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AN AIR TO AIR HEAT EXCHANGER FOR RESIDENCES

R.W. Besant, R.S. Dumont, D. Van Ee
Department of Mechanical Engineering

Introduction

A considerable amount of energy is required to heat the ventilation air in residences. Depending on the size and type of home construction, about one-quarter to as high as one-half of the heating energy consumed goes to heat the air. Even in a very well sealed house, air must be introduced to control excessive humidity, to control odours and to provide oxygen for the residents.

Typically in new house construction, about one-half air change per hour is found. That is, the volume of air inside the house is replaced about once every two hours. Using figures from a recent booklet [1], it can be estimated that the heat required to warm this air in the heating season amounts to about 25% of the total heating load (Table I).

TABLE I

Heat Loss Percentages from Typical House (1961-1975)

Ceiling	10 - 15
Walls	10 - 20
Basement	20 - 25
Doors and Windows	15 - 20
Air Change	20 - 30

By proper sealing techniques it is possible to lower the amount of air change, but a limit of about one-quarter air change per hour is the minimum one should allow. Another way to reduce the heat loss associated with the ventilation air is to use an air to air heat exchanger; in other words, to transfer the heat from the outgoing stale warm air to the incoming cold air.

An air to air heat exchanger will also reduce excessive amounts of water vapour in a dwelling. This aspect of the device is described in the last section of this publication, beginning on page 9.

It bears mentioning that an air to air heat exchanger will **not** be of any value in a poorly sealed home. The heat exchanger will only be of value if one can control the movement of air into and out of the house. If leaky doors, windows, electrical outlets, fireplace dampers, kitchen fan exhausts, bathroom fan exhausts, gas, oil or wood furnace chimneys provide alternate paths for the air to enter or leave the house, then the heat exchanger will be of little value. For new home construction, one would want to include the following features to control air leakage.

1. Use vestibule entrances with two doors for all exits from the house.
2. Use sealed windows, or if openable, casement or awning type windows—avoid double-hung or sliding windows.
3. Avoid sliding patio doors.
4. Ensure a complete vapour barrier seal around the house.
5. Use a recirculating range hood for the kitchen, rather than an outside venting type hood.
6. Vent the bathroom fan, if used, into the air to air heat exchanger.
7. Vent the dryer vent, into the air to air heat exchanger (electric dryer only).
8. If using fuel burning furnaces (gas, oil, wood, coal) completely isolate the combustion air and the chimney air from the house air. One way to do this is to build a tight enclosure around the furnace, and supply the combustion air and chimney air directly from outside the house. Alternatively, special ducting to supply combustion air and chimney air to the furnace may be used. A number of furnace suppliers are now testing such units.

With an existing home built to conventional standards, considerable changes along the above lines would be required to effectively make use of the air to air heat exchanger.

Design of the Air to Air Heat Exchanger

The design shown in this publication is one that was developed at the University of Saskatchewan by Professor R.W. Besant. The assembly details were worked out by Dick Van Ee.

In schematic form, the heat exchanger may be described as a vertical, parallel plate, counter flow heat exchanger. In Fig. 1 the design is shown. The operation of the device is as follows: Warm stale air from the house enters the exchanger at (1), travels vertically downward and exits at (2) giving up its heat to the incoming cool air stream. The stale air is then vented to outside the house. The cool outside air enters the exchanger at (4), travels vertically upward, and then leaves the heat exchanger at (3). It then passes on to the furnace return air duct where it is mixed with the air returning to the furnace. Alternatively, the fresh air may be vented directly into the living areas of the house.

It is critical that the air flows through the device be as shown, with the warm inside air travelling vertically downward, and the outside air vertically upward in alternate layers (Fig. 2 and Fig. 3). The spacing between the plastic sheets is 12.7 mm (0.5 inches). One fan is required to move the air streams through the heat exchanger. It is preferable to have the fan situated so as to cause a slight vacuum in the house. In our models we have placed the fan to blow the inside air out. In Fig. 4 the location of the fan and the drain pan for the condensate is shown.

As the moist inside air travels vertically downward, moisture will condense out of the air stream if the air stream is cooled below the dew point. If the air stream leaving the house is further cooled inside the heat exchanger below the freezing point of water, ice crystals will form inside the heat exchanger. In the design, therefore, one must provide some means of removing the moisture and ice. A drain pan at the base of the exchanger serves to collect the moisture. Under the freezing condition mentioned, one must periodically defrost the device. The frequency of defrosting depends upon several variables—the outdoor air temperature, the indoor air relative humidity, and the air flow rate through the heat exchanger. Under the worst conditions experienced on the Canadian prairies, one would have to defrost about once per day. In a mild climate such as Vancouver's, one would have to defrost only a few times per winter.

