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CMHC Industry/Science Seminar

# Controlled Ventilation with Exhaust Air Heat Recovery for Canadian Housing

Proceedings

Research and Development Division
Professional Standards and
Technology Directorate

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## INTRODUCTION

In late 1977 and early 1978 CMHC's Technology Division, in response to a growing number of complaints regarding condensation in houses, began to explore the potential for heat recovery devices used in conjunction with mechanical ventilation of houses. Since 1972 it has been a CMHC requirement that all electrically-heated houses financed under the National Housing Act be equipped with 100 cfm of exhaust fan capacity. However, experience has shown that many people will not use these fans in the winter, even in the midst of highly visible humidity/condensation problems, because they are aware of the heat which would be "blown away" by the fans. It seemed possible that the provision of the ability to recover a significant portion of this heat would eliminate this disincentive to use of the exhaust system. Thus, if heat recovery devices could be developed to the point of being economical and readily available, they might even be prescribed for NHA-financed new housing or at least that portion which is electrically-heated.

In considering what role it might play in encouraging the development of heat recovery equipment, CMHC's Technology Division at first contemplated entering into a research contract with a manufacturer of related equipment such as furnaces or exhaust fans. However, the Division of Building Research of the National Research Council had already issued, through Supply and Services, Canada, a call for proposals by manufacturers or consortia involving manufacturers for the development of controlled ventilation systems with heat recovery. It was therefore decided to await the results of this proposal call before undertaking any CMHC initiatives.

The proposals which NRC received were disappointing in terms of the amount of interest shown by large manufacturers and for this and other reasons NRC decided not to issue a contract for work on heat recovery.

In the meantime CMHC had become aware of research and development work in this area being conducted by a number of different people. Each was working on a different type of heat recovery device and there seemed to be little or no awareness of what the others were doing. It occured to the Technology Division that the most valid role CMHC might play in attempting to catalyze the development of heat recovery equipment would be to convene a seminar at which the various researchers could exchange their knowledge and experience. The rather cool response by industry to the NRC proposal call suggested that such a seminar could also serve the further function of exposing manufacturers to the work that was going on and exploring with them the potential market for such equipment.

Thus such a seminar was planned for 26 October 1978. Scanada Consultants Limited of Ottawa was engaged to assist in its organization, collect data on related activities outside of Canada, prepare a key-note address on cost, benefit and market considerations and prepare this summary. The seminar was held at CMHC's National Office in Ottawa. It was attended by people representing a broad cross-section of interests - universities, research organizations, manufacturers, government and consultants.

While it was perhaps disappointing that no clear direction emerged from the seminar, CMHC is nevertheless pleased with the results and satisfied that it accomplished its intended purpose - the exchange of information. In one day enough information and data were collected to form a picture of the state of the art in the areas of air-tightness, mechanical ventilation and heat recovery that would have taken many months to form by other means. As well, the information and data collected were simultaneously disseminated to a broad audience and hopefully have stimulated new ideas and further work. As a result CMHC has planned similar small seminars on other subjects.

The seminar was conducted in a fairly informal manner with a balanced mixture of speakers and discussion. The entire proceedings were tape recorded. Some speakers used prepared presentations and these are appended to this summary. Others spoke extemporaneously from notes or memory. In these cases a condensation of the tape transcript is appended. Unfortunately it has not been possible to reproduce slides used by some of the speakers.

## 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 eliminate both energy waste due to excess ventilation and condensation problems due to too little ventilation. The adoption of increased tightness and controlled ventilation may also permit the use of heat recovery equipment to reduce ventilation heat losses even further; however the cost/benefit relationship of such equipment must be closely examined. Mr. Platts estimated the maximum benefit that might be derived from increasing the air-tightness and incorporating a mechanical ventilation system with heat recovery would be $45 savings per year. Using a present value factor of 10, this would justify a capital expenditure of $450 but the cost of increasing the air-tightness alone was estimated to be just under $400. If a present value factor of 20 is used, the resulting justifiable capital expenditure of $900 would leave more leeway for the cost of the mechanical system. Such a factor would obviously never be considered in the free market but the federal government has already used similar factors in developing the proposed new energy code. Thus if the cost of this change were less than $900 it could conceivably be prescribed by government at some future time in the interests of energy conservation. Mr. Platts' calculations were based on the assumption that 1/3 air change per hour represents both the typical amount of ventilation (averaged over the heating season) now being experienced by post-war Canadian housing and a safe lower limit for ventilation to avoid humidity and air quality problems. This assumption, in turn, is based on 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 air-tightness 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 range of tightness - over half the houses were within + or - 20% of the average and over 90% were within + or - 45% of the average. As a point of reference as to how tight they were, a HUDAC experimental house in which great pains were taken to try to achieve a perfect air barrier was only marginally tighter than the tightest house in the large sample - for a given pressure it would have 87.5% as much leakage as the tightest house in the larger sample and 44% as much leakage as the average of the larger sample. This is perhaps an indication that it will be difficult to achieve a significantly greater degree of air-tightness in houses than is currently being achieved simply through the use of good building practices, good quality windows, etc.

Dr. Stephenson was careful to point out that the tightness as measured by a fan test is not the same thing as the rate of air change due to the variable forces of stack action, wind and combustion equipment. If a correlation exists between the two it is not known and NRC is investigating this correlation by conducting long term tracer gas tests on a number of houses.

NRC is doing only limited work on heat exchangers. They hope to monitor the performance of a heat wheel prototype produced by Ontario Hydro when it is installed in a HUDAC experimental house and also plan to do some laboratory tests on a Mitsubishi unit.

Dr. Stephenson was not optimistic that the $45 annual saving estimated by Mr. Platts as an upper bound could be achieved.

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 odor 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 air-tightness of a number of houses both with and without problems of various kinds and have developed a scale of "equivalent leakage area" versus susceptability 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.

<u>Section 2 Research on Heat Recovery Equipment</u>

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.

Mendel 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 skeptisism 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.

## CONCLUSIONS

In reading the following it is necessary to bear in mind certain distinctions -

Controlled Mechanical Ventilation -

- is the use of fans to provide all or part of the air change required in a house. It can be used in a house that is less than completely air-tight but is not necessary in a house that is very loose. It does not necessarily involve the use of heat recovery.

Heat Recovery -

- is the recovery of heat from exhaust air so that that heat can be put to some use in the house such as in pre-heating intake air.

Air-to-Air Heat Exchanger -

- is one method of heat recovery. Although it was the only heat recovery method discussed at this seminar it is not the only possible method.

The following then are the conclusions which seem to flow logically from the discussions at the seminar.

1) There is a need for Canadian housing to undergo the rather fundamental change from accidental ventilation to controlled mechanical ventilation in order to assure control of humidity and air quality. This need can be thought of quite independently of economics since it is strictly a matter of assuring the functional performance of the house.

2) The case for heat recovery, on the other hand, is entirely a matter of economics and is by no means clear cut. That is, the development of residential heat recovery equipment is at an early stage where it is not possible to draw firm conclusions as to its economic viability. It is certainly not possible to look at the boundary conditions and conclude that the economic viability seems assured. Someone who is pessimistic could look at those boundary conditions and conclude that they are discouraging but would not be justified in concluding that they rule out the idea. Further development would seem worthwhile.

3) It appears that the development of suitable hardware need not be a constraint because a variety of types of air-to-air heat exchangers show promise of being technically practical.

4) A key technical constraint to the wide-spread use of air-to-air heat exchangers for heat recovery will likely be the dependence of this method on having a very tight house in order to realize the full potential benefit of heat recovery. This requirement also effectively eliminates air-to-air heat exchangers from the existing house heat-recovery market. Other methods of heat recovery may not necessarily be similarly constrained.

5) It appears that at least some portion of new Canadian houses are being built at close to the maximum reasonably attainable degree of air tightness. Changes in building practices should be encouraged to bring all new housing to this level but much improvement beyond that level should not be expected.

## RECOMMENDATIONS

The following recommendations were not brought forward at the seminar. Rather they are needs for further work in this area which suggested themselves to CMHC and Scanada on review of the seminar discussions.

1) Although the immediate prospects for manufactured air-to-air heat exchangers do not seem good, builder or owner-fabricated heat exchangers of the type developed by the University of Saskatchewan may provide an interim means of recovering exhaust air heat in those case where it seems desirable to do so -

   e.g.:- builders who wish to emphasize energy conservation
   - native housing or other circumstances where high moisture loads create the need for unusually high ventilation rates
   - northern housing

   Therefore plans and fabrication instructions for such heat exchangers should be made available by CMHC or other agencies.

2) Other methods of heat recovery, not subject to the constraint of requiring a very tight house and thus perhaps suitable for both new and existing housing, should be explored. It seems likely that such methods will involve the use of heat pumps.

3) Dehumidification presents an attractive alternative to mechanical ventilation as a means of humidity control and would be even more energy conservative than mechanical ventilation with heat recovery. Further efforts to explore the feasibility of winter dehumidification and follow up on the work of Manitoba Hydro are therefore recommended.

4) Further efforts are needed to increase our knowledge of air-tightness and air change in houses in quantitative terms. This can only be accomplished by measuring air change rates for large numbers of existing and new houses. This would be facilitated if a correlation could be derived between air change rate and air-tightness as measured by the fan depressurization method since this would permit the use of this relatively simple test rather than the more complex tracer gas test.

5) There is a need to develop and test new techniques for improving the air-tightness of new houses. These techniques should be practical and suitable for use by merchant builders.

6) The changing numbers, ages and activity levels of house occupants together with cooling, laundry and other domestic activities creates a steadily changing ventilation requirement. To minimize energy loss through ventilation it is necessary to correspondingly minimize the rate of ventilation. There is a need to identify what control characteristics are required to optimize ventilation rates and to determine if the most recent developments in control technology could be applied to enable devices to be manufactured and marketed at prices suitable for the housing market.

APPENDIX A

Cost Benefit Scenario

R.E. Platts, Scanada Consultants

Market Scenario

C.E. Bonnyman, Scanada Consultants

A - 1 Mr. Platts' prepared presentation

A - 2 Condensation of Mr. Bonnyman's remarks along with his graphic material and information collected on work outside of Canada

A - 3 Discussion

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CONTROLLED VENTILATION WITH EXHAUST AIR HEAT RECOVERY FOR CANADIAN HOUSING

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Keynote address for the CMHC industry/science seminar 26 Oct 1978
by R.E. Platts, C.E. Bonnyman
Scanada Consultants Limited Ottawa & Toronto

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A - 1 Mr. Platts' Presentation

The end product, the Canadian house: We like to think of the house as an engineered product now, the end product of a big industry, nicely evolved over generations. And that it is, in many ways, but excepting at least one basic fundamental wherein today's model is unchanged from the millenia of predecessors.

The fundamental: the air that the house feeds to its occupants, and to furnace or fireplace for that matter, is "accidental", a matter of unplanned leakages in the building fabric.

Unplanned, undesigned, rather unstudied accidental leakages, varying substantially as you will hear today from Dr. Stephenson. Still loosely wasting heat energy in very many of our houses even as built now, but sometimes too tight in the same house next door, ie. not leaky enough to dissipate humidity and control condensation, odours, deposits of grease and tobacco tar.

The "accidental breather": Older housing in Canada leaks away through the cold winter at an average rate of perhaps 3/4 or 1 air change per hour (no one has ever measured or analysed them), accounting for about one quarter of the large heating bill of such uninsulated 2-storey prewar houses, or say a winter air change heat demand of $330 now (600 gal oil, or 18000 kWh). Recent bungalows might average about 1/3 ac/hr, entailing an ac heating demand about one fifth to one quarter of the much smaller heating bill, or say $64 (117 gal oil, 3400 kWh). The same applies for semis and row units.

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Often enough, today's housing runs at less than a quarter ac/hr, and even a fifth or less if electrically heated (with no combustion air demand pulling through a little more air), and these are often troubled and damaged with excessive condensation; one fifth ac/hr seems to be the general lower limit according to Ontario Hydro and NRC experience.

So 1/3 ac/hr represents a reasonable benchmark of well constructed trouble-free house construction in our cold country now, and it still throws away about 1/5 of our heating bill into air change. And under that is trouble; the lower limit of air change is very close to how we're building now much of the time.

So, on the one hand we want to tighten up to save energy - - probably we must tighten up - - and on the other hand we can not take the low cost route of simply tightening the envelope further: that way lies widespread trouble and damage.

Nor can we simply tighten up and treat our air, since dehumidifiers are limited intrinsically (at low cost and low energy usage) to drawing down to only 50% RH, no lower...And 50% is too high for the colder part of our winters, unless we go to special construction with triple glazing...open for discussion.

So, the evolving house now faces something that it rarely encountered through its history, a <u>fundamental change</u>: <u>in this case the change from accidental leakage to controlled ventilation with exhaust air heat recovery</u>, to meet the need for energy conservation and simultaneously ensure trouble-free performance of house and occupants.

That's a problem, with surprisingly little dollar savings to promote free-market changeover; but the fundamental will occur sooner or later and does represent a very large opportunity for

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industry. We will explore the potentials a little before handing over to the scientists and industry people who will come to grips with the need and the opportunity.

The savings potential of exhaust air heat recovery: Appendix 1 sets out the story: Given that our houses are now commonly built fairly tightly, exhaust air heat recovery can not save very much. And even to do that much the house envelope must be tightened "all the way", which work is a contentious part of the cost of the new "air handling package". It's a circle: we can save energy by living in an airtight house only if we blow air through to ensure air quality and avoid trouble, and recover its heat to save energy; and the tightness and the recovery are all one package entailing a capital cost.

The annual energy saving for a small dwelling in most of populated Canada is about 2300-2400 kWh or about 11 Mcf gas or 81 gal oil: about $45. Appendix 1 calculations lean heavily on the Saskatchewan work which in our view is outstanding household-scale work; much more on this today.

The present value of future savings: Put very simply, if the capital cost is not covered by a present value factor of 10 or less (applied to first winter's savings; with energy cost scenarios now it all tends to come out the same as straight "payback period") then it won't sell on the open market: people can hope to do better things with their money. That means that the installed cost of the controlled ventilation/exhaust air heat recovery package, including the radically tightened house envelope, can not exceed ($45 x 10) $450...clearly ridiculous.

From the country's point of view, considering both energy savings and avoidance of condensation damage, perhaps a present value factor of 20 makes sense (no higher: maintenance and replacement costs must be considered). From this viewpoint an installed

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package cost of up to (45 x 20) $900 may be acceptable, and merits thinking and effort.

(The partial approaches: There will be the Canadian compromise solutions popping up: Leave the house tightness about the same as now (zero extra cost), deploy kitchen and bathroom exhaust fans or a main exhaust fan to be used when needed to avoid excessive humidity troubles, as in electrically heated houses now, and stick heat exchangers directly on those. Extra cost is then only the exchanger costs...plus ductwork to deliver the replacement air to points some distance from the exhaust grills to avoid short circuiting of incoming to outgoing air. The savings: since the fans are needed part time only, and handle only a part of the air change (the rest continues as leakage without heat recovery), the savings can be but a fraction of a fraction of the above $45.)

The costs of supertight envelope: Working quickly and roughly with our work study/cost study of housing construction for HUDAC,* we can offer a first guess at air-tightening costs as if using established routines and materials in volume production of wood frame housing. First, we know from NRC work that exterior walls account for about 60% of the total leakage in today's houses (particularly of 2 storeys). We know from NRC and from our own thermography work that sills, headers and the conjunctions of walls to windows and doors account for most of that. Next the NRC work suggests that ceilings account for a fifth or so, including partition tops, plumbing stacks etc., and finally leakage through (not around) windows and doors comprises about a fifth or somewhat more.

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*Cost Study of a Two Storey Wood-Frame House, Scanada for The Housing and Urban Development Association of Canada, Jan. 1973.

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Assuming special care with overlapped polyethylene air barrier, and with limp "gasketry" or foam at all sills, headers and conjunctions, and complete make-good of barrier following all electrical work, we come up with something like 18 man hours and $90 in materials over and above today's "good practice" (which already deploys the polyethylene material, and we assume is deploying good projecting-type windows). Allowing for support labour too, and overheads and profits, we infer an overall extra cost (construction price) in efficient job flow of $390 for the airtight envelope.

If we take $900 as the highest reasonable present value of the whole controlled-air package, then we have at best something over $500 left, after envelope-tightening, to put into the air-to-air recovery system: Eric Bonnyman will start with that.

One more point first:

Living habits: do we throw it all away anyhow? Our house heating field study on windy Prince Edward Island* showed that wind exposure has a surprisingly high proportional effect on the heating bill of any house, but occupants' living habits apparently do not. (The Island sampling was entirely owner-occupied, with the connotation that the occupants cared about and husbanded their heating needs). Separate analyses since then indicate that frequent door opening accounts for a very small part of the heating bill, probably much less than $3 worth a year - - so much for the energy saving value of "air lock" vestibules! Of course, a habitual opening of windows for long periods, to control temperatures or for "fresh air" sleeping preferences, can negate the savings from exhaust air recovery or from anything else. Given an adequate air supply, and

*Heating Demand Realities Compared with Degree-Day-Based Predictions for Island Housing, Scanada for the Institute of Man and Resources, Charlottetown, October 12, 1977.

knowledge of the dollars lost through the open-window-in-January habit, householders will cure themselves of that habit.

Tomorrow's production model house may be an efficient performer with some costly conserving features which householders can blithely over-ride - - but in the main they won't. Eric will explore the features, costs, and opportunities implied in the fundamental switch to the hardware of controlled ventilation/ exhaust heat recovery.

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Appendix 1

POTENTIAL SAVINGS USING EXHAUST AIR HEAT RECOVERY IN HOUSES

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An exhaust/supply air heat exchanger saves energy by allowing us to live in an otherwise air tight house; the corollary is that it demands an airtight envelope to allow it to save energy. Air change can remain high enough to ensure air quality, humidity and odour control, but must be fed in through one point only. Hence the heat recovery "package" is the radically airtight envelope as well as the mechanical ventilation and heat exchanger: all feasible in new construction but all part of the cost. What are the potential savings from that package?

Example bungalow* 96 sq.m, 411 cu.m; 4444 celsius deg. days
[1036 sq.ft., 14500 cu.ft.; 8000 Fahren. deg.days]

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1) "As Now": Ample (and normal) lower limit air change, avg.1/3 /hr

Air change heat loss per°hr. = AC x air spec. heat x density x vol.
=.33 x .0003335 x 411 = .045 kWh/°C hr.
[86.1 Btu/°F hr.]

| | Annual kWh | Annual $\times 10^{-6}$ Btu |
|---|---|---|
| = annual load .045 x 24 x 4444 x .71**= | 3408 | 11.7 |

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2) "New package": Envelope infiltration AC .05/hr.
Heat exchanger effectiveness 0.9 (Both from Sask.)

| | Annual kWh | Annual $\times 10^{-6}$ Btu |
|---|---|---|
| Infiltration heat loss per°hr. = .05 x .000335 x 411 = .007 kWh/°hr. =annual load .007 x 24 x 4444 x .67** = | 500 | 1.7 |
| losses "past" heat exchanger (handling .28 AC/hr. to ensure total AC of .33, with above infiltration) =(1.0-0.9) (.045-.007) x 4444 x 24 x .67**= | 272 | .9 |
| Losses in mechanical venting say 50 watt net, (8 mons.) | 292 | 1.0 |
| | 1064 | 3.6 |

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3) Difference (annual savings, 1978 energy dollars)
= 3408-1064 = 2344 kWh [8.1 x $10^6$ Btu]
If heat supplied by oil at 60% seasonal efficiency, 29.3 kWh/Imp.gal.
100000 Imp.gal.

then saving = 81 gal. at 55¢ = $45/yr.

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*Applies also to 2 - storey,semi or row units of equiv. size
**allowing for "free heat" proportion of the loss for such a house

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A - 2 Mr. Bonnyman's Presentation

Picking up generally from Bob's theme, and working with the dollars left after he has taken out his portion to create a "supertight envelope" I would like to focus our attention for the next short period on three aspects...

First - the NEED and OPPORTUNITY in terms of market size

Second - another look at the ECONOMICS

Third - a brief review of what has been done, and what is apparently available, in other countries... especially in Europe, and in Japan.

We have on the program today some gentlemen who will be describing heat recovery units that have been developed here in Canada, and the brief overview of foreign products that I will present is not intended as a basis of comparison against Canadian development, but simply to be used as background information.

Also, our quick look at market size and opportunity is presented simply to add some perspective, and will be given further attention in the industry presentation this afternoon dealing with Manufacturing and Marketing Constraints.

Let us first look at the overall size of the market for installations in new housing. The level in Canada - i.e. single-detached, semi-detached, duplexes, and row units - is currently running at 160,000 to 180,000 per year. A large portion of these...about 75%...are single-detached. Ontario and Quebec markets combined account for half - about 85,000 to 90,000 per year - again the porportion of singles about 75%. The Prairies account for about 38,000 units per year, singles representing about 71%.

In considering the potential for sales of heat recovery units for the single dwellings within our market - assuming no 'forced need' i.e. imposed initiatives - and assuming the unit can be shown to

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have a reasonable payback period...that is, disregarding "need" based on social, enviromental, or political grounds...one could assume a market penetration of possibly 10% in the early years - i.e. a market demand in the range of 16,000 to 18,000 throughout the country. A 15% penetration would create demand of 24,000 to 27,000 units per year - a market value of perhaps $7. to $8. million. Now when we start talking such figures we are probably getting into the magnitude of numbers where it would be attractive for two or three manufacturers to go into production. Perhaps we will be provided with more insight into this aspect this afternoon. In the meantime, this identifies, in a rather simplistic fashion, the market opportunity in the new housing category.

What then is the NEED...from an economic supply viewpoint rather than technical. Let us take another brief look at the economics of a unit.

If, in fact, the heat recovery unit is able to capture only $45 worth of heat from the exhaust air, the system will of necessity have to be available at a fairly low price in order of offer an acceptable, let alone attractive, capital recovery period. For example, dealing with today's interest rates - with prime rate at 10% level - with the projected saving of $45 per year, to realize capital recovery in say 15 years, the investment must not exceed about $350. For capital recovery within a ten year period, investment must not exceed $280. Let us bear in mind that these are only "ballpark" figures, realizing that there are various scenarios that one can work with projecting different rates of energy cost increase, different inflation rates, interest rates, and so on.

Also please keep in mind that we are suggesting the level of potential sales in a competitive market, where a unit competes on the basis of economic feasibility, and is competing openly with other housing components and appliances for the consumer's dollar.

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An entirely different rationale can be presented if one wishes to focus more heavily on long-term energy policy and overall benefit to the country - i.e. if such a change is imposed in housing, which would not be different in kind from imposing insulation levels, or double-glazing. In such a situation the market demand could be up in the range of say 150,000 units per year... an annual dollar value of perhaps $40 million, or more. What then would be the reaction of the supply industry?

With this brief overview of market need and opportunity as background, let us look briefly at some of the features of units briefly in other countries...going back some 20 years to the initial development of the "energy wheel".

In the package of information which is available for you to pick up at coffee break or later on, are copies of excerpts from literature of various manufacturers, showing general concepts or details of their product or system...and also some other background data or articles.

Rather than going over then to any extent at this time let me simply name the generic types covered...

thermal wheel - original Swedish design of the munter wheel dates back about 20 years.
...it is still probably the most widely used form of heat recovery device, though in the last few years most of the improvement and new product development has been

parallel plate- in parallel plate units which is the second generic type

Also referenced in some literature are...

cross-flow tube battery -
matrix fan unit - acts somewhat like the thermal wheel.
Run-around coil system
Heat pipe battery -

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From the various literature, data was extracted relating to different systems, which is outlined on this chart. Please take note that the data on this chart does not refer solely to "residential" type or size units, but to the systems in general. It is simply data extracted and repeated here as listed by the manufacturer or writer of the article.

At this time I should mention that all of the product literature from abroad, from which the copies of excerpts were made, was collected by Gint Mitalas of NRC and was loaned to us to provide some background on the subject to help make this a more meaningful seminar.

A couple of very brief notes, and then I will close, and turn it back to John. As a matter of reference on these Mitsubishi units and Toshiba units in order to try to get some indication of cost. Now many of these are what I would call "room type", they're like an air-conditioning unit, wall-mounted or ceiling mounted, they are small units. Translating from the Japanese literature and converting yens into dollars so that we have the price in Japan yet in terms of our Canadian dollar, it looks as though these small units range in price from about $110 for the smallest up to about $260 - $270. Now again it does not prove anything, I realize but that is the sort of price range that they are on the market for in Japan. In order to try to get a little better fix on it, there were other components that they had shown, such as range hoods, that we could identify better with and in converting those prices, it appears that the prices for these other small articles were not far off the price that we would expect to pay for a similar item here in Canada. So in other words, I am suggesting that these prices are probably comparable to what we would expect to see for such a unit here in Canada. It sort of compares with the price for a small air-conditioning unit or a good humidifier, and so on. There's one question that I would just like to leave, and maybe some technical people would like to address their attention to this as we go on. The people such as Mitsubishi using this treated paper, they claim high transfer of latent heat through permeability of the treated paper. Now if in fact such occurs and if we do have water vapour transmission coming through from the warm exhaust air and again being picked up by the cold intake air, is this the type of units that we really need and wish to see here, because would this help to solve our humidity problem or would it simply just be changing our air and still leaving our humidity higher than we would like to have it. The humidity, remember we mentioned it as being one of the reasons for the need for ventilation. So with that I would like to close and turn it back to John, and if there are questions we certainly can address ourselves to the questions at the appropriate time.

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CMHC INDUSTRY/SCIENCE SEMINAR

CONTROLLED VENTILATION WITH EXHAUST AIR HEAT RECOVERY FOR CANADIAN HOUSING

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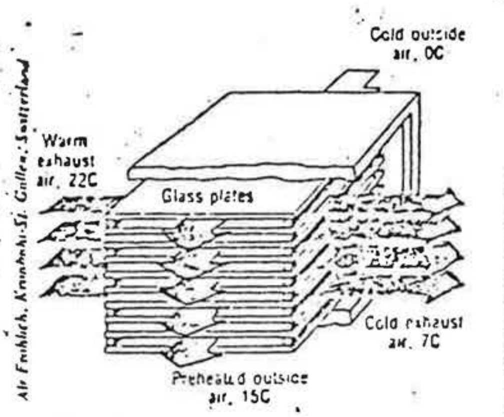
10A; 97B

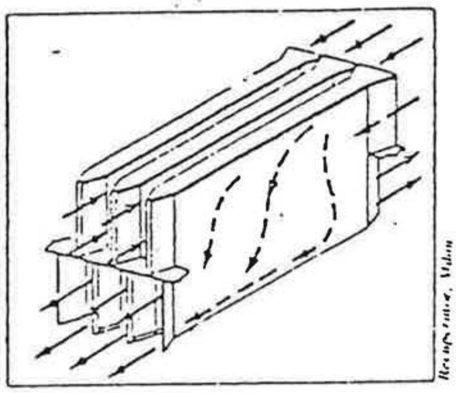
## SOME DATA RE: FOREIGN HEAT RECOVERY UNITS

| Country | Manufacturer | Type | Separ. Mat'l. | Listed Efficiencies: Sensible Heat | Listed Efficiencies: Latent Heat | Listed Efficiencies: Total Enthalpy Transfer | Est'd. Payback Period |
|---|---|---|---|---|---|---|---|
| Sweden | V.M.Christensen A/S "Genvex" | Parallel Plate | Al. | 62-68% | | | |
| Sweden | Flakt "Rexovent" | Parallel Plate | Al. | | | | |
| Sweden | Econovent "Munter's Wheel" | Wheel - Flat & Corrug. Foils | Inorg. Fibr. Mat'l. | | | 75% up to 90% | 1-4 yrs. |
| Sweden | Ljungdstrom | Wheel | Metal | 75-80% | nil | - | |
| Sweden | Econovent "Ex" | Parallel Plate | Corrug. Al.Foils | | | | |
| Japan | Mitsubishi "Lossnay" | Cross - Flow Plate | Plates & Fins of Treated Paper (asbestos) | 80% | 70% | 73% | |
| Japan | Toshiba | Cross-Flow Plate | Plates & Fins of Treated Paper (asbestos) | | | | |
| Japan | National | | | | | | |
| Italy | | Parallel Plate | Al. | peak 90% | | | 1-2½ yrs. |
| | | Parallel Plate | Glass | 60-65% | | | few mths. to several yrs. |
| | | "Run-around" Coil | | 60-75% | | | |
| | | Heat Pipe | Cu. | 55-70% | | | |

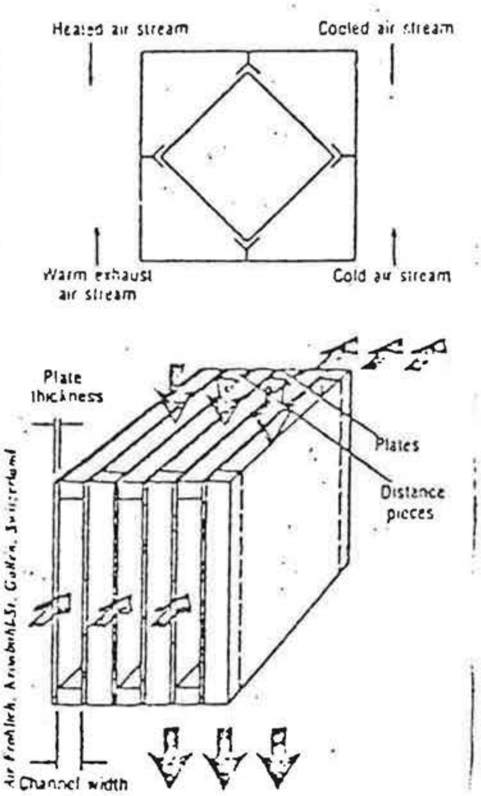
# PRINCIPLES AND ARRANGEMENTS OF SOME HEAT RECOVERY UNITS



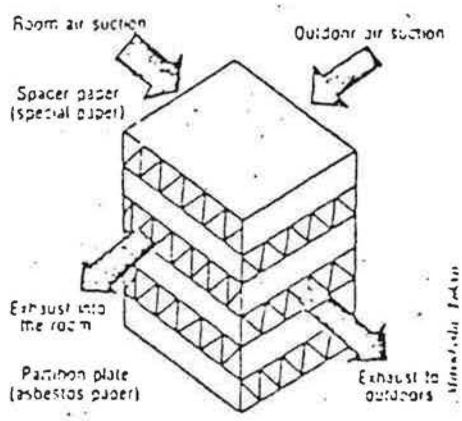

1 Principle of glass plate heat recovery unit.



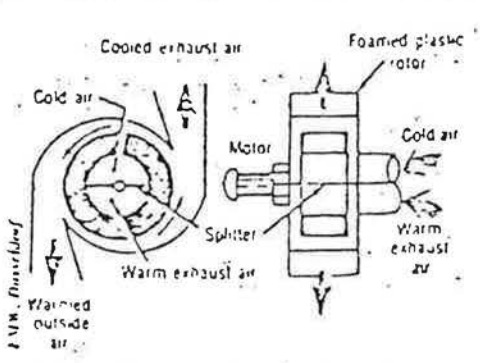
3 New Italian design aluminum plate heat recovery unit showing twin deck arrangement for air flow.




2 Cross flow design in a glass plate unit (top), and arrangement in a casing to provide parallel duct connections.




4 Japanese design of all-paper heat recovery unit permitting heat and mass transfer.




5 Matrix fan unit. The foamed plastic rotor acts both as a fan and a heat recovery medium

# Mechanical Design



Econovent consists of a supporting framework, containing the rotor and the drive motor. The framework consists of side plates connected by spacer plates, and forming a rigid box construction. The side plates are designed for easy connection to air ducts and for installation in an Econovent wall system as shown in Fig. 4.

Adjustable sealing strips are fastened round the periphery of the rotor and along the partition walls between the two air streams to prevent leakage.

The rotor is driven by a motor via a belt.

The main component of Econovent is the rotor wheel which is built up of alternately flat and corrugated foils of inorganic fibrous material, coated with a dessicant. The flat and corrugated sheets glued together form a multitude of axial flutes. The rotor material occupies about 15% of the face area.

## Operation

In operation the supply air passes through one half of Econovent and the exhaust air through the other half and in the opposite direction to the supply air. Thus the flutes are alternately passed by exhaust and supply air. As the exhaust air passes through the wheel the sensible heat is absorbed into the matrix and at the same time the hygroscopic nature of the flute walls attracts to itself the atmospheric moisture carrying the latent heat, which is also retained in the matrix. As the wheel rotates into the supply air section, the air passing through the flutes in the opposite direction picks up the sensible and latent heats and moisture retained by the matrix and transfers these back into the building.

Econovent is equipped with a purging sector. In this sector each flute is thoroughly flushed by fresh air before it enters the supply air stream. Tests have proved that the purge sector practically eliminates the transport of exhaust air into the supply air. See special section on 'The Purge Sector'.

