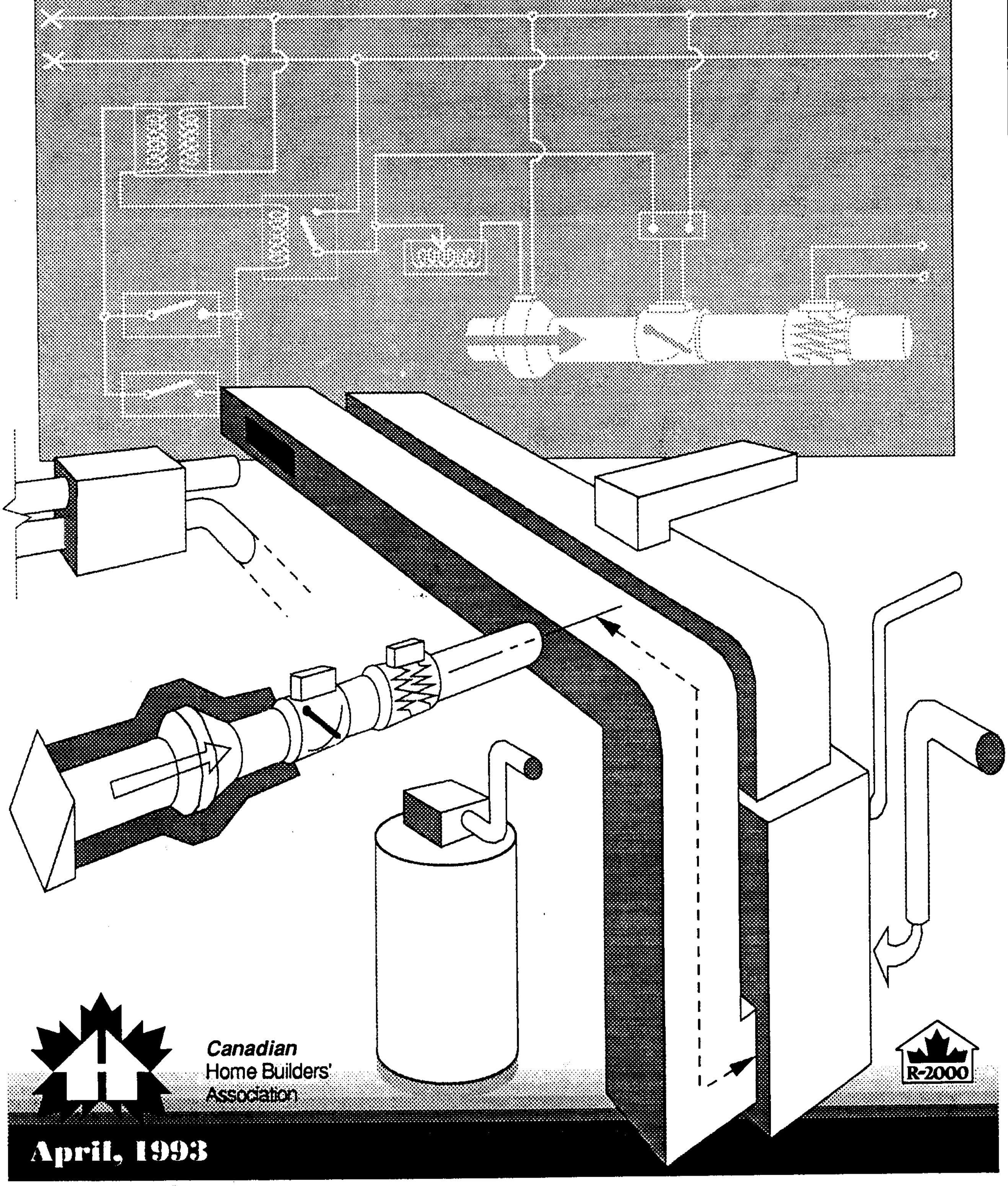
R-2000 Make-up Air Guidelines



Canadian
Home Builders'
Association

R-2000

April, 1993

Acknowledgements

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We would also like to acknowledge the contribution of manufacturers who made available their technical material for the purpose of this manual.

Design, layout and illustrations by *REIC (Consulting) Ltd.*

Table of Contents

1. Introduction

This manual is intended to show some, but not the only options for providing make-up air in R-2000 houses and help an R-2000 builder sort out and choose the best one for houses they build. These options are recommended as good building practice.

The sections of this book that are of most importance to builders are:

- Section 2, which shows how to minimize the amount of make-up air that needs to be provided; and
- Section 6, which offers a number of example systems.

The other sections deal with technical issues that may be of more interest to installers, but **builders should value the information so that they can discuss options with their installers and/or qualified R-2000 professionals and deal with their customers' questions.**

> Information that is of particular relevance to builders has been highlighted with a border like the one around this sentence.

In writing the manual, we know the following about R-2000 houses.

1. They have balanced ventilation systems such as Heat Recovery Ventilators (HRVs).
2. A competent and HRAI trained mechanical system designer and installer will be used.
3. Conventional, naturally aspirating combustion appliances are not allowed.
4. Energy use and comfort requirements of R-2000 require that make-up air inlets be controlled so they are only open when needed.

1.1 The Rules

All R-2000 homes must meet:

- local building codes;
- the R-2000 Technical Requirements; which calls up
- CAN/CSA-**F326**-M91 *Residential Mechanical Ventilation Systems* (ref 1).

F326 has requirements for *make-up air* which it defines as *outdoor air supplied to replace exhaust air.* The main concern is that the negative pressure or "suction" that exhaust fans can create in a tight house may:

- draw exhaust gases from fuel-fired appliances into the house rather than letting them go out the vent or chimney; and
- draw soil gases like radon, methane or humidity into the house.

F326 has requirements which put limits on the negative pressure that can be created by:

- the continuous (long-term) operation of ventilation equipment; and
- the intermittent (short-term) operation of exhaust devices including ones which are not part of the ventilation system.

In R-2000 houses with balanced ventilation systems, only the intermittent requirements are of real concern. The intermittent pressure control requirement in F326 can be summarized as follows:

If there is a *vented combustion appliance* (fuel-fired furnaces, hot water heaters, fireplaces, etc.) installed in the house, the simultaneous operation (at the same time) of the

- **ventilation system,**
- **the dryer, and**
- **the largest other exhaust device,**

must not create a negative pressure in the house of more than -5 Pascals unless the manufacturer of the combustion equipment has certified operation at a higher pressure. If the actual capacity of the dryer is not known, 75 L/s (150 cfm) is assumed.

When this document was written, the only combustion appliances not affected by the -5 Pa limit are those that operate with a completely *sealed combustion system* (combustion air is drawn in from the outside through a sealed air inlet, and exhaust products are vented to the outside through a sealed flue pipe).

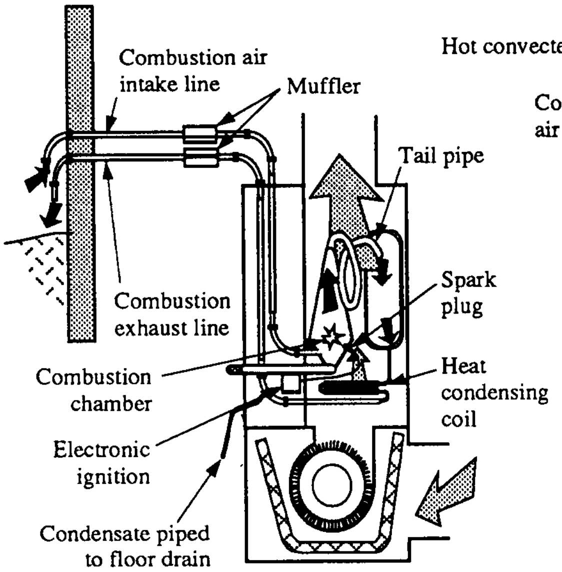
So far, **no manufacturers of appliances that draw air from inside the house have certified their equipment** for operation at negative pressures greater than -5 Pascals. This is true for **induced draft furnaces or hot water heaters, and all wood-burning fireplaces and stoves.**

1.2 Relation to Other Codes

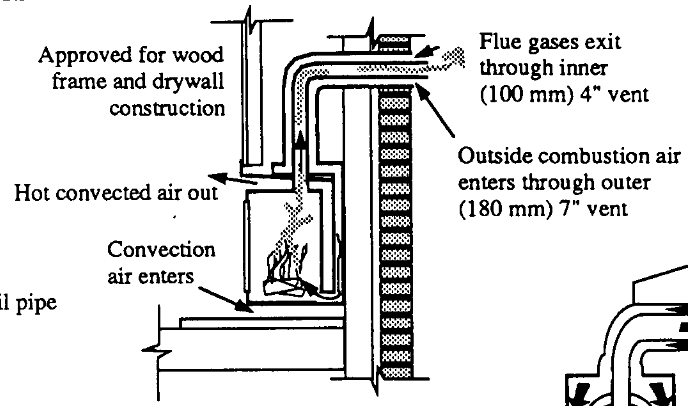
The National Building Code and, therefore, most provincial building codes, have make-up air requirements when there are *vented combustion appliances*. Systems which comply with F326 meet these code requirements.

Installation codes for fuel-burning appliances (gas, oil, or wood) have requirements for *combustion air* inlets. These are sized to replace only the air that is used by the appliance, not any other exhaust device. The easiest way to show compliance with both F326 and the appliance installation codes is to have separate *make-up air supplies* and *combustion air supplies*. Section 5.5.4 and Example System 5 in Section 6 show a way of using a combined inlet. We suggest that this approach be checked with local authorities before implementation.

