m^2-h to 4.56 m^3/m^2-h with a mean value of 2.83 m^3/m^2-h. These figures can be converted to a 50 Pa pressure difference from other information supplied in reference 14, to allow comparison with the Swedish prescribed levels mentioned earlier. The relative tightness at 50 Pa ranged from 4.67 m^3/m^2-h to 11.38 m^3/m^2-h, with a mean value of 8.15 m^3/m^2-h; these values are considerably higher than the prescribed Swedish levels.

Recent data indicates that leakage related to the building envelope in Sweden averages 6.3 m^3/m^2-h (measurements made at 50 Pa), and in the United States averages 25.3 m^3/m^2-h/17/.

From the above results, it appears that North American houses have much higher air leakage than Swedish houses. In the next section, methods of measuring naturally occurring infiltation in houses are described.

5. METHODS OF MEASURING AIR INFILTRATION

Air infiltration measurements in a dwelling are usually carried out by releasing a small quantity of tracer gas, mixing the air thoroughly, and observing the decay of the concentration of the tracer gas with time. By plotting the concentration versus time on semilogarithmic paper, a nominally straight line is obtained, whose slope is the infiltration rate. Tracer gases such as helium, sulfur hexafluoride, hydrogen, methane, nitrous oxide and radioactive krypton have been used. Reference 16 contains a listing of the work in this field. The main problem with the measurement of air infiltration is that the quantity is highly variable during the year, depending, as it does, on outdoor temperature, wind speed and direction/17/, and shelter from other buildings, trees and terrain/18/. In houses where fuel-fired heating plants use indoor air for combustion, additional air infiltration takes place due to chimney output/19/.

Air infiltration can also be estimated from records of indoor relative humidity, given estimates of the amount of water vapour generated within the dwelling. In this manner, water vapour is used as the "tracer gas". Attempts have been made to establish this correlation/11,15/ and the implication is, in general terms, that "tight" houses maintain higher humidity levels than "leaky" houses.

6. CORRELATIONS BETWEEN AIR INFILTRATION AND STRUCTURAL LEAKAGE

Several workers have reported good correlations between air infiltration and leakage area under specific weather conditions/17,20/, and a good understanding of the phenomenon is being developed.

From a study of indoor humdity levels in 24 houses during the winter in the Toronto area the following correlation between equivalent leakage area and air infiltration was inferred/11, 15/:

Equivalent Leakage Area (sq ft)	Inferred Air Infiltration (cfm)
0.75	30
1.50	60
2.00	90

A considerable amount of work is required to obtain reliable numbers for the above table. Differences in house exposure, location of openings and wind conditions can have a marked effect on the correlation.

The general direction of work in this field is towards determining whether a better control of air leakage of structures can be used to set upper and lower limits on natural or uncontrolled infiltration. The variability of natural air infiltration has been observed to be 5 to 1 depending on weather conditions/19/, and there is no assurance that ventilation will be high when it is actually needed. It is really questionable whether this method of providing fresh air to occupants will continue to be acceptable due to the high cost and strategic importance of energy on the one hand, and the possible buildup of hazardous materials because of insufficient ventilation on the other hand.

By providing a sufficiently air tight structure and controllable ventilation, it should be possible to "engineer" the optimum amount of ventilation in order to use the minimum amount of energy for space heating and to provide an acceptable level of air quality. Where sufficiently high ventilation rates are required over sufficiently long periods, heat recovery devices may be justified.

7. HEAT RECOVERY DEVICES

A seminar organized by Central Mortgage and Housing Corporation in October 1978 in Ottawa/21/, on the subject of controlled ventilation with exhaust air heat recovery, acted as a focal point for workers in this field, representing universities, research organizations, manufacturers, government, and consultants. The summary and conclusions of the proceedings/21/ are presented verbatim in Appendix 2. Briefly, the conclusions were that there is a need for Canadian housing to evolve from its present accidental ventilation to mechanical ventilation in conjunction with a much tighter building fabric. This would permit reduction of the amount of ventilation to the minimum necessary to control humidity and air quality, and thus eliminate energy waste due to excessive ventilation. The amount of capital justifiable for a heat recovery system depends on the amount of money saved by its use. In 1978 dollars, about $45.00 per year could be saved by a heat recovery device in a house with controlled air leakage and forced ventilation. The difficulties of tightening the building fabric of Canadian site-built houses were also expressed. No single building trade is responsible for the air-tightness of the building.

Manufacturers stated that the payback period for heat recovery devices must be 2 to 3 years in order to be attractive to the general public, and that unless the product could be sold for $90 to $135 (1978 figures) the market would be very limited. Several heat recovery devices were described, including a counterflow concentric pipe arrangement, plastic film heat exchanger, cross-flow paper heat exchanger, and rotary heat exchanger for residential and commercial applications.