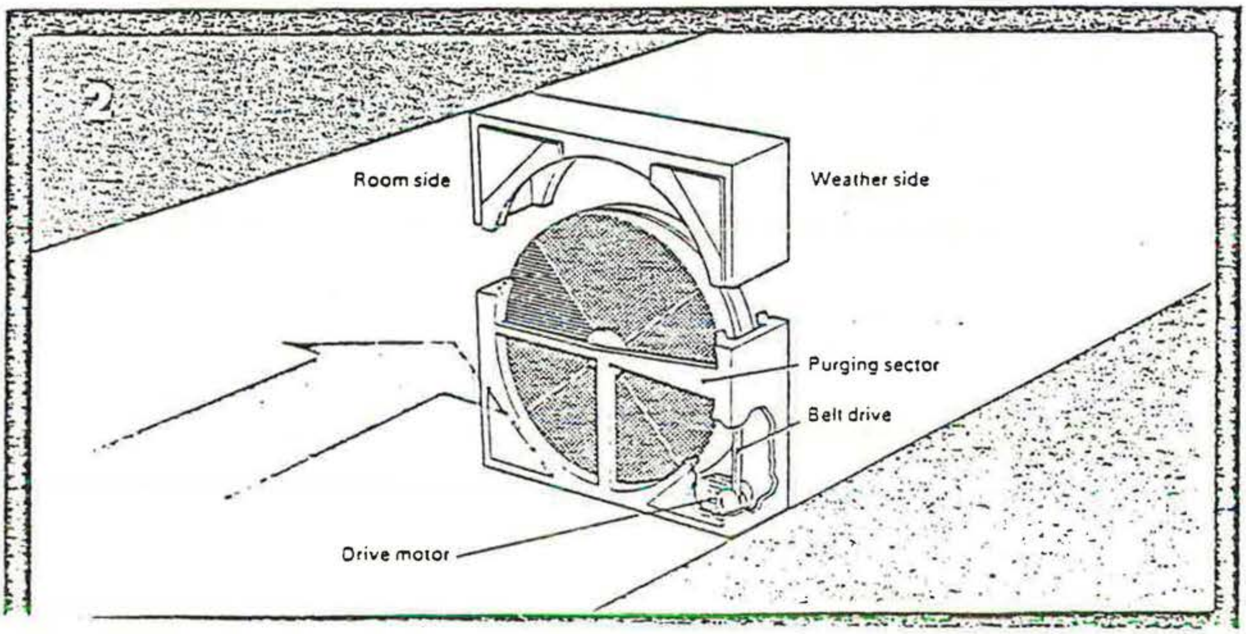
The extremely small flute size of the rotor material would appear to involve a risk of clogging with dust, fibres, etc. However experience from several hundreds of installations has proved that clogging is efficiently prevented by the self-cleaning effect obtained by the continuous change of flow direction through the material.

Naturally a certain protection of the rotor material must be made, and the following recommendations are given.

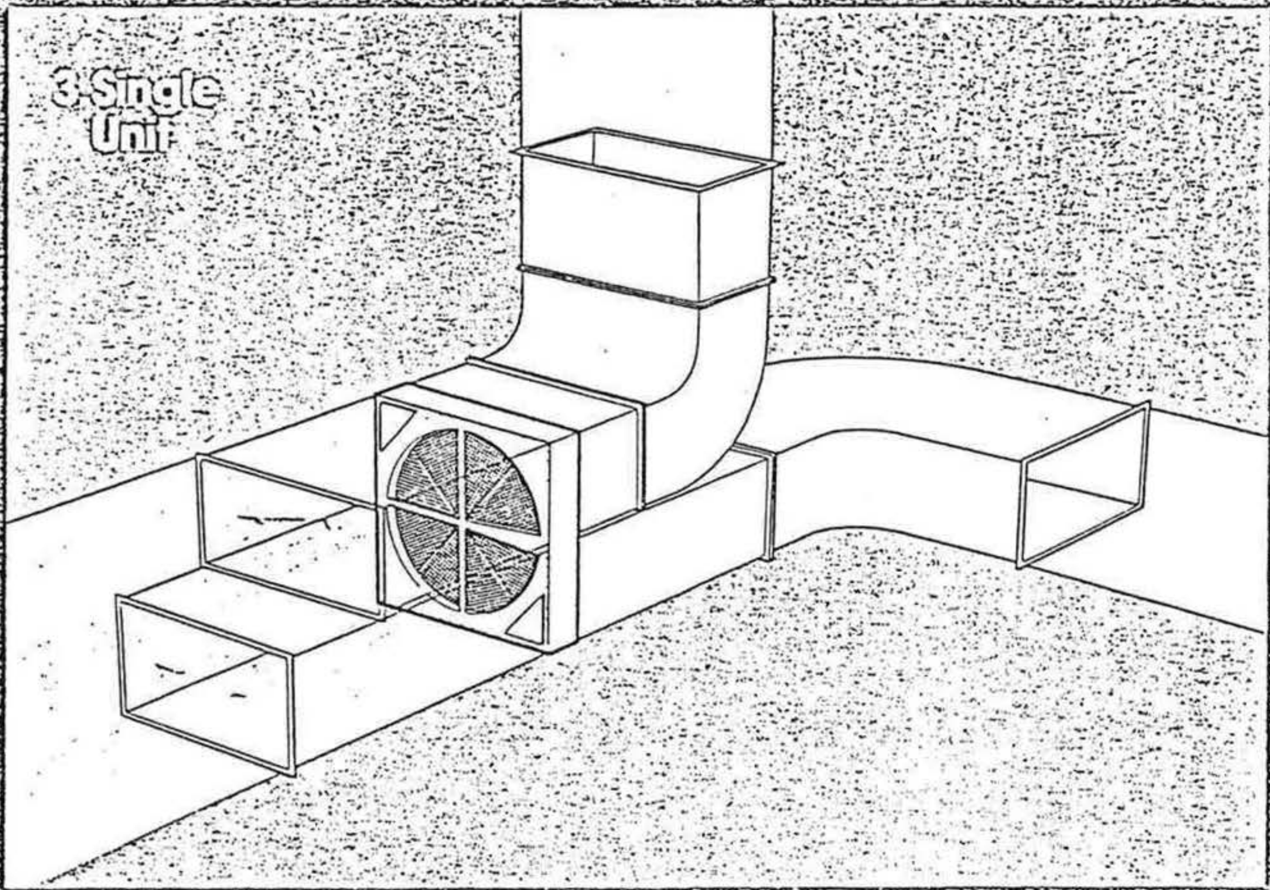
**Supply air**: Particles larger than the flute size, flies, fragments of plants, etc., can cause clogging. Thus a coarse mesh (1 mm) immediately behind the air intake louvre should be installed.

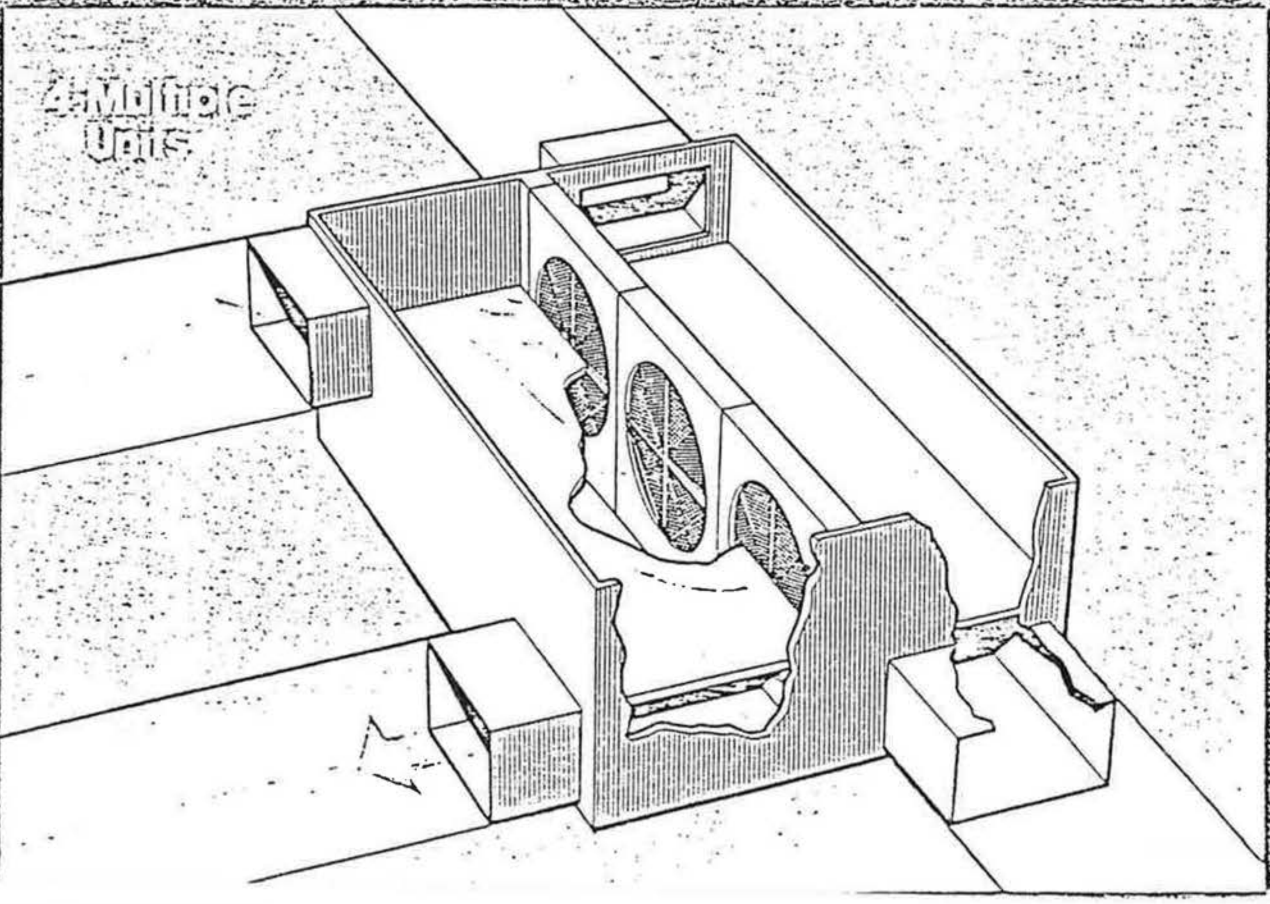
**Exhaust air**: The exhaust air in schools, offices, hospitals, shops, warehouses, etc., is clean enough to pass through the Econovent without any prefiltering. In industry, large particles, greasy or baking dusts, can cause clogging, and a prefilter in the exhaust air before Econovent should be installed.

Where the concentration of dust and particles has been greater than anticipated and clogging has resulted, it has proven easy to clean the rotor by vacuum cleaning.



# Incorporation into the System



*Reprinted from* The ENGINEER 20 November 1975



# Use the Munter wheel to recover your heat and make big savings

## A rotary heat exchanger that is used extensively throughout Scandinavia can achieve efficiencies of 90% and pay for itself in two years. By Paul Butler

FOLLOWING the installation of a waste heat recovery system on two new printing machines — a solvent coater and a gravure press — security and general printers Harrison and Sons is expecting to save around £30 000 a year on fuel bills.

Most printing machines need large quantities of hot air for evaporating off solvents in the inks and coating materials. Heat is often wasted because the solvent-laden air is commonly exhausted to atmosphere — perhaps after a solvent recovery process.

As fuel prices rose, Harrison decided on a scheme by which about 70% of the heat in the exhaust air stream can be recovered.

The key to the heat recovery system are two Munter's Econovent wheels — one for each machine — which are almost unknown in Britain but have been applied extensively in Sweden where they were developed about 15 years ago.

**Rotary exchanger.** Munter's wheel is in effect a rotary air/air heat exchanger fitted between the exhaust and supply air ductwork in a heating, cooling or ventilating system. A feature is the wheel's ability to recover both sensible heat — in the air stream — and latent heat — in the solvent vapour — achieving recovery efficiencies of 70-90% averaged over a season.

The wheel is not only suitable for heat recovery on printing machines. Many Scandinavian installations have been in hospitals, hotels and other public buildings. One of the few to be installed in Britain so far is in Overseas Containers' London headquarters at Beagle House.

The diagram shows how the wheel fits into the ductwork and is driven by a small electric motor and belt drive at about 10 rev/min. The two wheels at Harrison are each about 2 m (6 ft) diameter and 280 mm (11 in) thick and contain asbestos fibre sheet impregnated with lithium chloride.

Looking down the axis of the wheel is like looking at the end of a roll of corrugated paper. There is a multitude of axial flutes — the asbestos material occupying about 15% of the face area.

The fresh air supply from atmosphere passes through one half of the wheel and then to the air heaters on the machines. The exhausted air passes through the other half of the wheel in the opposite direction to the fresh air supply. Thus the flutes are alternately passed by exhaust and supply air.

As the hot solvent-laden exhaust air passes through the wheel the sensible heat is absorbed into the matrix and at the same time the hygroscopic properties of the lithium chloride on the flute walls attract the moisture carrying the latent heat. This is also retained in the matrix.

As the wheel rotates into the air supply section the air passing through the flutes in the opposite direction picks up the sensible and latent heats and moisture retained by the matrix and transfers these back into the system.

**Purge section.** To avoid transfer of exhaust air into the supply air a purge section on the wheel flushes each flute before it enters the supply air stream. This is particularly important in certain applications where transfer of insoluble airborne odours or particles between the airflows cannot be tolerated. The carry-over is claimed to be only 0·04% by volume.

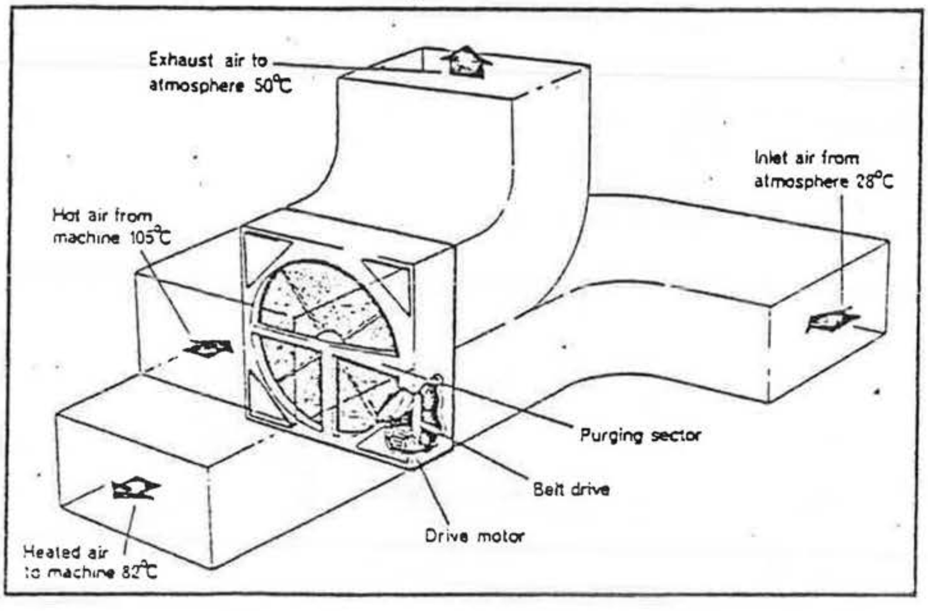
At Harrison the energy required for heating up the air supply to the coating and gravure machines to 420K (150°C) comes from a Wanson liquid-phase heater circulating Essotherm oil through gilled tubes. The heater has a maximum output of 12 700 MJ/h (12 million Btu/h), at which rate it consumes 0·39 $m^3$/h (85 gal/h) of 3 500-sec fuel oil.

While Harrison is still building up capacity on its new machines — they are operating at around 50% of potential capacity — fuel oil flow to the heater has been cut to 0·05 $m^3$/h (11 gal/h). This illustrates the enormous savings which will be possible as a result of installing the wheel.

Harrison's total bill for putting in the heat recovery system came to around £42 000—with the two Munter's wheels accounting for £11 000. Payback time is estimated by the company's consultants Michael Bird Associates to be 21½ months. Bird points out much of the £42 000 spent would have been necessary anyway for ductwork to carry exhaust air to atmosphere.

But by putting its own money into a heat recovery scheme — the company had hoped to borrow money through the Government's Energy Saving Loan Scheme but applied 'too early' — Harrison will be saving about £600 a week in fuel bills, and a good deal more if industrial oil prices start rising again. E

*How Harrison and Sons is using a Munter's wheel to recover 70% of heat from coating and gravure machines*



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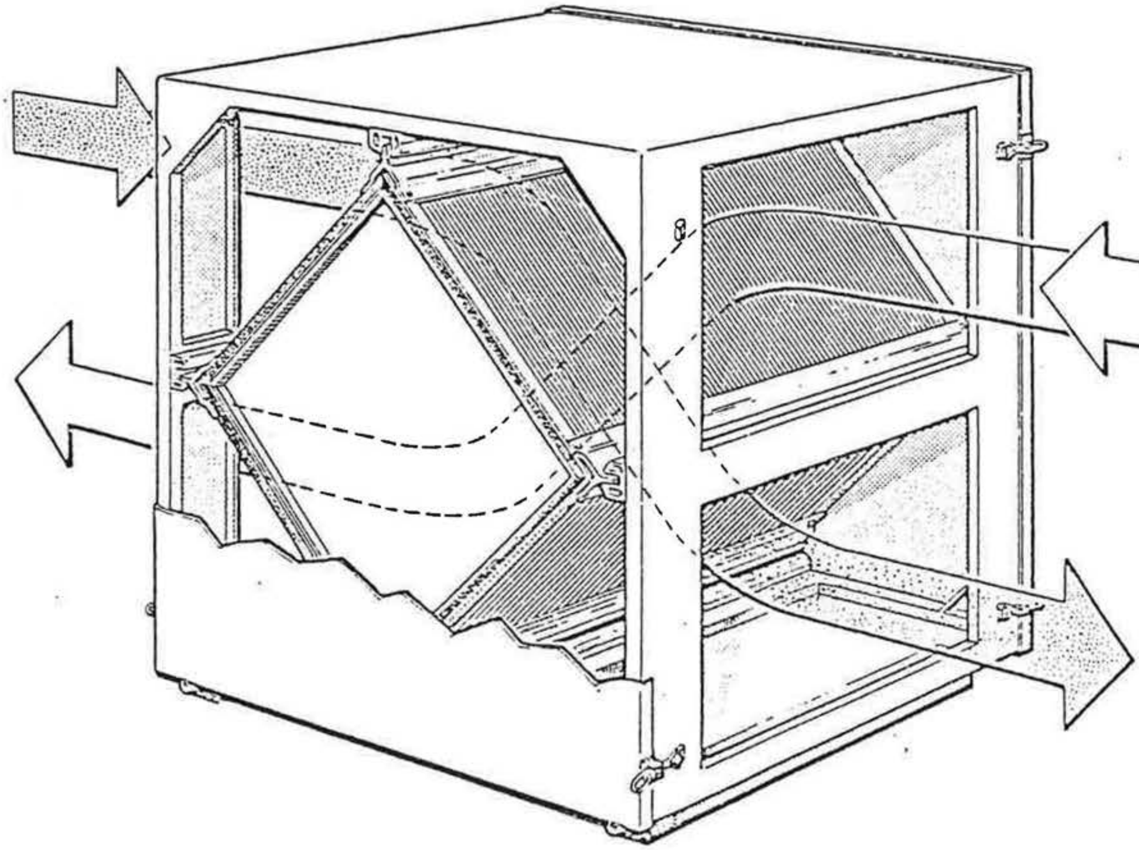


# Econovent EX

## cross-flow recuperator for energy recovery in ventilation system

Compared with rotating regenerators type Econovent EV or RT the cross flow stationary recuperator Econovent EX — where supply and exhaust air are completely separated — has both advantages and drawbacks. It is necessary to study the pros and cons and relate them to the actual project to choose the best alternative.

One can say as a general rule that the major field of application for Econovent EX is "wet" industry, where one wishes to transfer the high latent heat of the exhaust air into warm, dry supply air. Through the fact that the condensation heat of the exhaust air is transferred to the supply air, one can reach very high supply air temperature efficiency.

Another field of application for Econovent EX is where the vapours from solvents, gases or odours are transferred to an unacceptable rate in Econovent EV.

Typical applications:

Drying of wood and textile, laundries, paper mills, swimming halls, chemical industry and animal housing.

# mechanical design



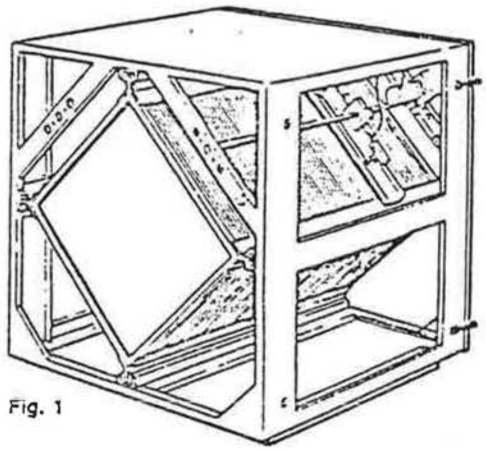


Fig. 1

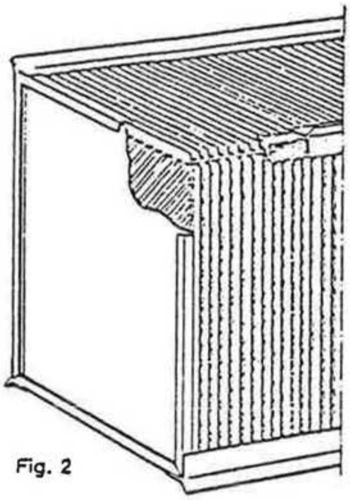


Fig. 2

Econovent EX recuperative heat recovery module consists of a sheet metal casing containing removable heat recovery packs made of corrugated aluminium foils. The casing has removable end covers on each side to enable connection to other modules, when high air flows require more than one module. In the bottom of the casing there are two pans to drain the condensate. There are four openings for connection to ducts.

The foils of the heat recovery pack, which are exposed to exhaust air, may be covered with a plastic film to prevent corrosion. The recovery packs can be pulled out of the casing to enable cleaning.

If required the module can be supplied with a freeze protection mechanism, i.e. a small lid gliding over the pack. The mechanism is located at the outdoor air entrance side of the pack. The lid is driven by a motor by means of a threaded rod attached to the casing. When using several modules — a module "train" — one of the modules (the master) has a drive motor mechanism and the other modules are slaved by the master module. The motor is designed for connection to mains 220 V, 50 Hz, single phase.

# function

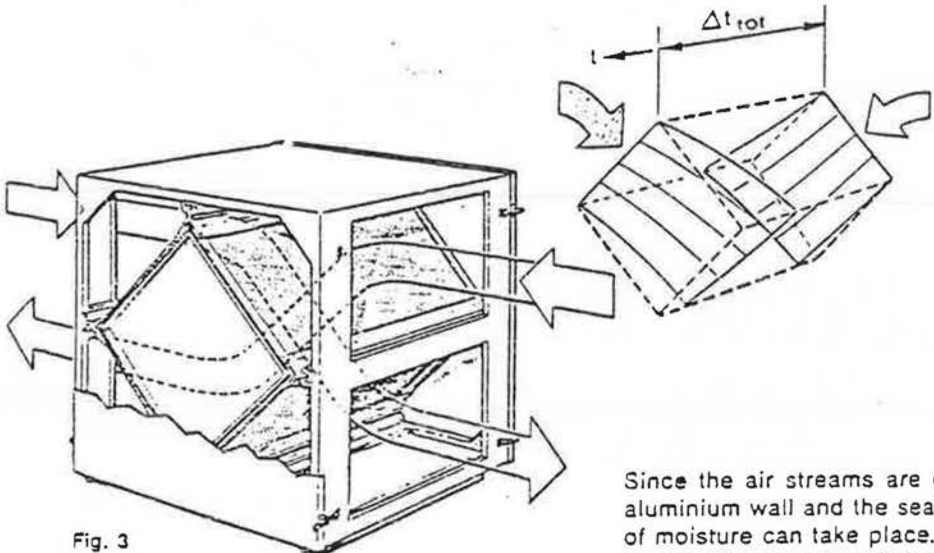



Fig. 3

In Econovent EX the air streams normally enter through the upper openings and flow diagonally through the module and exit through the lower openings. If condensate forms, it will be forced down the pack to the drain pans of the housing.

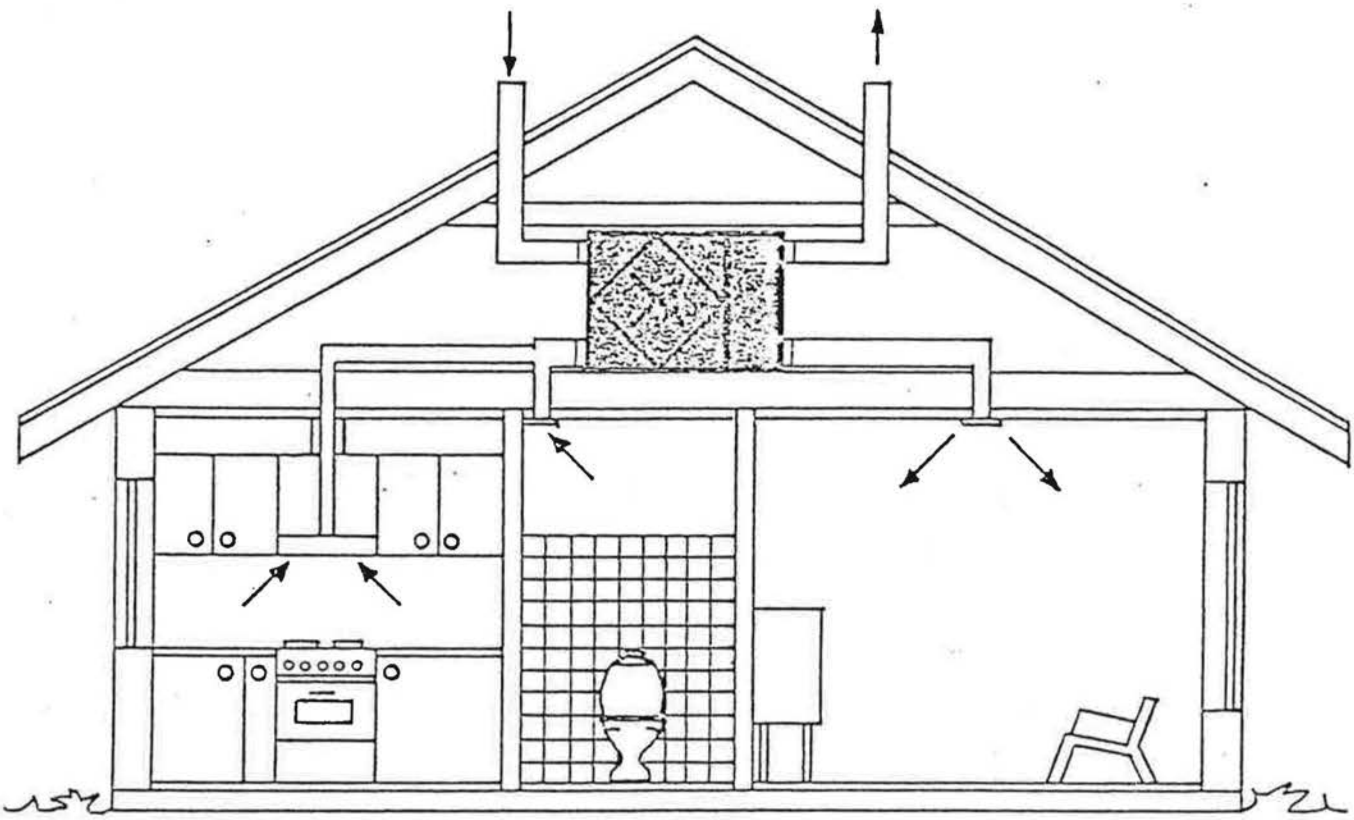
Since the air streams are completely separated by the aluminium wall and the seals of the housing, no transfer of moisture can take place. The same goes for vapours, gases, odours and particles. The temperature process in a cross flow exchanger like Econovent EX is complicated to describe verbally, but figure 3 shows the temperature process in principle.

Where the supply air cools the surface of the pack down to and below the dew point of the exhaust air, condensation takes place in the exhaust air flutes.

## VMC GENVEX unit for single-family houses.

## VMC INFORMATION

VMC GENVEX UNIT is an energy saving ventilation system, especially developed for highly insulated single-family houses, group- and semi-detached houses. Apart from improved economy, excellent interior climate conditions are achieved.



Earlier the air renewal used to be effected by natural means, i.e. through creyices, leakages and by opening windows.

Today energy savings are first of all obtained by insulating and draught-proofing the houses. At the same time you discover that not only the warm air is sealed in but also cooking smells, cigarette smoke and other impurities. Furthermore, this lack of ventilation leads to the probability of excessive condensation. Insurance companies and building authorities are aware of this problem.

The solution to the problem seems to be the placing of extractor fans but paradoxically, such ventilators function less effectively in highly insulated, sealed rooms. By the continuous sucking out of the air inside, a vacuum (non balanced ventilation) is created in the house.

# VMC/
# HEAT RECOVERY



## VMC GENVEX unit for single-family houses.

## TECHNICAL SPECIFICATION

VMC GENVEX UNIT is an energy saving ventilation and heat recovery system, especially developed for highly insulated single-family houses, group- and semi-detached houses.

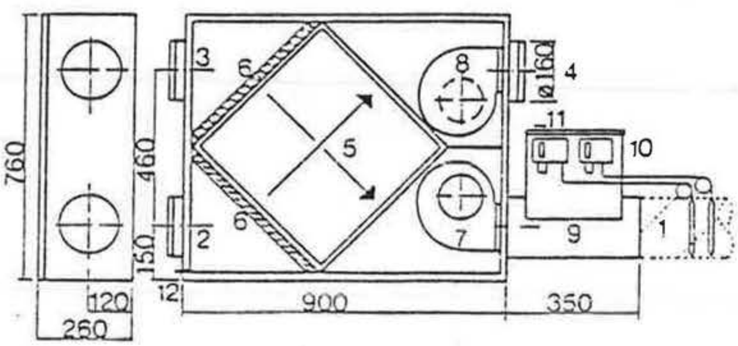
VMC GENVEX UNIT is a compact system, consisting of Cross Air-Flow Heat Exchanger, filters, injection and extraction ventilators with manuel switch from full to half speed.

Normally, the assembly is delivered with 2 thermostatically controlled electrical heating elements for stepwise switching on.

VMC GENVEX UNIT is available in a right-hand and left-hand model.

VMC GENVEX UNIT's Cross Air-Flow Heat Exchanger is manufactured of sea water proof aluminium. The heat transfer is carried out by thermal transfer through crosswise "stacked" aluminium sheets.

Dimensions and components




01. Injection canal
02. Extraction canal
03. Fresh air canal
04. Throw-off canal
05. Cross Air-Flow Heat Exchange
06. Filter
07. Injection ventilator
08. Extraction ventilator
09. Electrical heating elements
10. Thermostats for switching on of the heating elements
11. Fire thermostat
12. Condens outlet

VMC GENVEX UNIT is manufactured of spray coated electro-plate, in the colour orange. On the inside the unit is insulated.

VMC GENVEX UNIT has condens outlet. Connection 13/15 Cu-tubes.

VMC GENVEX UNIT recovers 55 - 75% of the heat, dependent on the temperature difference between the fresh and the extraction air, the quantity of air injected and ectracted and the humidity of the extraction air. A-47

In a normal single family house, the efficiency on annual basis will be 62 - 68% in average.

VMC GENVEX UNIT is equipped with noiseless centrifugal ventilators with temperature working range between ÷ 30° - + 60°.

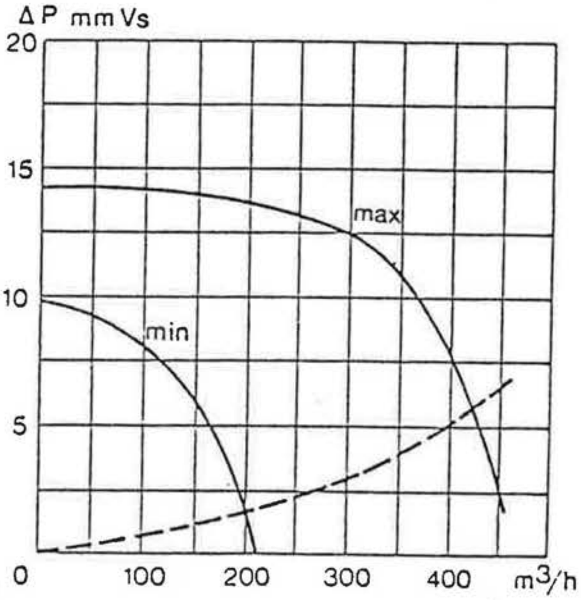
Data for ventilator

The ventilator wheel is of steel.

| | |
|---|---|
| Motor type: | E 160 - 4 |
| Volt: | 1 - 220 V |
| Max. current: | 0,3 A |
| Condenser: | 2 MF |
| No-load capacity per ventilator: | |
| Max.: | 55 - 70 W |
| Min.: | 22 - 25 W |

--- Pressure loss curve for VMC GENVEX UNIT.

Ventilator characteristics




VMC GENVEX UNIT contains 2 filters, fitted with washable viledon mats.