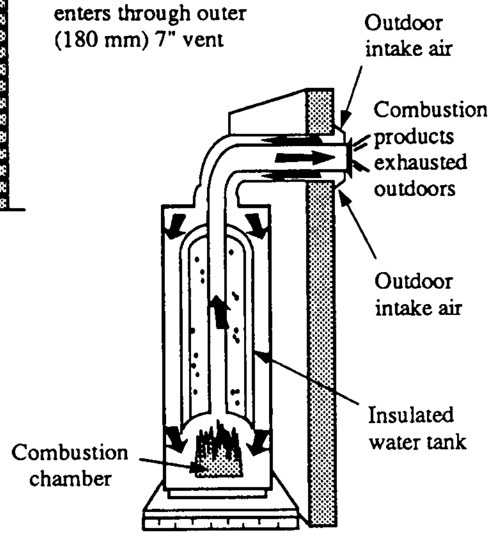
Sealed Combustion Appliances (No Pressure Limit)



Sealed Combustion Gas Furnace

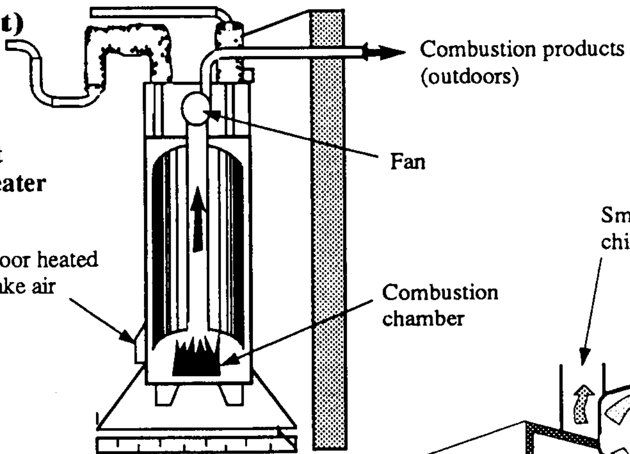


Direct Vent Gas Fireplace

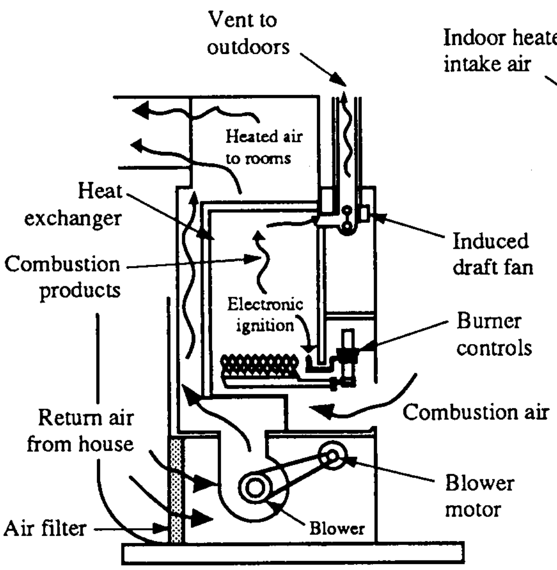


Sealed Combustion Gas-fired Hot Water Heater

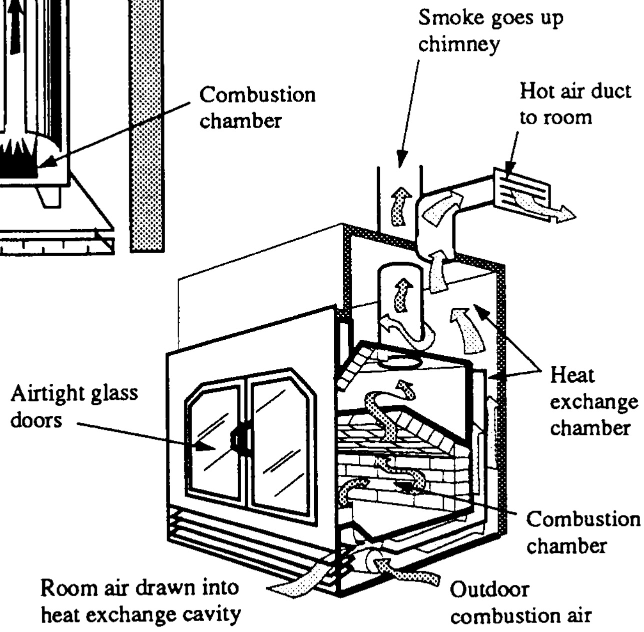
Vented Combustion Appliances (Affected by -5 Pa Pressure Limit)



Induced Draft Hot Water Heater



Induced Draft Furnace



Fireplace

2. Make-up Air Strategies

The size, complexity, and cost of the make-up air system needed in the house depends on the heating and exhaust appliances that are going to be installed. Therefore:

- The builder should know what he can do to eliminate or reduce the size of the make-up air system.
- The designer and installer of the make-up air system must understand the design requirements of both the heating and the ventilating systems. The use of a single company to address both needs is recommended.
- The builder and mechanical designer must start discussing options very early in the design process.

Figure 2.1 is a flow chart which helps a builder choose the best make-up air strategy for his application. The reference numbers refer to the applicable sections in the manual.

2.1 Avoid Vented Combustion Appliances

You can eliminate the need for make-up air by using electric or sealed combustion heating and hot water heating appliances or direct vent gas fireplaces, and not using wood fireplaces or stoves.

- Sealed combustion, gas-fired furnaces and hot water heaters are widely available at little cost premium over the other types of appliances allowed in R-2000 houses.
- Sealed combustion, oil-fired furnaces and boilers are also available. The cost premium over other types allowed in R-2000 is probably less than the cost of the make-up air system that you would need to install.
- **Make-up air must be considered when there is a wood-burning fireplace or stove.** If a fireplace is necessary for your market, use a direct vent gas fireplace if possible. If you do use wood-burning appliances, make sure you understand the cost implications.

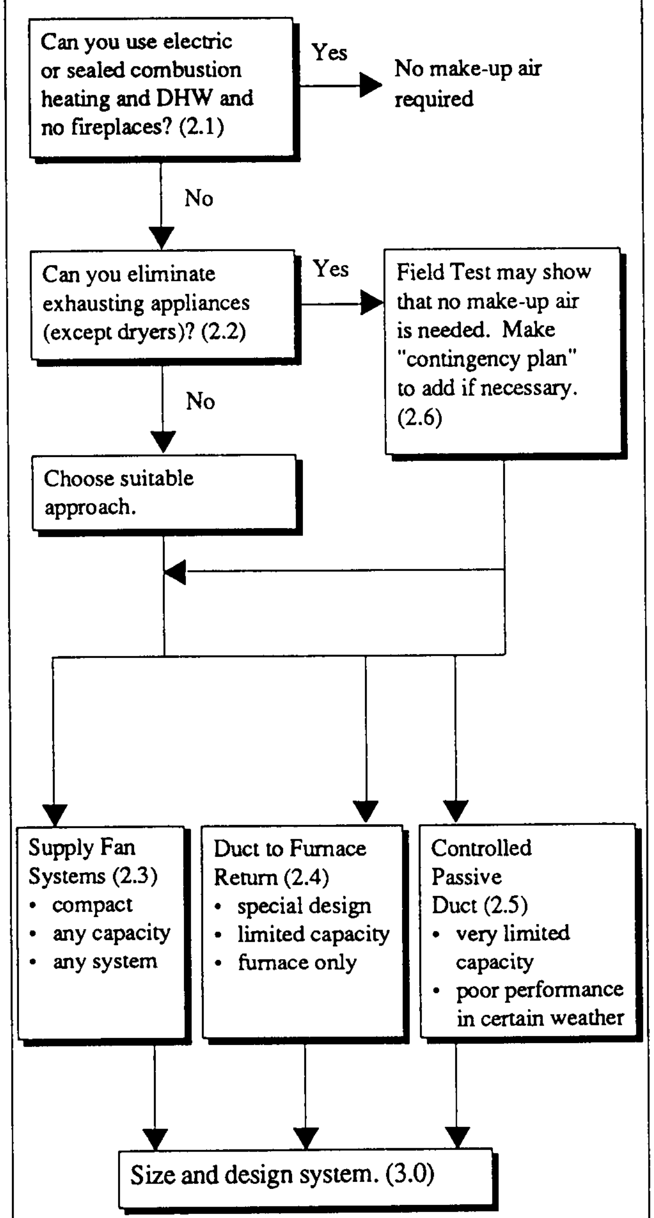


Figure 2.1
Selecting a Make-up Air Strategy

2.2 Limit Exhaust-Only Appliances

Where a vented appliance or fireplace which draws air from inside is necessary, the designer/builder should minimize the exhaust capacity of the appliance. Measures that should be considered include:

- A range top grill fan is not recommended. Notify the homeowner on this (see Appendix A).
- Use an HRV which does not go into an exhaust-only mode during defrost.

  Note: Some installers are installing a "tee" and damper on HRV supply ducts to help compensate for the effects of HRVs which have an exhaust mode defrost. **This does not fully compensate for the exhaust and the only way of determining the result of this installation is by field testing.**
- Supply a dryer of known and reasonable exhaust capacity (most dryers exhaust at a rate closer to 50 L/s (100 cfm) than the 75 L/s (150 cfm) default rate used for dryers).
- Ventilate bathrooms with the HRV rather than using individual exhaust fans.
- Direct the exhaust from central vacuum cleaners to the basement rather than the outside.
- Use recirculating range hoods and rely on the HRV to supply general kitchen exhaust. Many people prefer exhausting range hoods and they are a requirement if gas ranges are installed.

If the only exhaust device is a dryer, make-up air requirements will be limited and field testing (see 3.2) may show that you don't need it at all. If there is a second exhaust device, provision of a make-up air system will most likely be required.

There are three basic approaches to providing make-up air.

2.3 Install a Separate Supply Fan System

A supply fan which turns on when needed (possible control options are discussed in Section 5.5), can provide a compact and controllable system that is applicable to a wide variety of situations. A control device is necessary because running the fan when not needed would incur unnecessary energy costs.

Some method of heating, mixing and/or distributing incoming air without discomfort is also needed.

Examples 1 and 2 in Section 6 are supply fan systems. There are some manufacturers which have developed packaged systems working along this line. Example System 6 in Section 6 shows a package that has a built-in hot water heating coil which could draw off a DHW tank.

Figure 2.2 shows the basic components of supply fan systems. Options for various components are discussed in Section 5.