8. AREAS REQUIRING FURTHER WORK

From consideration of the state of the art of infiltration, air leakage and air contaminants, problems with humidity control and the high cost of energy, it appears that further work is required in four areas:

(i) Control of air tightness in Canadian housing

(ii) Development of controls for ventilation systems based on the critical air contaminant(s)

(iii) Development of hardware to provide adequate air mixing and exhausting, and recovery of waste heat at a justifiable cost

(iv) Investigation of air treatment devices to remove contaminants.

Site-built houses in Canada are assembled by half a dozen or so trades working in concert to build a structure which may or may not be particularly air-tight. Even when special measures are taken to make a conventionally built building air-tight, only marginal improvements are observed/14/. In Sweden, a variety of techniques have been successfully developed for tightening new buildings/22/ and similar methods may be applicable to Canadian buildings.

The critical contaminant which should determine the ventilation requirements of the house may differ from house to house depending on the local sources of contaminants, such as particulates and odour from cigarette smoke, water vapour, formaldehyde, radon gas and others. The ventilation requirements may be different from one site to another, from one family to the next, from one period of time to another, and from one season of the year to another. Suitable controls for maintaining acceptable levels of air quality are not available.

In tightly built houses which have no central air handling system, it may be necessary to provide a means of mixing, diluting and exhausting indoor air, and to provide a heat recovery device where justifiable economically. A balance between efficiency and cost needs to be established for heat recovery devices for residential use.

Particular cases of contaminants should be investigated to find alternatives to exhausting large quantities of air, such as the electrostatic filtration of the radioactive daughter products of radon, or chemical reactions to remove such contaminants as nitrogen oxides and formaldehyde by recirculation of house air over a "regenerator".

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APPENDIX 1

RADON AND DAUGHTER PRODUCTS

Radon is a radioactive gas which is produced during the radioactive decay of radium. Radium ($^{222}_{88}$Ra, half-life 1600 years), occurs in concentrations of about one part in 10^{12} of most materials. Through α decay, which is of no consequence in rock or earth, a radium atom becomes radon gas ($^{222}_{86}$Rn), an inert, odourless, colourless gas which diffuses out of the material into the air. The gas may get inhaled, and some may be exhaled before it further decays with a half life of 3.8 days. Some may dissolve in water on the cells of the respiratory tract, and if some atoms decay, the α particles may damage the epithel cells, or trigger the mechanism by which cancer is initiated. More likely, the radon gas will be exhaled and will further decay in the air to become four shortlived radioactive daughter products/7/

$$^{226}_{88}\text{Ra} \xrightarrow[\text{1600 years}]{\nearrow \alpha} {}^{222}_{86}\text{Rn} \xrightarrow[\text{3.8 days}]{\nearrow \alpha} {}^{218}_{84}\text{Po (Ra A)} \xrightarrow[\text{3.1 min}]{\nearrow \alpha} {}^{214}_{82}\text{Pb (Ra B)}$$

$$\xrightarrow[\text{26.8 min}]{\nearrow \beta} {}^{214}_{83}\text{Bi (Ra C)} \xrightarrow[\text{19.7 min}]{\nearrow \beta} {}^{214}_{84}\text{Po (Ra C')} \xrightarrow[\text{164 usec}]{\nearrow \alpha} {}^{210}_{82}\text{Pb (Ra D)} \xrightarrow[\text{20 years}]{\nearrow \beta}$$

All four daughters are highly active solids which will attach to air-borne dust or condensation nuclei, and will likely be deposited in the respiratory tract. The A and C' daughters are α-emitters, and present a considerable hazard if inhaled.

Safety Limits

There is no well-defined threshold concentration of air-borne radioactivity below which exposure is harmless, but maximum permissible levels (MPL) have been set over the years. The units are:

picocurie per litre (pCi/ℓ)
or bequerel per m^3 (1 pCi/ℓ = 37 Bq/m^3)

The working level unit (WL) is defined so that the concentration of 1 pCi/ℓ of radon in equilibrium with its daughter products will give 0.01 WL.

Most international advisory committees on radiation protection seem to agree in recommending a MPL value of 0.03 WL for work rooms (40 hr/wk exposure) and 0.01 WL for living quarters. The corresponding values for professional exposures are 10 times higher.

Since radon is rarely in equilibrium with the daughter products, the WL-values of 0.01 and 0.03 may correspond to radon disintegration rates of 2 and 6 pCi/ℓ respectively.

Exhalation or Outgassing of Radon/2, p 399/

The exhalation rate E (atoms/(m^2.s)) is measured by enclosing a sample of the material in a container for 10-14 days and following the growth of radioactivity. The maximum disintegration rate of radon in a room of volume V and surface area A with zero air exchange is

$$R_{max,o} = \frac{A}{V} \cdot E$$

For a normal-size room, $\frac{A}{V} = 2\ m^{-1}$, so that a maximum disintegration rate of 1 pCi/ℓ corresponds to an exhalation rate of E = 19 atoms/(m^2.s).