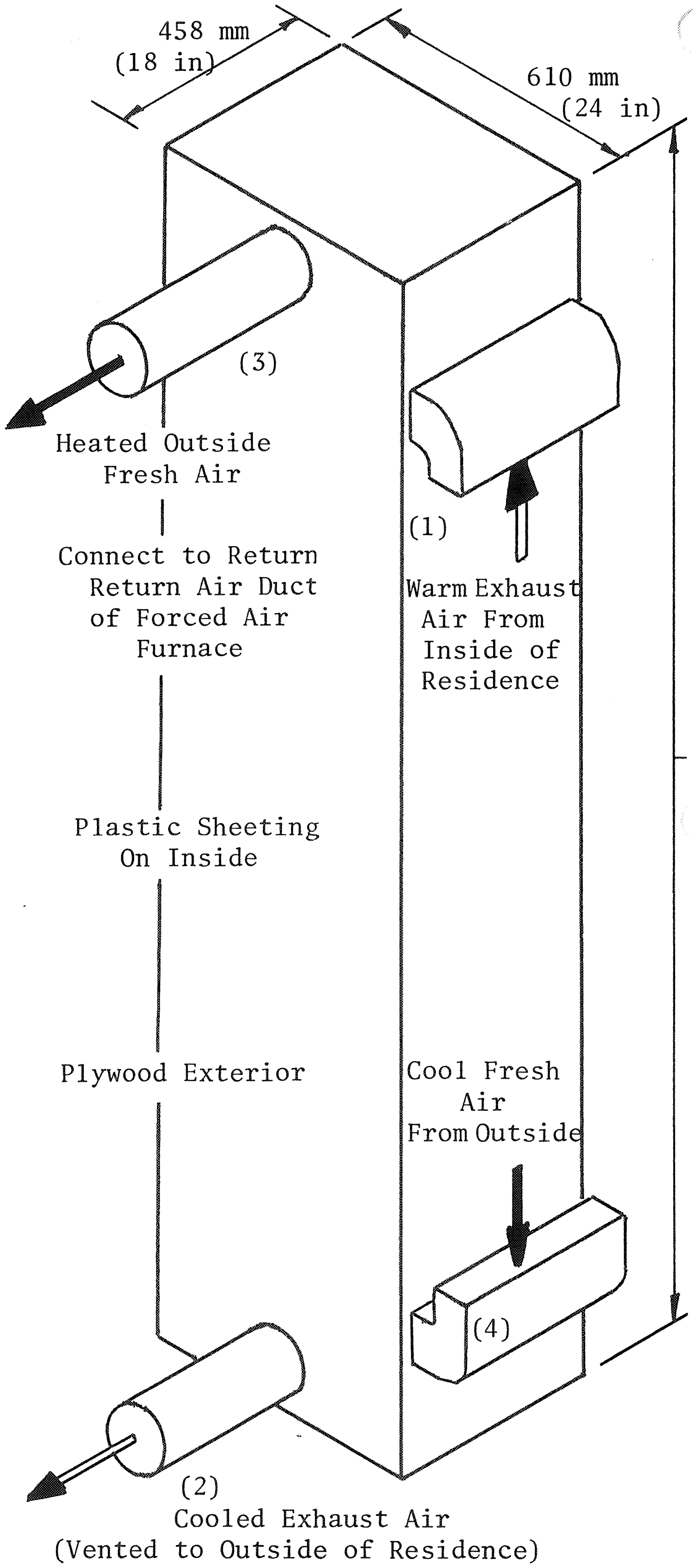


FIGURE 1 - RESIDENTIAL AIR TO AIR HEAT EXCHANGER (For clarity the outside insulation and part of the ductwork are omitted from the drawing.)

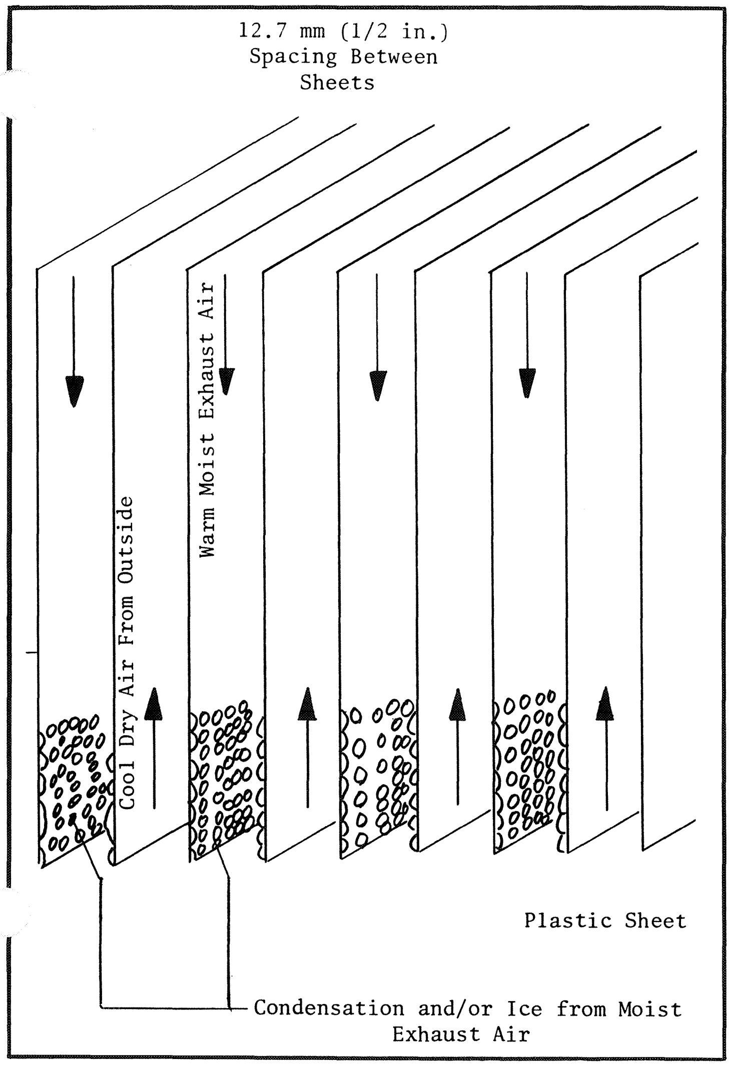


FIGURE 2 - AIR FLOWS THROUGH AIR TO AIR HEAT EXCHANGER

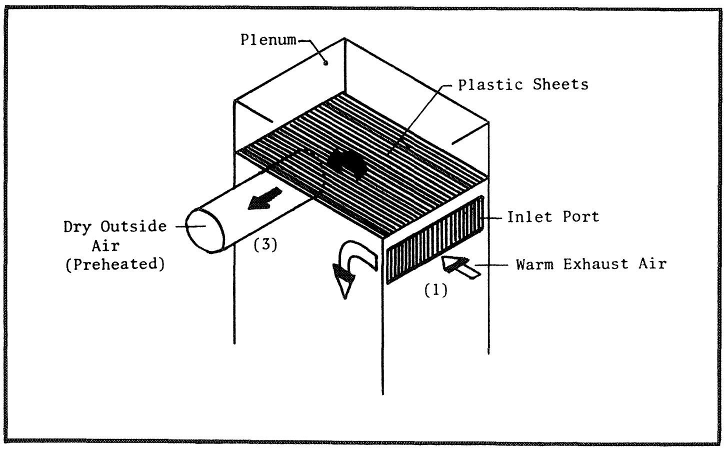
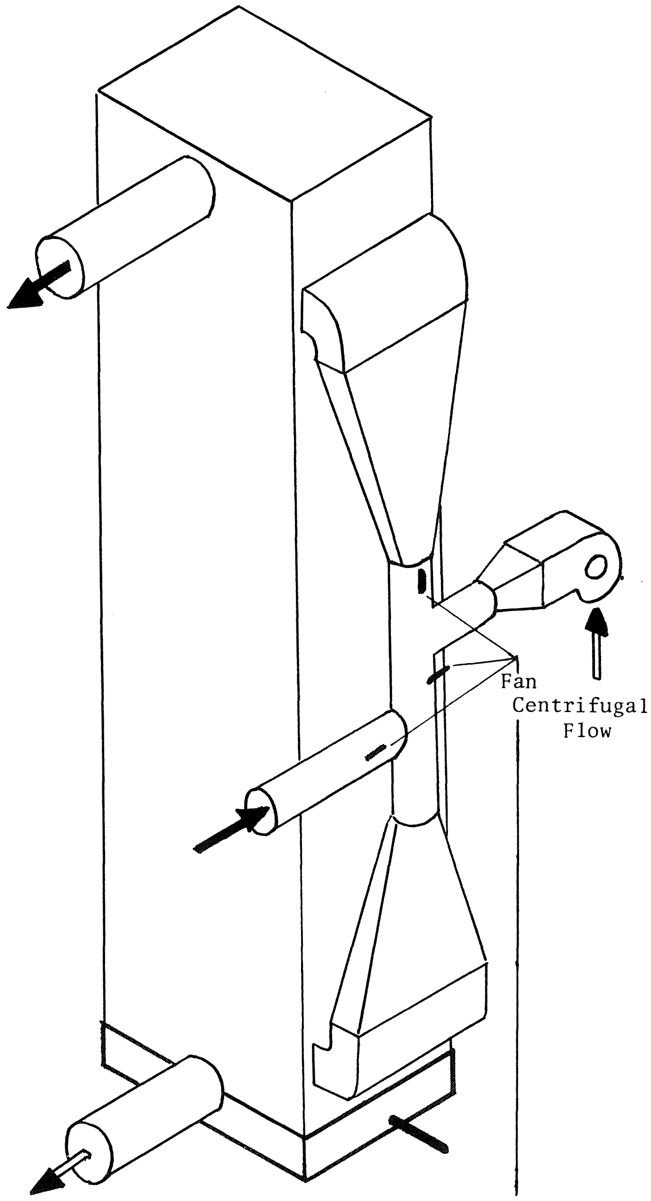