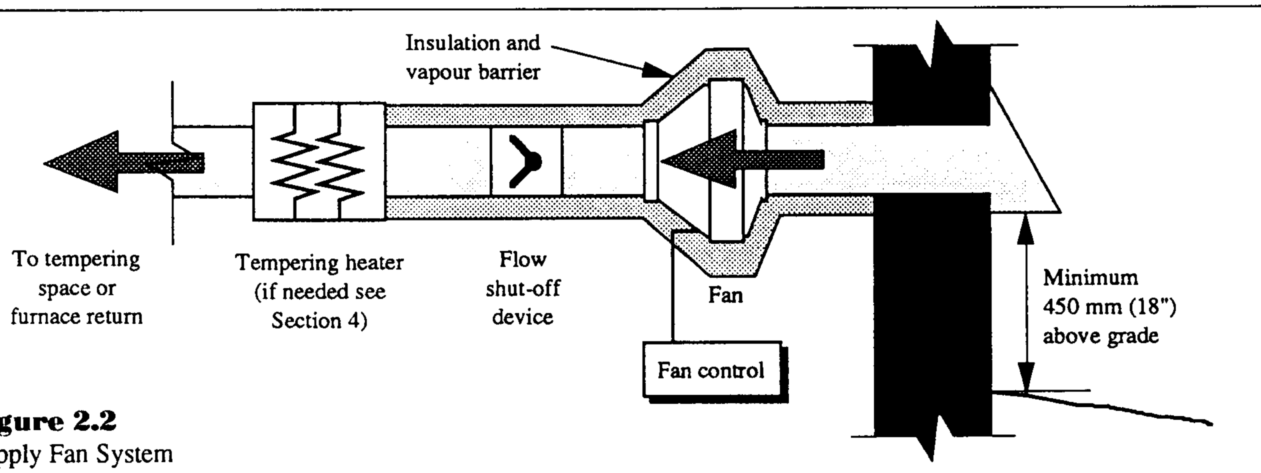


Figure 2.2
Supply Fan System

2.4 Install a Duct to the Return Air Duct of the Furnace

A make-up air duct connected to the return air duct of a forced air furnace uses the "suction" of the furnace fan to bring in make-up air. This avoids an extra fan but the interlink with the furnace raises important design issues.

- You need a flow control device like a mechanical damper and a control system which opens it and makes sure the furnace fan is running when make-up air is needed.
- In fuel-fired furnaces, cold air reaching the heat exchanger can cause condensation problems which could void the warranty on the furnace. Some manufacturers require the air temperature to be 15.5 °C. Incoming air may have to be heated depending on climate, the volume of incoming air, the volume of air being circulated by the furnace and how it is being distributed. The connection to the return duct should be at least 3 m upstream from the furnace to allow for mixing.
- The capacity of the air inlet depends on the furnace duct design and the inlet affects the duct design.

The design, installation and set-up of these systems must be done by a person who understands the requirements of the furnace and duct system.

Figure 2.3 shows a basic schematic of the system. Options for various components are discussed in Section 5. Example System 3 in Section 6 is of this type.

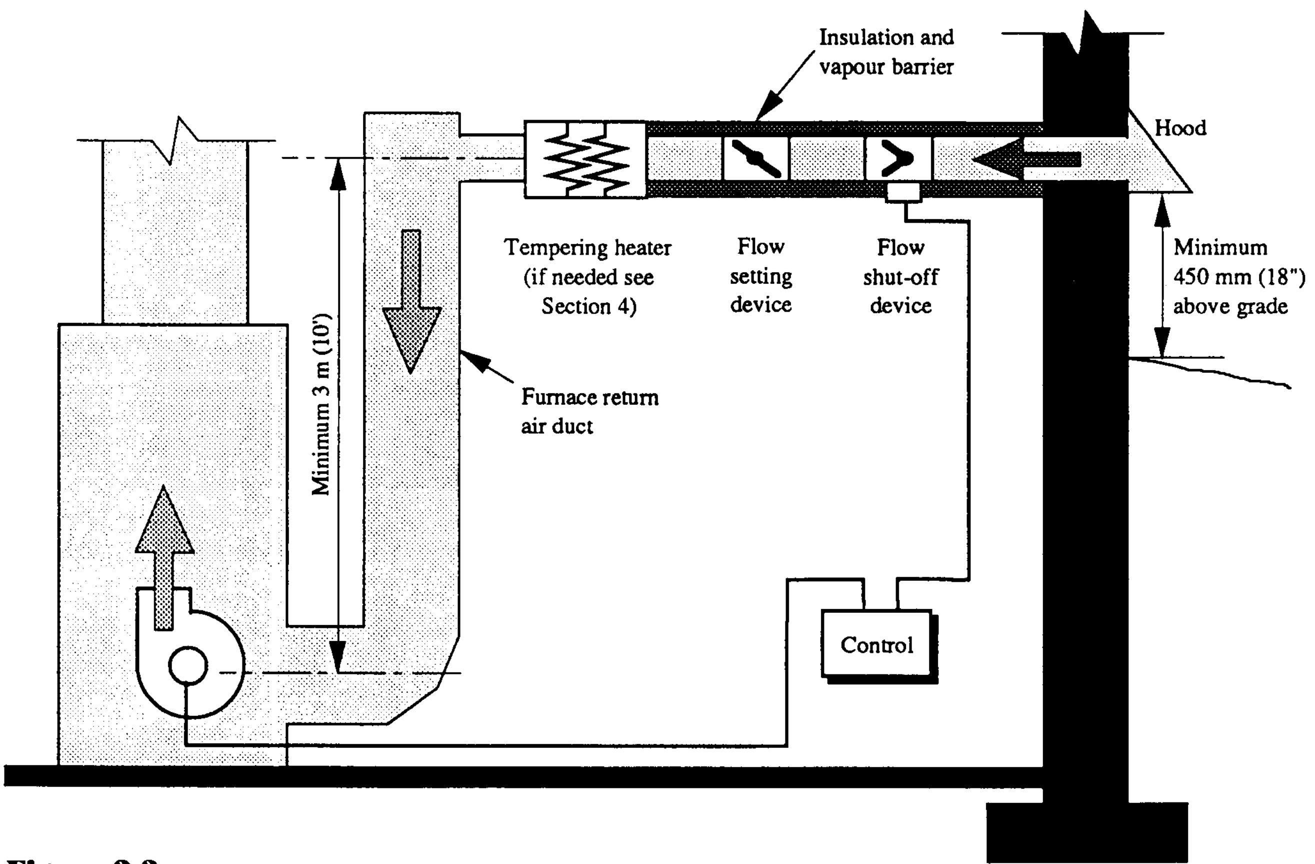


Figure 2.3
Duct to Furnace Return

2.5 Controlled Passive Inlet

A passive inlet (no supply fan) works by adding leakage area to the house at a location and time that can be controlled. It is not the best option unless the volume of make-up air required is very small because:

- the driving pressure is so small (5 Pascals) that very large openings are required; and
- their performance can depend on their location and wind conditions. If the outer end of the duct is in a leeward position, it may even be sucking air from the house.

Such large openings cannot be left open all the time without excessive energy consumption and discomfort from cold air entry. A control device such as a mechanical damper, which only opens when make-up air is needed, is necessary.

Figure 2.4 shows a basic schematic of the system. Options for various components are discussed in Section 5. Example Systems 4 and 5 in Section 6 are passive duct systems.

2.6 Show Compliance by Field Testing

One can calculate the required size of make-up air systems prior to construction (see Section 3.1), but the calculations use conservative assumptions. F326 also allows showing that pressure limits are met by field testing in the completed house (see Section 3.2). This nearly always shows that the required size of the inlet is smaller than the calculated size.

Using a field test procedure (such as the one in Section 3.2) nearly always reduces the size, or even eliminates the need for, make-up air inlets.

To take advantage of this, a builder must:

- use a qualified person to do the test; and
- make provisions for installing an inlet if testing shows that it is necessary.

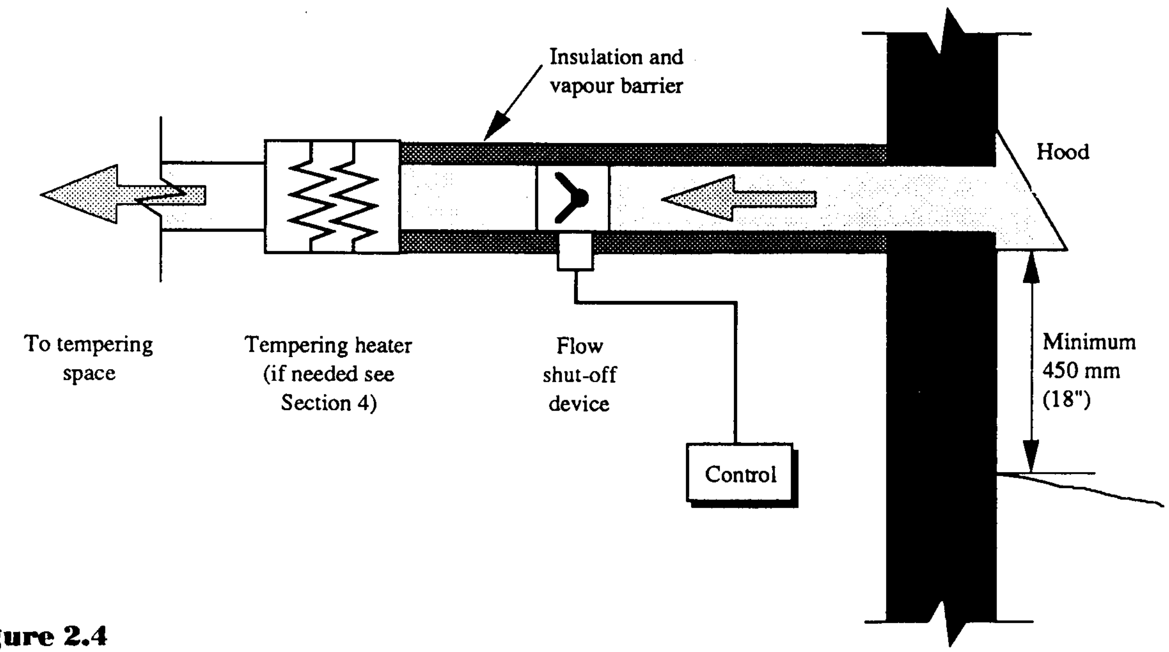


Figure 2.4
Controlled Passive Inlet

3. Sizing Make-up Air Inlets

Once it has been determined that make-up air inlets are required (Section 2), the size of the inlet can be calculated.