VMC GENVEX UNIT is normally delivered with one canal heating element, fitted on the injection canal of the unit.

The capacity of the electrical heating element is 2 x 500 W, stepwise switching by 2 thermostats.

The canal heating element is fitted with security thermostat. The canal heating element is available with other capacities.

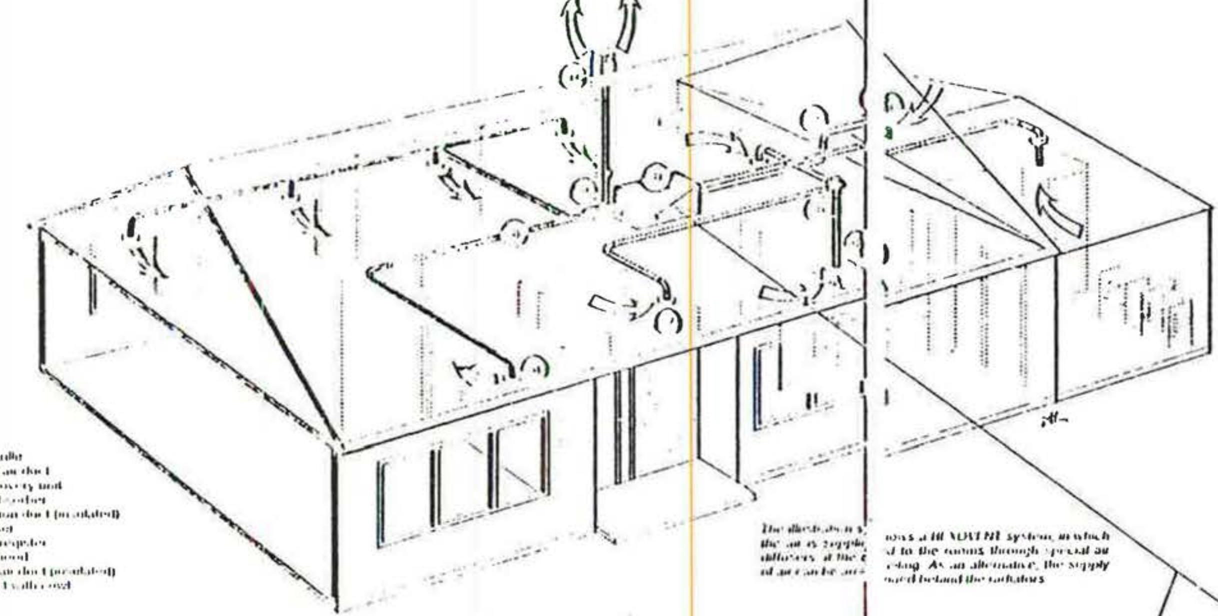
VMC GENVEX UNIT is connected to 200 V/J, 6 or 10 A, dependent on the capacity of the heating element.

V.M. CHRISTENSEN A/S

KLIMATEKNISK AFD. FABRIKSPARKEN 22, DK—2600 GLOSTRUP. TLF:(01)263800

# REXOVENT – a complete system for heat recovery and ventilation

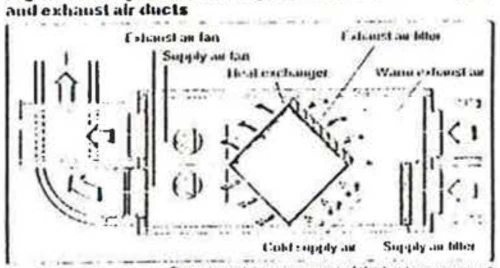
The system is delivered as a package. All components are standardized, thus appreciably simplifying the installation work.



1 Louvre grille
2 Outdoor air duct
3 Heat recovery unit
4 Sound attenuator
5 Distribution duct (insulated)
6 Air diffuser
7 Exhaust register
8 Cooker hood
9 Exhaust air duct (insulated)
10 Roof duct with cowl

*The illustration shows a REXOVENT system in which the air is supplied to the rooms through special air diffusers at the ceiling. As an alternative, the supply of air can be arranged behind the radiators.*

## High-efficiency heat recovery unit with separate supply and exhaust air ducts




*Diagrammatic arrangement of the heat recovery unit*

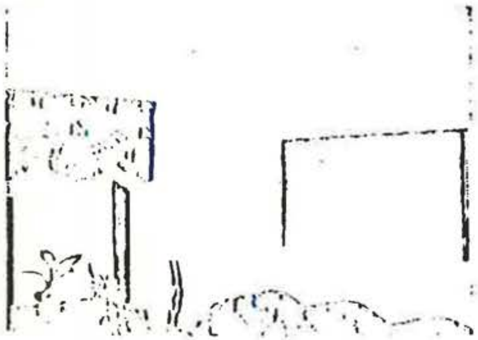
The heat recovery unit is the core of the REXOVENT system. The unit is compact and lightweight and is easy to install. The supply and exhaust air fans are of centrifugal type and can be wired for single-speed or two-speed operation or can be equipped with variable thyristor speed controllers. The filters, heat exchanger and fans are easily accessible for inspection and cleaning.

The heat exchanger is of the cross flow type. It consists of cross-laid flat and corrugated aluminium strips. This arrangement provides a large number of passages through which the supply and exhaust air flow along completely separate paths.

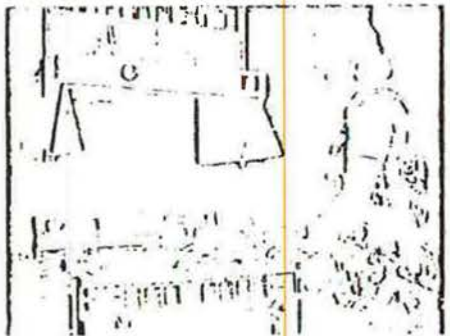
In view of the very high efficiency of the heat exchanger, frosting may occur in the exhaust air passages of the exchanger at low outdoor temperatures. Variants of the unit are therefore available for different climatic zones, and automatic defrosting by electric heating or by electric heating combined with briefly reduced supply air flow is provided.

*The efficient Flakt heat recovery unit reduces appreciably the cost of energy and is thus an extremely profitable investment.*

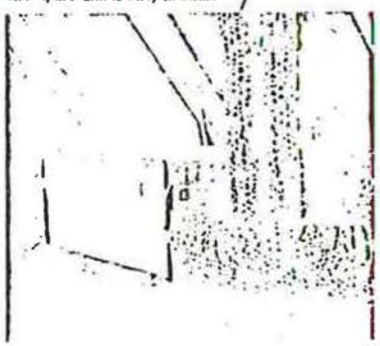
*The air entry pieces and diffusers provide a uniform and stable supply of cold clean air.*



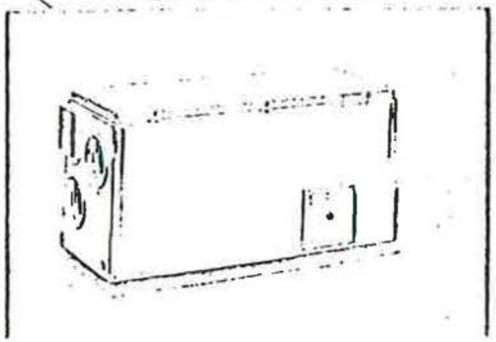
*The cooker hood has a large volume and thus efficiently extracts cooking odours at a low air flow.*



*The heat recovery unit occupies little space and is easy to install.*



*The heat recovery unit is insulated on the outside. It is compact (1000 mm long, 400 mm wide and 180 mm high) and weighs no more than 37 kg.*

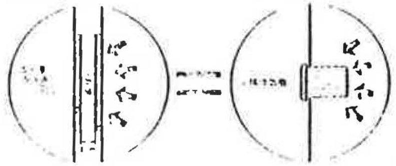


# 音をシャットアウト!

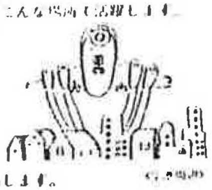
●高い遮音効果で室内を騒音から守ります。

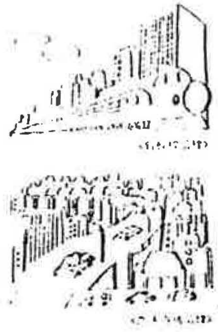
空港周辺や、線路、道路に面した住宅の騒音対策用にピッタリの換気扇です。内蔵した熱交換素子で外部の音をシャットアウト。強力な遮音効果を発揮します。

★遮音効果は防音窓用ペアガラスに相当します。



●こんな場所で活躍します。





# 暑さ(寒さ)をシャットアウト!

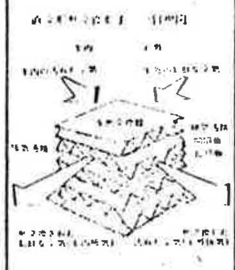
●換気をしても室温をほとんど変えません。

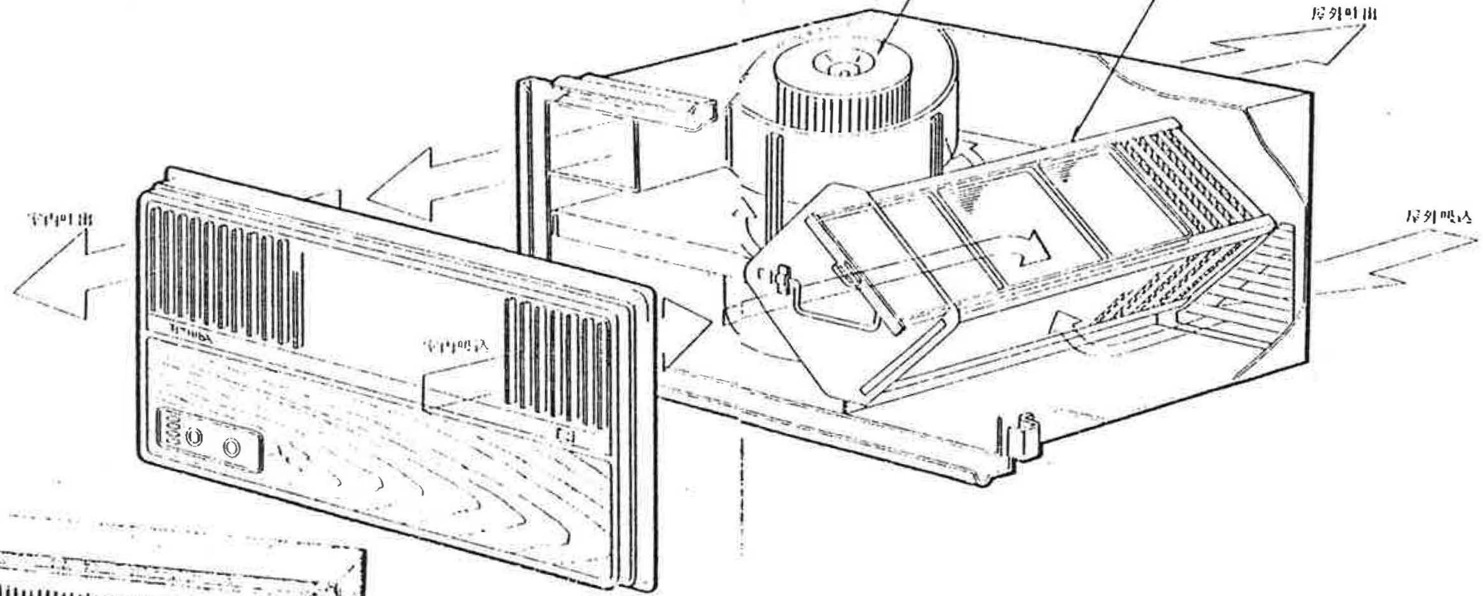
部屋を閉めきりがちな冷(暖)房時ほど大切なのが換気。ところが室内が暑く(寒く)なるといって敬遠しがちなのも事実です。そこで活躍するのが、この空調換気扇。内蔵した熱交換素子の働きで、室内の冷気(暖気)を逃がさずに換気。室温をほとんど変えません。

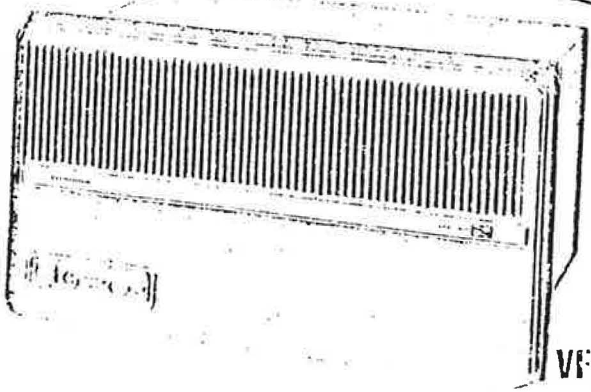
〈暖房時の働き〉

〈冷房時の働き〉

★これが"熱交換"の心臓部!!

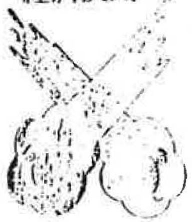




VFE-16M

## 経済換気

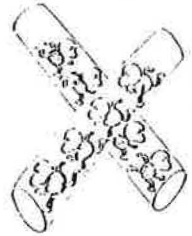


汚れた空気を外に排気すると同時に、直交形熱交換素子より新鮮な外気を温(冷)めて吸気します。ですから、冷(暖)房時の換気による損失が少なくなります。

## 安定換気

一般の換気扇は、排気量と同じ量の空気を取り入れなければ、その効果は減少してしまいます。その点〈空調〉換気扇は同時吸排方式。ですから、密閉された部屋でも安定した換気ができます。

## 清潔換気

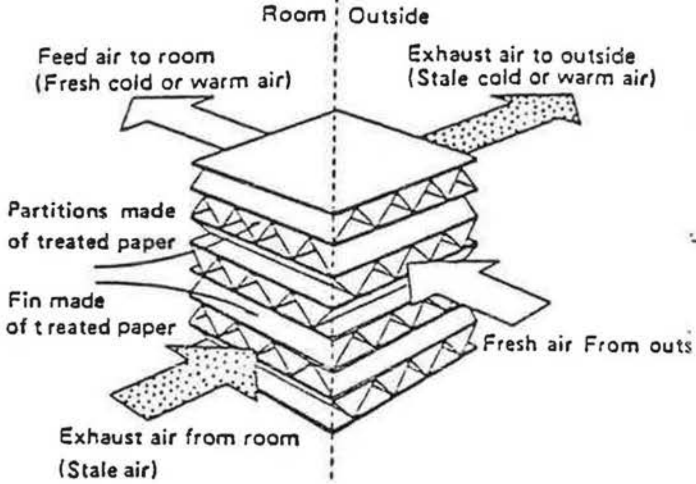


排気通路と吸気通路が違いますから、いつも新鮮な外気を室内に運び、快適な環境をつくります。

# 1. CONSTRUCTION AND PRINCIPLE

## 1.1 Construction

Lossnay is a cross-flow total heat exchanger constructed of plates and fins made of treated paper. The fresh air and exhaust air passages are totally separated, allowing the fresh air to be preconditioned to the temperature and humidity levels of the room air without mixing with the exhaust air.




## 1.2 Principle

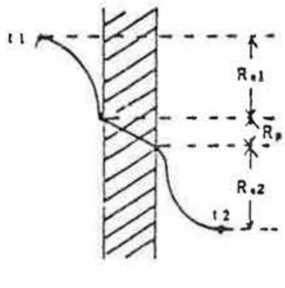
Lossnay's principle of operation is based on the heat transfer properties and moisture permeability of treated paper. Total heat (sensible heat plus latent heat) is transferred to the fresh air being introduced into the system via the medium of treated paper. This principle is easy to understand if you conduct this simple experiment:

Roll a sheet of paper into a tube and blow through it. Your hand holding the paper will immediately feel warm. If cold air was blown through the paper, your hand would feel cool. Thus, heat is readily transferred via a paper medium.

## 1.3 . Total Heat Exchanging Mechanism

**(1) Sensible heat exchange**

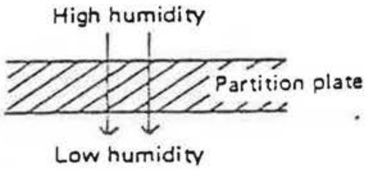
Sensible heat is transferred from higher to lower levels of the element. Although paper is usually regarded as a heat insulating material, it exhibits as far as gas-to-gas phases are concerned, a high thermal conductivity comparable to copper and aluminum (a 3% maximum thermal conductivity difference).




$R_{a1}+R_{a2} \gg R_p$

**(2) Latent heat exchange**

Latent heat is transferred from higher to lower levels of the element because of partial pressure differences. Capillarity caused by condensation on the element is not always a prerequisite to latent heat exchange and the element is not always moistened even under highly humid conditions. Energy is released when condensation occurs and gained after the osmosis.



# APPENDIX B

## Recent Testing of Air-Tightness of Housing

Dr. D.G. Stephenson
Division of Building Research
National Research Council

B - 1 Dr. Stephenson's Remarks

Thank you very much. My participation this morning will be to try to explain or to try to indicate what activities we have at DBR that relate to this question of the viability of heat recovery devices. It has been mentioned by Mr. Platts that we've made some measurements, over the years, on the air leakage of houses and in recent times we have been doing somewhat more of that for a reason I will mention in a moment. We have not however been in the business of developing or testing heat recovery devices per se. It was mentioned by John that we had, about a year ago, asked for proposals, thinking that we might in fact be able to justify some of the funding that was available for energy conservation to be spent on contracts in this field. Partly because the proposals we had were not all that compelling and partly because we thought there was some homework that needed to really be done before that stage, we did not carry through with that, although it is still a possibility.

But the work that we are doing, and the objective of this work, is connected with the needs of the energy conservation code, or if you like the new Measures for Energy Conservation in New Buildings. The committee that prepared this booklet that just came out this year asked our division, something over a year ago, to look into the feasibility of having some kind of a test, or way of checking the tightness of houses that might be suitable for calling up in a performance type of code, and if that proved to be feasible - and the reason that they thought it might be was that we had heard that Sweden had in fact taken that step just about the time the committee were asking us to look into it. If it was feasible, then the following question was: "What level of tightness would it be appropriate to expect or to require?" So we accepted this request and developed a test. I shouldn't say developed a test because it is a test that has been used by people in our division earlier, and certainly has been used by others, particularly Ontario Hydro. We have looked up the simple fan pressurization or fan suction method of checking the air leakage characteristic of a house. I have to be clear here, in case some of you are not familiar with this. The air leakage characteristic is not the same thing as the infiltration that will occur under normal operation. When you put a fan on and you draw a small negative pressure on the house, you measure how much air will leak in under those conditions and it isn't fair to infer that that has anything more than a vague connection with the amount of air that will actually leak in and leak out during the course of a whole normal heating season. But a fan test does give you a measure of how tight the enclosure of the house is, which with subsequent work may be related to this annual infiltration and consequently the dollars or the Btu's lost as a result of this infiltration. So our feasibility study then looked at the suitability of that test and in particular what it would cost to carry out such a test on a smooth flow basis, or the sort of basis that may apply if it were called up as part of the building energy conservation measures and at the same time we wanted to see what the range of results that you would get with houses as they are currently being built, not houses that have been especially tightened up, but the way they are being built today. For this purpose we had the assistance of the local builders - members of HUDAC here in the National Capital. Just over 25 builders responded to our request for a chance to check newly constructed houses after they were finished and before they were occupied and during the past summer we had a contractor using the simple test method check about 70 newly constructed houses. We know that doing the first batch of 70 is not a fair basis for getting any firm figure of what it would cost on a more routine basis. But for what it is worth, the cost of doing those tests and not counting the cost of buying the equipment which is relatively simple and in this case was made available by NRC, has been just under $150 per house to do this test. Whether that says that is unlikely to ever be used with a building code or whether it is likely to be used, I don't propose to speculate on here, but it is a data point that the committee certainly will consider. I don't think that it is completely out of the question and certainly it is pretty high. The benefits need to be pretty substantial to justify that additional cost just for inspection.

The results that we got - Mr. Platts mentioned that there is a wide variation - in fact, there is a wide variation, but it isn't as wide as we had thought it might have been. We have this sample of 73-74 houses. Over half of those houses were within + or - 20% of the average and virtually all of them or over 90% were within + or - 45% of the average. The units that we got by themselves are not terribly meaningful, but where the average number is 0.8 then half of the houses fall between 0.6 and 1.0 and all of the houses in fact fall between 0.4 and 1.2. So it is not quite as wide a spread as we thought we might have obtained, but these are newly built houses. The builders have not been taking special care to make them tight, but at least they have been building to what are current good standards and the houses have not aged, cracks have not opened up due to wood shrinking and whatever else may cause cracks to open up with time. These were all built within a year of the time they were tested.

Question: Did the builders know that they were going to be tested when they were building.

They didn't know this when they were building, but the builder, when asked if he had some houses available offered them. They weren't ones he was particularily reluctant to have checked; but they were not built specially with this test in mind. The sample of 70 as I say is drawn from something like 25 different builders. We did not want in principle more than 3 houses from any one builder. In some cases we had more than 3, and in other less but on average about 3 houses of each of 25 different builders.

Just a word about these units before I pass on. The way we try to relate these leakage measurements for houses of different sizes is to take the leakage in cubic meters per second and divide it by the total area of the air barrier - everything from grade level up the walls and across the ceiling, the area where it is supposed to have a barrier to air leakage. We expressed this in cubic meters per second and divided it by the area in square meters so the units that I am talking about here are meters per second multiplied by a factor of $10^{3}$ so that in fact we are getting something $0.8 \times 10^{-3}$ cubic meters per second per square meter. That is not a number that we are able to very readily appreciate as a connection to air infiltration. This rate by the way coincides with a relatively small differential pressure produced by the fans system. We test over substantial range of $\Delta P$ but then read off from a plot of flow vs. P what the flow would be at, in fact, 1/10 mm of water or 10 pascals of pressure. This is small but perhaps about the kind of average $\Delta P$ that might apply over a whole heating season. We don't know exactly what that average $\Delta$ P would be however.

Now the second part of our activity in DBR beyond making these measurements is to try to get the connection between results determined in this way and what the whole heating season air infiltration average value might be. And for that the part of the Division of Building Research that operates in Saskatoon has modified the conventional tracer gas method to make it suitable for continuous monitoring of infiltration. We have used that apparatus in fact, checked it with some of these houses that have been measured by our contractor and the intention is to use similar apparatus both here in Ottawa and in Saskatoon to monitor, on a continuing basis or over a period of several weeks at a time, the infiltration/exfiltration that occurs under the normal weather conditions, wind effects, and so on. In this way establish the connection between actual infiltration as it affects the rate of heat loss or dollar loss and the tightness as determined by the simple fan test.

In addition to the sample of 75 houses that have been tested, we have also been involved with HUDAC in the monitoring of the performance of four houses that they built; 3 of which are upgraded with special effort made to make them tight and extra insulation added reflecting what may be an appropriate level for new construction. The fourth house built to the standards that have applied in the recent past for an electrically heated house. We will be monitoring the leakage in these houses periodically with this tracer gas apparatus. We have measured it with the fan test and the standard house, the one that reflects recent construction, is not tighter. It is not far off the lower limit of the range that we have found from this larger sample. But it is not the tightest of the ones we have tested. The tightened house, however, is marginally tighter than the tightest house we have found in the other sample. I said the other sample all fell within the range of 0.4 to 1.2. The tightest HUDAC house came at 0.35. So it is just slightly tighter than the best of this sample that's currently on the market and HUDAC, in the building of that house, went to considerable effort to achieve higher tightness than in their standard house which came in at just a bit over 0.5.

In the HUDAC houses there is provision for mechanical ventilation. There are arrangements for a fan to exhaust air from the house and a fan to supply air to the house. Ontario Hydro have indicated an interest in finding a place to try out the heat exchanger that Mr. D'Silva mentioned they were working on, and we anticipate fairly soon that a unit from Ontario Hydro will be installed in one of these houses. It is not there at present but it is intended that it will go in and all the instrumentation to monitor in fact how much energy actually is recovered by this unit throughout the whole heating season. The instrumentation is in place and we expect to have the results from that monitoring for almost the whole heating season by next spring. We put this ventilation equipment in anticipating that in fact with these tightened houses it would be necessary to provide mechanical ventilation; that they would be tight enough that you couldn't rely on the accidental ventilation to provide sufficient ventilation to control humidity or air quality. However, let me remind you of this regarding the tightened house, the one where they did the sort of thing that Bob said might cost you $300 for tightening them up (Platts: "Probably $400") and he was assuming that gets you a 100% really tight house. Our experience with the tight HUDAC house is that it is not by any stretch of the imagination without any air leakage. In fact it is only marginally tighter than the tightest houses that other builders have been putting up. There would still be a substantial amount of accidental ventilation there, and consequently, if you only use the fans to give you the air quality you need, the amount of mechanical ventilation will be less than if you were providing all of your needs and consequently the potential for recovering some heat from this exhaust air will be less. I think that when we see the numbers in the spring from the HUDAC house, they'll fall substantially short of Bob's figure of $45 worth of energy savings, or at least they may fall short of that. That is one of the pieces of information that we need to support or to modify the estimates that have been made on the basis of the calculations that Bob Platts mentioned.

One other point I intended to make. In the 3 upgraded or tight HUDAC houses, one of those has an air-type solar heating system, one has a heat pump heating system and the other one is conventional electric resistance, and all three are built with the same degree of tightness so far as the shell is concerned. But when we did the test, it was quite apparent that there was something different about the solar air heated system one. You need to think about it for only 30 seconds or less to realize that what was happening is that the air collector array is directly connected to the house. The air circulating through the house comes through that collector system, and therefore any leaks in the ducting to or any leaks in the collectors themselves appear as leaks in the shell of the house. Therefore, that needs to be taken into account in assessing the economics of an air type of solar system versus a liquid type or versus something like a heat pump where you don't have that additional feature that contributes to air infiltration. This house was between the tight house, at 0.35, and the ordinary house, at 0.54, in air tightness. So it was about 0.5.

We are not systematically evaluating heat exchanger equipment. We're interested in this. If heat exchangers are economically viable and if it is possible to make houses tight and still be economical by virtue of using the heat exchanger for recovering part of the heat in the exhaust air, then this will clearly bear on the question of what sort of criteria might be appropriate in a performance type of standard for ventilation. We are interested in that question, wanting to know what the economics are, what the industry people see as the situation here. But we are not actively involved in evaluating them other than in this one HUDAC house trial, at the present time. We are, however, hoping to obtain one of these Japanese heat exchangers that Eric Bonnyman showed. We have tried to buy one. We have not succeeded yet, but we do expect to get one of those for really just a "look-see" in the laboratory. We may be able at some stage to give it a brief field trial, just to see what the actual performance might be to confirm, if you like, for our own satisfaction that the claimed performance is realistic in terms of use in a Canadian house. We are not really directly looking at the question of how much ventilation you have to have in order to achieve a given or an acceptable quality in the house. We are interested in the subject but not directly looking at it, and that I believe is what Saul is going to speak about as far as the Ontario Hydro work is concerned.

## B - 2 DISCUSSION

Professor Besant related the results of testing during the winter of 1977-78 on existing houses in the Saskatoon area. Twenty houses of wood frame construction built between the early 1940's and 1975 were tested, using the fan test, for air tightness and then, using the tracer gas technique, for air change rate during the heart of the heating season. They varied between 0.62 air changes per hour and 1.71 air changes per hour with the average about 1.0 air changes per hour. Dr. Stephenson pointed out that this was higher than NRC had found in some limited testing of houses built 10 to 15 years ago. These houses had an average rate of about 3/8 of an air change per hour over the whole heating season. It was pointed out that the discrepancy could be related to whether the volume of air being considered included the basement volume or not. Professor Besant thought that the figures he had quoted related to the complete volume (including basement) but stated that it was the variation he had wanted to emphasize. He pointed out that the furnace is a major reason why we have a high change rate in a house.

In response to a question, Dr. Stephenson confirmed that in doing a fan test, all of the leaks not attributable to the construction, such as through back flow dampers on exhaust fans or through chimneys, are blocked off.

Mr. Atkinson felt that the relationship between the test results on the HUDAC Mark XI houses and those on the larger sample suggests that some Builders in Canada are currently building houses that are as tight as we can reasonably get because he didn't think we could get anything much tighter than the Mark XI houses. Dr. Stephenson agreed. Although it is proposed to go back and check some of the tighter houses in the sample of 75 to ensure there were no mistakes, it appears now that the tightest of those houses were almost as tight as the tightened-up HUDAC houses which is a pleasant surprise.

Mr. Stricker related an experience Ontario Hydro has in working with a builder who was having heating problems in one of his subdivisions. They found that, out of 10 models the builder was using, one was particularly leaky due to a certain detail on an overhang over a garage or front porch. The builder eventually eliminated that model because there was no convenient way to correct that detail.

APPENDIX C

AIR-TIGHTNESS AND AIR QUALITY

S. Stricker
Supervising Engineer
Utilization Section
Electrical Research Department
Research Division
Ontario Hydro

Mr. Stricker did not use prepared notes but showed a number of overhead projector slides which illustrated the main points he wished to make and elaborated on these points. The following pages contain copies of those slides as well as summaries of Mr. Stricker's elaborations (where the slides are not self-explanatory) and his responses to issues and questions raised by others.

AIR TIGHTNESS

- WHY?

LOWER LIMITS ON AIR CHANGE

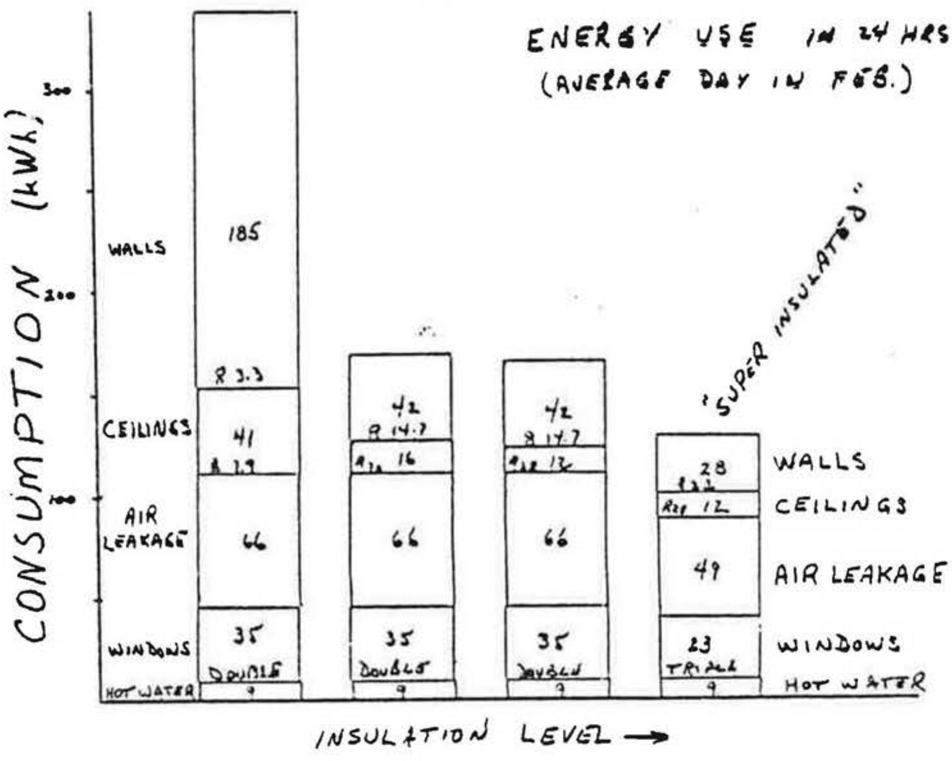
- WHAT ARE THEY?

CONTROL OF VENTILATION

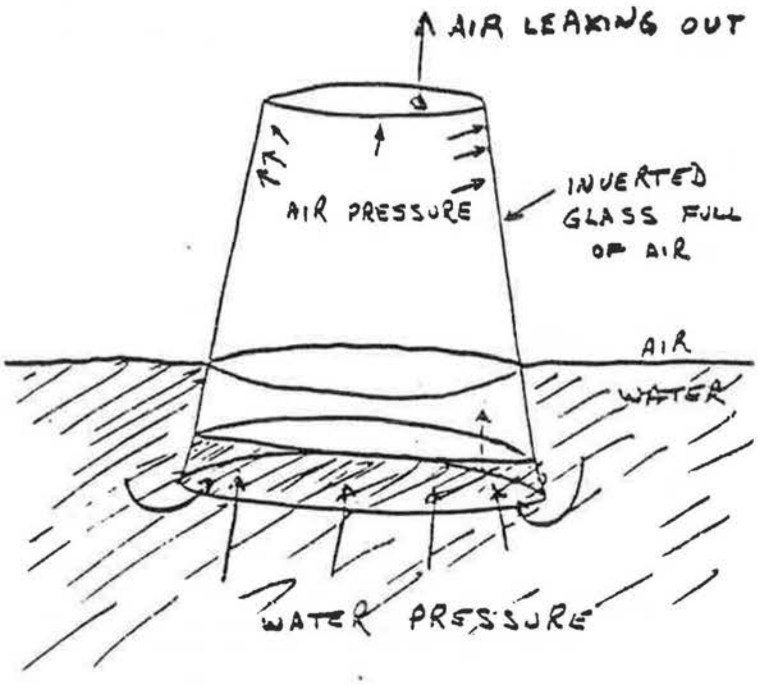
- HOW?