FIGURE 3 - DETAIL INDICATING AIR FLOW PATHS AT TOP OF EXCHANGER



— Dampers to Allow
Unit to be Rapidly Defrosted.

To Defrost, the 3 Dampers
are Simply Rotated 90 Degrees

FIGURE 4 - HEAT EXCHANGER INCLUDING DUCTWORK, FAN, DAMPERS AND DRAIN PAN

Defrosting can be accomplished in a number of ways. One way is simply to turn off the fan. Depending on the outdoor air condition and the degree of frosting, the frost will fall to the drain pan in anywhere from a few hours to a few days.

An alternate defrosting mode, more suitable for colder climates, is to reroute the inside air flow and block the outside air flow so that the frost accumulation on the plates is removed. This defrost mode can be achieved by rotating the three dampers shown in Fig. 4, causing the outside air flow to be blocked and the warm inside air to travel through the outside air path inside the heat exchanger. In the construction details section of the plans, the ducting layout that allows the defrost mode to operate is shown.

Performance of the Device

Detailed performance data for the heat exchanger can be found in a technical paper by Besant, Brooks, Schoenau and Dumont[2]. A summary of the performance data is presented in Fig. 5. The graph shows the heat recovery ratio of the device whose dimensions are shown as a function of the air flow through the device. Note that as the air flow increases, the heat recovery ratio decreases. Thus one should operate the device at the flow rate specified (less than 0.05 m^3/s or 100 cfm). The heat recovery ratio is a relative measure of the amount of heat that is actually transferred as compared with a heat exchanger that is infinitely long. The maximum effectiveness attainable in any heat exchanger is 1.0.

In an average residence with interior volume of approximately 450 m^3 (16,000 ft^3), a flow rate of about one-quarter air change per hour should be sufficient to keep the house air pleasant. This would amount to an air flow of about 0.031 m^3/s (70 cubic feet per minute) continuously through the heat exchanger. Following installation of the device, one can vary the air flow to suit the particular requirements of the house. In general, if excessive humidity in winter or high odour levels are present, the air flow should be increased. If low humidity or dryness are present and odours are not a problem the air flow may be reduced. Under normal operating conditions (i.e. no frost buildup), the outside air introduced to the heat exchanger should be raised to within a few degrees Celsius of the temperature of the air inside the house. To illustrate, the example in Fig. 6 shows a temperature rise that could be expected from the device in a cold winter situation on the Canadian Prairies. Note that the outside air has been raised in temperature from -35° C(T_4) to +16.7°C (T_3). At these conditions

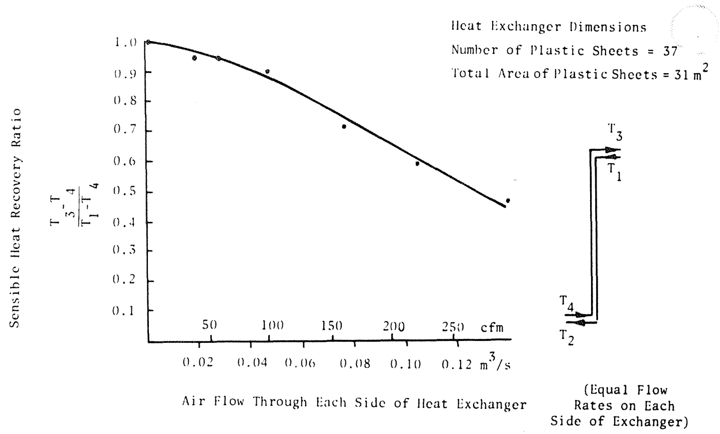


FIGURE 5 - HEAT EXCHANGER PERFORMANCE AS A FUNCTION OF AIR FLOW

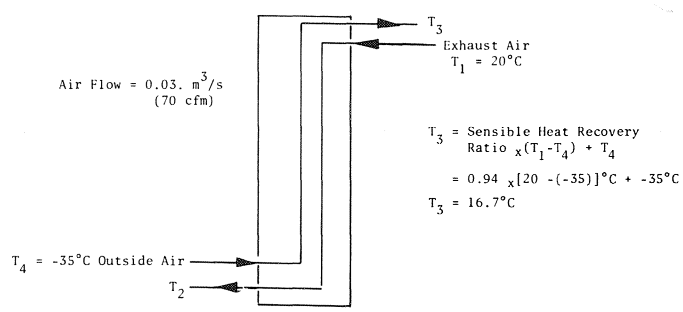


FIGURE 6 - HEAT EXCHANGER PERFORMANCE ESTIMATE

the sensible heat recovery amounts to about 1900 Watts (6400 Btu/hr). To put these energy saving figures in perspective, a typical residence constructed to present (1977) standards would have a heat loss of about 15,000 watts (51,000 Btu/hr) when the outdoor air temperature falls to -35°C.