Builders should know a little about sizing so that they have an idea of how big a make-up air system the house is going to need, and to be able to discuss alternatives with the designer.

The size of the inlet required depends on the size of exhaust devices installed, the tightness of the house, and what basic type of make-up air system is used.

3.1 Design Stage Calculations

3.1.1 HRAI Method

A detailed make-up air duct sizing method is provided in the *Design Manual for Residential Mechanical Ventilation Systems,* published by the HRAI (ref 2). Table 3.1 is a summary of their method which assumes that the ventilation system operates in a balanced flow condition.

3.1.2 Using HOT-2000 Output

HOT-2000 (Version 6) gives an *Estimated Air Flow to Cause a 5 Pa Pressure Difference* and *Estimated Air Flow to Cause a 10 Pa Pressure Difference*. The first value can be inserted into Step 7 of Table 3.1.

HOT-2000 uses very conservative assumptions of envelope leakage (equivalent to 0.6 AC/h @ 50 Pa) if actual air tightness test results are not used. Field testing may show that make-up air requirements are actually less than calculated.

3.1.3 Sizing Supply Fan Systems

If a supply fan is used to provide make-up air, it must be chosen to provide at least the flow determined in Table 3.1 with the attached ductwork. The flow capacity against 50 Pa of resistance can be used for preliminary planning purposes.

There are fans available that can bring in 50 L/s (100 cfm) through 100 mm (4") ducts, and 150 L/s (300 cfm) through 150 mm (6") ducts (ref 4).

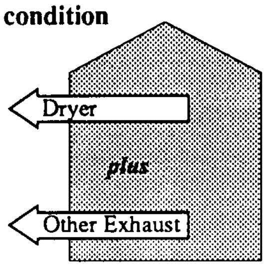
3.1.4 Sizing Passive Inlet Ducts

Column 1 of Table 3.2 shows the flow that can be provided through ducts at 5 Pa. Choose a duct that provides the required flow calculated in Step 8 of Table 3.1.

3.1.5 Sizing Inlet Ducts Connected to Furnace Return

Column 2 of Table 3.2 shows the flow that can be provided through ducts at 20 Pa. This can be used as an estimating value for inlet ducts connected to furnace return ducts. Field verification of the flow rate is necessary because the actual capacity will depend on the furnace duct design. Choose a duct that provides the required flow calculated in Step 8 of Table 3.1.

Procedure for Determining Make-up Air Capacity Required

1	**Determine depressurization limit of fuel-fired appliances.** -5 Pa unless manufacturers of all combustion equipment have certified a depressurization level limit of greater than -5 Pa. (Check with R-2000 professional.)	- _______
2	**Determine exhaust flow at reference flow condition** (assumes balanced ventilation). Dryer Exhaust (default 75 L/s) _______ L/s *plus* Next Largest Exhaust _______ L/s Equals 	_______ L/s
4	**Total Envelope Area** (a) ($m^2 = ft^2$ divided by 10.75)	_______ m^2
5	**Normalized Leakage Area (NLA)** For ordinary R-2000 (b), use .05 cm^2/m^2	_______ cm^2/m^2
6	**Equivalent Leakage Area (ELA)** (c) = NLA _______ cm^2/m^2 x Total Envelope Area _______ m^2	_______ cm^2
7	**Estimate leakage through envelope at depressurization limit for -5 Pa** **ELA x 0.15**	_______ L/s
8	**Determine flow of make-up air required** flow from Step 2 minus flow from Step 7 (if value is less than zero, no make-up air provisions are required)	_______ L/s

Notes

a) Includes top floor ceiling, above-grade walls and basement floor and walls.

b) Estimate based on a building air tightness of about 2/3 of the R-2000 maximum (that is 1.0 Air Change per Hour (AC/h @ 50 Pa)). If the house is expected to be tighter, or the actual air tightness test result is known, you can adjust the factors proportionately (for example, if expected air tightness is 0.5 AC/h, use NLA of 0.025).

c) A measured ELA from an air tightness test can be inserted here if you know it.

Table 3.1

Flow Provided by Inlet Ducts of Various Diameters

Duct Size mm (in)	(1) **Flow at -5 Pa** L/s (cfm) (Use this column to size passive duct systems)	(2) **Flow at -20 Pa** L/s (cfm) (Use this column if hard connecting to furnace return)
100 (4)	8 (15)	20 (40)
125 (5)	10 (20)	33 (65)
150 (6)	20 (40)	50 (100)
175 (7)	33 (65)	70 (140)
200 (8)	50 (100)	100 (200)
225 (9)	70 (140)	140 (280)
250 (10)	100 (200)	190 (380)
300 (12)	150 (300)	300 (600)

Note

The above duct sizes assume an *equivalent duct length* of 30 m (100 ft) which is enough for a hood, rodent screen, 3 m of **rigid** duct, a flow control damper, a heating coil and 2 – 3 elbows. If "flex duct" is to be used, specify duct that is one size larger.

Table 3.2

3.2 Field Testing

The form on the following page was developed by the Ontario Home Builders' R-2000 Program to measure the actual pressures caused by exhaust appliances. The following notes address the reference numbers we have placed on the form.

1. The maximum allowable pressure difference for "continuous" operation of the ventilation system should not be a problem in R-2000 houses with balanced ventilation systems.

2. One possible advantage of testing with combustion appliances operating, is to demonstrate that the inlet provided meets the need for *combustion* and *make-up air*. Be forewarned, however, that by doing this the builder and test agency may be attracting some liability.

3. If the heating duct system is drawing a large portion of its return air (whether through intentional openings or duct leakage) from a room or basement where a combustion appliance of concern is located, this can cause a local depressurization which can lead to combustion product spillage. If found, this should be corrected prior to further testing.

4. Only intermittent requirements are of concern in houses with balanced ventilation systems.

3.2.1 Sizing a Make-Up Air Inlet From Test Results

If the pressure difference measured at *reference flow conditions* is greater than -5 Pa additional make-up air must be provided. There are two ways of sizing the system.

1. Measure the exhaust flow that it takes to create 5 Pa depressurization, and the exhaust flow it takes to create the pressure measured at reference flow condition (this can be done with some door fan testing equipment). The difference is the make-up air flow capacity required.

2. Estimate the total exhaust flow at reference conditions by adding up fan capacities, and multiply it by the sizing factor taken from Table 3.3. The result is the required make-up air flow.

   Example: If a dryer with an assumed flow of 75 L/s and another fan of 50 L/s create 8 Pa of negative pressure in the field test, the make-up air required is

   (75 + 50) x 0.5 = 67 L/s

   The sizing methods of Sections 3.1.3 to 3.1.5 can be used to design a make up air system.

Sizing Factor

Measured Pressure Difference at Reference Flow Condition	Sizing Factor
5	0.00
6	0.29
7	0.42
8	0.50
9	0.57
10	0.62
11	0.65
12	0.69
13	0.71
14	0.73
15	0.75
16	0.77
17	0.78
18	0.80
19	0.81
20	0.82

Table 3.2

OHBA DEPRESSURIZATION TEST REPORT R-2000

NOTES

1. Indicate units by circling where appropriate.
2. Do not conduct test with more than 12.5 km/h (9 mph) wind.
3. Test to be carried out at time of Final Inspection or when house is substantially complete.
4. Maximum allowable pressure difference is 5 pa in all conditions if any *non-direct-vent** fuel-fired, vented combustion appliances are present.
5. Maximum allowable pressure difference for ventilation system only test condition is 10 pa where there are no *non-direct-vent** fuel-fired, vented combustion appliances present.
6. **Reference Exhaust Condition:**
   a. Ventilation system in operation
   b. Dryer in operation (simulate at 75 l/s exhaust if not present at time of test)
   c. Next largest exhaust appliance in operation. (May be the HRV in defrost mode, even if close-looped)

* *direct-vent* refers only to sealed combustion units.

SEE OVER FOR COMPLETE PROCEDURE DESCRIPTION

EXHAUST APPLIANCES

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______

COMBUSTION APPLIANCES

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______

BUILDER

Type of Home (Bungalow etc)

House Address

______
______
______
______

TEST EQUIPMENT

Make:

Type:

TEST CONDITIONS

Date of Test[note 3] dd/mm/yy

Wind[note 2] km/h(mph)

Static Envelope Pressure START: ______ pa

END: ______ pa

TEST RESULTS

Ventilation System Pressure Change[note 5] ______ Pa

Reference Exhaust Condition Pressure Change[note 6] ______ Pa

TEST FIRM INFORMATION

Name ______

Address ______

______

______

CERTIFICATION

I CERTIFY THAT THIS TEST HAS BEEN PERFORMED IN ACCORDANCE WITH THE TEST PROCEDURE SET OUT IN CSA F326-M91, PARAGRAPH 11.2.2(A)(i), OR 11.2.2(b)(i)

Date mm/dd/yy

Tel: ______

Name ______

R-2000 ID ______

Signature

PROCEDURE:

1. Close and latch all windows, doors and other openings. fill floor drains and plumbing traps with water or seal.
   NOTE: *Intentional openings such as HRV inlets and outlets, fan outlets and make-up air inlets should not be sealed. As much as possible, the house should be in "normal operation" mode.*

2. Seal combustion air inlets and chimneys/flues for combustion appliances, including fireplaces and, wood stoves, before performing test.
   NOTE: *(Sealing of combustion air inlets and chimneys/flues) is not required if the combustion devices are operated during the test, and there is no combustion spillage from any appliance during the test.*

3. Set an exterior pressure tap approximately 25 feet from dwelling unit and connect to measuring device. Locate measuring device at or near grade level inside the dwelling unit.