Slide 1

This slide illustrates that, as houses become better insulated, heat loss due to infiltration/exfiltration becomes a more significant portion of total heat loss. In the bar graphs heat loss through basement walls is included under "WALLS". In doing the calculations on which these graphs are based, Mr. Stricker assumed that, due to the porosity of conventional insulations, increasing insulation levels have no appreciable effect on air-tightness until the large panel rigid plastic insulations are used.



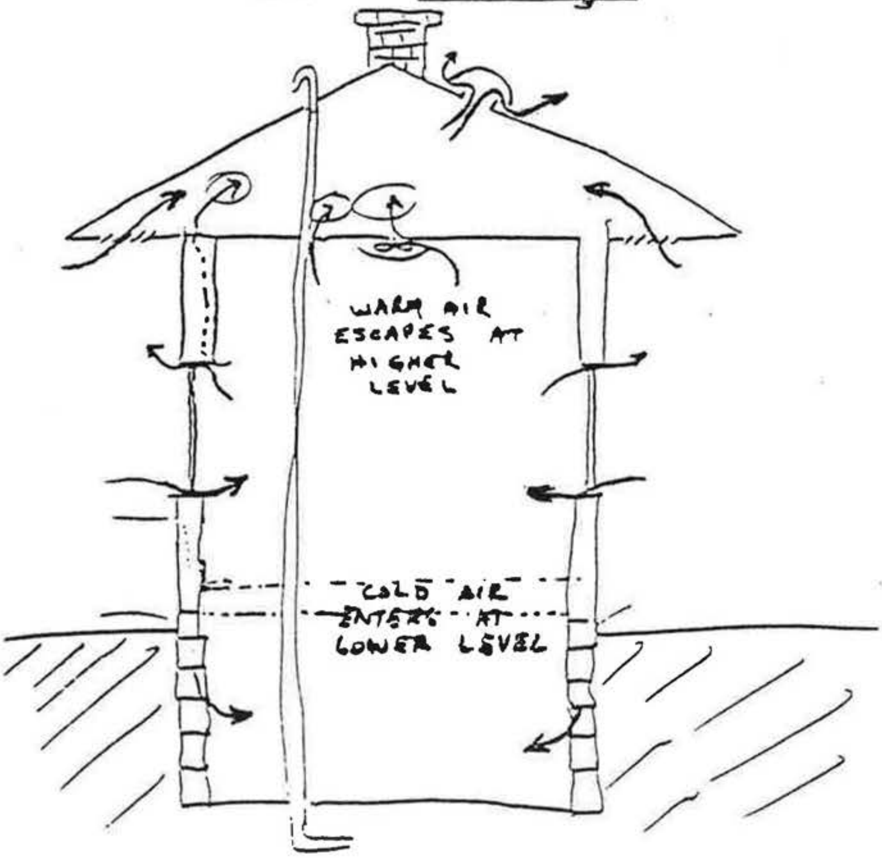

Slide 1




"STACK EFFECT"

Slide 2

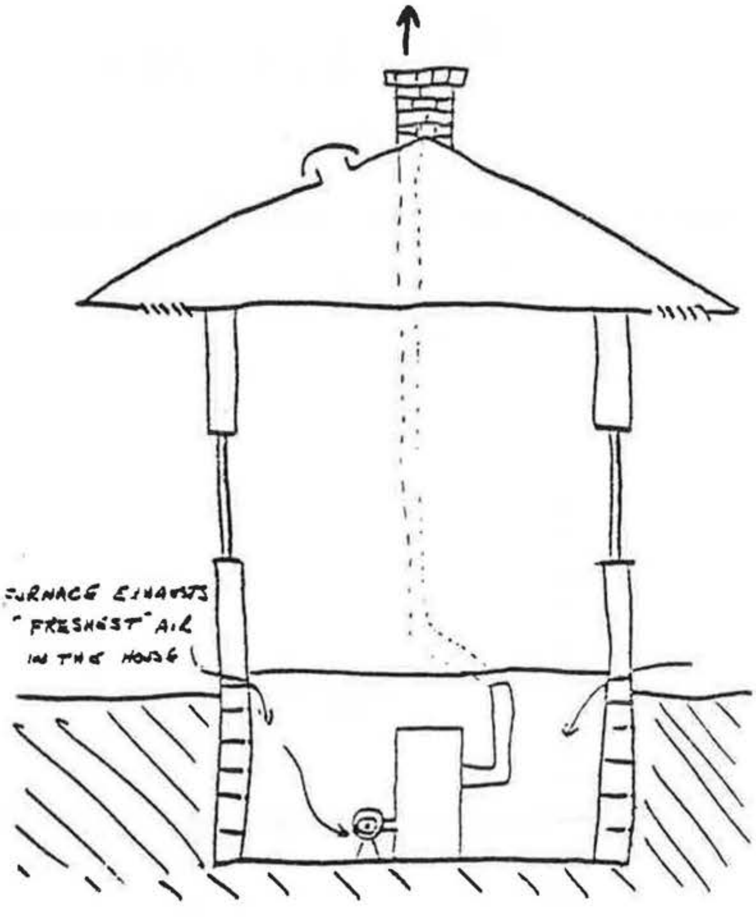
# Air Leakage



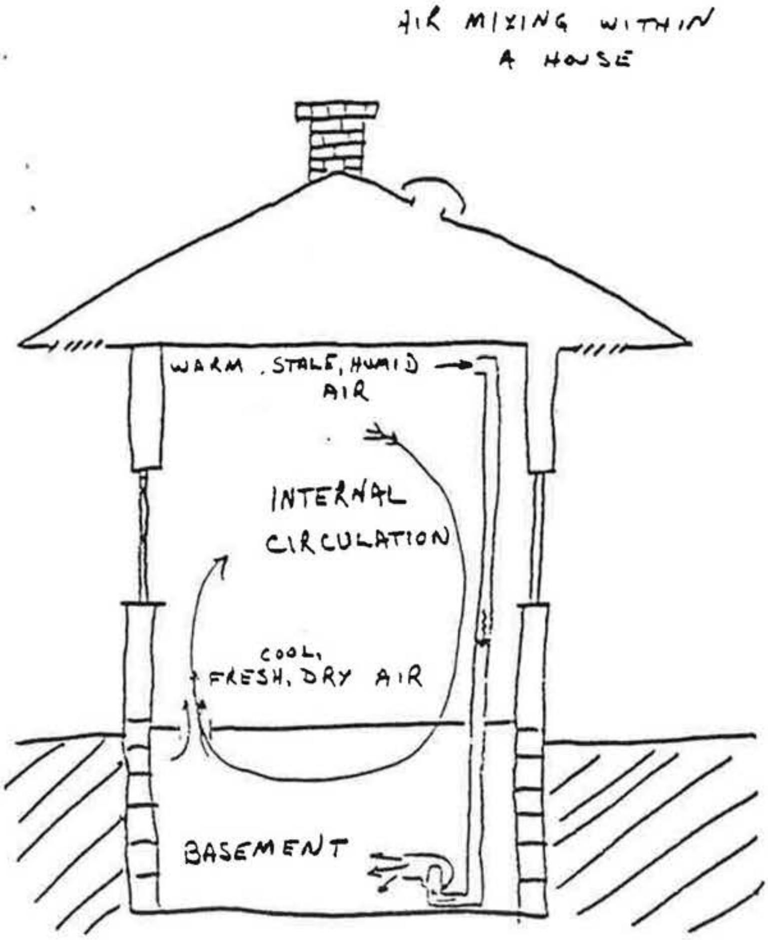
WARM AIR ESCAPES AT HIGHER LEVEL
COLD AIR ENTERS AT LOWER LEVEL

Slide 4 and 5

This slide illustrates the point that a good part of the fresh air infiltration enters the basement and, unless there are cold air returns in the basement, the forced air circulation system will be circulating relatively stale, humid air while the furnace is supplied with nice fresh air for combustion. This can be corrected by a circulation system such as illustrated on Slide 5.




Slide 4


AIR MIXING WITHIN
A HOUSE
WARM, STALE, HUMID
AIR
INTERNAL
CIRCULATION
COOL,
FRESH, DRY AIR
BASEMENT

Slide 5

## FRESH AIR REQUIREMENTS:*

1. TO SUPPORT LIFE – 1½ CFM
2. TO CONTROL ODOUR – 7→25 CFM
3. TO CONTROL HUMIDITY – 15 CFM

PER OCCUPANT

FAMILY OF 4 REQUIRES

60 → 100 CFM

* As per ASHRAE Guide

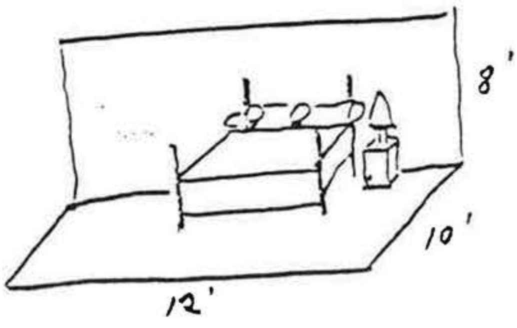
Slide 6

Slide 7

Mr. Stricker related the incident of a couple with an electrically heated house who complained of waking up every morning with a headache. Investigation revealed that their house was extremely tight and they slept with windows and bedroom door shut. Calculations and testing indicated that after 7 1/2 hours the carbon dioxide level in the room would approach that which would cause the first stages of asphyxia.

TOO LITTLE VENTILATION

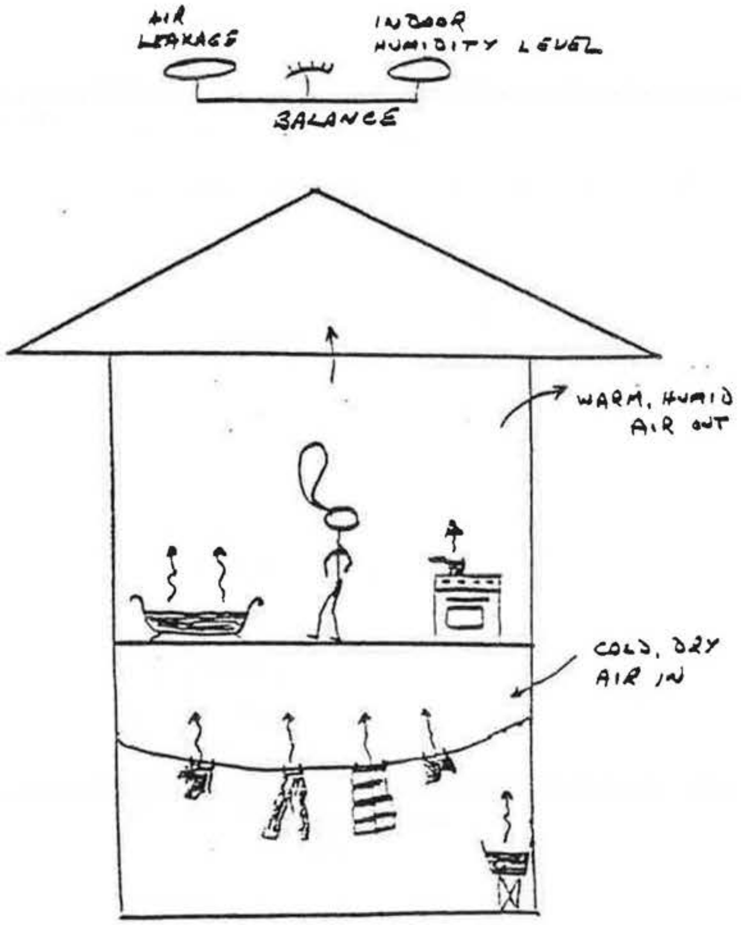
1. ASPHYXIA
2. ODOUR
3. MOISTURE PROBLEMS.

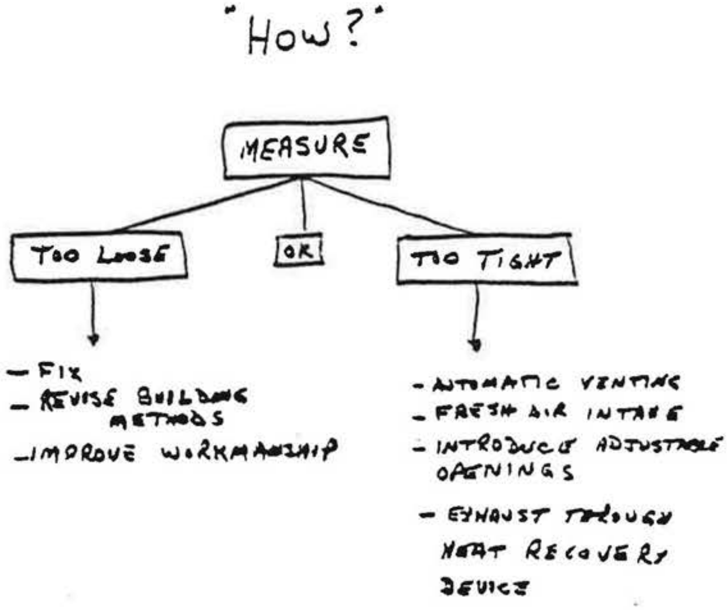



HEADACHE IN 7.5 HRS

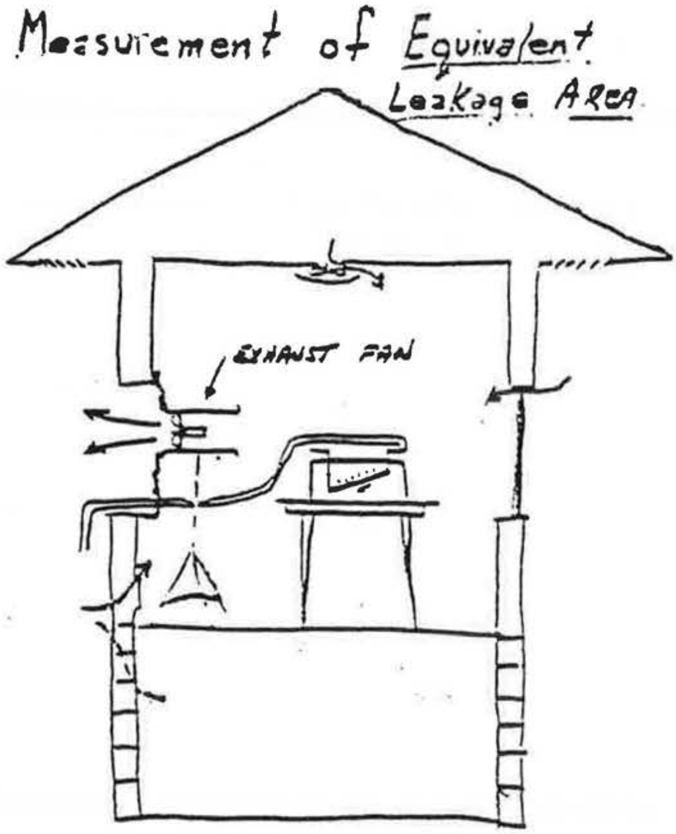
Slide 8

Indoor humidity level is established by a balance between the production of moisture by such activities as breathing, washing, cooking, etc. and its removal by air movement through the house, both of which processes are normally not controlled. Moisture production can be controlled to some extent by such actions as venting clothes driers and providing moisture barriers over basement floors.




"How?"
MEASURE
TOO LOOSE
OR
TOO TIGHT
- FIX
- REVISE BUILDING METHODS
- IMPROVE WORKMANSHIP
- AUTOMATIC VENTING
- FRESH AIR INTAKE
- INTRODUCE ADJUSTABLE OPENINGS
- EXHAUST THROUGH HEAT RECOVERY DEVICE

Slide 9

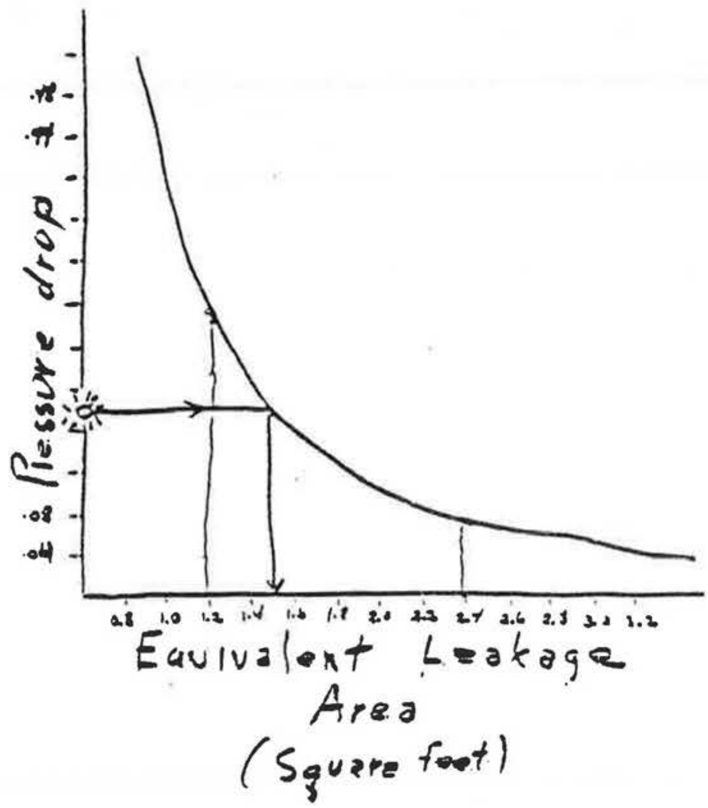



Slide 10

Slides 10 and 11

Mr. Stricker explained the method of air-tightness testing Ontario Hydro has been using for about 11 years. They use an axial vane fan which delivers 1575 cfm unrestricted and has a known pressure-flow characteristic. The fan is installed in a window and sealed to the window frame with a sheet of polyethylene. A manometer used to measure the difference between indoor and outdoor pressure is zeroed and the fan is turned on. Within 1 1/2 seconds a stable pressure drop is achieved. Using this pressure drop and the pressure-flow characteristic of the fan, the flow is derived and these two values (pressure and flow) are used to derive the leakage area of the house in terms of an equivalent amount of sharpedged orifice. In fact these two steps have been simplified by developing (by calculation) the pressure drop vs. equivalent leakage area curve shown in Slide 11. The accuracy of this method has been verified by opening a window to create a known increase in the leakage area. The increase in "equivalent leakage area" corresponding to the resultant change in pressure agrees very closely with the actual increase. The bottom scale of slide 11 shows the range of equivalent leakage areas which Ontario Hydro has measured.

They have observed a significant amount of leakage through concrete block walls thus confirming data published several years ago by NRC. Professor Besant said that he had also measured significant leakage through concrete block walls.


Pressure drop
Equivalent Leakage Area (Square feet)
0.8
1.0
1.2
1.4

Slide 11

Slide 12

They have observed that cold air returns formed by covering the bottom of joist spaces often extend to the ends of the joists and, being under negative pressure, draw air in through gaps in the exterior sheathing because the insulation is very porous to air flow.

The factors which influence air-tightness are influenced by a variety of trades but none has the overall responsibility.

SOURCES OF AIR LEAKAGE

1. Window and Door Seals (1/3 of the total)

2. Openings for Plumbing and Wiring.

3. Gaps in Exterior Sheathing.

4. Porous Concrete or Cinder Block.

5. Chimneys, Fireplaces

Slide 12

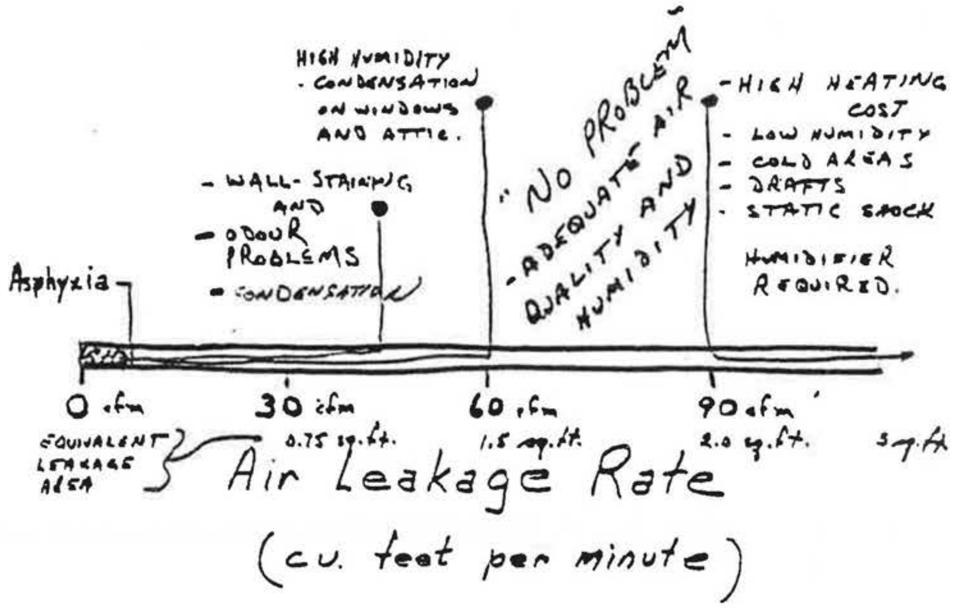
Slide 13

The cfm figures are theoretical requirements. The "equivalent leakage areas" are from Ontario Hydro's experience.

Mr. Stricker pointed out that this chart shows their general experience but there are always exceptions such as tight houses which experience high heating costs due to being located in high wind areas or due to condensation reducing the effectiveness of the insulation.

He feels that it is unlikely that it will be possible to build houses with less than 0.5 sq. ft. of equivalent leakage area.

The fresh air requirements of a household will vary with living habits. For instance, if the occupants are away from the house for most of the day, the average rate of fresh air supply could be much lower due to the storage effect of the house volume.




Correlation between Air Leakage, Leakage Area and ventilation problems

Slide 14

Mr. Stricker felt that, if a standard for air-tightness of houses were to be implemented, it should be expressed as equivalent leakage area since the fresh air needs of the occupants are independent of the house size in most cases. The only exception would be the case of intermittent occupancy in which case the fresh air storage of a larger house could be used.

Professor Besant pointed out that while the discussion so far had dealt with the need to keep humidity from getting too high in order to avoid condensation problems, some work by his colleague Professor Green and others suggests that it would be desirable, from a health point of view, to have humidity somewhat higher than we are accustomed to thinking of - say 40% to 50% RH. Mr. Stricker felt that although this may be desirable the challenge of building a house that could tolerate, say, 50% RH at -10°F could not be met by our present methods. He suggested that attempts to achieve such levels through the use of power humidifiers is already resulting in severe problems such as rotting roof structures, wet insulation or damaged ceilings.

STANDARD OF AIR-TIGHTNESS

- EQUIVALENT LEAKAGE AREA?

Floor Area/(House Volume)

- EQUIVALENT LEAKAGE AREA?

House Envelope Area

- CUBIC FT. PER MINUTE?

Sq. Ft. of House Envelope (at given pressure diff.)

- EQUIVALENT LEAKAGE AREA?

Slide 14

# APPENDIX D

## PIPES-WITHIN-A-PIPE HEAT EXCHANGER USED IN PROVIDENT HOUSE

S.G. Angus
Hooper & Angus Associates Ltd.
Consulting Engineers

Mr. Angus explained that heat recovery was desirable in Provident House for two reasons:

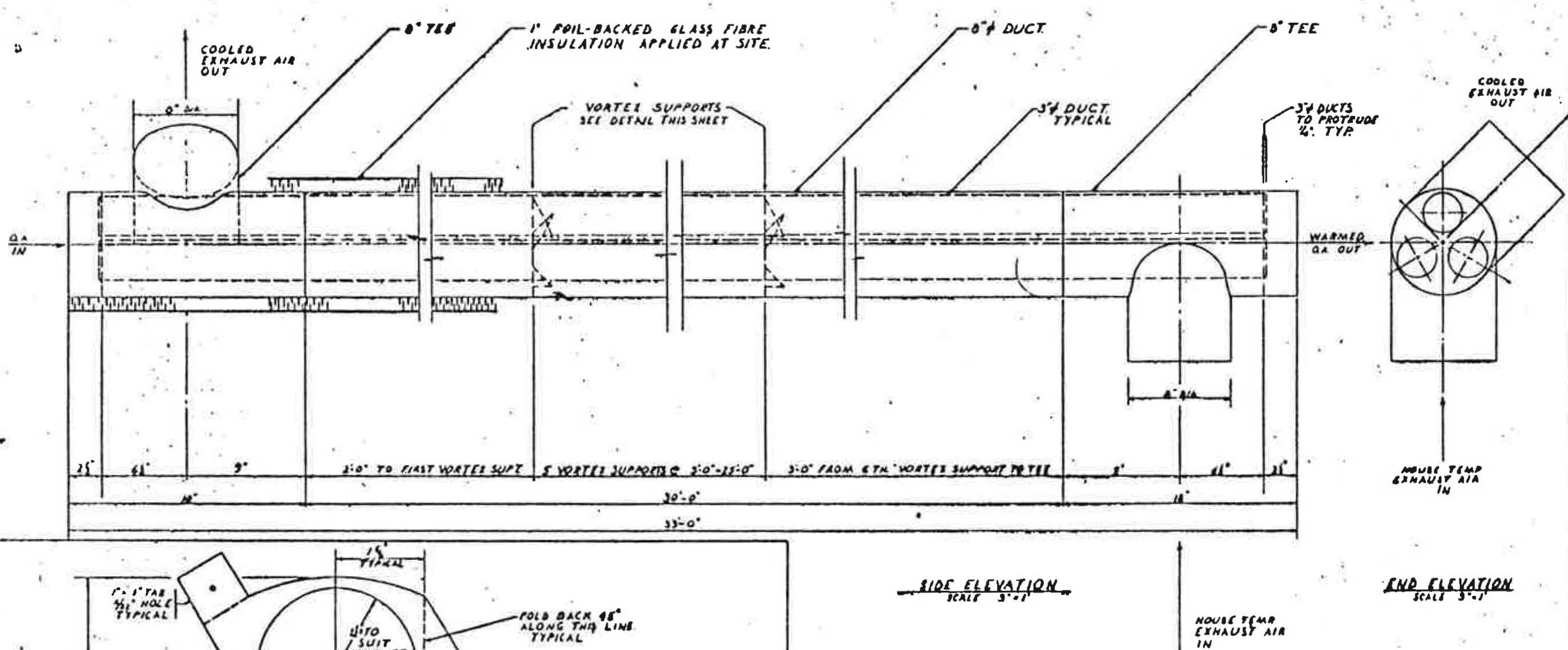
a) the house was expected to be very tight so a mechanical ventilation system was incorporated and

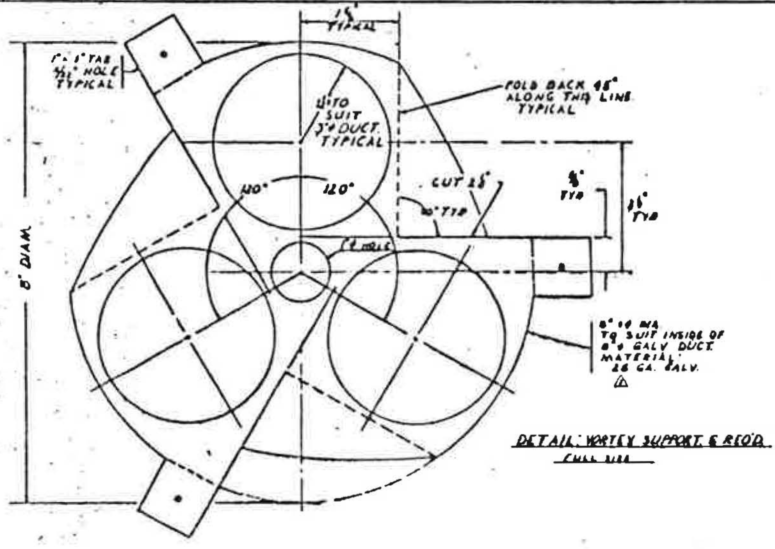
b) the cost of the solar system was so high that anything which would reduce its size would be worthwhile.

As nothing small enough was available commercially, his firm designed a heat exchanger that could be economically fabricated as a "one-off". It consists of three 3" galvanized steel ducts within an 8" galvanized steel duct. The 3" pipes carry the intake air and are supported, within the larger pipe, on sheet steel webs which also serve to create turbulent flow. The ducts can be assembled in any desired length. 33 ft. was used in Provident House and this gives a theoretical effectiveness of 60%. The unit was installed with a slight slope to allow condensation to drain out one end. The cost, not installed, was $250 at the end of 1976. Of this, $51 was for materials. The design has the disadvantage that it has to be taken completely apart to clean and thus is subject to decreasing effectiveness due to fouling of the heat exchanger surfaces. It is operated by the occupants. One switch turns on both the intake and exhaust fans which are quite inexpensive ($75 total) due to the small flows and pressures involved. The intake flow is designed to be 75% of the exhaust flow in order to draw a negative pressure in the house.

In fact it has not been possible to monitor the Provident House installation since the ventilation system is seldom used. This is because the fans are located in a place where their noise is annoying. Also, the building has not proved to be as tight as originally expected due to one major air leak which has yet to be sealed so it has not been necessary to use the system to control moisture.

Mr. Sulman observed that the cost of the heat exchanger itself was seldom very important compared to the final installed cost of the system and he suggested that if future houses were to include such systems they should be designed to minimize the cost by reducing the amount of ductwork.




DETAIL: VORTEX SUPPORT 6 REQ'D
FULL SIZE

NOTES:

MATERIAL

2 8" ϕ 28 GA. GALV. TEES
30' 8" ϕ 28 GA GALV. SNAP LOCK DUCT
100' ± 3" ϕ 30 GA GALV SNAP LOCK DUCT
6 26 GA GALV VORTEX SUPPORTS
2 26 GA GALV TUBE SHEETS.
SOLDER

FABRICATION:

VORTEX SUPPORT 6 REQ'D
CUT DISC
CUT & BEND FLAPS
MAKE HOLES
ASSEMBLE WITH DUCTS

TUBE SHEETS 2 REQ'D
CUT DISC 8" ϕ TO FIT IN 8" GALV. TEE
MAKE 3 3" ϕ HOLES AS
SOLDER TUBE SHEETS TO TEES ALL AROUND AIR TIGHT
SOLDER 3 3" ϕ TUBES TO TUBE SHEETS ALL AROUND AIR TIGHT WITH 3" ϕ TUBES PROTRUDING ⅛"

GENERAL
ASSEMBLE IN CONVENIENT LENGTHS FOR TRANSPORTATION & INSTALLATION.
INSULATE AT SITE AS SHOWN.
INSTALL SLOPED ½" IN 8'-0" DOWN TO O.A. INLET.
HANG FROM 2x3 PURLINS WITH STRAP HANGERS SPACED 8'-0"
TAPE ALL DUCT JOINTS WITH APPROVED DUCT TAPE

| REVISIONS | |
|---|---|
| JUNE 25/75 | ISSUED FOR PRICING |
| MAY 27/75 | ISSUED FOR CONSTRUCTION |
| △ AUG 5/75 | REVISED FOR CONST |

ENVIROGETICS Ltd.