An energy saving house being constructed by the Saskatchewan Government in Regina with the energy conserving features listed in Table II, has a heat loss of only about 5,000 Watts (17,000 Btu/hr).

TABLE II

Insulation Levels for Energy Conservation House

Surface	Area m^2	Effective Thermal Resistance °Cm^2/W	°Fft^2hr/Btu
Ceiling	94	10.6	R60
Walls	190	7.0	R40
Floor	94	4.8	R27
Doors	3.6	3.2	R18

Note that as the insulation levels are raised in a building, the proportion of heat loss associated with the ventilation air also rises.

Construction Plans

The device is constructed out of plywood, plastic sheeting, and nails. The construction is of a sandwich type, starting with the bottom layer of plywood. The plastic sheet is then laid on top of the plywood, and the plywood laminations are added as shown in Fig. 7, Step 1. The laminations are nailed to the plywood sheet and the plastic is rolled over the top of the laminations, and the second set of wood strips is nailed on (Step 2). This process is continued until a total of 37 layers have been added. At this time, a final layer of plywood identical to the bottom layer is nailed on. At the slots, the plastic can be stapled.

The ductwork and drain pan must be fabricated for the exchanger. A sheet metal shop can provide these custom-made pieces. Alternatively, the wood plenums shown in Fig. 9 may be built using plywood.

Materials List

Plywood (Pressure Treated) : 2 - 610 mm x 2.286 m x 12.7 mm (24" x 90" x ½")
38 - 51 mm x 610 mm x 12.7 mm (2" x 24" x ½")
38 - 51 mm x 1.778 m x 12.7 mm (2" x 70" x ½")
38 - 51 mm x 1.651 m x 12.7 mm (2" x 65" x ½")

The dimensions listed are suitable for a basement with a 2.43 m (8') ceiling. If the clearance is less than 2.4 m, shorten the long dimensions of the plywood to fit. Allow about 150 mm vertical clearance for installation.

Plastic Sheeting : 90 m of 0.91 m wide roll of 0.15 mm thick polyethylene (300 ft of 3 ft wide roll of 6 mil polyethylene)

Nails : galvanized

Insulation : Approximately 50 mm (2 in.) of fiberglass covering or equivalent for the exterior is recommended. (Rigid fiberglass preferred.)

Duct work : As shown in Fig. 8. Alternatively, the wood plenums shown in Fig. 9 may be built.

Drain Pan : As shown.

Fan : Capacity of approximately 0.071 m^3/s (150 cfm). A variable speed range hood fan is suitable.

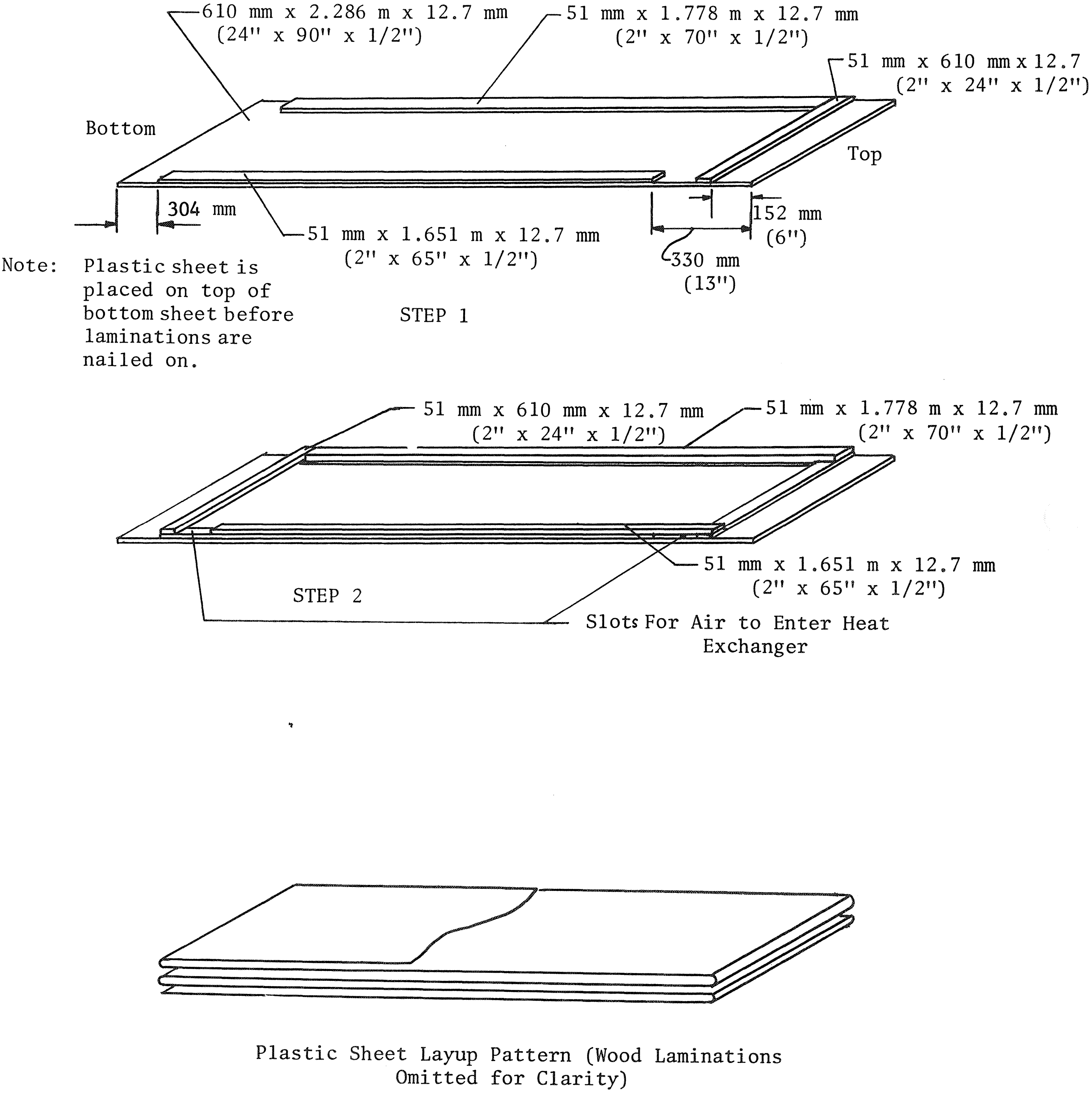
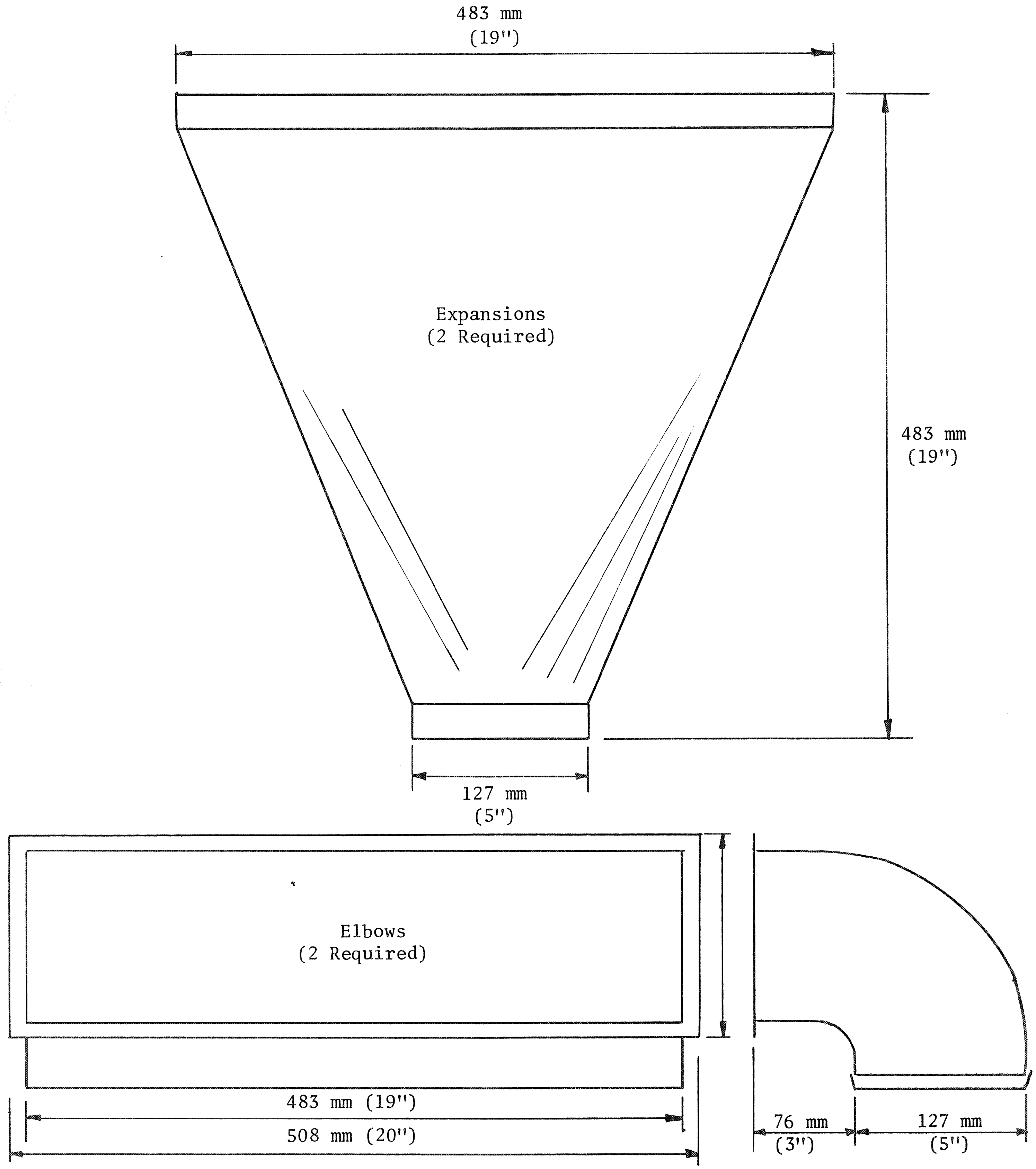