4. Switch off ventilation equipment and any other appliances that exhaust air to exterior. Record measured pressure difference. This is the starting or "rest" pressure.

5. Switch on all equipment used to provide the Minimum Ventilation Capacity. Record the pressure difference. The difference between this measurement and the rest pressure is the MVC or "continuous" depressurization.
   NOTE: *Where the house includes a forced air system, locate the measuring device in the same room as any non-direct vent* combustion device and carry out the test both with and without the forced air system in operation.*

6. Switch on the dryer and the individual piece of exhaust equipment that creates the highest intermittent air exhaust. Record the pressure difference. The difference between this measurement and the rest pressure is the Reference Exhaust Condition or "intermittent" depressurization.

7. Unseal any openings sealed for test.

* Direct-vent refers only to sealed combustion units

WIND:
The test must be performed with wind conditions of less than 12.5 km/h (9 mph).

INSTRUMENTS:
The test must be performed using an instrument capable of measuring 0 to 10 pa (0.0 to ..05 inches W.G.) range, with a sensitivity of 2 pa (.01 inches W.G.).

Houses with NON-DIRECT VENT* combustion appliances

Not Allowed	O.K.	O.K.	O.K.	Not Allowed
	-5 pa or device limit	0 pa	+5 pa	+10 pa continuous

Houses with only DIRECT-VENT* combustion appliances (or no combustion appliances)

No Intermittent Limit	O.K.	O.K.	O.K.	O.K.	Not Allowed
	-10 pa continuous	-5 pa	0 pa	+5 pa	+10 pa continuous

- *"CONTINUOUS" =* *Ventilation System in **"Minimum Ventilation Capacity"** Mode*
- *"INTERMITTENT" =* *Ventilation system as above plus **Dryer plus Next Largest Exhaust Device** (Reference Exhaust Condition)*

4. Tempering Methods

One of the most difficult issues in dealing with make-up air is how to introduce cold air in a way that avoids discomfort to the occupants, or damage to the heating equipment. Builders must work with their mechanical contractors to find an approach that works for their applications.

4.1. Tempering Without Direct Heating

There are some approaches that don't heat the incoming air directly.

1. Introducing the make-up air into a "tempering space", where:
   - the intermittent entry of cold air is not a major discomfort problem; and
   - the incoming air can pick up heat by mixing with indoor air before reaching a place where comfort is critical.

   Many builders in less severe climates have found that they can get away with introducing make-up air into a heated, but unlived in, basement or mechanical room. To minimize problems:

   - make sure you use an inlet control (see Section 5.4 and 5.5); and
   - make sure there is a heat source in the space. Having it independently controlled by a thermostat is desirable and possible with electric baseboard or hydronic systems.

2. **If a forced air heating system** is employed, connect the make-up air duct to the return duct of the furnace. This allows mixing with the air circulated by the furnace. How much air can be mixed this way is limited by the equipment and comfort of the occupants.
   - Manufacturers of some **fuel-burning furnaces** require that the air entering a furnace should be no colder than 15.5 °C to avoid condensation on the heat exchanger. This temperature depends on the percentage and temperature of outdoor air introduced to the circulating system. The HRAI Design Manual (ref 2) provides a method of calculating it. For most climates and heating systems, **introducing more than about 30 L/s (60 cfm) of unheated outdoor air could cause problems** and may void the warranty of fuel-fired furnaces.
   - The limit for **electric furnaces** is based more on comfort, so you may get away with a rate of 60 – 75 L/s (120 – 150 cfm).

With these restrictions, only houses with small make-up air requirements (where the only exhaust device is a dryer) are suitable candidates for this approach to tempering incoming air. Where requirements are larger (there is another exhaust device), heating incoming air will probably be necessary.

4.2. Heating Make-Up Air

In houses in severe climates, or where there is no suitable tempering space, heating the incoming air may be required. Section 5.6 discusses the selection and installation of electric and hot water duct heaters.

Sizing Make-Up Air Heaters

The amount of heat required to raise the incoming air temperature is calculated by the equation:

Heating Capacity Required (watts) =
1.2 x Air Flow (L/s) x Temperature Rise Needed (°C).

For calculating the heater capacity, the Temperature Rise Needed will be the difference between the outdoor design temperature and the entry temperature desired. For most systems, an entry temperature of 15 °C is adequate.

A Note About Energy Costs

Understanding how make-up air systems impact energy costs can be confusing. To understand it, think of the house as a box and consider the following statements.

- Any air removed from the house by an exhaust fan will be replaced by cold outdoor air.
- The replacement air comes into the house through unintentional openings, or through a make-up air system.
- Any cold air that enters the house must be heated to room temperature.
- Heating this incoming air consumes energy, and it takes money to supply this energy.

This means:

1. There is no difference in the energy required to heat the house with or without a make-up air system, as long as the make-up air system does not supply air at a greater rate than the exhaust rate.
2. If the make-up air supply rate is greater than the exhaust rate (this could happen with systems that use fans), additional energy will be required to heat the additional air.
3. If the make-up air is being heated with a more expensive fuel than the rest of the house (for example an electric duct heater in a gas-heated house), there will be an additional energy cost.
4. If a make-up air system is open when the exhaust fans are off, there will be an additional energy requirement arising from the increased infiltration. This is why we require controlled inlets.

Most R-2000 builders rely on their mechanical contractors to select and install the make-up air system components. One common exception is with inlet hoods. It is often most practical for the builder to locate and install these during framing and insulation. The balance of the system can then be installed by the mechanical contractor.

5.1 Hoods

Application

Make-up air entry hoods are cold air inlet hoods and must meet the following requirements. A source of good ones are distributors of HRVs.

Selection

- Should be easy to seal to building air barrier.
- Should provide for connection of duct vapour barrier.
- Must have rodent screen of 6 mm (1/4") or larger mesh.
- Any insect screens must be removable for cleaning and should be three times larger in area than the duct they service.
- Hood has to be at least as large as the duct.

Installation Details

- Locate at least 450 mm (18") above grade in an area accessible for cleaning.
- Seal to building air barrier.
- Locate in an area free of contamination sources, such as exhausts, appliance vents, gas meters, garages, vehicle parking spots, and garbage collection areas.
- Clearly label, on the outside, as all intakes.

Homeowner Instructions

- Requires periodic cleaning. We suggest spring and fall.

5.2 Ducting

Selection

- Rigid, non-combustible ducting is recommended.
- If flex duct is used, it should be one size larger.

Installation Details

- All ducts, at least to the location of any tempering heater, must be insulated to 0.5 RSI (R3) and protected with an air tight vapour barrier to prevent condensation on the exterior of ducts.

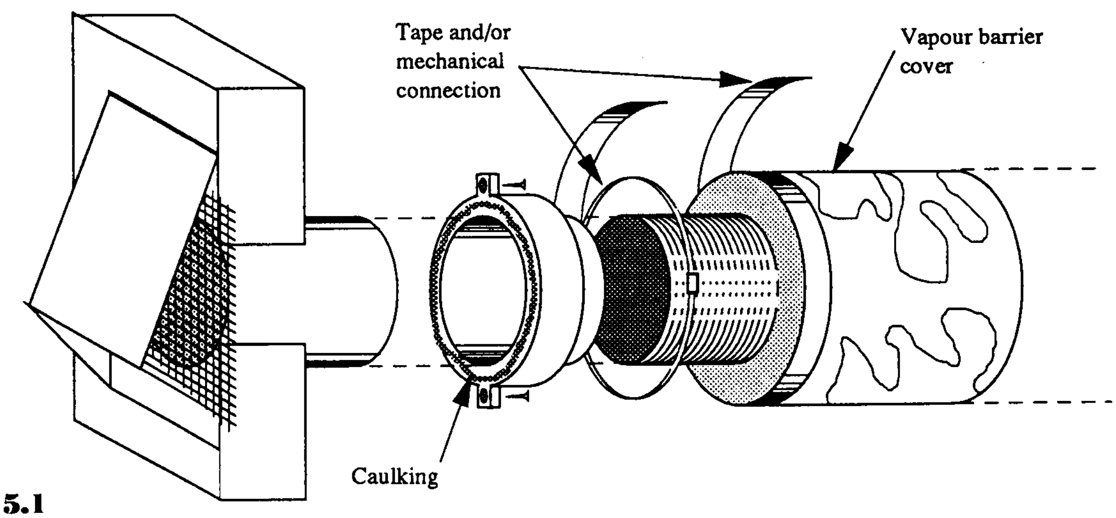
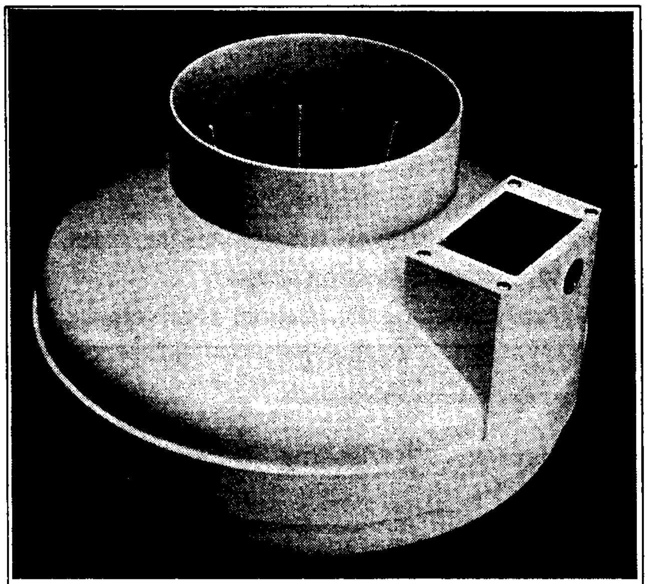


Figure 5.1
Inlet Hood with Vapour Barrier Connection

5.3 Fans



Inline Fan with Plastic Housing

Selection

- Fan must be rated to handle untempered outdoor air.
- Fans with plastic housings are less susceptible to condensation on the outside of the housing.
- Select fan based on sizing notes of Section 3.1.3. The needed capacity must be provided taking into account the resistance of the attached ductwork. The capacity rating at a resistance of 50 Pa is the minimum suggested.
- Some installers select a standard fan of relatively high capacity and install a speed control to set it to the best rate. This has the advantage of allowing adjustments if the homeowner changes exhaust capacity.