ARCHITECT PLANNER
JOHN HIX

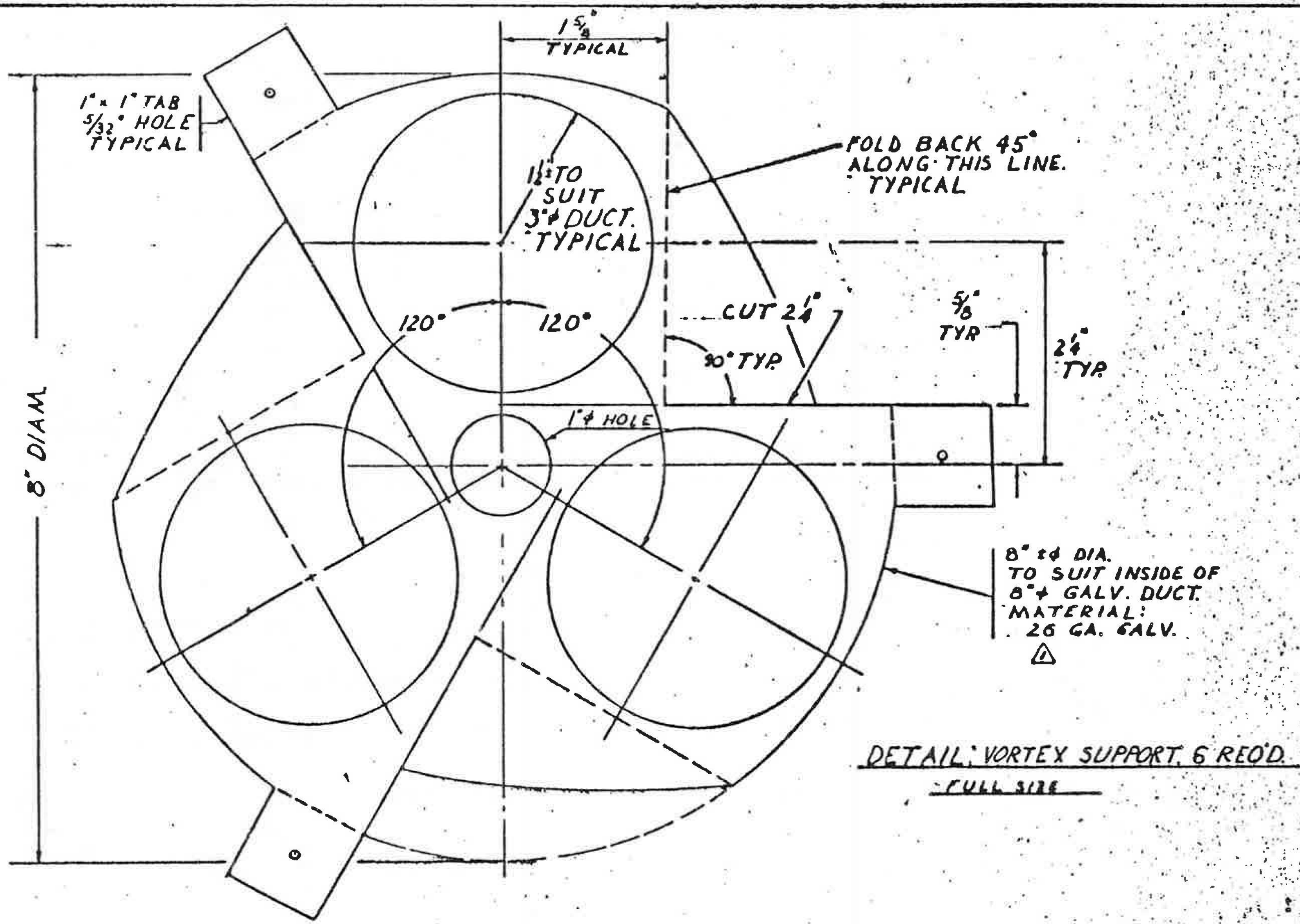
MECHANICAL ENGINEER
FRANK HOOPER

**Provident House**
KING TOWNSHIP
ONTARIO

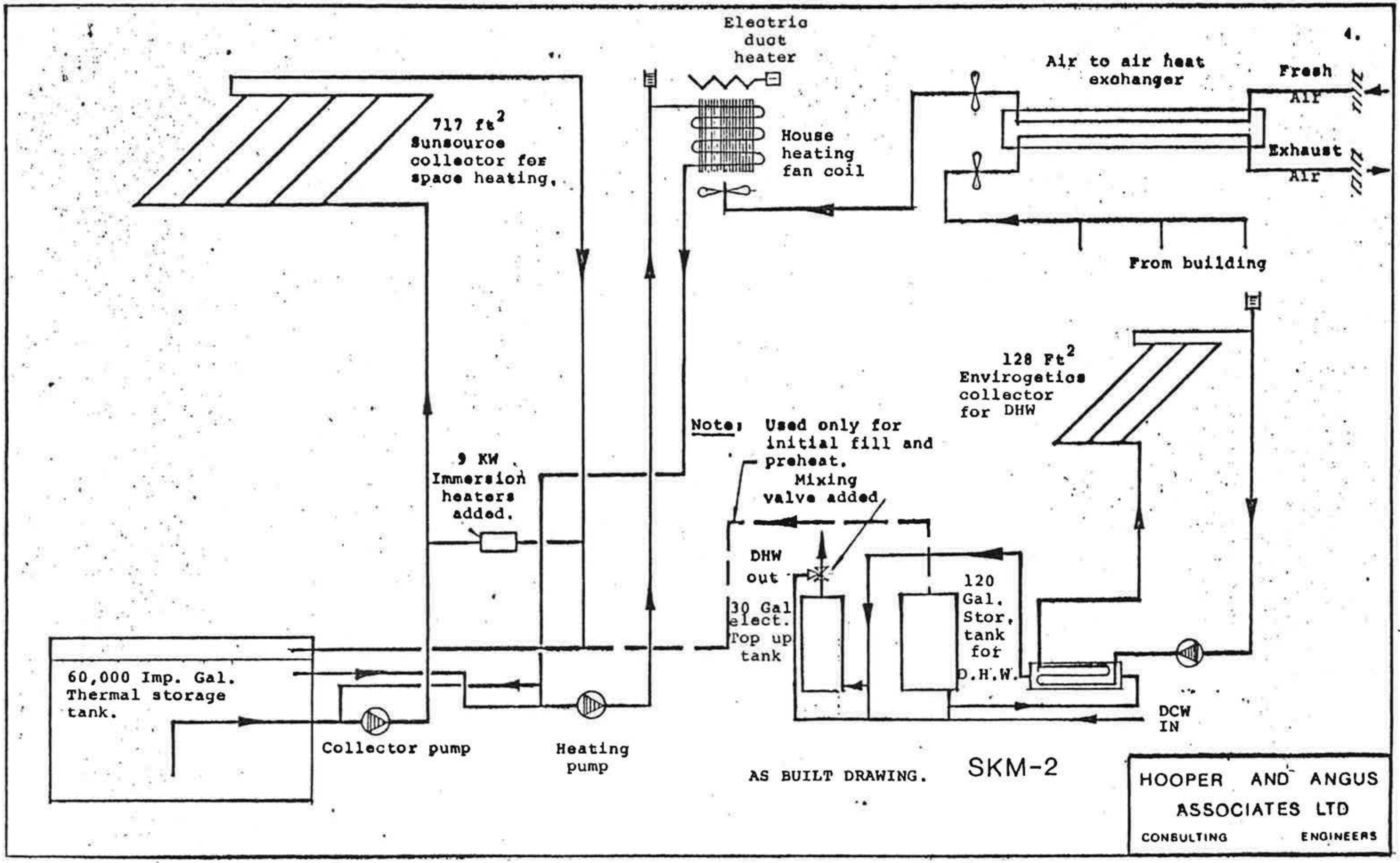
SHEET TITLE
HEAT RECLAIMER
FOR VENTILATION AIR

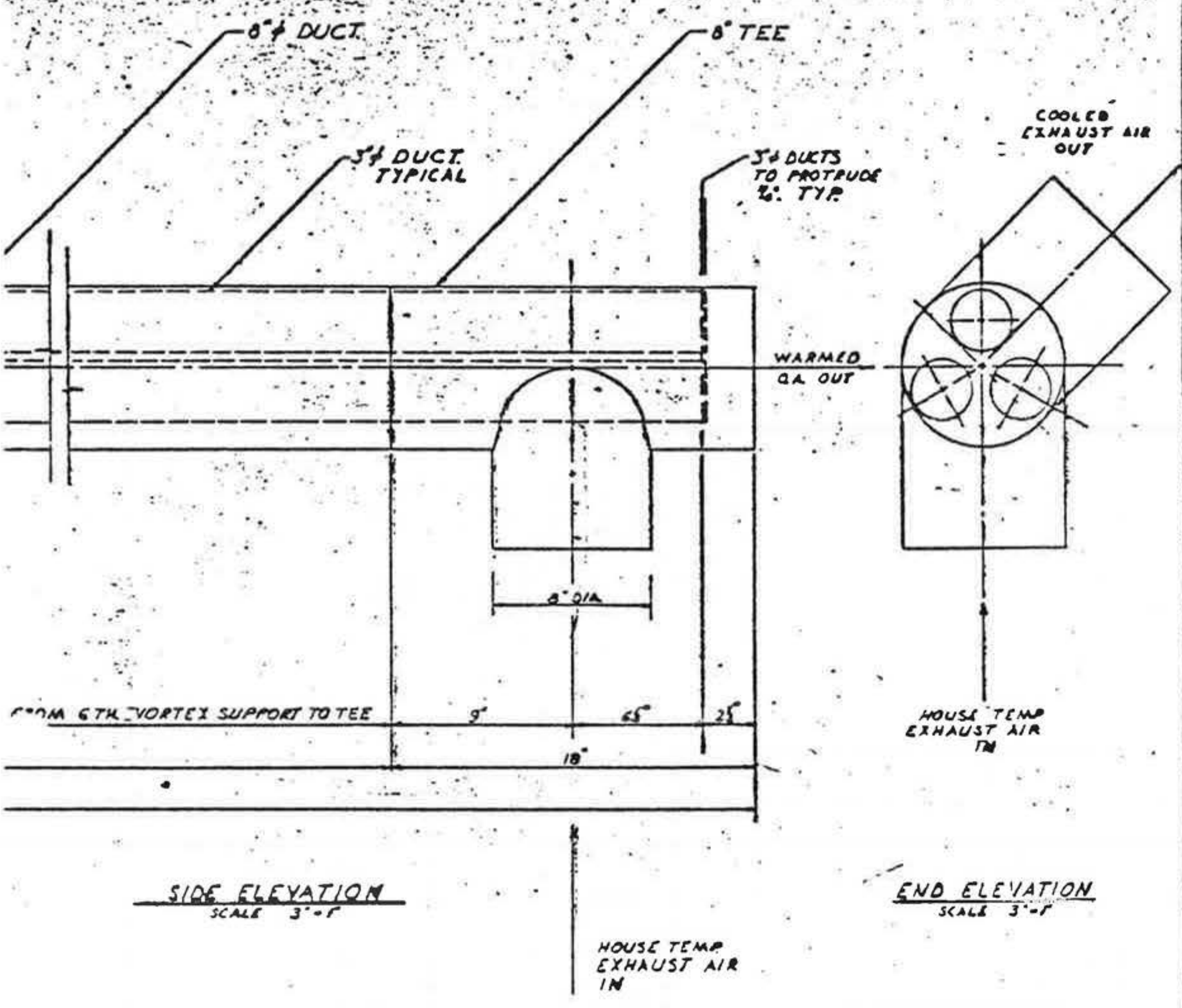
| DRAWN BY | CHECKED BY |
|---|---|
| J.V.I. | |

| SCALE | DRAWING NO |
|---|---|
| AS NOTED | M6 |
| PROJECT NO | |
| E-7501 | |




DETAIL: VORTEX SUPPORT, 6 REQ'D.
FULL SIZE


4.
Electric duct heater
Air to air heat exchanger
Fresh Air
Exhaust Air
717 ft2 Sunsource collector for space heating.
House heating fan coil
From building
128 Ft2 Envirogetics collector for DHW
Note: Used only for initial fill and preheat.
Mixing valve added
9 KW Immersion heaters added.
DHW out
30 Gal elect. Top up tank
120 Gal. Stor. tank for D.H.W.
60,000 Imp. Gal. Thermal storage tank.
Collector pump
Heating pump
DCW IN
AS BUILT DRAWING.
SKM-2
HOOPER AND ANGUS ASSOCIATES LTD
CONSULTING ENGINEERS




D-6

| REVISIONS | |
|---|---|
| JUNE 25/75 | ISSUED FOR PRICING |
| JULY 21/75 | ISSUED FOR CONSTRUCTI… |
| △ AUG 2/75 | REVISED FOR CONST |

F. C. HOOPER

J. HIX — ARCHITECT

ENVIROGETICS Ltd

ARCHITECT PLANNER
JOHN HIX

MECHANICAL ENGINEER
FRANK HOOPER

# Provident House

KING TOWNSHIP
ONTARIO

SHEET TITLE
## HEAT RECLAIMER
FOR VENTILATION AIR

DRAWN BY: J.V.I.
CHECKED BY:

SCALE: AS NOTED
PROJECT NO.: E-7501
DRAWING NO.: M6

…TES:

…ATERIAL: △
- 2 8"ϕ 28 GA. GALV. TEES
- 30' 8"ϕ 28 GA. GALV. SNAP LOCK DUCT
- 100' ± 3"ϕ 30 GA. GALV. SNAP LOCK DUCT
- 6 28 GA. GALV. VORTEX SUPPORTS.
- 2 26 GA. GALV. TUBE SHEETS.
- SOLDER

…ABRICATION:

VORTEX SUPPORT 6 REQ'D.
- CUT DISC
- CUT & BEND FLAPS
- MAKE HOLES
- ASSEMBLE WITH DUCTS

TUBE SHEETS 2 REQ'D.
- CUT DISC 8"±ϕ TO FIT IN 8" GALV. TEE
- MAKE 3 3"±ϕ HOLES AS
- SOLDER TUBE SHEETS TO TEES ALL AROUND AIR TIGHT
- SOLDER 3 3"ϕ TUBES TO TUBE SHEETS ALL AROUND AIR TIGHT WITH 3"ϕ TUBES PROTRUDING ¼".

…ENERAL
- …SSEMBLE IN CONVENIENT LENGTHS FOR TRANSPORTATION & INSTALLATION.
- INSULATE AT SITE AS SHOWN.
- INSTALL SLOPED 1½" IN 8'-0" DOWN TO O.A. INLET.
- HANG FROM 2"x2" PURLINS WITH STRAP HANGERS SPACED 5'-0".
- TAPE ALL DUCT JOINTS WITH APPROVED DUCT TAPE

# APPENDIX E

## TESTING AND ANALYSIS OF A HEAT WHEEL HEAT EXCHANGER

Dr. M. Shoukri
Ontario Hydro Research Division

E - 1 Dr. Shoukri's paper

E - 2 Discussion

# THE PERFORMANCE OF AIR-TO-AIR REGENERATIVE ROTARY HEAT EXCHANGERS FOR WASTE HEAT RECOVERY IN RESIDENTIAL VENTILATION SYSTEMS

by

M. Shoukri, Ph.D., P. Eng

and

N.S. D'Silva, P. Eng

Ontario Hydro Research Division
Toronto, Ontario

presented at the

CMHC Industry/Science Seminar on Controlled Ventilation with Exhaust Air Heat Recovery for Canadian Housing, Ottawa, 26 October 1978

# NOMENCLATURE

| | | |
|---|---|---|
| $A$ | - | heat transfer area on side designated by subscript, $ft^2$ ($m^2$) |
| $A_c$ | - | area available for longitudinal conduction on side designated by subscript, $ft^2$ ($m^2$) |
| $c$ | - | specific heat, $BTU/lb_m{}^\circ F$ ($kJ/kg^\circ C$) |
| $C$ | - | heat capacity rate of fluid = $\dot{m}c_p$, BTU/hr (W) |
| $C_r$ | - | heat capacity rate of rotor = 60 $m_r c_r N$, BTU/hr (W) |
| $h$ | - | heat transfer coefficient, BTU/hr $ft^2{}^\circ F$ ($W/m^2{}^\circ C$) |
| $k$ | - | thermal conductivity of the rotor material, BTU/hr ft °F (W/m°C) |
| $\dot{m}$ | - | mass flow rate of fluid, $lb_m$/hr (kg/h) |
| $m_r$ | - | rotor mass, $lb_m$ (kg) |
| $N$ | - | rotor speed, rpm |
| $NTU_o$ | - | overall number of transfer units |
| $Q$ | - | Ventilation air volumetric flow rate, $ft^3$/min ($m^3$/s) |
| $T$ | - | air temperature, °F (°C) |
| $W_\ell$ | - | leakage rate, ($ft^3$/min) ($m^3$/sec) |
| $W_{c.o.}$ | - | carryover rate, $ft^3$/min ($m^3$/sec) |

## Subscripts

| | | |
|---|---|---|
| i | - | inlet |
| o | - | outlet |
| e | - | exhaust |
| s | - | supply |

## 1. INTRODUCTION

With the increased cost of energy supply, considerable efforts have been directed towards energy conservation. Conservation houses are intended to be nearly air-tight to cut down on different sources of energy losses. This development will increase the need for forced mechanical ventilation systems to be provided in future homes. In such ventilation processes, air at room temperature is exhausted to the outside and replaced by cold or hot air (depending on the season) which ought to be heated or cooled to the room temperature respectively. The energy losses associated with these processes are considerable and tend to make air-tight homes less economical to operate.

However, some of this loss, hopefully most of it, can be reclaimed by providing an efficient heat exchange between the exhausted and intake air. The air-to-air regenerative botany heat exchanger, which is sometimes referred to as "thermal wheel" can be used effectively for this purpose. It has two main advantages over other types of heat exchangers, namely, compactness and high effectiveness.

As shown in Figure 1, the thermal wheel consists of a cylindrical rotor packed with an air permeable media having a large surface area that is exposed to the air streams and transfers it to the cool one. The rotation of the wheel provides a flow of energy from the hot to the cold air streams. Although the design and performance of regenerative rotary heat exchangers is, more or less, well established for large industrial applications, small units to handle residential ventilation rates are lacking.

The development of a small air-to-air rotary heat exchanger for residential applications was undertaken by the Mechanical Research Department of Ontario Hydro. Our contribution is limited to the demonstration of the principle and evaluation of its potential use for residential applications. So far, the study included the construction and testing of a prototype heat exchanger as well as the formulation of a numerical model to predict of the performance of regenerative rotary heat exchangers which proved to be very useful in optimizing future designs of this type of heat exchangers.

## 2. THE PROTOTYPE HEAT EXCHANGER

### 2.1 Construction

The rotor was constructed of 26 gauge utility grade aluminum sheet (0.4 mm thick). The aluminum sheet was corrugated by passing it between two crimping rolls. The head of a horizontal milling machine was used to turn the rolls as shown in Figure 2. As the required length of corrugated sheet was produced, the lower crimping roll was replaced by a smooth one. Two layers of the sheet metal, a corrugated one and a flat one, were passed through and tightly coiled on a 16 mm steel shaft to form the rotor. The rotor was mounted in a reinforced aluminum frame which was divided into two separate sections as shown in Figure 3. A chain and sprocket arrangement was used to rotate the wheel in the range 3 - 12 rpm by changing the geer ratio. Reinforced rubber seals were used to reduce the leakage from one stream to the other. The final dimensions of the rotor were 400 mm in diameter and 300 mm in length.

## 2.2 Performance Tests

The performance tests of the prototype were carried out in the winter season using the experimental set up shown in Figure 4. Outside air was drawn through duct 1 and room air was drawn through duct 3. This arrangement closely simulated winter operation in a residential installation. The simulated home conditions ie, duct 3, were controlled using a heater and humidifier. Temperature and flow measurements were carried out in the locations specified in Figure 4.

The experimental data are presented in terms of five dimensionless groups usually used to describe the performance of regenerative heat exchangers which are listed in Table I.

Figure 5 demonstrates the increase of sensible heat recovery rate with increasing ventilation rate and the initial temperature difference between the supply and exhaust ducts. By converting the heat recovery data into effectiveness data, as shown in Figure 6, the effectiveness is shown to decrease slightly with increasing ventilation rate, within the tested range, and to be independent of the initial temperature difference. The average effectiveness was in the order of 73%.

The effect of unequal mass flow rates in the supply and exhaust ducts is also demonstrated in Figure 7 where decreasing the parameter Cmin/Cmax resulted in increasing effectiveness. So far as the effect of rotational speed is concerned, it was expected that an increase in the rotor speed would lead to higher effectiveness. However, when tests were carried out in the range of 3 - 12 rpm, no significant difference in effectiveness was observed apparently because the rotor heat capacity was too high due to its large mass. A quantitative explanation of this point will be shown later.

One of the important considerations in designing and operating rotaty heat exchangers, is the air leakage and carry over from one duct to the other. Figure 8 shows a schematic of the leakage paths in the thermal wheel. Leakage at the rotor face across the seals is a function of the pressure difference between the two ducts and can be reduced by minimizing this pressure difference and by the use of proper seal. However, in situations where leakage from the exhaust duct to the supply duct cannot be tolerated, the supply duct should intentionally be kept at slightly higher pressure than the exhaut one. Carry over is the air which is entrapped in the rotor passages as it rotates from one duct to the other. Carry over rate is easily predicted as the product of the void volume times the rotational speed. Tracer gas analysis technique was used to assess both leakage and carry over in the prototype. The results are shown in Figures 9 and 10. Details of the construction and performance data of the prototype heat exchanger were included in reference/1/.

Although the exercise of constructing and testing the prototype rotary heat exchanger showed good potential. Two problems were noticeable:

1. The 73% effectiveness observed was less than the expected effectiveness based on the design procedures specified in different heat exchanger handbooks/2,3/.

2. The total weight of the rotor was about 30 kg which may be undesirable for the use in residential applications.

## 3. THE NUMERICAL MODEL

In order to better understand the interaction between the different design parameters so that our design can be optimized, a numerical model was formulated in which the governing differential equations for the heat transfer between the rotor matrix and the air streams were solved using a finite difference scheme similar to that presented in/4/. However, the effect of heat conduction in the rotor material in the longitudinal direction, parallel to the flow direction, was included in the formulation which was neglected in/4/. Details of the numerical model were presented in/5/.

The results demonstrated that the longitudinal heat conduction is an important parameter and that a conduction parameter defined as:

$$\lambda = \frac{kAsc}{C_s} \left[ 1 + \frac{Aec}{Asc} \right]$$

should be included into the list presented in Table I. Some of the results of the numerical model as related to the prototype performance are shown in Figures 11 and 12.

The effect of longitudinal heat conduction is shown in Figure 11 which shows the predicted effectiveness when the longitudinal conduction is neglected ( $\lambda$ = o) as compared to the case when $\lambda = 0.2$. By using the value of 0.2 for the conduction parameter, which corresponds to the prototype condition for flow rate of 0.04 $m^3/s$ (85 cfm), the effectiveness is much lower than that obtained by neglecting the conduction effects. This explains why the prototype showed a lower effectiveness than the designed value.

The effect of the rotor heat capacity is shown in Figure 12. It is clear that increasing the rotor capacity Cr results in higher effectiveness up to a value of 5 for the parameter Cr/Cmin beyond which no significant improvement is achievable. Since Cr is proportional to the product of the rotor mass and its rotational speed, and since the prototype was operated beyond this critical ratio, no significant effect of changing the rotor speed was observed.

## 4. CLOSURE

The results of this work were used to design a new rotary heat exchanger using a honeycomb structure made of foil papers having a thickness of 1/10 of the metal sheet used for the prototype. This will result in a much lighter heat exchanger. The reduction in the area available for longitudinal conduction will result in higher effectiveness while the reduction of the rotor capacity should not affect the effectiveness significantly as long as the ratio Cr/Cmin is properly chosen as shown earlier.

The numerical model was used to optimize the new heat exchanger design for ventilation rates of 0.02 - 0.045 $m^3/sec$ (50-100 scfm). The final specifications were:

Rotor diameter = 40 cm
Rotor length = 18 cm
Total weight = 5 kg
Average effectiveness = 85%

Performance tests are currently carried out for this heat exchanger. It will be installed in a HUDAC conservation house No 2 in Ottawa in the near future so that field experience could be also established.

## ACKNOWLEDGEMENTS

To Dr. T. Ellis for his involvement in the early stages of this work.

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TABLE I

$\eta = F(C_{min}/C_{max},\ C_r/C_{min},\ NTU_o)$

$$\text{EFFECTIVENESS} = \eta = \frac{(\dot{m}C_p)_s(\Delta T)\ \text{ACROSS THE WHEEL IN THE SUPPLY DUCT}}{(\dot{m}C_p)_{min}\ (\Delta T)\ \text{SUPPLY AND EXHAUST INLETS IN THE WHEEL}}$$

$$\frac{C_{min}}{C_{max}} = \frac{(\dot{m}C_p)_{min}}{(\dot{m}C_p)_{max}} = \text{CAPACITY RATE RATIO OF THE TWO STREAMS}$$

$$\frac{C_r}{C_{min}} = \frac{m_r C_{pr}\ N}{(\dot{m}C_p)_{min}} = \text{CAPACITY RATE RATIO OF THE ROTOR MATRIX TO THE MINIMUM FLUID}$$

$$NTU_o = \frac{(hA)_s}{C_{min}} \left[\frac{1}{1 + (hA)^*}\right] = \text{OVERALL NUMBER OF TRANSFER UNITS}$$

$$(hA)^* = \frac{(hA)_s}{(hA)_e} = \text{CONDUCTANCE RATES}$$

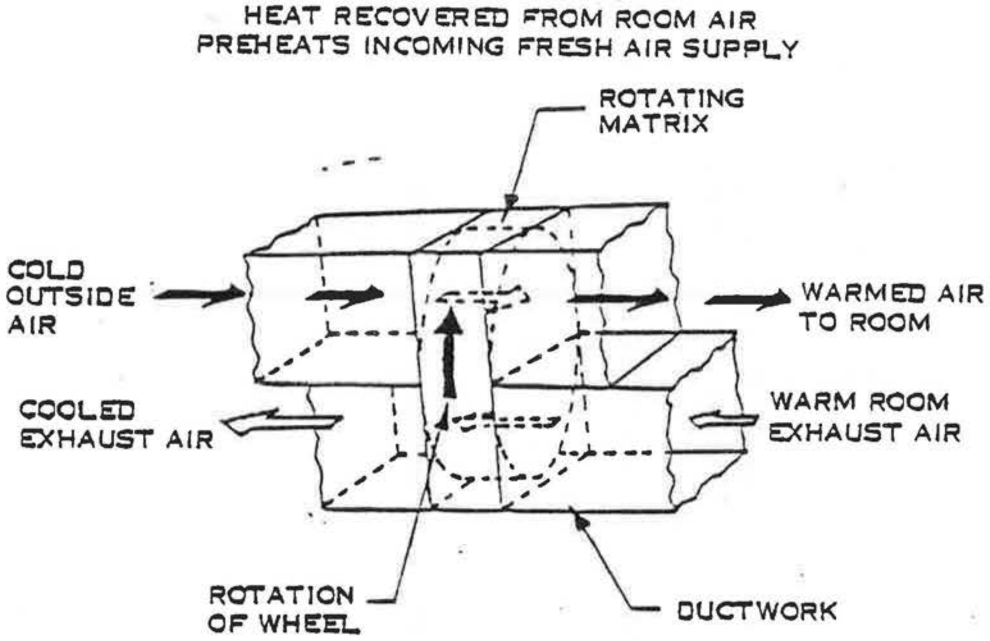



FIGURE I

OPERATION OF THE THERMAL WHEEL

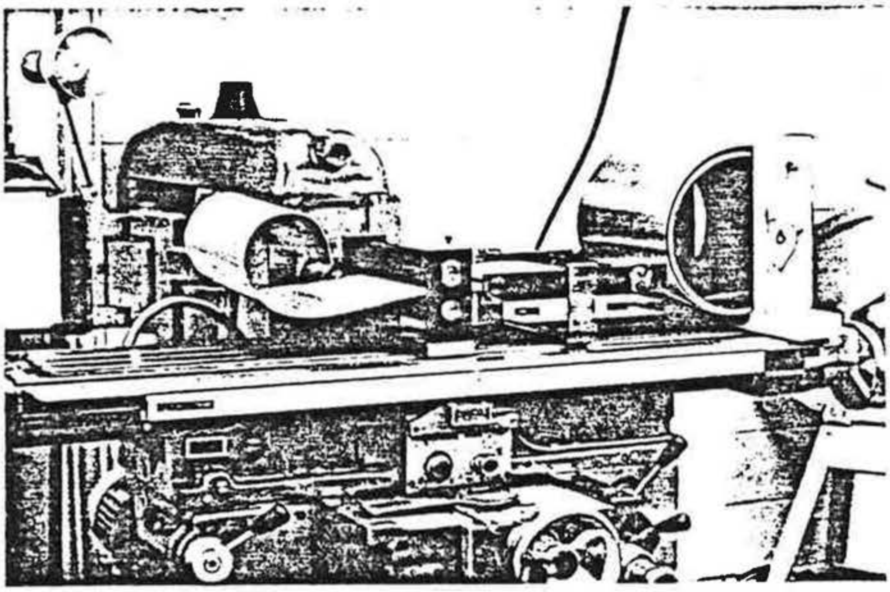
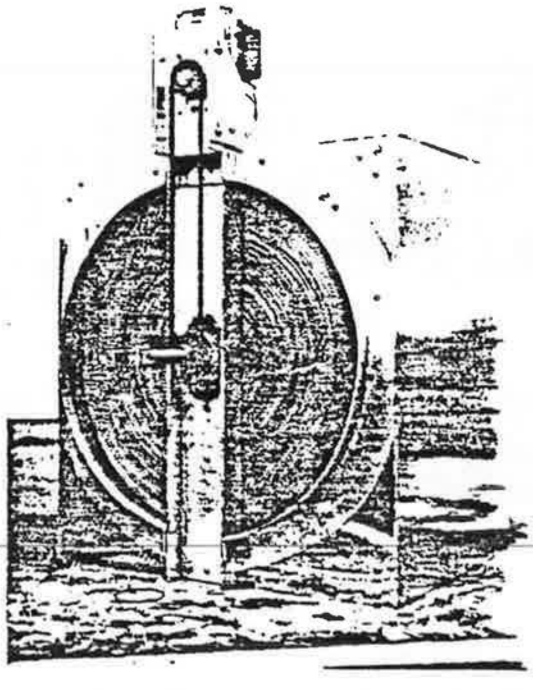