FIGURE 7 - CONSTRUCTION SEQUENCE FOR LAMINATIONS



Also Required: 3 - 127 mm dia. (5") tees
3 - 127 mm dia. (5") dampers
6 - 127 mm dia. (5") ducts
2 - Outside air vents (dryer vent types are satisfactory)

FIGURE 8 - SHEET METAL PARTS

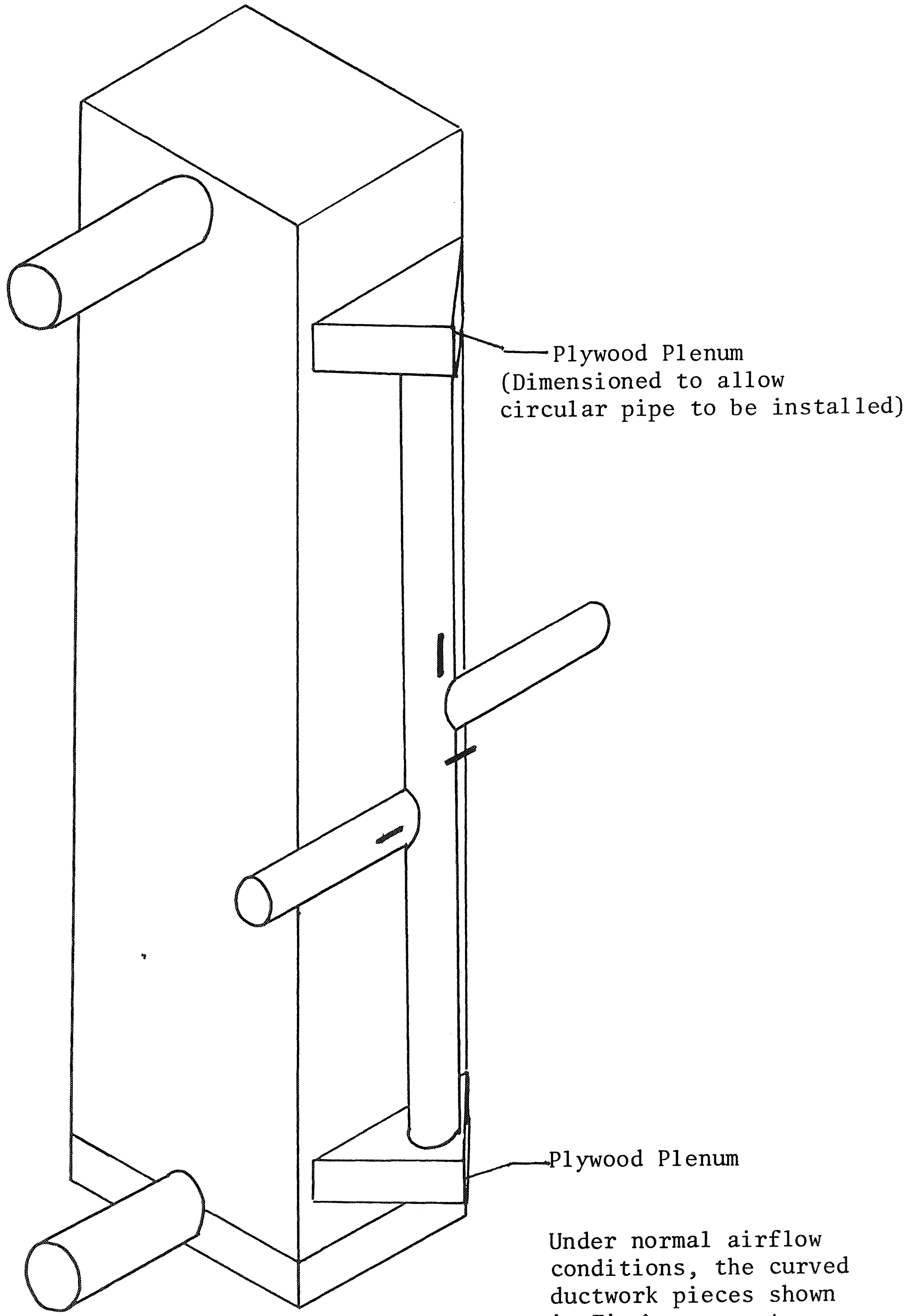


FIGURE 9 - ALTERNATIVE DUCTING COMPONENTS

Water Vapour Reduction

A number of the heat exchangers described in this pamphlet have been constructed and installed in houses. One has been installed in the Saskatchewan Conservation House in Regina. It has been found that the heat exchanger can reduce excessive amounts of water vapour which can cause large amounts of condensation to occur on the windows. This high relative humidity indoors occurs most frequently in well-sealed residences that are heated by electricity or solar energy. The sources of moisture in the residences are cooking, bathing, evaporation from plants, and toilets. In relatively new houses with concrete basements, a large amount of moisture will evaporate from the concrete floor and uninsulated walls. As well, a large amount of water vapour is stored in the building materials of the house during the summer months, and much of this is evaporated into the air during the winter.

The heat exchanger described has successfully removed large amounts of water vapour from the houses where the units have been installed.

Method of Control

Because humidity control appears to be one of the most attractive features of the heat exchanger, it is advised that the device be operated with a humidistat; that is, the exhaust fan on the device should be controlled by an on-off humidistat, available from heating and plumbing suppliers. A humidistat with contacts that close on rising humidity is required.

To give you some idea of the amount of moisture removed: a calculation indicates that for an air flow of 0.033 m^3/sec (70 cfm) through the heat exchanger, with an indoor relative humidity of 30% in the dwelling, approximately 20 kg (20 liters) of water would be removed per day under winter conditions. Depending on the outdoor air temperature, a considerable amount of this moisture will condense and possibly freeze in the heat exchanger. Under normal operating conditions, the air to air heat exchanger will act to lower the relative humidity in the dwelling, and the amount of moisture that is to be removed will be reduced as the indoor humidity level reduces. With intermittent operation of the heat exchanger, the defrosting problem will be considerably reduced.

Solar Preheater Option

In situations where large amounts of water vapour inside the house cause very frequent defrost cycles to be required for the heat exchanger, one possible solution is to install a relatively inexpensive solar collector to preheat the cold outside air entering the heat exchanger so as to allow the unit to defrost on its own. The solar collector described below will raise the temperature of the incoming air by approximately 20° C on a sunny day, allowing the unit to defrost. As shown in Figure 10, the solar collector mounts on the southfacing wall of the house, preferably under an eave to block the summer sun. The outside air enters at the lower part of the solar preheater, travels vertically upward, reverses direction, travels to the bottom of the collector and exits on the right hand side of the device. An insulated duct takes the air inside the house to the heat exchanger.

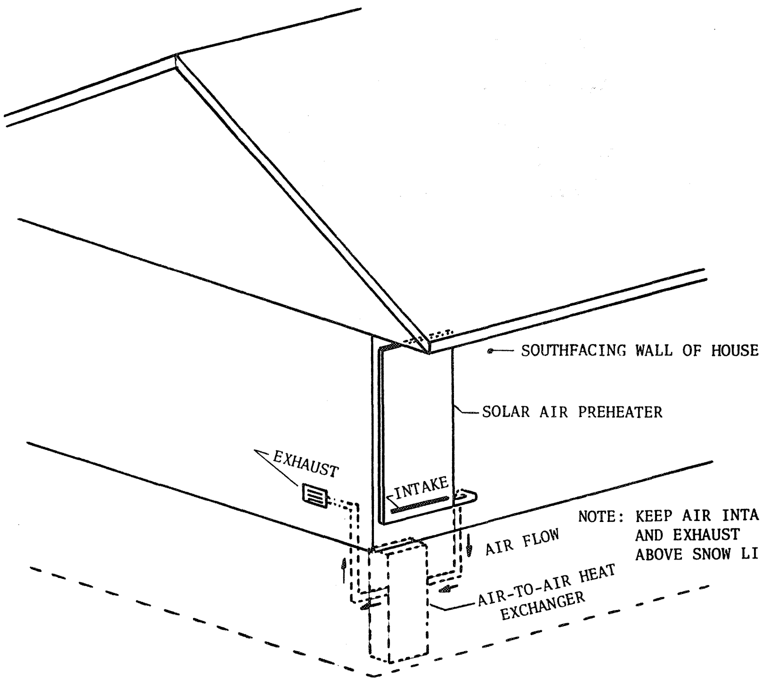


FIGURE 10 - POSITIONING OF SOLAR AIR PREHEATER ON SOUTH WALL OF DWELLING

Construction of the Device

The assembly of the solar collector is shown in Figure 11. Further details are provided in Figures 12 to 15. The overall size of the device is designed to allow use of one 4 ft. x 8 ft. sheet of plywood. At the time of writing, metric plywood sheets are not available. However, once the sheets are available, the size will be 1.2 m x 2.4 m, a size slightly smaller than a 4 ft. x 8 ft. sheet. The dimensions of the unit may be adjusted to accommodate metric plywood sheets when they become available. An important construction feature that should be observed is careful sealing of all joints so as to prevent air leakage. Silicone sealant, although costly, will be the most satisfactory for this purpose.