Installation Details

- Condensation of interior humidity can form on the exterior shell of the fan. Figure 5.2 shows ways of controlling this.
  - Building a sealed and insulated metal housing for the fan.
  - Wrapping insulation and providing an air/vapour barrier over the fan. The manufacturers of some inline duct fans allow this.
  - Leave the fan exposed, but place a drip pan underneath. If the fan operates infrequently and in a heated space, the condensate can re-evaporate from the drip pan and fan housing when the system is not operating.
  - One could use a fan mounted outside, but protected from the weather. There are fans rated for outdoor use.

  The selected option should be approved by the manufacturer.
- Mounting method should include vibration isolation from the ducts and the structure of the building.

Homeowner Instructions

- Manufacturer's maintenance information is to be left on-site and the homeowner needs to be briefed on requirements and equipment location.

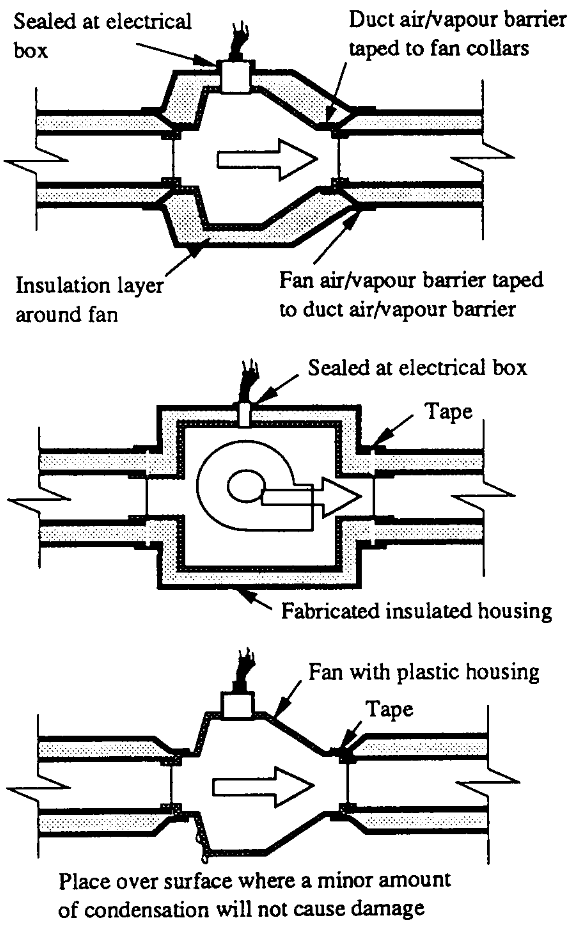


Figure 5.2
Avoiding Condensation on Fans

5.4 Flow Shut-Off Devices

Application

In an R-2000 house, the make-up air system must close when it is not needed, or energy costs would be prohibitive. A "gravity-operated backdraft damper" will not work because the leakage flow is in the same direction as the fan flow. Two basic options are available.

Spring Loaded Damper

In a **separate supply fan system that does not connect to a furnace return,** the recommended method is a spring loaded damper. This will open when the fan is turned on, and close against normal indoor to outdoor pressure differences.

A spring loaded damper may, or may not, work in a **separate supply fan system to a furnace return.** The concern is that the damper may not close against the suction pressure of the return duct. This will have to be checked for each installation.

Motorized Dampers

Motorized dampers of one sort or another **can be used for all types of systems.** They can be obtained in three basic types.

- Mounted in inlet hoods — giving the advantage of not needing to be insulated and protected from condensation;
- In an inline configuration;
- Terminal units for mounting at the end of a duct — one manufacturer provides a CGA approved combustion air system of this configuration. Example System 5 in Section 6 shows this used as a combined make-up air/combustion system, appropriate when there is no fireplace in the house.

Most of these dampers operate on 24 Volts and can be obtained in either normally open, or normally closed, configurations. Motorized dampers need a control system to tell them when to open or close.

Selection

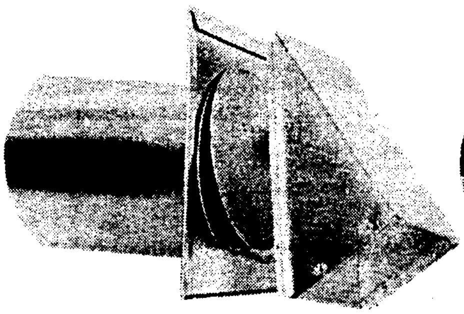
- Normally open (power closes, spring opens) motorized dampers must be used for combined combustion air/make-up air systems, and are a good idea for all make-up air systems.

Installation Details

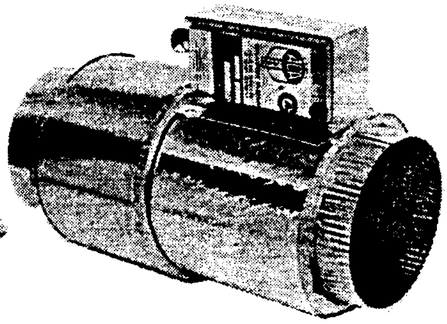
- Install according to the manufacturer's recommendations.
- The damper must be insulated and provided with a vapour barrier. The dampers shown are supplied with insulated bodies.

Homeowner Instructions

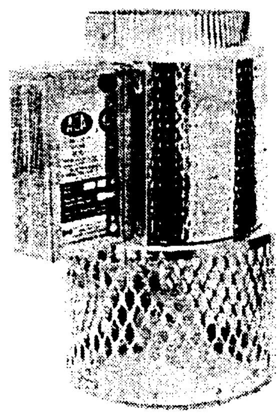
- Manufacturer's maintenance information is to be left on-site and the homeowner needs to be briefed on requirements and equipment location.



Hood Mounted



Inline



Terminal Mounted

Motorized Dampers

5.5 Controls

There are two proven methods of sensing the need for make-up air.

- detecting that one or more of the exhaust devices which could cause depressurization are operating; and
- detecting that a vented combustion appliance needs to operate.

The control options described in Sections 5.5.1 to 5.5.5 are based on these principals. The actual systems diagrammed in the Example Systems of Section 6 have been selected from a great many options. A good controls designer or installer could present other options that perform the same functions.

Researchers have explored a number of other control options using entirely different principles than those listed above. These include pressure controllers that sense house depressurization, and controllers that sense whether combustion product spillage is occurring. These may hold promise for the future but cannot yet be considered as acceptable options.

Selection

Depends on the applications discussed in the following sections.

Installation Details

- Understanding and installing controls is not a job for amateurs. All installations should be done by qualified personnel.
- All wiring must conform to the local electrical code and electrical utility requirements.
- The installer should test all interlinked components in all modes of operation and report successful testing to the builder, in writing.

Homeowner Instructions

- The air switch in the dryer vent may require periodic cleaning.
- Other elements of an automatic control systems are not normally a homeowner maintenance item. If there are special operation instructions (such as when a wall switch has been provided for operating an exhaust appliance that is interconnected with the supply fan), the homeowner must be briefed.
- All manufacturer supplied information is to be left on-site.

5.5.1 Direct Interlink of Supply Fan with Exhaust Fan

Application

This simple approach can be used when there is one large exhaust device of concern and this can be mounted to operate from a manual switch. Its use can be limited because the operation of many of the exhaust devices of concern is controlled by an appliance-mounted switch. Connecting to this may void CSA and electrical utility certification. Note that all wiring is line voltage.

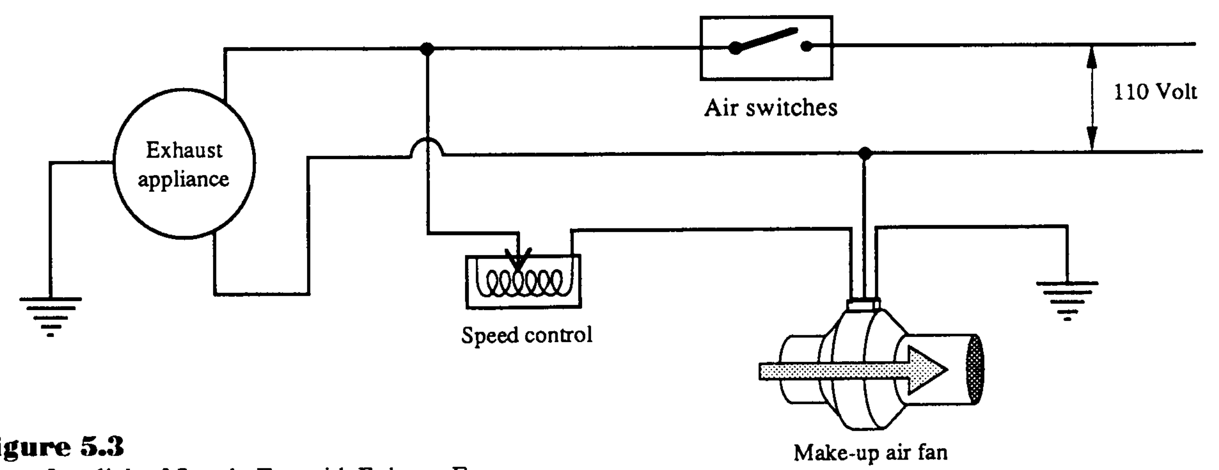


Figure 5.3
Direct Interlink of Supply Fan with Exhaust Fan

5.5.2 24 Volt Interlink of Supply Fan with Exhaust Fan(s)

Application

Examples 1, 2 and 6 in Section 6 use variations of this approach which can be recommended when there is more than one exhaust device of concern.. Low voltage wiring is used for all control connections and it is entirely independent of the actual exhaust device, so that CSA and electrical utility certification is not affected. Flow-sensing switches in the ducts of the exhaust devices trip the relay to start the fan when any of the connected exhaust devices are on.