FIGURE 2
PRODUCING THE CORRUGATED SHEET METAL



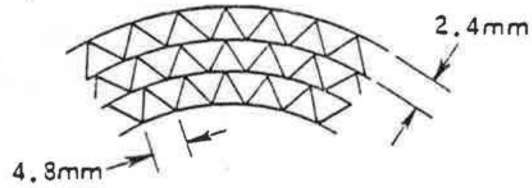



FIGURE 3
THE ROTOR AND ITS DRIVE

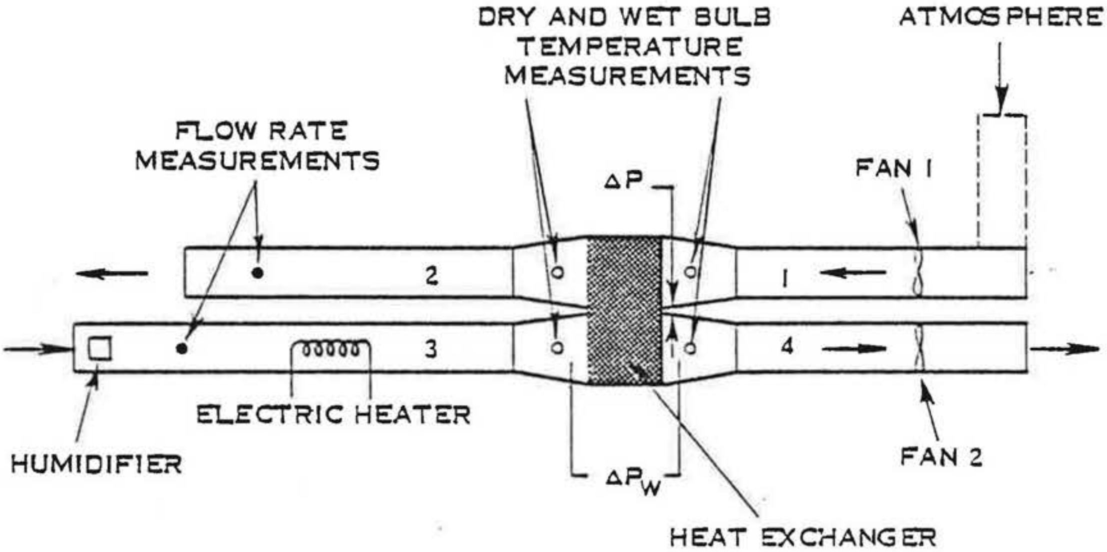



FIGURE 4

SCHEMATIC DIAGRAM OF THE TEST ARRANGEMENT

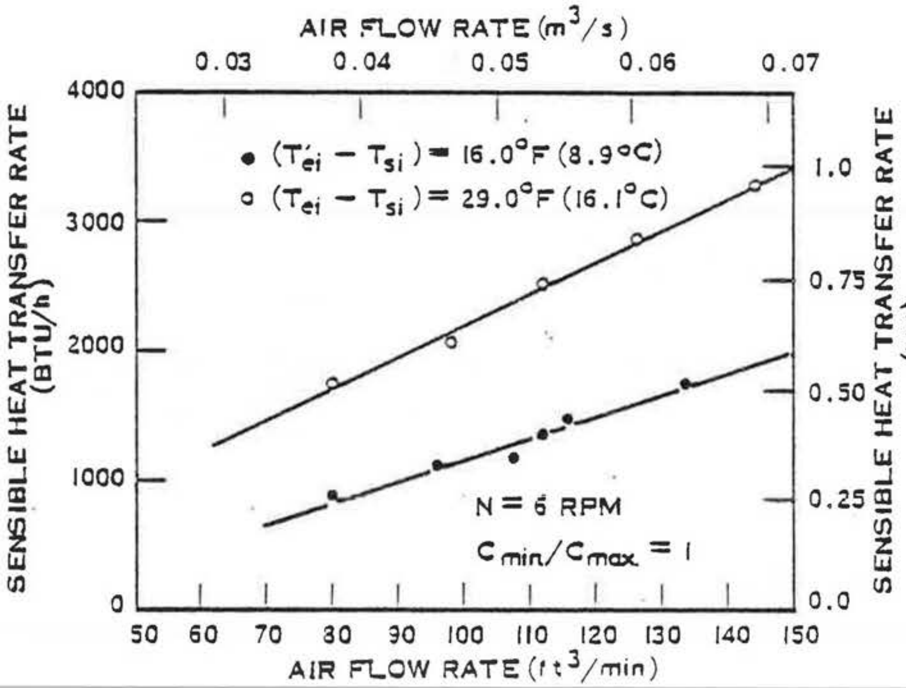



FIGURE 5

THE EFFECT OF THE AIR FLOW RATE AND
AVAILABLE TEMPERATURE DIFFERENCE
ON THE HEAT TRANSFER RATE

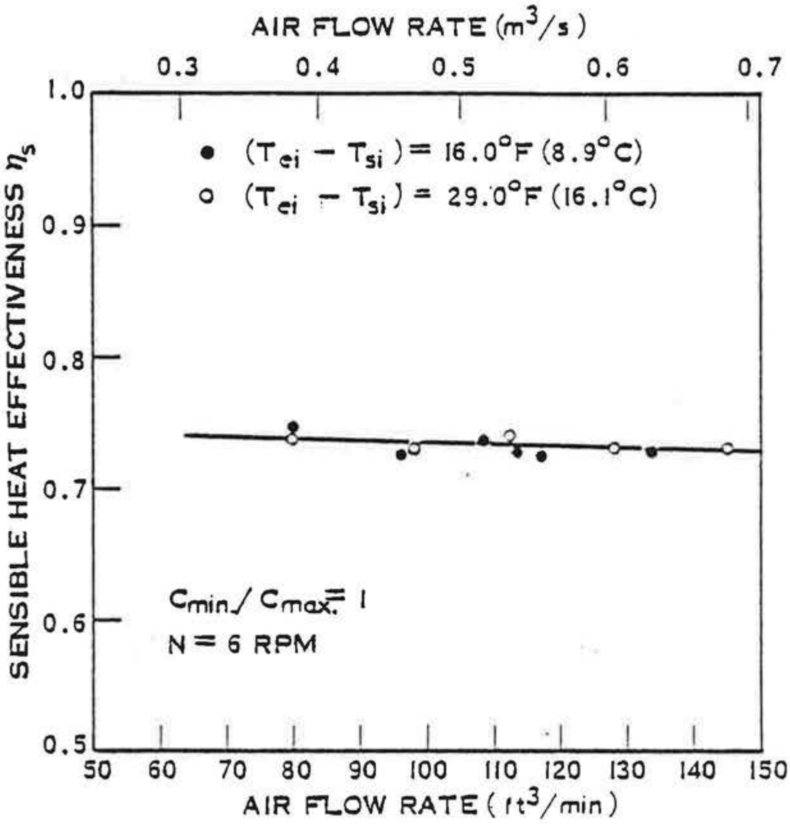



FIGURE 6

THE EFFECT OF THE AIR FLOW RATE
ON THE HEAT EXCHANGER EFFECTIVENESS

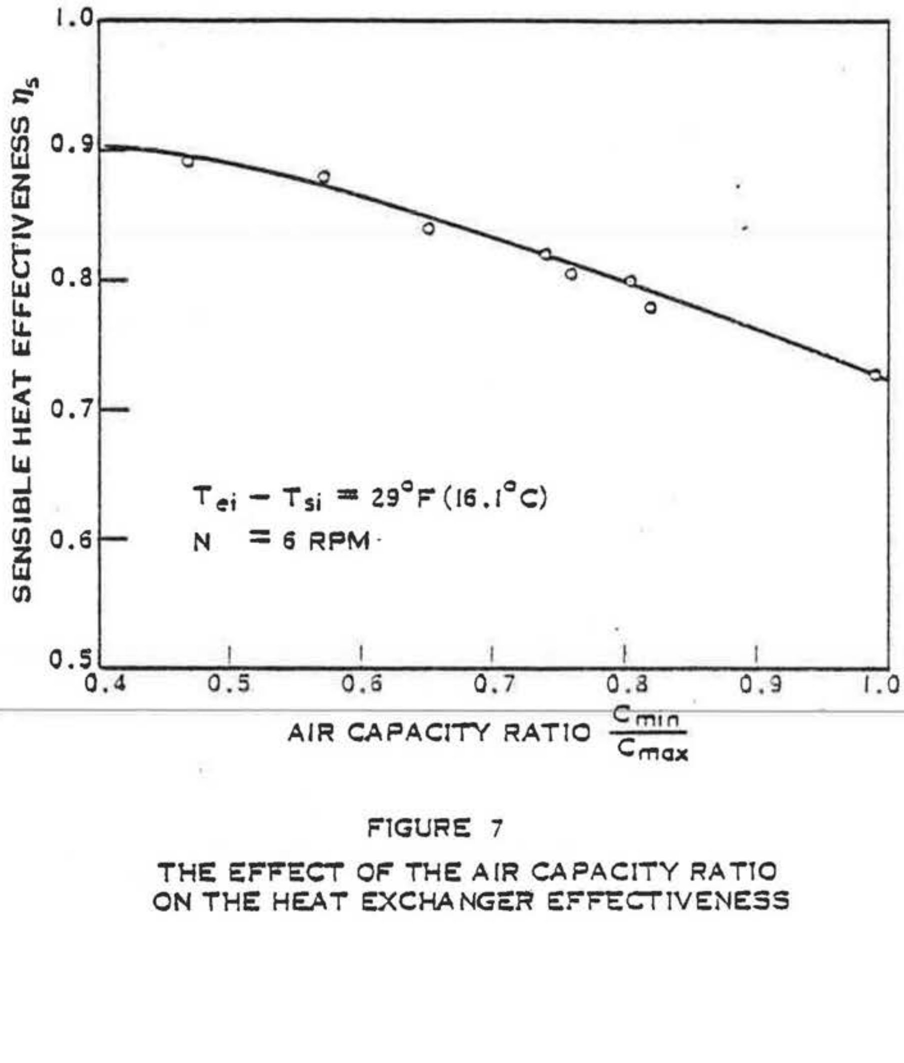



FIGURE 7

THE EFFECT OF THE AIR CAPACITY RATIO ON THE HEAT EXCHANGER EFFECTIVENESS

(EXHAUST DUCT IS KEPT AT A LOWER STATIC PRESSURE THAN SUPPLY DUCT)

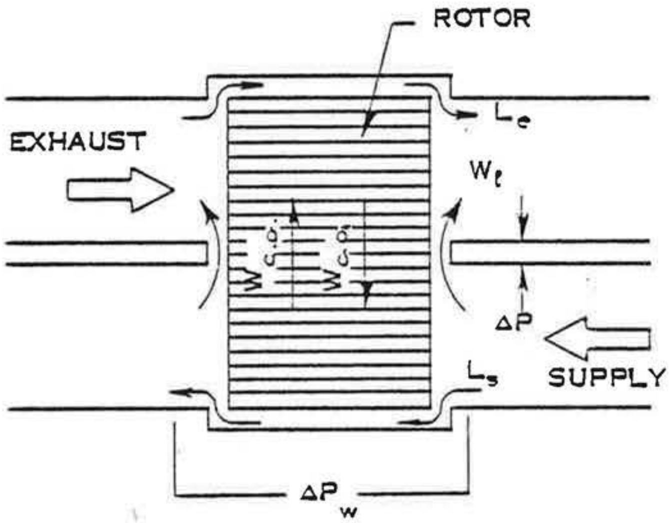



FIGURE 8

LEAKAGE AND CARRY—OVER IN ROTARY HEAT EXCHANGERS

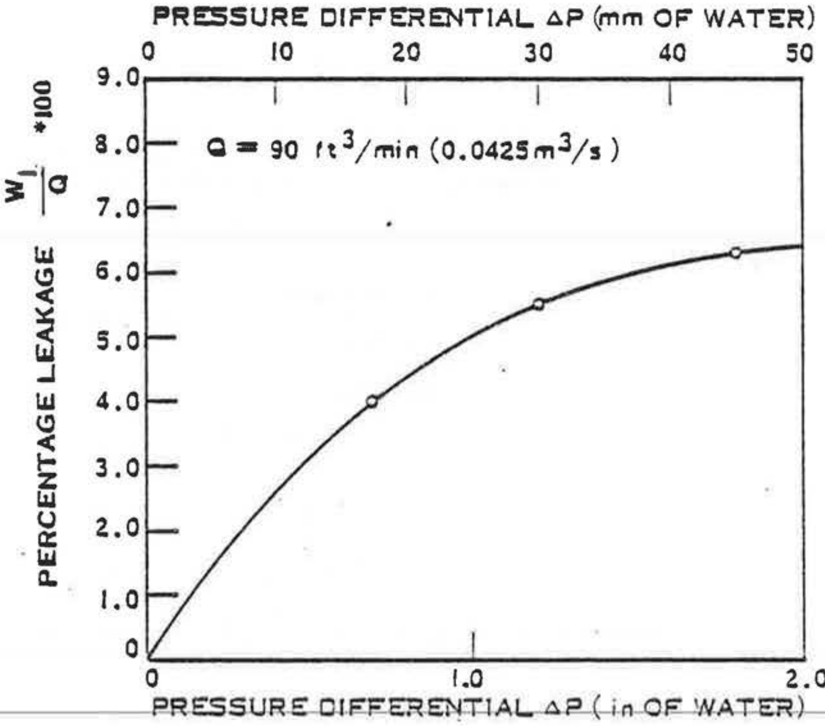



FIGURE 9

LEAKAGE RATES AS A FUNCTION OF THE PRESSURE DIFFERENCE BETWEEN THE TWO DUCTS

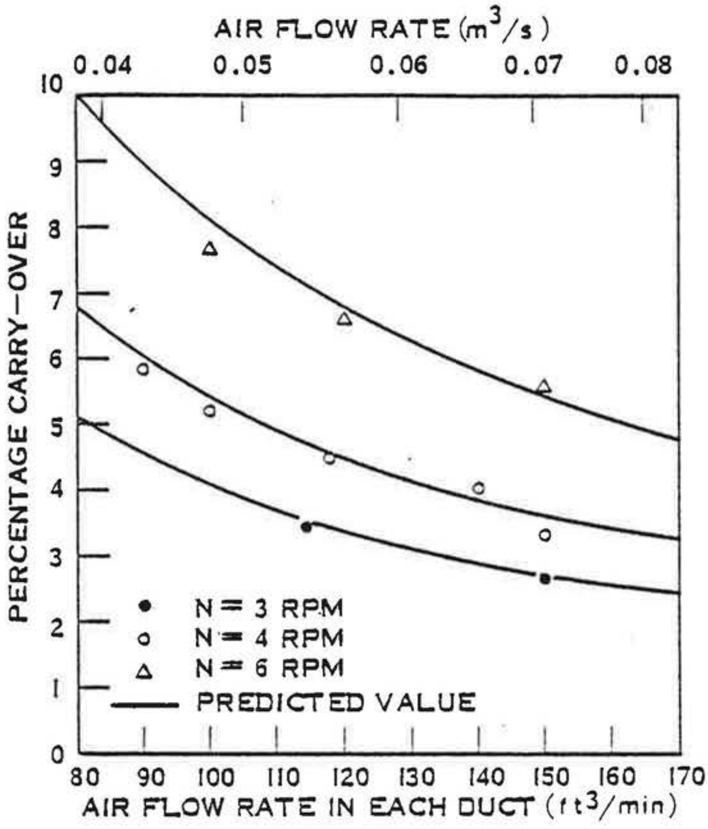



FIGURE 10

CARRY—OVER RATES IN THE TESTED WHEEL

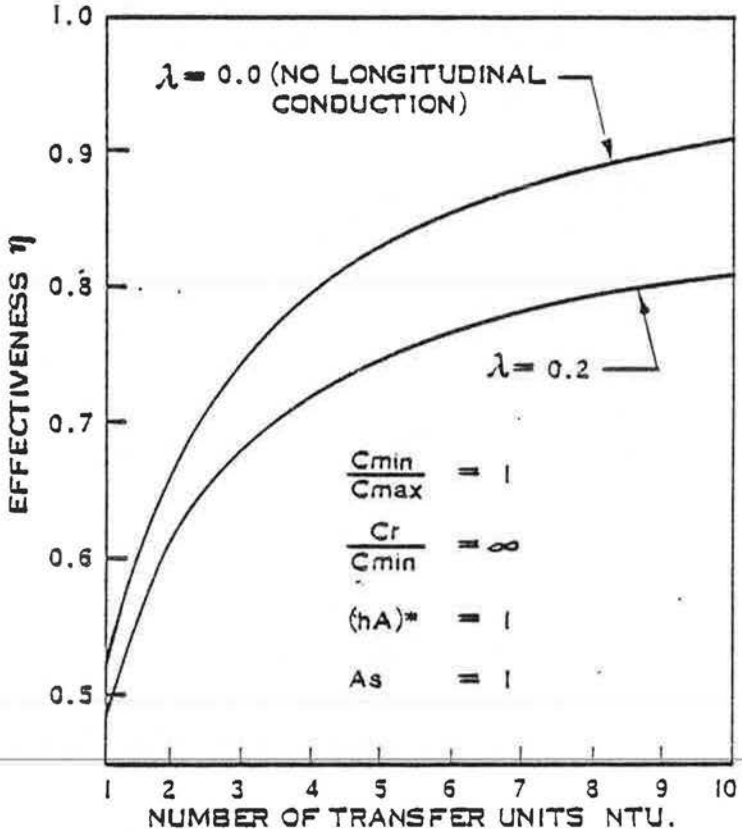



FIGURE II

THE EFFECT OF LONGITUDINAL CONDUCTION

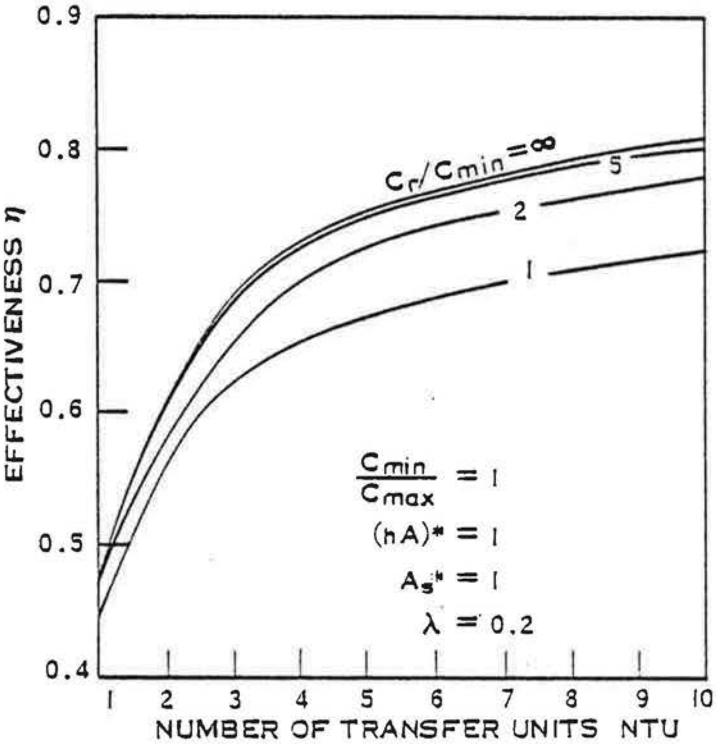



FIGURE 12

THE EFFECT OF $C_r/C_{min}$ ON THE ROTARY HEAT EXCHANGER EFFECTIVENESS

E - 2 DISCUSSION

Dr. Shoukri passed around a sample of aluminum foil honeycomb similar to the type which they planned to use in their second prototype. There was discussion regarding the possible difficulty in cleaning the small cells of the honeycomb. The wheel is intended to be demountable and weigh about 10 lb. It could be removed and washed in the laundry tub but it is unlikely that it would be cheap enough to be considered disposable.

Dr. Shoukri was not prepared to predict the cost of this design although he didn't think it would be very expensive.

He expected the second prototype to produce a pressure drop along its length of 0.15 in. of water and have a face velocity of 300 ft./min. at a flow of 50 standard cfm. The first prototype produced a pressure drop of 0.4 in. of water. The second prototype is designed to operate at a rotational speed of 6 R.P.M.

# APPENDIX F

## A SIMPLE PLATE TYPE HEAT EXCHANGER

Prof. R.W. Besant
Department of Mechanical Engineering
University of Saskatchewan

Professor Besant did not use prepared notes but showed a number of 35 mm slides and spoke to these. Although it has not been possible to reproduce the slides his words have been transcribed fairly faithfully and are generally sufficiently descriptive to be understandable without the slides. He has provided copies of some of the graphs shown in the slides and these are reproduced here.

Gentlemen I want to get back to more mundane things. I brought along a piece out of our local real estate journal that is sent out to all of the house owners in Saskatchewan. It says your home must breathe, implying that maybe we have large holes in the house, or maybe the walls of the house oscillate in and out, and it goes on... "If you have vapour problems and condensation on your windows, simply open the window and let it out. It costs nothing." Gentlemen, I think we have a very large problem on our hands, in terms of communication. And if there is a problem associated with where we are going today in heat recovery, it is the communication problem. People just don't know. There is an enormous amount of mis-information out there, and I think that it will take a period of years before the public can be made more aware of the problems and before the industry can put together the kind of units that are really going to be useful.

I thought I would show a few slides illustrating kinds of problems that people run into. Here we tested out a brand new window in our cold room test cell. It was a triple-pane window. Mind you, we had it rather chilly on one side and room temperature on the other, about 35 below 0 on the cold side and the warm side was room temperature and normal room humidity. This is a picture of the window about 2 1/2 hours after we had the test underway. Inside of a day you couldn't see out of that window, it was that frosted up. And we hadn't gone out of our way to pressure this thing up so that we had a flow through the window. Windows leak. But probably more serious is the problem of what happens in attics. This is a picture taken by Harold Orr. I think it was built in Manitoba. Possibly John Hockman would recognize the environment as undoubtedly he has seen it many times. If one does the simple calculation as to how much water vapour is generated in the house over the winter, you will soon come to a conclusion that you are looking at something like a ton of water. Now if 20% of this lands up in your roof, because that is the way it escapes, you have got a lot of water up there. Here we have a piece of plumbing coming out through the roof and we can see that we have some very serious problems with the vapour barrier or whenever somebody tries to go through with a piece of plumbing or something like that. We can see that they've resorted to all sorts of gimmicks to try and block off the leaks but been totally unsuccessful. If one does the calculation of how fast the air will leak out of a house through a crack even, it is really quite surprising. Just for example, on a crack with a 2 Pa of pressure difference which is about 1 mm thick we will be looking at about 20 cfm going through that crack, if the crack is of the order of 10 m long. Now a 10 m long crack is not unusual in housing, that kind of crack occurs along the baseboards, along the main beam of the house, around the foundation, it is really quite common. If one were to increase the size of that crack by a factor of 2 we'd be looking at a crack flow rate of 150. In other words 8 times as much flow through that. So what sort of pressure differences are we looking at in houses? If we were to say let's look at a 40° temperature difference, then possibly we have a pressure difference of about 7 Pa in 15' of height whereas if it were to go to a 60° difference then it would increase proportionately. The surprising thing is that the wind is probably even more important. Although I quoted figures on a small crack, we can see that with wind we may be looking up to 40 Pa of pressure difference in a 20 m/hour wind or 30 km/hour wind. It is a pretty shocking pressure difference that could be created across a crack in the window, or door. When you integrate this over the entire winter, that is when you get the problem, not when someone opens or close the door. Opening and closing doors is not very important. It is the continuous leaks that are important. Then we see some other attempts to seal off cracks and what we find is that the installers like to stuff in fibreglass batts to fill in the holes and they make wonderful filters. We have known this for years, we have used fibreglass as furnace filters for years, and yet they think somehow they're going to make good leak preventors - they don't. This is a ceiling fan, and we can see that we got a little bit of a problem here with an electrically heated house and we put a ceiling fan in to try to vent this off into the attic. The best thing is to put a bucket up to catch the water. I think these houses are shocking situations and probably are somewhat the extreme because they represent a very severe environment, not an Ottawa or Toronto environment but a prairie and northern prairie environment. It is a difficult environment but the main part of it is the evidence is so clear. It collects over the winter. In other houses it doesn't collect over the winter, but I suspect we have somewhat the same kind of problems. We can see what happens to the installer of a vapour barrier when he comes to handling a pipe - he just doesn't bother closing it off at all. What may I ask would be the result of the electrician coming in with this kind of wiring - a catastrophe, if it isn't a structural one. A typical thing would be somebody going through the wall with a pipe and trying to seal it off in this manner. There is nothing to back up the sealing compound and get a proper seal. More serious of course is the problem of the accumlated rot that has been mentioned this morning. In the extreme of course it destroys the walls and possibly even more seriously is this picture of the CN Tower in Saskatoon where we had a couple of pieces of siding fall down that weighted 1/2 a ton. Fortunately no one was injured or killed, but when we look back to where was the problem, it was in the vapour barrier. So I think that I just tried to create the kind of background as to what we are faced with in terms of building structures, and air tightness of building structures. For housing it is obviously a large problem. Our tests have suggested that there are very few houses that are very air tight.

We were interested in developing the heat exchanger. Our purpose was to come up with a heat exchanger that could fit into the economic framework that was suggested this morning. That is we don't have a lot of dollars to play with and still come on to the market and be cost effective. One of the main problems was the cost of materials. The more I worried about the cost of materials and the reliability of the system, the more it seems to play towards plastics, and in particular to polyethylene. So we have decided to go with a heat exchanger of the type that I just showed you there. It was a well insulated box, and that was our first test vehicle. It was tested in a cold chamber where we could maintain well below freezing temperatures on one side and room air on the other side and the relative humidity was around 30% - 35% range on the warm side. It is simply a counterflow heat exchanger. Here is a picture of one being made, here we are using a plywood as a frame and polyethylene sheets for the heat transfer material. One would wonder if plastic is a very good heat transfer material. The answer is that the main resistance to heat transfer, in such heat exchangers, is in the air itself, not in the materials of the heat exchanger. So using this technique we build up any number of layers and test it out inside the heat exchanger under freezing conditions to see what sort of problems we run into with condensati;on defrosting. This is looking up inside the heat exchanger. We see water in there and see frost up the sides. And if we carried out the test even longer, it really got pretty frosty in there. The question is if we are going to operate it in this fashion, are we not going to experience significant losses in performance. Of course, we are going to fall off in performance. Here I present a graph, in terms of the temperature ratio, that is the warming effect on the incoming air versus the temperature difference between the inside and outside versus the number of transfer units (Figure 1). Here we have the performance as a function of the air speed in the heat exchanger, we can see that as we push more and more air through it (Figure 2), of course the performance is going to fall off. And if we push it hard enough then the conductivity of the heat transfer surface itself is going to start to play a more important role. So we were looking for high performance and not low performance because if we wanted to get anything out of this we felt that we had to go after a high performing type of heat exchanger. It is in the very coldest part of the winter that one is most interested in the heat recovery business. When the temperatures are modest outside, a well insulated building simply doesn't need to recover heat. It is probably dumping energy, excess energy that it must dump in order to maintain a reasonable temperature. What we found of course is that the performance was very, very sensitive to which way we had this thing orientated.

If you turned this thing upside down, you couldn't possibly come up with this kind of performance. In fact the maximum performance we experienced, working against gravity, with this type of heat exchanger was about 50% - 55%. So it is very important that one works with gravity if you are going to maintain high efficiency. Now that doesn't say that the efficiency or the heat transfer mechanism is enhanced per se but simply the air doesn't do an end run on you. Because if you let the air do an end run, it will. By working such that when the air is being cooled it is flowing down and when it is warmed it flows up, gravity is working with you. Only that air which is being warmed when it is going up will tend to move up, and only that air which is being cooled will move down and the air which hasn't will tend not to. We don't have the cellular, three dimensional kind of structures developing in the flow pattern. Here we have the performance of the heat exchanger as a function of time (Figure 3). We can sort of see what the effect of frosting is, here we have a temperature of 30 below on one side, room temperature on the other, relative humidity about 30% - 35% on the warm side, and we see this kind of a drop off in performance. In spite of the drop off in performance, we see that it takes many days to really drop down very significantly. And if you were just talking about a single day, then maybe the drop in performance is a small penalty to pay. The flow rate fell off too so that in time, if we look at a period of days then the flow rate through the heat exchanger would have fallen off significantly for the same pressure drop across it. I should point out that pressure drop through this type of heat exchanger was very small indeed, because we were not working with high flow rates through a packed heat exchanger.

I show this picture, some of you may recognize it, the Saskatchewan Conservation House, because it was one of the first buildings that the heat exchanger was installed on. The house is unique in terms of its design of super-insulated walls - R 40 in the walls, R 60 in the ceilings. Here we have the materials of the vapour barrier, the polyethylene and the acoustical caulking compound.

Question:

Did you just trowel on the caulking compound to make the seal?

Well, it took 5 man-days to put on the vapour barrier for this house. That was our estimate of the time involved. And the vapour barrier was installed on the inside of the building. Here we have the picture of one of the electrical outlets and behind each electrical outlet we had polyethylene pans installed. So that one could get a complete seal around the electrical outlets on the outside of the building. Here's the vapour barrier in place, and one can see that there was a lot of caulking compound for this. This house was tested subsequent to completion, and it was found that in spite of the efforts that went in to sealing it absolutely, indeed it is not possible to seal it absolutely. We found that we had an air change rate of about 5% or 20 cu. ft. per minute in the building.

That is in winter. It was tested over a period of about a week, so I think it was a representative kind of test.

There are two floors. The vapour barrier is taken out through the frame and back again around the ends of the floor joists. The carpenters had to participate in the installing of the vapour barrier in order to get from the first to the second floor.

Well, we've since put up a number of buildings, putting the vapour barrier on the outside of the 2" x 4"'s. Because this wall is a 12" wall, putting 2/3 of the insulation at least beyond the vapour barrier at every point means that the vapour barrier can go on very fast indeed. The vapour barrier, under these circumstances, can go on in a matter of a day on a two storey house. So it chops the time very significantly by putting the vapour barrier outside the first layer of 2" x 4"'s and seeing to it that every place you maintain at least 2/3 of the insulation outside the vapour barrier.

Question:

The method of construction would be then to build the inner frame then put the vapour barrier on and then put a sheathing on there and then put your over frame.

Yes. I guess, there are at least 1/2 dozen houses in the Saskatchewan area that have done that now.

This monster, I am somewhat ashamed to say is the heat exchanger in the house. We didn't realize when we gave them the heat exchanger just what they were going to do with it, and that is what they did with it. They made it look like a basement monster. We have since decided that what we did here was inappropriate. We built in the capability of defrosting the heat exchanger by reversing the flows. We have since decided that we can defrost the heat exchanger quite easily using other methods, for example, just blowing out, turn on the dryer, any number of ways to defrost and not reverse the flows. Of course, what we found in the actual operation of the house with these dampers that could reverse the action is that the kids coming through the house - and there are a thousand visitors a week - thought that these were things to continually operate and they were operated. It made collecting data very difficult. Nevertheless our measurements suggest that the performance of this heat exchanger is about 80%

heat recovery. This is the furnace unit that is used in the same house, the return air which comes in a little bit cooler, is dumped into the air circulating system and the air circulating system in the houses goes whether the house requires any heat or not. The energy consumption on this house for heating purposes is about 5 GJ/year compared to standard housing, 1975 vintage, at about 200. One of the reasons it's small of course because we have shutters on windows. Another reason one might consider shutters on the windows is that if you don't have shutters on the windows in a very severe climate, you're going to have condensation on the windows if you want your relative humidity to climb up. So on this particular design then we're trying to make the point that people probably should be thinking more about shutters on windows. If you do then you can let the relative humidity climb a little bit more in the building without any condensation at all. These are motorized from the inside. These had a pretty good work out with 1000 visitors per week. It's 3 inches of polystyrene in an aluminum box and then there's a black sealing rubber that they bump up against and there's a slip clutch on the motor.

Question:

What's the CFM of the heat exchanger?

It's designed to operate about 60 CFM or at 200 depending on what the demand is. It's continually vented at about 60 then when we have a special need we can pick it up to the higher rate.

Question:

What's the size of the heat exchanger?

That heat exchanger had about 300 sq. ft. of active area. It's actual size was 2' x 2' x 7' high. We don't think that was the best way to go for such a heat exchanger. Now we are looking at ones that are about one quarter of that and getting close to the same effectiveness.

Question:

Was there a specific reason to keep it vented at 60 CFM all the time?

Well, I just decided that that was a good rate of ventilating in case we had a family living in there, but with that rate of visitors there is no family living in there, it's just a visitors' house. They ultimately hope to put a family in but I understand there won't be one this winter.

Probably a more dramatic illustration of the heat exchanger and how it worked was when we installed it on a hog barn. Those who are familiar with hog barns will know that the environment there is very severe indeed. Generally the relative humidities in hog barns are running 75% - 80%. The dust level is very high because of the food handling techniques and indeed the environmental considerations are so severe that I had hog food suppliers come to me and say "Well can't you do something for us because our customers are coming to us and saying the food is no darn good in winter and yet in the summer they say it's great." It's the same food, so they suspect maybe the environmental conditions are involved. What the farmers have been doing in the past is just trying to tighten their barns as much as they can and then putting big fans on and trying to blow out against all that tightness to the point where it is very difficult to open or close the door on the building. I should say it is very difficult to open one, but watch out when they close!

We convinced one farmer that we wouldn't interrupt his operation and that if anything went wrong with the heat exchanger, he was free to shut it off and forget it. It was installed in November.

It uses a solar pre-heater. We had a pyronometer mounted and here is a typical chart that one would get off such a device. On a sunny day the upper curve suggests that we're getting, with the ordinate increasing there, a very large amount of solar radiation, and the lower curve was a cloudy day and this is a typical output from the collector. The collector was capable on a sunny day of a pre-heating the air 30° to 40° Celsius. So it was quite a significant bump in temperature coming in and the function of the pre-heater was to defrost the heat exchanger. However, it could conceivably give it a little bit of boost in terms of its performance too. But the main function was to defrost the heat exchanger so we didn't have to worry about that end of things in plugging up over the winter. The rate of airflow was about 1500 CFM. The air came in at the bottom of the heat exchanger and was discharged out the back through the ducts. The ducts are shown here. We made the thing in modules which were 4' long. One of their main concerns was dust handling. We found out that the heat exchanger plates, the polyethylene plates, wash clean, so indeed it was a very sound way to operate the device, to have it so it washed itself out. The fan is inside the barn.

This is a picture under the heat exchanger during the operation. We dared to look under there and get a picture of the water dripping down on a day that wasn't too cold. You can see the water dripping off the heat exchanger surface here. There was a lot of condensation and in fact during the worst part of the winter we had a lot of ice accumulated there. Ice piled up under the heat exchanger several feet deep due to the condensation we had coming out of there. The cost of the heat exchanger was about $700 for materials and $700 for the labour. Our estimate of the dollar saving on electrical heat, which was what the farmer was faced with - he was paying bills of $5,000 a year for heating the year before - was $1,700. So in fact he has a one year pay back. If one looks at the animal barn game there are some tens of thousands of these types of barns on the prairies alone and one could see that it could play quite an important role. We feel that if the barn is designed properly that the heat load on the building could be virtually eliminated by using heat recovery techniques.

So far it's a do-it-yourself kind of thing. We have about three hog barn farmers that are making their own this year. We have made a number. We're making some for chicken barns, this fall, and we made about 25 for housing units. So we hope to collect a lot more information this coming year in terms of its performance. We're a little bit shy on information on housing units because we simply haven't had a good monitoring program for all the housing units that we now have them in and most of them got installed sort of late in the winter and we just didn't get adequate data off them, but we look forward to a much better year this coming year.

Question:

It is fair to infer that you are really counting on the condensation in order to get the wash down, if you didn't have that would you perhaps ...

We may have more dust problems if we didn't get that condensation, yes I agree.

Question:

Is there any filter at all put onto the exhaust fan before it hit the exchanger?

No, no filters.

Question:

Couldn't you just apply a water nozzle, spray?

That's the way we tought we would operate, in fact, that's the way we designed so we could get at it and wash it down. It wasn't necessary. We could just depend on it self cleaning. We never did wash it down.

Question:

John Hockman has built units of this type based on your work and he said something about flutter of the polyethylene sheets if you don't balance the pressures. What's your experience?

The pressure drop in the heat exchanger itself is hardly measurable. It's sort of like 1/100 of an inch because we're not running the air through that fast. It's conceivable certainly that if you are going to push it a little bit harder that you can get a potential flutter problem.

J. Hockman: Yes, we were running at higher flows.

Yes, I think you have to be careful that the system is balanced. You have to pressurize both sides rather than pressure and suction. You deflate one side and inflate the other and build up of very high pressure drop on one side and very little on the other.