Ordinary concrete may show exhalation rates on the order of 150 - 200 atoms/(m^2.s), which leads to $R_{max,o}$ = 10 pCi/ℓ for a completely sealed off room with all concrete surfaces. If the room is ventilated with n ach of radon-free air, the maximum radiation level will be

$$R_{max,n} = \frac{\lambda}{\lambda+n} \cdot \frac{A}{V} \cdot E = \frac{\lambda}{\lambda+n} R_{max,o}$$

where λ = decay constant for radon = $7.554 \times 10^{-3}\ h^{-1}$

If n = 1 ach, $\frac{R_{max,n}}{R_{max,o}} = \frac{.0076}{1.0076} = 0.8\%$, ie the radiation level will be 0.8% of the original level.

The ventilation rate required to reduce the level in the sealed room from 10 pCi/ℓ to the allowable level of 1 pCi/ℓ is n, where

$$\frac{.0076}{.0076 + n} \times 10 = 1 \text{ pCi}/\ell$$

whence n = 0.068 air changes per hour

Some alum shale based light weight concrete has an exhalation rate ten times higher than ordinary concrete/2, page 400/. In this case, the necessary ventilation rate becomes 0.75 ach. Because of the long half life of radium (1600 years), the ventilation requirement does not change appreciably with time.

Risk Factor

Epidemiological studies on miners/2, p 412/ have shown an increased frequency of lung cancer in proportion to the radon daughter levels in the mines. In most cases, miners were smokers, and differences between smokers and non-smokers could not be isolated. The risk factors are found to be between 200 and 450 incidences per working level month and million persons, according to the 1977 report of the U.N. Scientific Committee on the Effects of Atomic Radiation. One working level month corresponds to an exposure of 170 hours in a radon concentration of one working level (1 WL)/2, p 412/. Because of the long latency period of lung cancer, the effects of recent radiation exposure will not be seen until the year 2000 or so.

APPENDIX 2

EXCERPT FROM CMHC INDUSTRY/SCIENCE SEMINAR "CONTROLLED VENTILATION WITH EXHAUST AIR RECOVERY FOR CANADIAN HOUSING"/21/

SUMMARY AND CONCLUSIONS

The seminar was essentially divided into four sections as follows:

1. Basic economic and technical framework within which to consider the subject of mechanical ventilation and heat recovery.
2. Results of current and recent research work on heat recovery equipment.
3. Viewpoint of the manufacturing industry and its reaction to the previous presentations.
4. General discussion.

Section 1 Economic and Technical Framework

Bob Platts of Scanada Consultants lead off this section with a presentation on the rationale behind controlled ventilation systems and the possible benefits of heat recovery. He pointed out the need for Canadian housing to evolve from its present accidental ventilation to mechanical ventilation used in conjunction with a much tighter building fabric. This would permit reduction of the amount of ventilation to the minimum necessary to control humidity and air quality and thus indicative but not definitive testing over a number of years by NRC and Ontario Hydro.

Eric Bonnyman of Scanada presented various estimates of market size based on the fact that there are 160,000 to 180,000 starts of low rise housing in Canada each year. Thus a 10% penetration would be a market of 16,000 to 18,000 units. Discussion revealed that about 10 1/2% of new housing starts or 18,000 units are electrically heated. This is the segment of the market most in need of mechanical ventilation to control humidity and the segment for which it might be prescribed first.

Mr. Bonnyman then presented data on heat recovery equipment being used in other countries. This indicated that these products are most advanced in Sweden and Japan and that the parallel plate type is the most commonly used. As a point of reference, the Japanese Mitsubishi residential heat recovery unit sells on the Japanese market for about the same price as a room air conditioner.

Don Stephenson of NRC reviewed the activities of the Division of Building Research in this area including a recent project to determine the feasibility of including an airtightness test for houses in a performance type energy code. 70 newly built houses in the Ottawa area were tested by using a window-mounted fan to draw negative pressure in the house and measuring the air flow at various pressures. The test cost $150 dollars per house and indicated a surprisingly small

The final speaker in Section 1 was Saul Stricker of Ontario Hydro who reviewed some of the basics of air leakage and air movement in buildings and related Ontario Hydro's experience in field studies of air movement in houses. He pointed out that, as insulation levels are increased, heat loss due to air leakage becomes an increasingly larger proportion of total heat loss, approaching 50% in a "superinsulated" house. Air leakage therefore needs to be controlled but reducing it too much results in problems not only with humidity but also with odour control and, in extreme cases, with simply not having enough fresh air for breathing. Ontario Hydro has investigated at least one case of the latter phenomenon.