Materials List

Plywood - ½ in. thick 4 ft. x 8 ft. 1 sheet (12 mm) (1.2 m x 2.4 m)

Spacers - 2 in. x 2 in. (38 mm x 38 mm) 40 lineal feet (12 m)

Sheet metal - 28 gauge (.32 mm) 4 ft. x 8 ft. (1.2 m x 2.4 m) - 1 sheet
Painted flat black or dark green on both sides

Fibreglass glazing - 4 ft. x 8 ft. - 1 sheet (1.2 m x 2.4 m) (Alternatively - glass may be used)

Battens - 1½ in. wide (38 mm) 30 lineal feet (cedar)

Angle brackets - 1½ in. x 1½ in. (38 mm x 38 mm)

Screws and grommets - 100

Galvanized nails

Ductwork - 4 in. (100 mm) flexible plastic (dryer vent type is suitable)

Port through wall of house - dryer vent type is suitable

Galvanized flashing - 125 mm x 1.25 m (5 in x 49 in)

Humidistat - Contacts to close on rising humidity

Paint - Flat Black for absorber

List of References

1. **Keeping the Heat In**, Energy Mines and Resources Canada, August 1976.
2. Besant, R.W., Brooks, E.E., Schoenau, G.J. and Dumont, R.S., "Design of Low Cost Ventilation Air Heat Exchangers," presented at Heat Transfer in Buildings Conference, Belgrade, Yugoslavia, September 1977. International Centre for Heat and Mass Transfer.

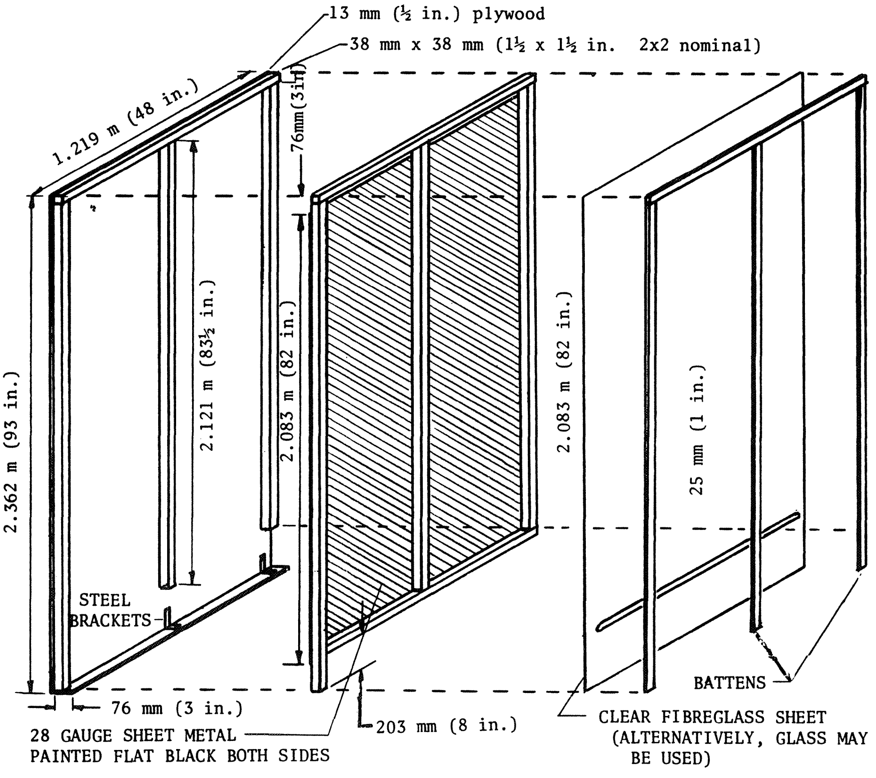


FIGURE 11 - SOLAR AIR PREHEATER ASSEMBLY

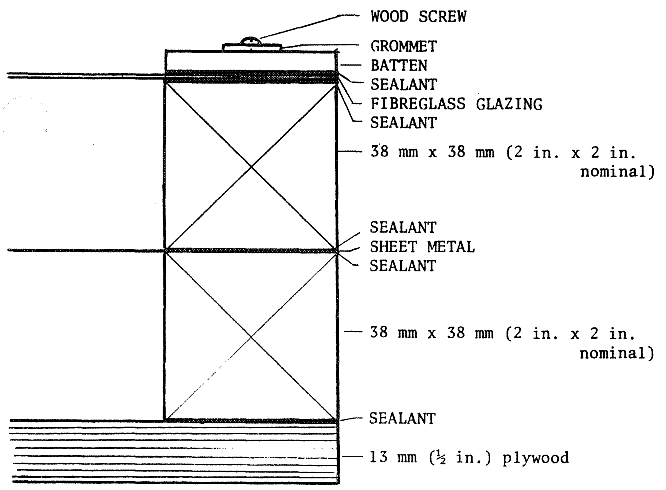


FIGURE 12 - DETAIL OF SOLAR AIR PRE-HEATER (Section)

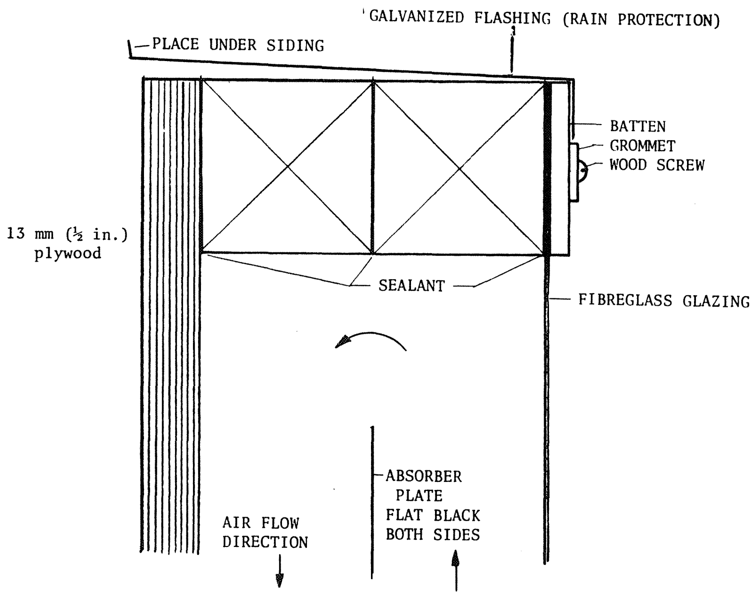


FIGURE 13 - DETAIL OF TOP OF SOLAR AIR PREHEATER (Section)