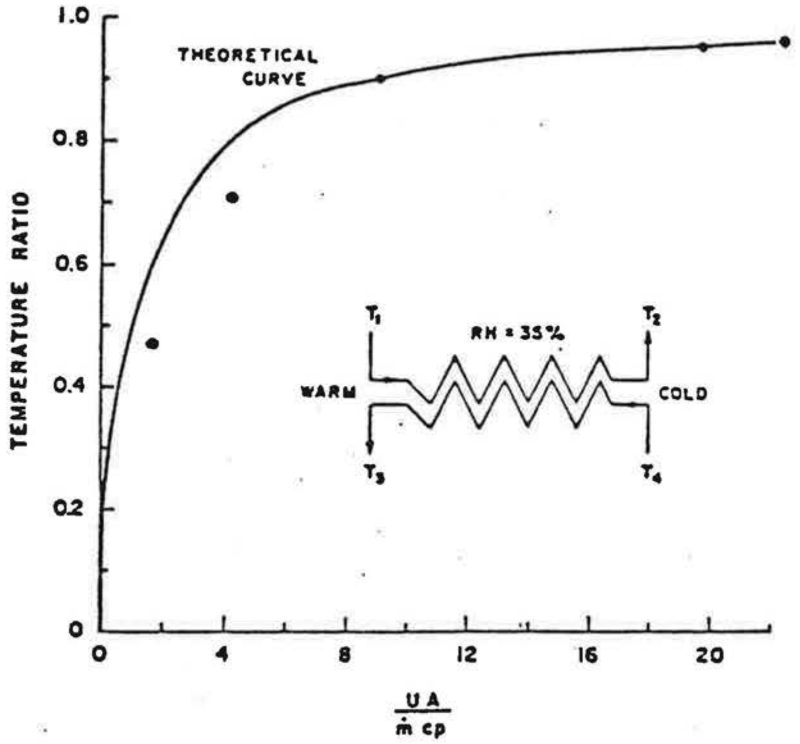
Prof. Besant:

I think it would be possible to circumvent those problems by molding plastic in such a way that there were spacers and also going to a little bit thicker material in the heat transfer surface than the 6 mil polyethylene that we're been using.

Question:

I was wondering how your set-up would compare with cross-flow heat exchangers that you can buy for farm use?

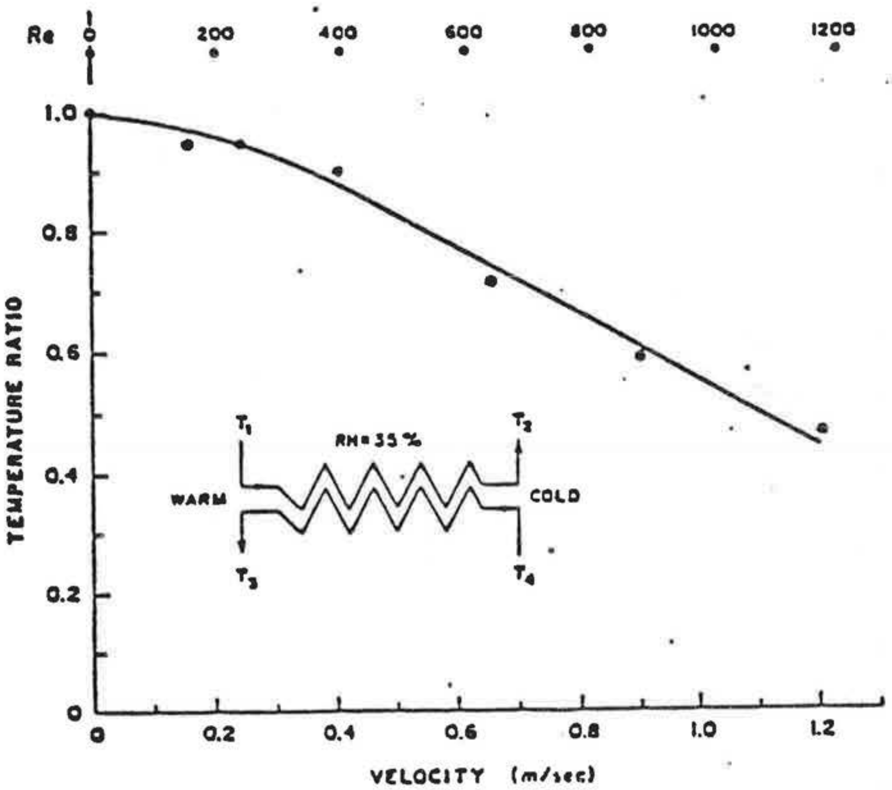
Heat exchangers have not been widely used on the prairies for buildings. One, because the cost of energy has been so low, but secondly because of frosting problems. The very time that you want the heat exchanger for a hog barn, is sometime in November through to the 1st of March. You don't need it any other time. And that's exactly when you are going to have frosting problems. Most heat exchangers that run into serious frost-up problems tend to frost up fairly quickly and block off the flow completely. Our experience with this unit was that it never was a problem. That's why we were so happy with it. As a matter of fact when he let us do it on his barn he said you do the one end of the barn but by partway into December he decided that we were doing the whole thing.




AIR TO AIR HEAT EXCHANGER PERFORMANCE

TEMPERATURE RATIO $\frac{T_3 - T_4}{T_1 - T_4}$ VS $\frac{UA}{\dot{m}\, c_p}$

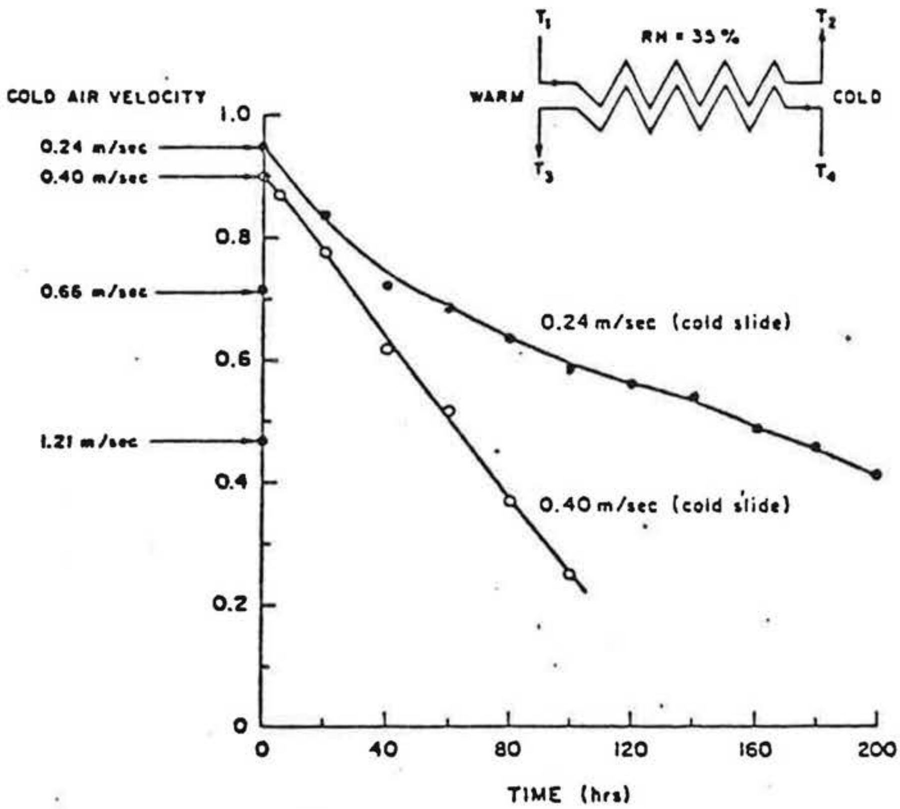
Figure 1.




AIR TO AIR HEAT EXCHANGER PERFORMANCE

TEMPERATURE RATIO $\frac{T_3 - T_4}{T_1 - T_4}$ VS AIR VELOCITY

Figure 2.




AIR TO AIR HEAT EXCHANGER PERFORMANCE

TEMPERATURE RATIO $\frac{T_3 - T_4}{T_1 - T_4}$ VS TIME (hrs)

Figure 3.

# APPENDIX G

## EXPERIENCE WITH HEAT WHEEL HEAT EXCHANGERS IN COMMERCIAL AND INDUSTRIAL BUILDINGS

R.L. Dorey
McCarthy & Robinson Ltd.

Mr. Dorey also used 35 mm slides and spoke extemporaneously. Unfortunately projector noise on the tape virtually ruled out a verbatim transcription of his remarks. What follows, therefore, is a point-form summary of the main items of discussion.

- McCarthy and Robinson has sold and built rotary air-to-air heat exchangers for the past 15 years and has about 300 units installed across Canada

- Many are installed in electrically-heated apartment buildings but they are also used in auditoriums, hospitals, schools and other large buildings

- The rotary heat exchanger was originally developed in 1907 by a Dr. Ljunstrom of Denmark and has been used extensively ever since - originally in power houses and, in the past twenty years, more and more in industrial and commercial buildings

- It has not been used in non-apartment residential construction

- M. & R. don't know, at this stage, whether heat wheels can be economically feasible at the small scale required for housing and are somewhat doubtful that they can. It may be that some other type, though lower in efficiency or with other problems, may be more suitable for this market.

- The mechanical complexity of heat wheels has two effects:

  a) It tends to make them more expensive than other types

  b) It requires maintenance which home owners are not equipped, trained or inclined to provide.

- The most expensive part of a rotary heat exchanger installation is bringing the exhaust and intake ducts together

- The air flow must be counter-current to achieve any kind of reasonable efficiency

- M. & R. have found that a rotational speed of 15 rpm gives the optium compromise between efficiency of recovery and mechanical reliability

- M. & R. guarantees 80% efficiency even though they have achieved as much as 96%

- In commercial buildings the last few percentage points of efficiency are not important. In fact in some installations it is necessary to be able to slow the rotor down at certain times to decrease its efficiency since all the heat it can recover is not required due to high internal heat gains in the building

- The medium M. & R. use in their wheels is a mesh knit from 0.010" diameter aluminum or stainless steel wire. It is knit in the form of a round sock of about 6" diameter then flattened and corrugated so it will not nest. The object is to have high surface area with low mass. This mesh was originally developed for use in military landing matts and is also used in de-misting towers and so is much more readily available than the honeycomb material such as Ontario Hydro is using

- Due to the openness of the mesh and the fact that the air flow constantly changes direction, plugging up of the wheel with air-born particles has not been a problem except under the most extreme conditions

- Cross-flow of air from the exhaust to the intake or vice-versa is controlled by balancing pressures and the use of seals. It is less of a problem on large wheels since the area increases with the square of the diameter but the length of the leakage path is only proportional to the diameter

- Heat wheels can be used with high humidity exhaust air, such as at swimming pools, without frosting up by designing the system to have high velocity air-flow, say, 800 to 900 ft./min. The air is cooled from say 80°F to 0°F in the 10" thickness of the wheel which only takes a small fraction of a second. This results in "reverse sublimation" of the water vapour. It goes from vapour to solid without going through the liquid state and thus does not coat the medium surfaces but blows out of the wheel as snow or ice crystals

- Other media that are used include knitted plastic mesh and asbestos paper honeycomb impregnated with lithium chloride. The difference in medium material seems to have no appreciable effect on efficiency. It is the surface area which is important

- There are four basic types of mechanical air-to-air heat exchangers:

  Rotary - eg. McCarthy and Robinson, Ontario Hydro

  Plate Type - e.g. University of Saskatchewan

  Heat Pipe - refrigerant in pipe end which is in exhaust steam is vapourized and vapour pressure drives it down to the other end in the intake steam where it condenses and gives up its latent heat of vapourization. The liquid runs back to the first end by wicking or due to a slight tilt of the pipe and the process begins again

  - very efficient but very expensive
  - tend to be used more for air-to-liquid, air-to-solid and solid-to-solid than for air-to-air
- "Run around Glycol Coil"
  - two coils - one in exhaust stream, one in intake stream. Refrigerant picks up heat from one and is pumped to the other
  - efficiency is relatively low (35 - 50%) but permits intake and exhaust ducts to be widely separated
- M. & R. experience less problems with decrease in efficiency due to longitudinal conduction because their medium presents a very thin, convoluted conduction path compared to the corrugated aluminum sheet used in Ontario Hydro's first prototype

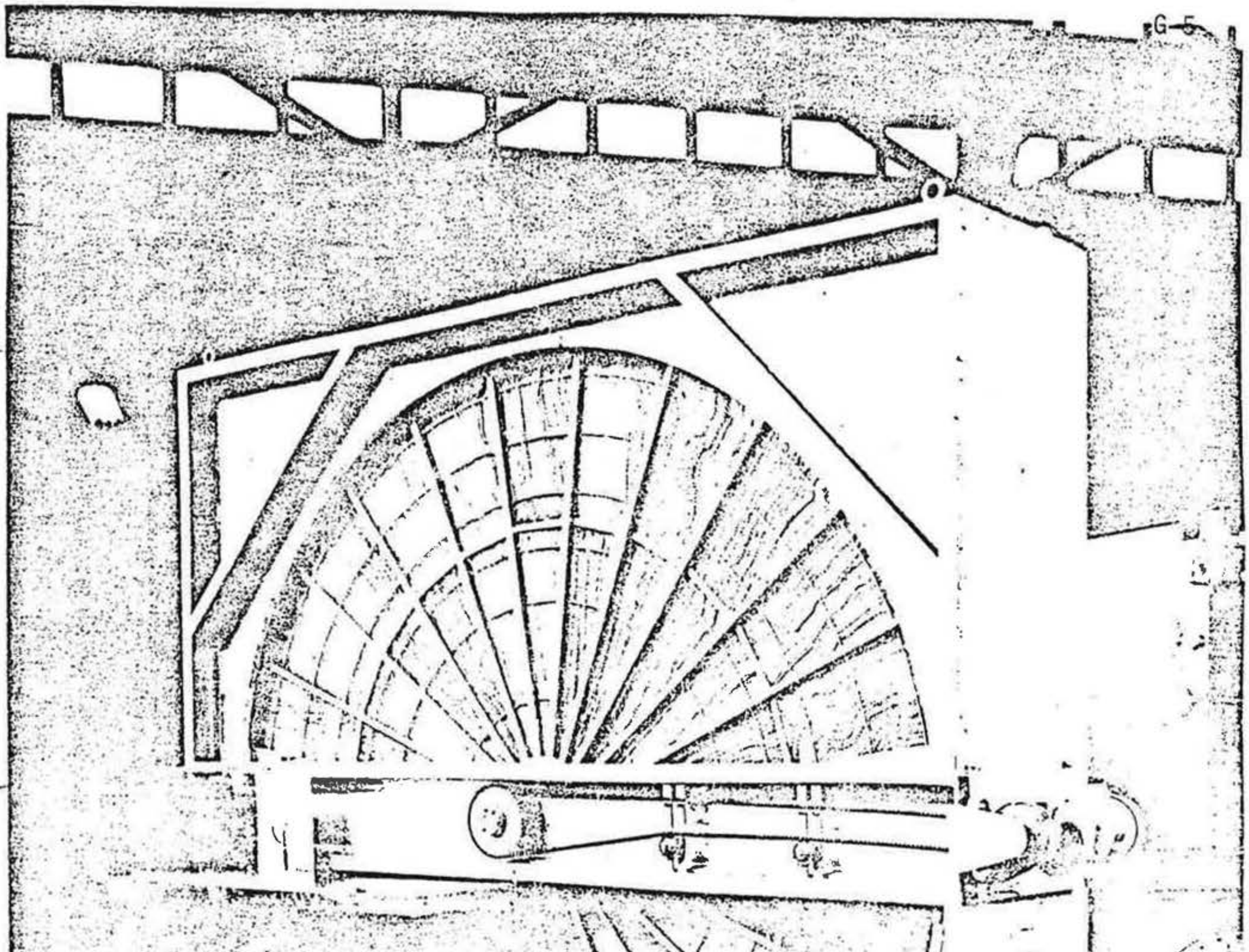
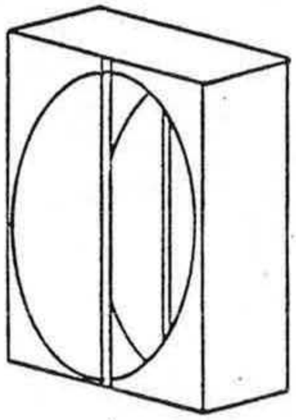


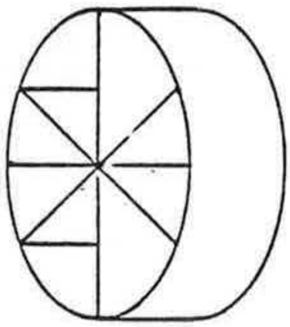
PHOTO #1

# Regenerator Components

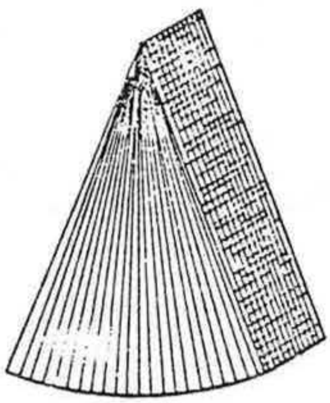
cat. pg. A-2



Frame



Rotor



Media Segment

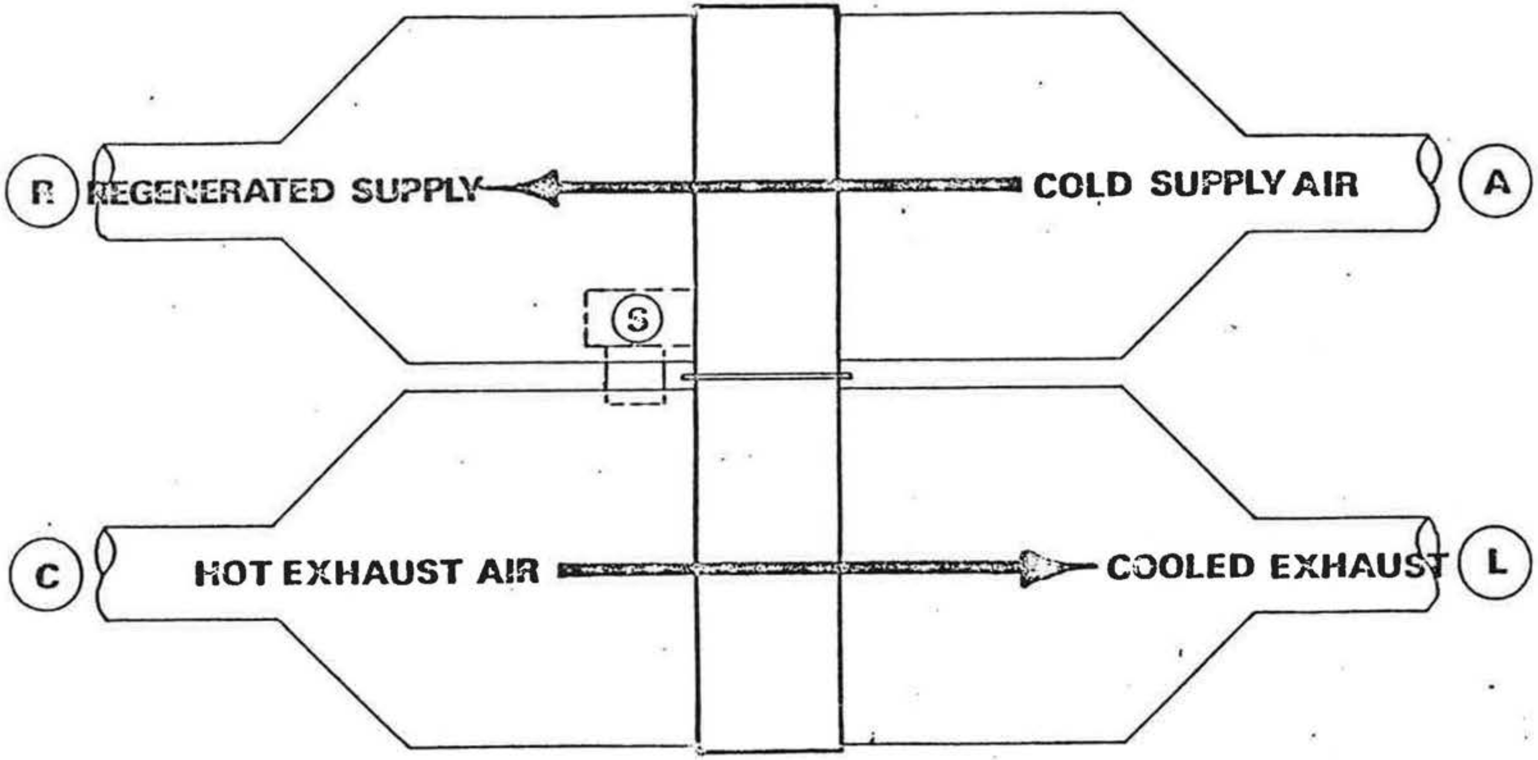
INSTRUCTIONS

1. Lay mounting frame, printed side down, on flat surface.
2. Place prepared transparency face down on frame.
3. Apply the "SCOTCH" Magic Transparent Tape provided, along all 4 edges of the transparency to attach same to frame.

MODE D'EMPLOI

1. Placez le cadre sur une surface unie, le côté imprimé dessous.
2. Placez le transparent à l'envers sur le cadre
3. Appliquez le ruban M[illegible] Transparent "[illegible]" sur les [illegible] côtés du [illegible] pour le [illegible] au cadre.

# Counter Current Air Flow




**SCHEMATIC**

(C) CONTAMINATED EXHAUST AIR ENTERING REGENERATOR

(L) CONTAMINATED EXHAUST AIR LEAVING REGENERATOR

(A) FRESH SUPPLY AIR ENTERING REGENERATOR

(R) FRESH REGENERATED SUPPLY AIR (HEATED)

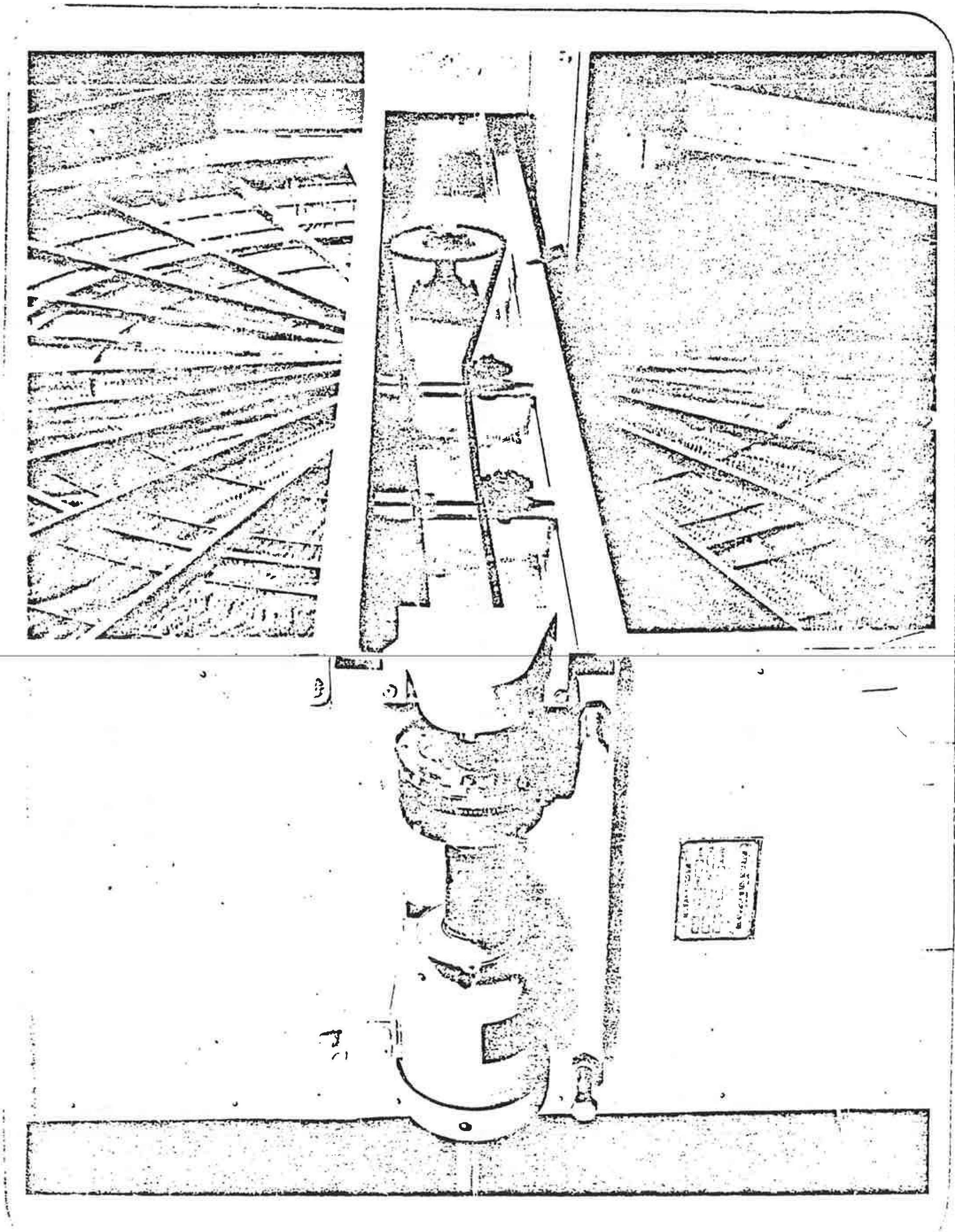
(S) SCAVENGER DEVICE

MODE D'EMPLOI

1. Placez le cadre sur une surface unie, le côté imprimé dessous.
2. Placez le transparent à l'envers sur le cadre
3. Appliquez le ruban Magique Transparent "SCOTCH" sur les 4 côtés du transparent pour le coller au cadre.

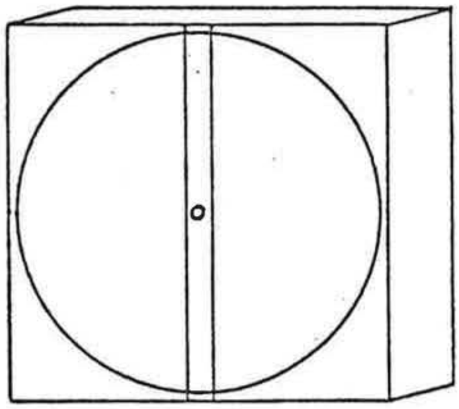
INSTRUCTIONS

1. Lay mounting frame, printed side down, on flat surface.
2. Place prepared transparency face down on frame.
3. Apply the "SCOTCH" Magic Transparent Tape provided, along all 4 edges of the transparency to attach same to frame.