Ontario Hydro have developed an air tightness fan test similar to that used by NRC but somewhat simpler in that only one reading is required and it measures "equivalent leakage area" rather than flow. They have used it to measure the airtightness of a number of houses both with and without problems of various kinds and have developed a scale of "equivalent leakage area" versus susceptibility to problems. The main sources of air leakage were found to be -

- window and door seals (1/3 of total)
- openings for plumbing and wiring
- gaps in exterior sheathing
- porous concrete or cinder blocks
- chimneys and fireplace

This suggests that most of the trades who work on a house have some influence on its air-tightness but none has the overall responsibility.

Section 2 Research on Heat Recovery Equipment

Stuart Angus of Hooper and Angus Consulting Engineers described a heat exchanger his firm had designed for a solar demonstration/experimental house. A simple assembly consisting of three 3" metal ducts carrying intake air within an 8" exhaust duct was chosen for ease of fabrication as a "one-off". Although it was 33 ft long, its small diameter permitted easy placement in the house without consumption of useful space. An efficiency of 60% was predicted although this had not yet been verified in the field.

Mamdu Shoukri of Ontario Hydro Research Division described the detailed laboratory testing and mathematical analysis they had conducted on a small (16" diam.) rotary heat exchanger prototype they had made. This work is expected to provide a firm scientific basis for prediction of the effect of various parameters such as medium mass surface area and rotational speed on recovery efficiency. The first prototype's efficiency was measured as 73%. A second prototype being fabricated was expected to have 85% efficiency. It was planned to install this second prototype in the HUDAC experimental house mentioned by Dr. Stephenson.

In addition to describing his development of a simple plywood and plastic plate-type heat exchanger, Bob Besant of the University of Saskatchewan described some prairie experiences with air leakage in housing and problems resulting therefrom. He showed some impressive slides of condensation-generated ice in attics and workmanship problems resulting in vapour barrier gaps. He described the extensive efforts to achieve a perfect air/vapour barrier on an experimental house in Regina and how even this had failed to achieve perfect air-tightness. An air change rate of 5% per hour was measured over a period of a week in the winter.

Professor Besant's heat exchanger consisted of polyethylene sheet folded back and forth over a plywood frame to form a series of parallel sheets separating the intake and exhaust flows. It is suitable for do-it-yourself or on-site fabrication and provides about 80% heat recovery. The first one was used in the experimental house mentioned above and about 25 others have since been installed in houses in Saskatchewan. A larger version has proven quite successful used on a hog barn where, despite the feed particles in the exhaust air the exchanger surfaces have remained clean due to the self-washing action created by condensation and melting of moisture in the exhaust air.

Bob Dorey of McCarthy and Robinson Ltd. described some of his company's experience in 15 years of providing large rotary heat exchangers for commercial, industrial and apartment buildings. He reviewed the four main types of air-to-air heat exchangers - flat plate, rotary, heat pipe and "run around" glycol coil - and suggested that even though the rotary is ideal for large buildings something simpler requiring almost no maintenance, such as the flat plate type, might be better suited for houses. He pointed out that the most expensive part of any air-to-air heat exchanger installation is not the exchanger itself but the duct work and structural changes needed to bring the exhaust and intake flows together.

Section 3 Manufacturing Industry Viewpoint

Both Don Wheeler of Lennox Industries (Canada) Ltd. and Keith McQuarrie of Electrohome Limited indicated that manufacturers are likely to be rather reluctant to embark on the development of this type of product if it is necessary to rely strictly on free market demand. They expressed skepticism that consumers would be interested in investing a few hundred dollars in a product to achieve the kind of saving postulated by Mr. Platts. They suggested that a payback period of no more than 2 to 3 years is necessary. David Crump of Canadian Chromalox supported this view. Mr. McQuarrie felt that the automatic demand created by a government authority, such as CMHC, prescribing the use of the product would be much more encouraging to manufacturers. However, Mr. Wheeler pointed out that, even if this were the case, a product which is only suitable for the new housing market is not as interesting to manufacturers as one that can also be sold for use in existing houses.

Section 4 General Discussion

Apart from some interesting technical points which were brought up and which are recorded in Appendix K, a great deal of the general discussion concerned the question of the economic feasibility of air-to-air heat exchangers. The manufacturing representatives were quite unanimous in the view that short payback periods are necessary to get consumers to invest in energy conserving devices of their own free will. Others felt that perhaps Canadians are becoming more energy conscious than they are given credit for. It was suggested that perhaps the system could be sold not on energy conservation and economics but on the need to protect the house against structural damage. It was also suggested that the government, in the interests of both energy conservation and protection of housing, might be prepared to take a more liberal approach to the question of payback period and present value factor when considering whether or not to prescribe such equipment.