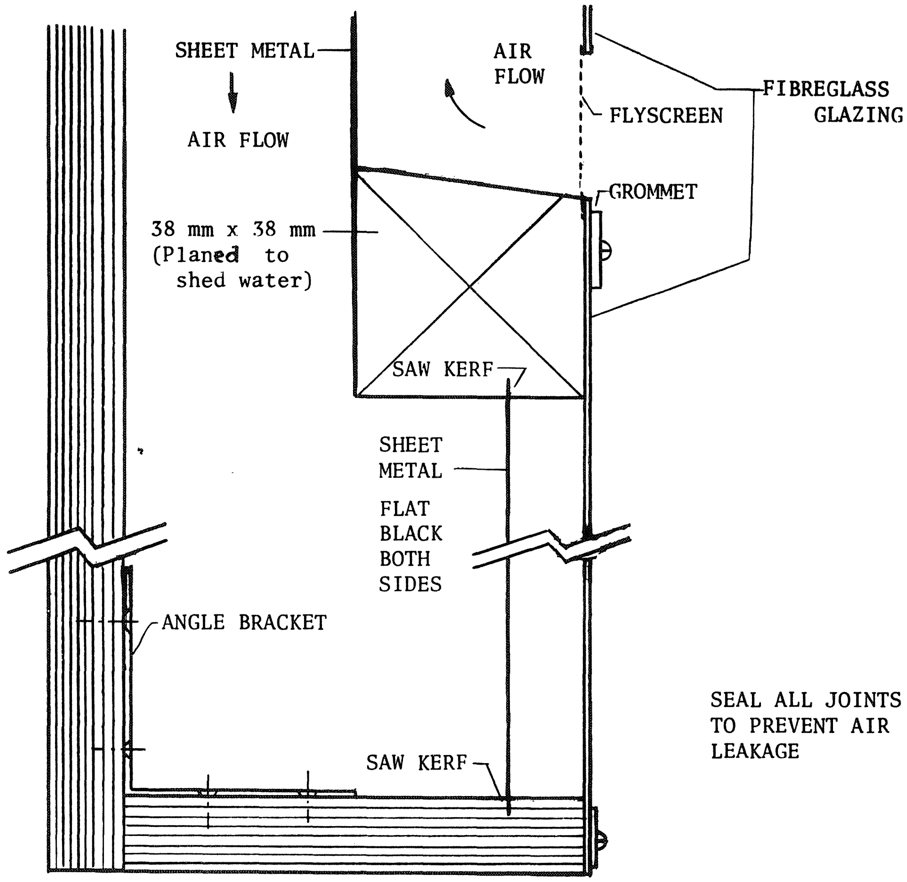


FIGURE 14 - DETAIL OF BOTTOM OF COLLECTOR (Section)

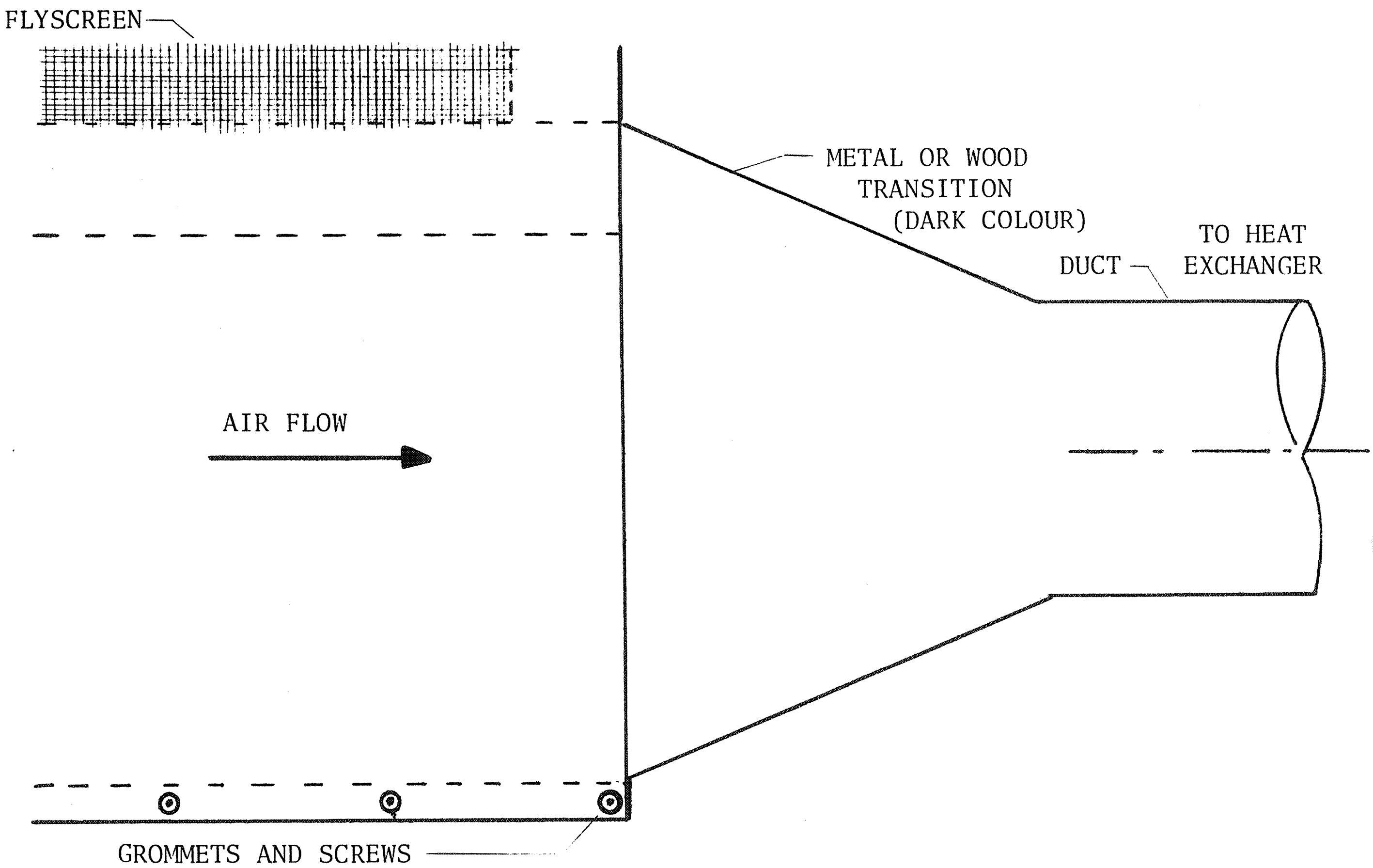


FIGURE 15 - DETAIL OF BOTTOM OF COLLECTOR (Elevation)