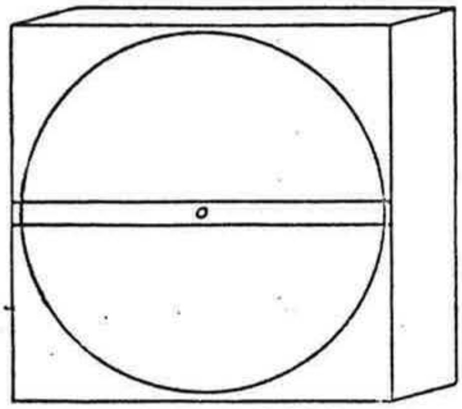


# Regenerator Installation Positions

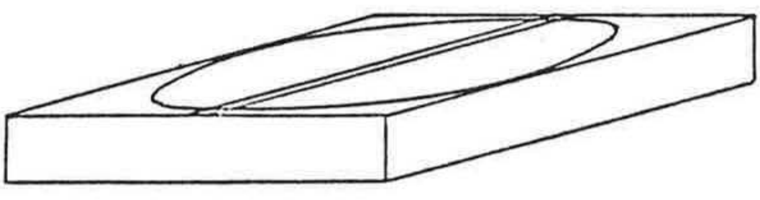
cat. pg. A-2



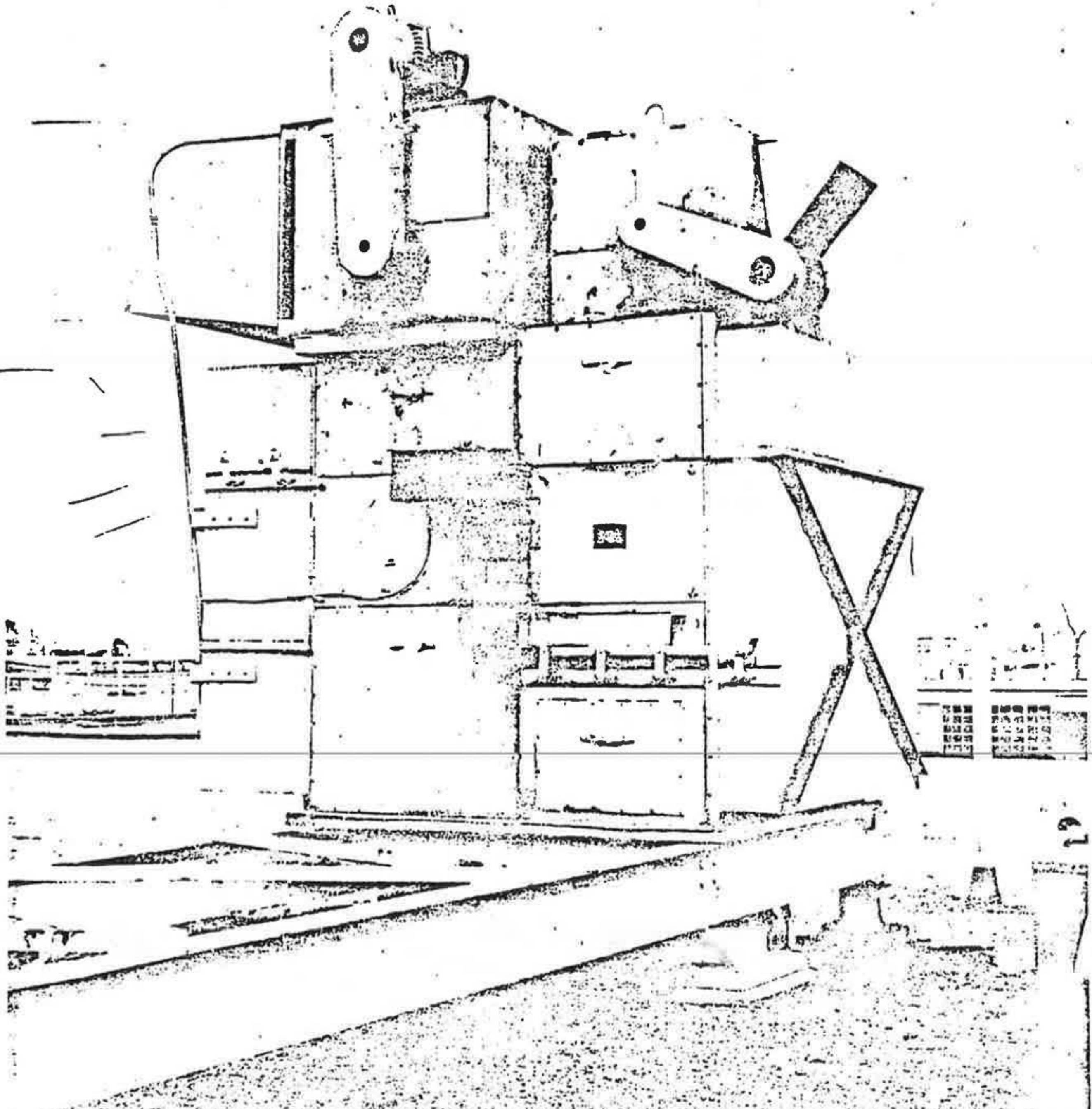
style VV

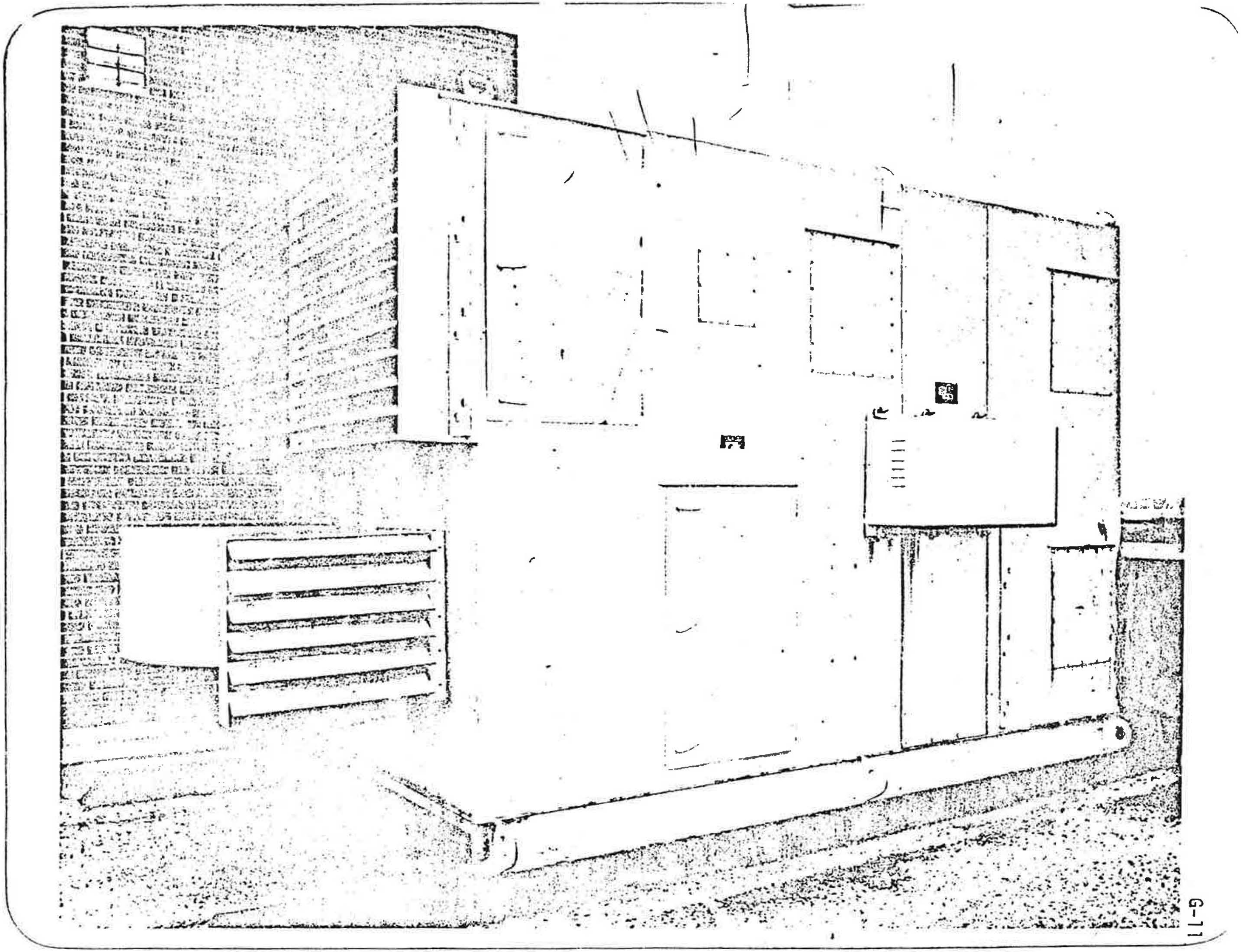


style VH



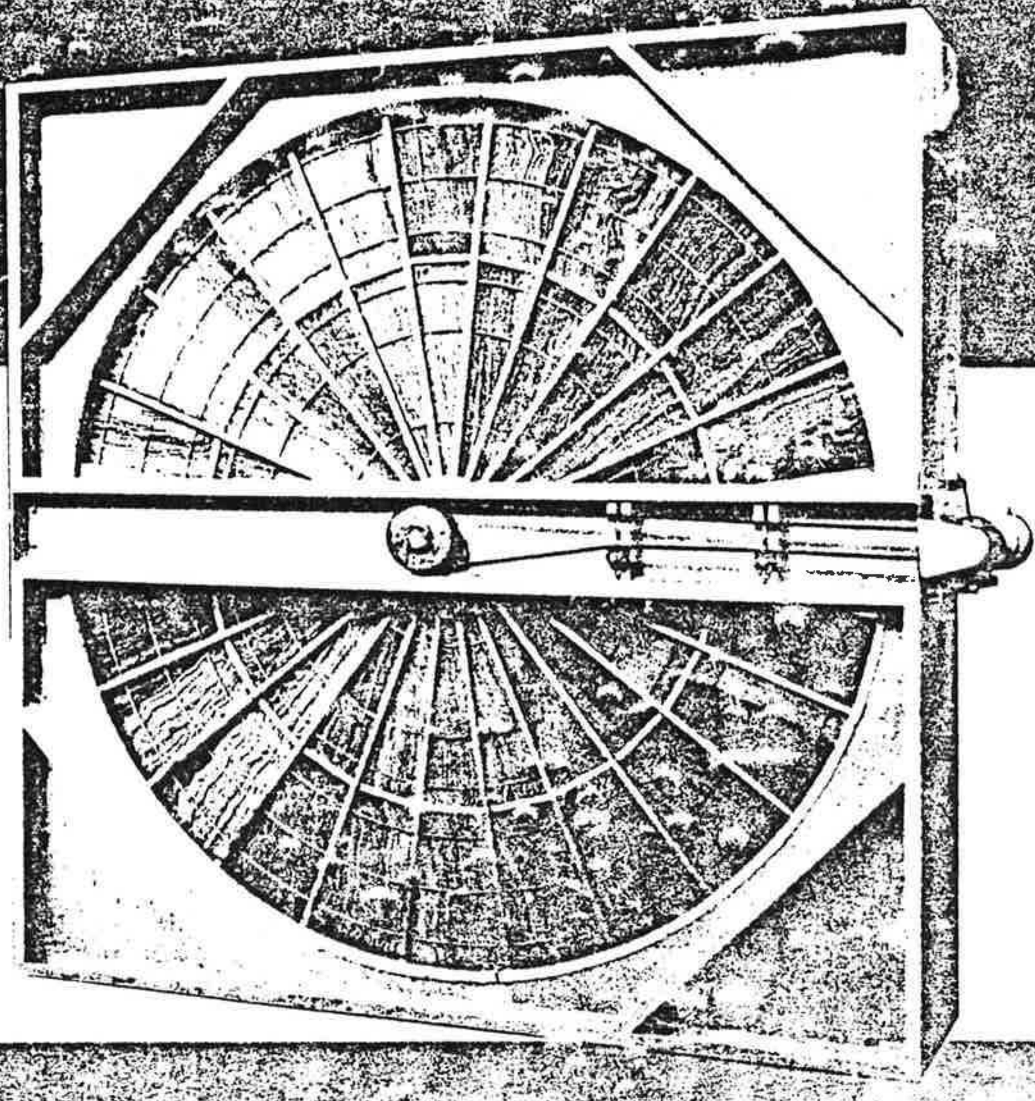
style H





G-12

# ENERGY CONSERVATION

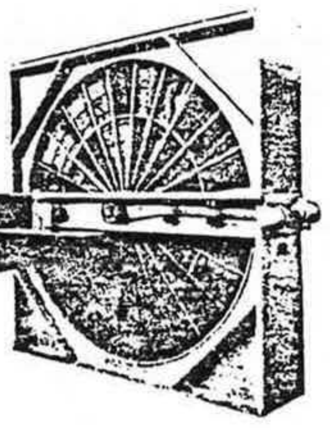


McCarthy & Robinson Ltd

# Regenerative Heat Conservation

## WHAT IS A REGENERATOR?

A Regenerator is a mechanical air-to-air heat exchanger consisting of a segmented rotor filled with heat transfer medium, mounted in a supporting frame.
The heat transfer medium is usually knitted, corrugated metallic mesh packed in the rotor segments so that the volume it occupies is approximately 3% metal and 97% void.
It is installed in a ventilation system so that one half of the unit is contained within a warm air duct, and the other half in an adjacent cold air duct. Heat is transferred from the warm to the cold air by means of the heat transfer medium packed in the slowly turning rotor.
Cross contamination is reduced by means of mechanical seals and a scavenger device.
A Regenerator may either be installed as one component in a "built up" ventilation system (illustrated at left) or incorporated into a self contained "Package" with integral fans, filters, dampers, controls and etc. (illustrated below)



REGENERATOR
C/W Scavenger

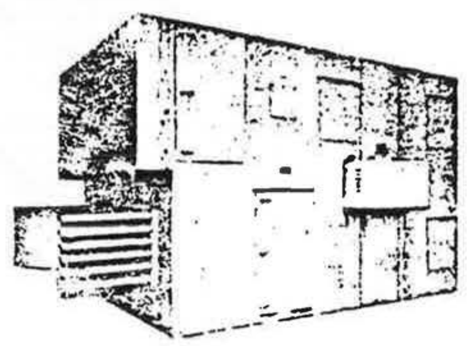
## WHY USE A REGENERATOR?

It reduces fuel consumption and equipment size by either heating cold supply air with BTU's recovered from warm contaminated exhaust air on the heating cycle, or by precooling supply air on the air conditioning cycle.

## WHERE CAN A REGENERATOR BE USED?

Consider a Regenerator on all process and building exhaust air systems and all central air conditioning systems.
Regenerators are presently operating on building comfort heating and cooling systems utilizing contaminated exhaust air from washrooms — kitchens — dining areas — gymnasiums — swimming pools — laboratories — hospital wards — operating rooms — general living and working space.

Process exhaust air systems include hot contaminated air from heat treat furnaces — drying and bake ovens — food roasting and processing ovens — welding areas — etc.



REGENERATOR "PACKAGE"
STYLE VHP

## WHO DESIGNS THE SYSTEM?

McCarthy and Robinson Ltd. can furnish regenerators and/or package units to fit your system design, or can undertake total system design engineering, specifications of all components, supply and installation of the complete system including ducts, hoods and installation as required.

**McCarthy & Robinson Ltd.**

**Regenerative Heat of Canada Ltd.**

# Regenerative Heat Conservation

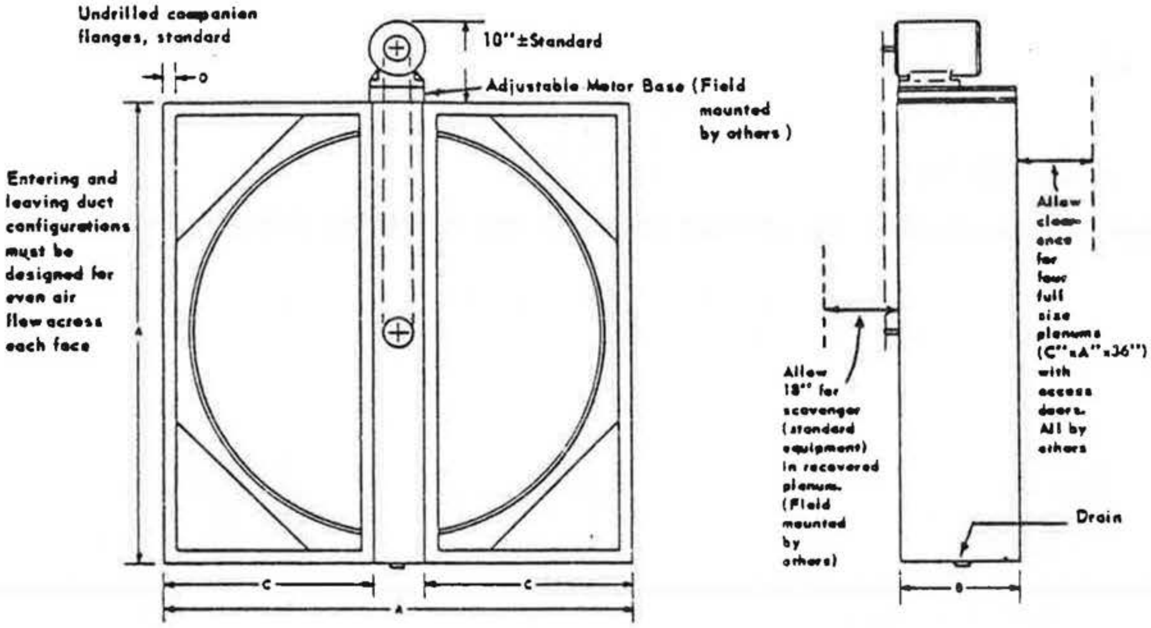
## CANADIAN USERS LIST

**PARTIAL LIST OF MORE THAN 200 REGENERATORS BUILT AND INSTALLED IN CANADA SINCE 1964 HANDLING APPROXIMATELY FOUR MILLION CFM**

| | | |
|---|---|---|
| **INDUSTRIAL** | | |
| Mica Co., Hull | 2,700 CFM | Oven Exhaust |
| Du Pont, Ajax | 70,000 CFM ( 3 units) | Mfg. Area Exhaust |
| Canada Illinois Tool, Toronto | 7,000 CFM | Heat Treat Furnace |
| Thompson Products, St. Catharines | 40,000 CFM ( 3 units) | Heat Treat Furnaces |
| Stauffer Chemical, Toronto | 21,000 CFM ( 2 units) | Oven Exhaust |
| Cdn. Pittsburg Ind., Clarkson | 70,000 CFM ( 2 units) | Mfg. Area Exhaust |
| Standard Tube, Woodstock | 15,000 CFM | Welding Shop Exhaust |
| **G. S. W. Limited, Fergus** | **60,000 CFM** | **Bake Oven Exhaust** |
| **INSTITUTIONAL (Schools)** | | |
| University of Saskatchewan | 400,000 CFM (11 units) | Classroom & Lab Vent. |
| Rehabilitation Center, Quebec | 47,000 CFM ( 2 units) | Swimming Pool Vent. |
| Carleton University | 13,000 CFM | Lab Ventilation |
| Cornwall School, Cornwall | 10,500 CFM | Classroom and Gym |
| Workmans Compensation, Quebec | 60,000 CFM ( 7 units) | General Ventilation |
| Hollycrest School, Toronto | 2,800 CFM | Classroom Ventilation |
| Educational Centre, Truro | 40,000 CFM ( 2 units) | General Ventilation |
| **INSTITUTIONAL (Medical Facilities)** | | |
| Alexandra Hospital, Goderich | 17,000 CFM | General Ventilation |
| Riverside Hospital, Ottawa | 2,100 CFM | O.R. Ventilation |
| University of Saskatchewan | 200,000 CFM ( 9 units) | Veterinary Hospital |
| Port Perry Hospital, Port Perry | 10,000 CFM | Hospital Ventilation |
| St. Josephs Villa, Dundas | 56,000 CFM | General Ventilation |
| St. Augustine Hospital, Quebec | 11,000 CFM | Hospital Ventilation |
| Sr. Citizens Home, London | 45,000 CFM ( 3 units) | General Ventilation |
| **COMMERCIAL** | | |
| Holiday Inn, Ottawa | 10,000 CFM | Garage Ventilation |
| Peterborough Examiner, Peterborough | 10,000 CFM | Press Room Ventilation |
| Place Bonaventure, Montreal | 500,000 CFM (16 units) | Convention Hall |
| Ontario Hydro, 5 locations | 22,000 CFM ( 6 units) | General Ventilation |
| Scotia Square, Halifax | 70,000 CFM ( 3 units) | General Ventilation |
| Gilbeys, Toronto | 33,000 CFM ( 2 units) | General Ventilation |
| Saguenay Inn, Arvida | 7,200 CFM | Cafeteria Ventilation |
| **RESIDENTIAL (Apartment Buildings)** | | |
| St. James Town, Toronto | 250,000 CFM (18 units) | Kitchen |
| Crescent Town, Toronto | 167,000 CFM (11 units) | and |
| Delzotto Buildings, Toronto | 76,000 CFM ( 3 units) | Bathroom |
| Heathcliffe Buildings, Toronto | 115,000 CFM (10 units) | Exhaust: |
| Kaizer Building, Halifax | 153,000 CFM ( 7 units) | Corridor |
| Ronark Buildings, London | 48,000 CFM ( 3 units) | Supply |
| Apartment Buildings, Ottawa | 45,000 CFM ( 5 units) | |

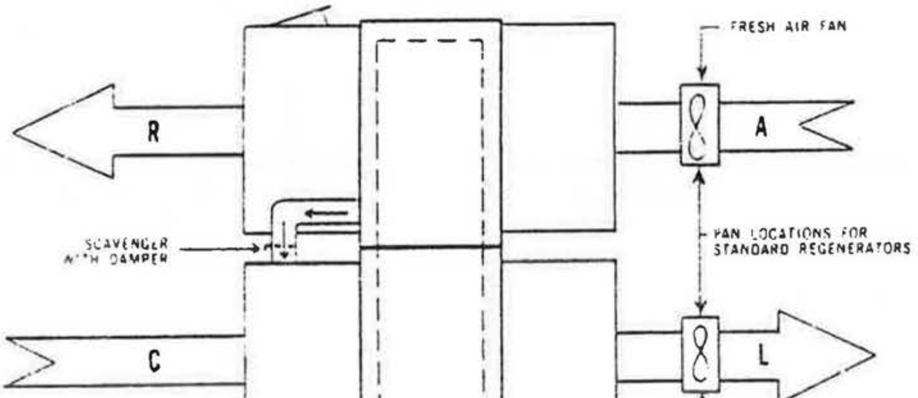
**McCarthy & Robinson Ltd.**

**Regenerative Heat of Canada Ltd.**




## PHYSICAL DATA-STANDARD REGENERATORS

| MODEL | RANGE-CFM (0.5" - 1.6" wg.) | DIMENSIONS IN INCHES | | | | SHIPPING WT. APPROX. | | DRAIN | HP | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | TYPE A | TYPE B&C | IPS | A | B&C |
| 6 | 1500-2700 | 43 | 23 | 18½ | 1¼ | 650 | 850 | 1" | 1/3 | 1/3 |
| 10 | 2500-4500 | 54 | 23 | 24 | 1½ | 800 | 1050 | 1" | | |
| 14 | 3500-6300 | 62 | 23 | 28 | 1½ | 900 | 1200 | 1½" | | |
| 20 | 5000-9000 | 73 | 23 | 33½ | 1½ | 1150 | 1500 | 1½" | | |
| 28 | 7000-12600 | 84 | 23 | 39½ | 1½ | 1800 | 2350 | 1½" | | 1/2 |
| 40 | 10000-18000 | 101 | 23 | 46½ | 1¼ | 2300 | 3000 | 1½" | | |
| 50 | 12500-22500 | 112 | 25 | 51½ | 1¼ | 3000 | 3900 | 2" | | |
| 60 | 15000-27000 | 124 | 27 | 57 | 1¼ | 3600 | 4700 | 2" | | |
| 70 | 17500-31500 | 134 | 27 | 61 | 1¾ | 4100 | 5400 | 2" | | |
| 80 | 20000-36000 | 142 | 27 | 65 | 1¼ | 4600 | 6000 | 2" | | |




C = CONTAMINATED EXHAUST ENTERING REGENERATOR

L = CONTAMINATED EXHAUST LEAVING REGENERATOR

A = FRESH AIR ENTERING REGENERATOR

R = FRESH AIR AFTER REGENERATOR, WITH RECOVERED HEAT

MANUFACTURED AND DISTRIBUTED

McCARTHY & ROBINSON (1966) LTD.
321 Progress Ave.
Scarborough
M1P 2Z7

McCA .TD.

TORONTO

# APPENDIX H

## SUMMARY OF THE CURRENT STATE OF THE ART

Dr. D.G. Stephenson
Division of Building Research
National Research Council

Dr. Stephenson was asked to summarize the current state of the art regarding tightness of housing, mechanical ventilation and heat recovery as assessed from his own experience and the various presentations and discussions to this point in the seminar.

When you asked me, I didn't realize quite what I was agreeing to John. But, nevertheless, what I am going to tell you is what I've got out of it. I am not sure if its what was there, or whether it is my own biases just coming back.

I think that we have seen in the discussions on hardware that clearly hardware is not going to be the problem. There are devices available, it is not a technical problem therefore, it is an economic one. Coming back to what Bob Platts said, it all hinges on how much benefit there is going to be and how much the things are going to cost. Bob made his guesses, but I think that the real hard work that has to be done is some field trials to confirm his guesses or perhaps to show how optimistic he has been and that the benefits perhaps are a lot smaller than he has estimated.

Even when you are being optimistic - there is not much. I think we are likely to come to the conclusion, that mechanical ventilation is a must, but whether it is coupled with a heat recovery unit or whether we just have mechanical ventilation and accept the heat loss that is associated with it in order to get the benefits is an open question. But the evidence that we have seen kicked around today would suggest that it is more likely to be on the no heat exchanger than on the heat exchanger side. This is the conclusion, I think is to be drawn from some of the comments we have had. But clearly, work has to be done. One can't sort of just draw that conclusion and say that that is the end of it. I think that studies such as the work at the University of Saskatchewan or at the Regina House using the University of Saskatchewan plate exchanger or the work that Hydro and ourselves are going to do trying their exchanger in the HUDAC house or the applications of exchangers that the last gentleman talked about in smaller scale units will establish, when you put them into a real house and let them run over a real heating season, operating them when it is advantageous or when the mechanical ventilation is necessary, but not operating them at other times, this will establish really what the dollars per year savings figure is. It will probably be substantially less than Bob's upper limit and if that is so the possibility of being able to justify a capital investment, especially if you take David's point of view that the present worth factor has to be pretty small, when you multiply a small saving by small present work factor, you don't have a lot to play with in a way of capital investment.

If we say, therefore, it is an open question on the heat exchanger, but look at the matter of forced ventilation or mechanically controlled ventilation versus accidental, I don't think the situation is in the same state at all. There, everything that we have seen seems to indicate a must for some kind of mechanical ventilation if we are going to accidently drop the air leakage by inadvertent means down to a level that is acceptable. But even here we need to have some more precise data on what it costs to make a house tight. The schemes that have been tried in the experimental houses, the HUDAC houses, or the Regina House or others, so far seem to indicate that it is not all that cheap to tighten up the house. The labour of doing it is substantial even if materials are not. There will be some benefit but the results that I mentioned this morning with the HUDAC house show that even when you try fairly hard, you still fall a good way short of a completely sealed or no accidental leakage. I think it is still an open question of how far you can justify going in actually tightening up the house. And that also needs more field studies, more support, if you like, by organizations such as CMHC or perhaps the National Research Council to let builders try out devices or techniques for tightening up a house and someone to come along and evaluate what benefit comes from the extra expenditures of about $100-$200-$300, whatever the figure may be. And it is only out of those kinds of studies that we can expect to come to an appropriate criterion or level for air tightness that might be used in a performance-type of code or that would be something that a builder could incorporate in his normal production and hope to sell to a market that is pretty cost conscious.

The lower limit, where we start to require forced ventilation, seemed to have been perhaps more adequately established by the work that Saul talked about by Ontario Hydro some years ago. But even there, I think we should recognize that it is not the same level, it isn't 60 cfm minimum all the time. It is 60 cfm perhaps at some times of the day, other times it might be half of that or at times when we are producing high amounts of moisture, more odor from cooking, or something, the amount might be much higher. So there is still work to be done as I see it in establishing this lower limit and how it relates to the activity in the house and then once we know what that is, it will be easier going to establish the appropriate tightness and the degree of mechanical ventilation we have to provide to get that needed ventilation when it is needed, and to avoid having it at the other times of the day, or the week, when it is not needed but is still costing us money for heat if we accept it as a uncontrolled and accidental ventilation. Now there were a lot of interesting points about the hardware, but I think the most interesting one is what it can be made and marketed for and what it will do in actual practice and only time will tell on both.

# APPENDIX I

## ASSESSMENT OF MARKET OPPORTUNITIES FOR RESIDENTIAL HEAT RECOVERY EQUIPMENT

D. Wheeler
Lennox Industries (Canada) Ltd.

Mr. Wheeler spoke extemporaneously without notes or graphics. The following is a summary of his main points.

- Even if it were made mandatory that new electrically heat houses have heat recovery equipment and assuming that this constituted 10 1/2% of 180,000 new housing starts or 18,900 houses per year, this market would not be terribly exciting to a manufacturer of Lennox's size bearing in mind the number of companies who might be competing

- If the product sold at the retail level for $150 it would probably represent a manufacturer's price of about $75

- Even if the product could be sold at a reasonable price, installation cost could make it uneconomic

- Consumers are unlikely to invest in any equipment of this nature which requires more than a three or four year payback period. For example, Lennox offer a package consisting of electric ignition, automatic vent damper and night setback thermostat for $250 over the cost of a regular furnace. It is estimated to save about 25% on fuel bills or, say, $125 a year. Even so it is not an easy package to sell

- The retrofit market is much larger and therefore more interesting although the problems of accessing that market are recognized

- Perhaps mechanical ventilation systems with heat recovery could be sold on the basis of the need to protect the house from humidity-related damage which is affecting the building industry severely. However this protection could be provided more simply, although with some additional loss of energy, by providing a fresh air inlet duct with a humidistat-controlled damper

- The increasing tightness of houses is already creating problems with the supply of combustion air for furnaces. Mr. Wheeler foresees the day when fuel furnaces will draw all combustion air from outside the house and this mechanism for creating house ventilation will thus be lost

- When and if heat recovery devices are put on the market there will be a need for proper standards and certification by some agency such as CSA to protect the consumer against false claims as to efficiency

APPENDIX J

# ASSESSMENT OF MARKET OPPORTUNITIES FOR HEAT RECOVERY EQUIPMENT

K. McQuarrie
Appliance Division
Electrohome Limited

Electrohome Limited a wholly Canadian owned company is best known for it's Consumer Electronics products. Canadians are not as aware of the fact that the company has been involved since the early 1930's in the manufacture and marketing of portable home comfort products including humidifiers, dehumidifiers, fans, electric heaters, etc. More recently central home comfort components such as furnace humidifiers and air cleaners have been added to the product line.

Our Appliance Division has also in the past few years participated in the research and development of solar systems and other energy conserving products. One such product that we have prototyped for a commercial application is an air to air heat exchanger incorporated into a ventilating fan.

We have a very definite interest in opportunities emerging for any energy conserving product that falls within our capability to manufacture and sell.

We have over the course of the past 5 or 6 years developed a standard format for presenting to our executive committee our evaluation of all the factors that impact on the probable success or failure of a new product venture.

I trust that a brief review of this format will provide some insight into the new product decision making process and help in identifying restraints that may exist on the market entry of the product under discussion today.

The many factors having an influence on the introduction of a new product are examined under separate titles as follows:

SCOPE AND PURPOSE

- What is the product and what is it's purpose.
- How many models, sizes, etc. are required.
- What unique features will it offer in the marketplace.
- Who needs or uses the product.

ENVIRONMENT

- What is the size of the market? It is growing, shrinking, static.
- What economic environmental factors influence the market?
- How many competing companies are there? What are their strengths, weaknesses?
- Are there federal, provincial, municipal laws or policies that influence use or sale of the product?

CAPABILITIES

- Do we have people with the skills required?
- What development time is required?
- Do we have the capacity to manufacture the product?
- Do we have an established marketing and distribution network able to handle the product?

ASSUMPTIONS

- Sales projections by units, dollars.
- Material costs.
- Interest and exchange rates.
- Tarrifs.
- Product life cycle status.

GOALS AND OBJECTIVES

- Sales targets.
- Return on investment.

POLICIES AND STRATEGIES

- Does the product fit into our divisional or corporate plans for long range growth?
- Pricing and discount policies.
- Do present corporate policies require change to accommodate sale of the product?

PROGRAMS AND PROJECTS

- What tasks are required in order to achieve our objectives?
- Critical path plans with key dates.
- Who will be assigned to each task?

HUMAN RESOURCES

- Is additional staff required ?
- Is a separate organizational structure required to achieve the objectives?
- Is special training required?

PHYSICAL AND FINANCIAL RESOURCES

- What capital investment is required for:

  - Facilities?
  - Equipment?
  - Tooling?
  - Inventories?
  - Accounts Receivable?

- What return can be expected on capital invested?

- What will be the monthly cash requirement to support the proposed plans?

There is no doubt that the key factor in any new product decision is the bottom line figures.

In the light of the above what might be the manufacturing and marketing constraints holding back the introduction of a product that will control ventilation and achieve some measure of exhaust air heat recovery?

TECHNOLOGICAL

- From a technological point of view we see few if any constraints. We have viewed today some of the work done in this area by researchers and found that the approaches taken are valid. Some development work is still required in terms of manufacturing processes in order to optimize the product cost/value relationship.

The next two constraining factors are very much interlinked.

TIME

- We at Electrohome do not have people sitting, as it were, waiting in the wings for the product we are discussing to come along. If legislation dictated the immediate incorporation of such a product into new buildings tomorrow it would take some time for us to complete the development of the product and introduce it to the market. The speed with which we would undertake to do this would depend upon the relative merits of such a venture as compared to other ventures being proposed by other company divisions and the projected rate of return.

FINANCES

- The same can be said of our financial restraints. The holders of our corporate purse strings must of course choose the best ventures in which to invest available funds. Their selection is made again on the basis of best return on investment.

MARKETING

- The key constraint is one of marketing. Any well directed company will avoid any expenditures of time and effort directed at anything but a well defined and widely perceived market need. Needs in the market place are most easily, and in Canada most often, defined in terms of past and present sales figures for the product of another company already on the market. To be the first on the market with a new product requires a significant commitment on the part of a company to any business endeavour. When you are the first to do it development costs are high, product advertising and promotion costs are high, sales costs are high with a good deal of missionary work required with all links in the distribution chain, let alone the end consumer or user.

We at Electrohome have for several years projected a need for an exhaust air heat recycling controlled ventilation product for the well insulated well sealed home. Our question is "When will it be required?"

Will the owner of an energy efficient home perceive the need for our product until there is some evidence of damage to his home due to excessive humidity? Will the builder of energy efficient homes with his overiding concern for low price ever see the need for such a product?

If the above customers for such a product are left to identify the need on their own the market will be a long time on developing.

If on the other hand building code writing authorities, sensitive to the need, change their codes to incorporate such a product, the market will develop rapidly and in fact the manufacturers' ability to supply may be taxed.

How could CMHC help to implement the establishing of the product in the marketplace in terms of reducing the impact of or eliminating constraints?

1. The funding of the product development work would counter any time or financial constraints that may exist.

2. Rewriting building codes or CMHC specs so as to make the product a requirement would ensure that the need was readily perceived in the marketplace. Timing of such changes should be carefully worked out between CMHC, code writing bodies, and the supplying industry.

3. In terms of product development I'm sure that if CMHC made their expertise related to dwelling ventilation and any other product - building interface requirements available to industry it would be a benefit.

# APPENDIX K

## GENERAL DISCUSSION

After Mr. McQuarrie's presentation there was a period of general discussion. The following does not attempt to record all of this discussion but is a summary of the more significant points brought forward.

Mr. Lange of Enercon Building Corporation in Regina related his company's involvement in building a house for the "mass market" which was designed to be passively solar heated. The house was under construction in Regina with a projected completion date of December 1978. It has the following characteristics:

- R 30 insulation in the basement
- R 40 insulation in upper walls
- R 55 insulation in the ceiling
- carefully installed vapour barrier which it is hoped will reduce infiltration to 0.1 to 0.2 air changes per hour
- heat exchanger of the type developed by Professor Besant
- no furnace
- 300 watt back-up heating

It is anticipated that the annual cost of heating this house will be about $50 and that an extra cost of about $3/sq. ft. over ordinary construction is involved for such items as:

- the heat exchanger
- the mechanical management of the passively-collected heat
- the extra labour using conventional subtrades
- the extra material using conventional insulating materials

This gives a payback period of 5 to 7 years based on Regina costs for natural gas or around 3 years based on the cost of fuel oil or propane as used in rural areas.

Mr. Hockman described some work Manitoba Housing and Renewal had done with Manitoba Hydro in testing a modified air conditioner for use as a dehumidifier. In MHRC's native housing with large families living in small houses they experience as much as 85 lb. of water vapour generation per day. With electric heating, the cost of removing this moisture by ventilation is about $75 per month. The use of a dehumidifier was therefore attractive since it would eliminate the need for so much ventilation and even the energy used to run it would be given up to the house as a form of electrical heat. Laboratory testing of the modified air conditioner indicated it could not remove sufficient moisture to maintain a safe humidity level under the conditions MHRC was concerned with. However, it has apparently been used successfully in some urban houses with lower rates of moisture generation.

Mr. McLean of Keep-Rite pointed out that in manufacturing products for incorporation in housing, such as exhaust fans, they have found it necessary to have two products lines - a better quality line for sale to home owners and a lesser quality line for sale to builders - because many builders are not willing to pay extra for quality.

Mr. Raz discussed the assistance programs the Department of Industry Trade and Commerce has available related to energy. There is a program to provide assistance in reducing energy consumption in industrial processes and assistance has always been available for basic research on new products whether energy-related or not. However, there is no assistance program for product development of any kind.

Mr. Haysom outlined CMHC's position on the question of pay back periods and present value factors. He pointed out that CMHC was planning to prescribe the new Measures for Energy Conservation in New Building for all NHA-financed housing and that the insulation levels contained in the "Measures" are based on a present value factor of 18. It was recognized that if a homeowner realized that the added cost of achieving these levels might take several years to be recovered he might not decide to buy such levels. However the government, in developing an energy code based on a present value factor of 18, was making that decision for the homeowner in the interest of the country's need to conserve energy.

Dr. Stephenson pointed out that a given energy conservation measure might have a long pay back period but could result in a lower monthly total for mortgage payment plus heating bill and that, if this were the case, there would surely be no difficulty in selling such a measure to consumers.

Mr. Leadbeater thought that the need for sophisticated ventilation systems might be somewhat less urgent if good quality exhaust fans were used and properly installed now. He pointed out that CSA have two standards in this area - one for the fans and one for their installation - but these are not prescribed by any authority. Mr. Haysom thought there might be some merit in CMHC's Engineering and Inspection Group's considering the inclusion of these standards in Residential Standards.

Mr. McDonald of the Ontario Ministry of Housing mentioned his ministry's concern with moisture damage of housing and said they are looking into the feasibility of attic pressurization as a means of reducing air leakage from the house into the attic. Mr. Platts said that this is an effective method and has been used successfully for Artic housing. The attic should be pressurized just enough to overcome the stack effect pressure difference across the ceiling.

Mr. Stricker agreed that attic pressurization was a better method than attic exhausting since exhausting air from the attic would only draw more air through the inevitable leaks in the ceiling. He related some testing Ontario Hydro had done to investigate the possibility of using the attic as a free solar preheater for ventilation air. They found that even at night they were drawing 1 1/2 KW of heat out of the attic and this was of course the heat in the air being drawn up through the ceiling.