Options

There are a number of different types of flow-sensing switches including ones commonly called "air pressure switches" and "sail switches". Air pressure switches are recommended.

5.5.3 24 Volt Interlink of Motorized Damper with Exhaust Fan(s)

Application

Recommended for use with duct to furnace and controlled passive duct systems.

Low voltage wiring is used for all control connections and it is entirely independent of the actual exhaust devices, so that CSA and electrical utility certification is not affected. Flow-sensing switches in the ducts of the exhaust devices open the damper when any of the connected exhaust devices are on.

Options

There are a number of different types of flow-sensing switches including ones commonly called "air pressure switches" and "sail switches". Air pressure switches are recommended.

5.5.4 Interlink with Gas Appliances

Application

There are *combustion air* dampers which are approved for interconnection with gas- and oil-fired appliances. If the inlet is sized to supply *both make-up air* and *combustion air*, a single inlet can serve both purposes. Example 5 in Section 6 shows a control diagram for a system that opens the motorized damper when either a gas-fired hot water heater, or furnace, is called on for heat. **Note that some appliances may require different control connections. The correct connection method must be determined from the damper or appliance manufacturer.**

The combined inlet must be larger than the size of the make-up inlet size in Section 3. An allowance for an additional 15 L/s (30 cfm) will provide combustion air for 110,000 BTU combined capacity of induced draft appliances.

The system shown does not deal with the provision of make-up or combustion air for fireplaces.

5.5.5 Furnace High Speed Control

Application

If the make-up air system is going to be connected to the return air duct of a forced air furnace with a two-speed fan, there are two reasons to have the furnace switched to high speed when the make-up air control damper is open:

- the make-up air duct can be sized to bring in air at the higher suction pressure; and
- the higher flow rate allows more outdoor air to be brought without cooling the furnace heat exchanger to the point that it can cause condensation.

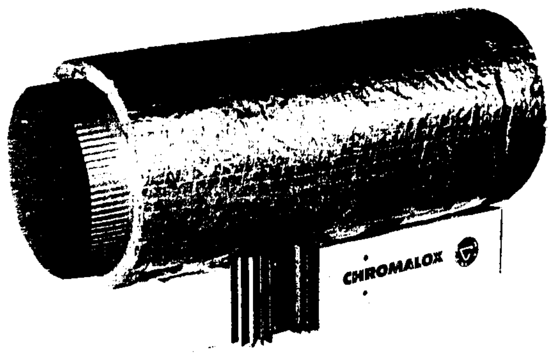
The wiring is effectively the same as for interlinking an air conditioner to the furnace fan. Example System 3 in Section 6 shows a common method. The furnace manufacturer's connection details should be used.

5.6 Duct Heaters

It would be very nice to avoid using duct heaters. They, and their controls, add cost, complexity and reliability concerns to the system.

Unfortunately, sometimes we cannot avoid the need for direct heating of the incoming air. The selection, design, and installation of the duct heaters and controls must be done by competent personnel.

5.6.1 Electric Duct Heaters



Duct Heater with Proportional Control

Application

Electric Duct Heaters are designed to operate when there is a proven air flow, and **should not be used in passive systems**. They are an option for systems with a separate supply fan or a duct to the return air duct of a forced-air furnace. Simple on/off controls are not usually adequate. At minimum, we suggest "staged" controls. Proportional controls which regulate the output to a steady temperature are the best type.

Selection

- Section 4 provides sizing information. Heaters of sufficient capacity usually require 240 Volts (110 Volt heaters are available).
- Heater must be certified by the manufacturer for use with cold outdoor air, CSA approved, and supplied with:
  - an automatically resetting thermal shut-off which turns off the heating coil when duct temperature exceeds 55 °C;
  - a manually resetting shut-off which interrupts power to the coil when duct temperature exceeds 100 °C; and
  - a flow-proving switch which prevents heater from operating if there is insufficient air flow through the duct.
- Typical systems come supplied with a contactor, a transformer for thermostats, and a thermostat control.
- The best systems available have proportional temperature controls (ref 5). Others have two stage heaters — the minimum recommended — because of the wide range of air temperatures to be expected.

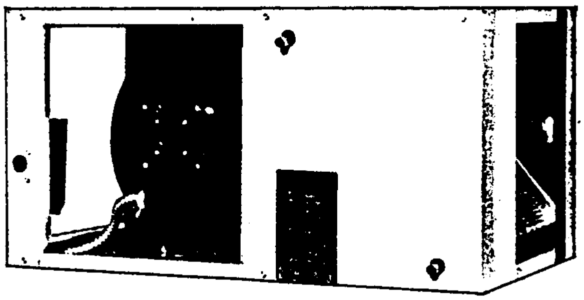
Installation Details

- Ducting must be non-combustible.
- No combustible materials should be placed in the vicinity of the heater.

Homeowner Instructions

Condensation collection has proven to be a problem in some installations. Condition and operation of electric duct heaters should be checked by a qualified person on at least an annual basis.

5.6.2 Hot Water Duct Heaters



Packaged Hydronic Fan Coil Unit

Application

The potential application of hot water duct heaters goes beyond hydronically heated houses. All houses have a source of hot water — the domestic hot water heater.

One Canadian manufacturer sells a package fan coil system that has been used successfully for make-up air applications in the Arctic (ref 5). The unit has dimensions of 12" x 14" x 22" and can heat 95 L/s (200 cfm) of incoming air by from - 35 °C to 10 °C (-30 to 50 °F), using 60 °C (140 °F) water available from a gas-fired hot water tank. Example System 6 shows a schematic of a system using this package.

Electric hot water tanks do not have the heating capacity to keep up this rate of heating (about 5 kW).

Selection

- The coil and hot water circulating system should be selected and designed by someone familiar with the sizing of hydronic coils, because the coils' heating capacity will depend on the flow rates and supply temperature of entering air and water.
- A low temperature fan shut-off or freezestat is needed in case the hot water supply is restricted.

Installation Details

- Verify acceptability to local authorities. Most will not have experience with such a system.

Homeowner Instructions

- All manufacturer supplied information is to be left on-site.

5.7 Flow Setting Devices

Application

If a make-up air system connects to a furnace return duct, it must have some way of setting the flow to the correct level. A standard balancing damper is usually adequate.

Supplying fan-based systems with a speed control allows using a standard fan for most installations, and adjusting the flow for needs found by site testing, or if the homeowner makes a change in equipment.

The best way of setting the flow rate is by adjusting flow to control the maximum negative pressure measured during field testing.

6. Example Systems

The following six example make-up air systems provide a "shopping list" of systems which should cover most R-2000 applications. All are based on the same 7.5 m x 18 m bungalow with full basement in an Ottawa climate. This house would have 535 m^2 of envelope area, so the estimated leakage flow, at 5 Pa, using the calculations in Section 3, is 40 L/s (80 cfm). The six systems shown are:

Example 1	**Separate Supply Fan to a Heated Tempering Space**
Example 2	**Separate Supply Fan Connected to a Furnace Return Duct**
Example 3	**Duct to Furnace Return Air**
Example 4	**Passive Duct to a Heated Tempering Space**
Example 5	**Combined Make-Up Air/ Combustion Air System**
Example 6	**Package Supply Fan System with Hydronic Coil**

The heating and control methods shown for each system are appropriate for that system, but there are other approaches including some shown in other examples.

Two things that the examples should show all builders are that:

- selecting, designing and installing a make-up air system requires competent people; and
- avoiding the need for a make-up air system by avoiding vented combustion appliances is highly desirable.

Example System 1
Separate Supply Fan System to Tempering Space

General Application

- Best way of meeting large make-up air requirements.
- Can be applied to houses with any kind of heating system.
- Finding way of tempering incoming air is a key issue.

Example Shown

House with
- Estimated Leakage Flow through envelope at 5 Pa — 40 L/s.
- Baseboard electric heat.
- Fireplace.
- Exhaust Devices:
  - Dryer — assumed capacity 75 L/s (150 cfm);
  - Range hood — known capacity 60 L/s (120 cfm);

Make-Up Air Required

- Minimum 75 + 60 - 40 = 95 L/s (190 cfm).
- Designer chooses to use 100 L/s (200 cfm) fan with speed control and interlinked to turn on if either the dryer or range hood turns on.
- Tempering provided by introducing air into mechanical room with independent thermostatically controlled heaters (4 kW installed). These should not be on often.

Comments

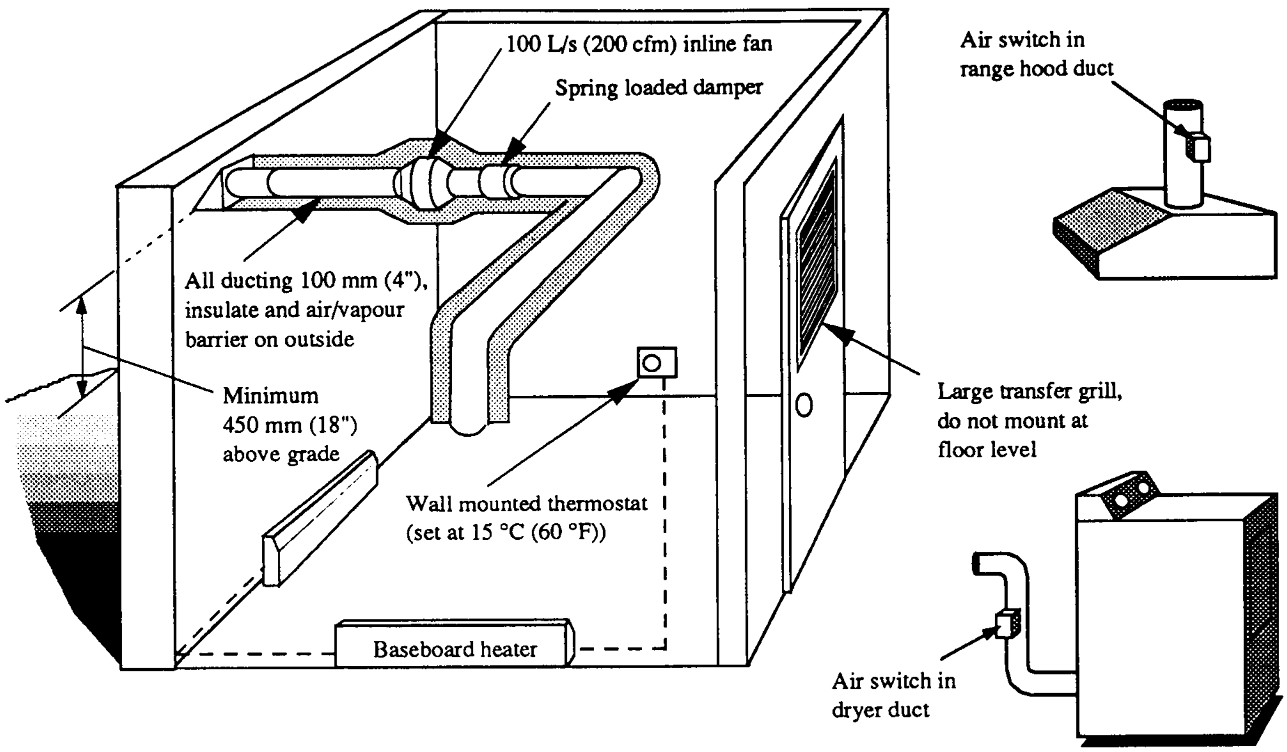
- Fan must be rated for outdoor use.
- Baseboard heaters will avoid freezing, but room will not be comfortable.
- Field testing may allow reducing fan speed.

Options

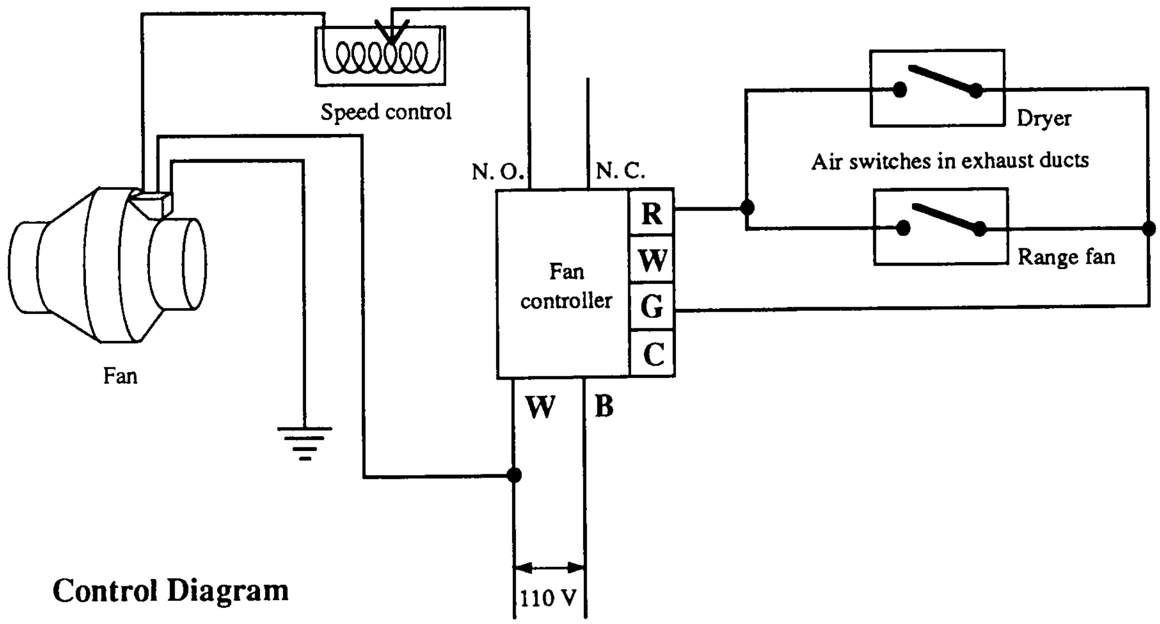
- Dumping air into heated basement without enclosure possible, but could make entire basement uncomfortable.

Component Costs

• Hood	20
• Fan	200
• Spring loaded damper	30
• Baseboard heaters	100
• Wall thermostat	15
• Controls	180



Make-Up Air System to Enclosed Workroom



Control Diagram

Example 1
Separate Supply Fan to a Heated Tempering Space

Example System 2
Separate Supply Fan System Connected to Furnace Return Duct

General Application

- Can meet large make-up air requirements.
- Assumes forced-air system.
- Duct heater required for anything more than about 30 L/s (with gas furnace).

Example Shown

House with
- Estimated Leakage Flow through envelope at 5 Pa — 40 L/s.
- Forced-air induced draft gas furnace with single speed fan.
- Induced draft DHW.
- Exhaust Devices:
  - Dryer — known capacity 55 L/s (110 cfm);
  - Range hood — known capacity 60 L/s (120 cfm) because gas range used.

Make-Up Air Required

- Minimum 55 + 60 - 40 = 75 L/s (150 cfm).
- Designer chooses to use 75 L/s (150 cfm) fan turned on if either the dryer or range hood turns on.
- In Ottawa climate, a duct heater of 2 kW will keep temperature in return duct over 14 °C.

Comments

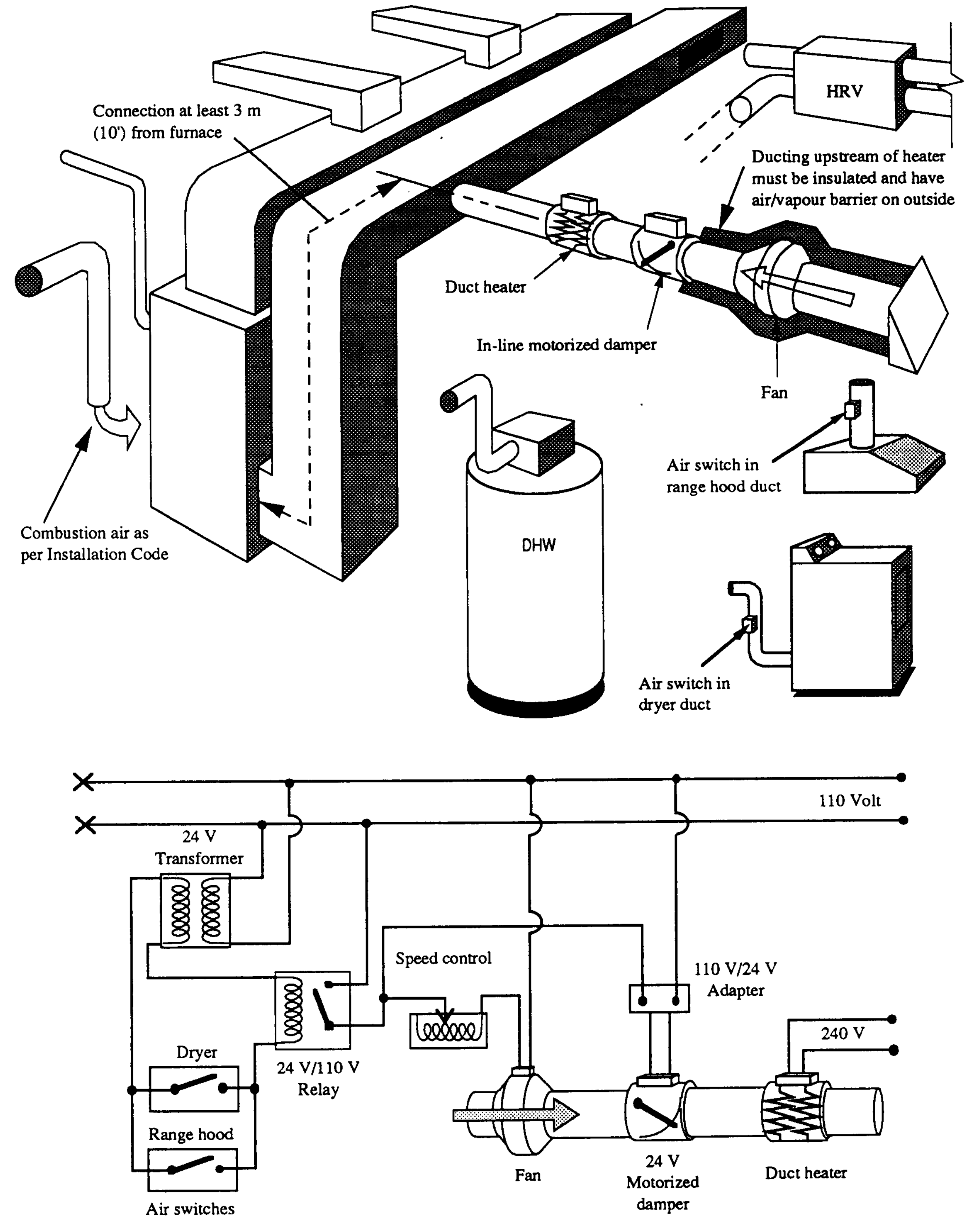
- Fan must be rated for outdoor use.
- Field testing will probably allow reducing fan speed.
- Motorized damper used to provide positive shut-off.
- Suggest that system be installed at end of return duct to achieve maximum mixing.
- Duct between heater and return duct will get cold enough to condense on coldest days unless insulated and air/vapour barrier installed.
- Combustion air duct still required by Code.

Options

- Hydronic fan coil unit shown in Example System 6 could be adapted to this system.

Component Costs

• Hood	20
• Fan	200
• Motorized damper	100
• Duct heater	225
• Controls	120



Example 2
Separate Supply Fan Connected to a Furnace Return Duct

Example System 3
Duct to Furnace Return Air

General Application

- Limited capacity — an 8" duct can only provide about 100 L/s (200 cfm).
- Assumes forced-air system.

Example Shown

House with
- Estimated Leakage Flow through envelope at 5 Pa — 40 L/s.
- Forced-air, electric furnace with two-speed fan.
- Fireplace.
- Exhaust Devices:
  - Dryer — assumed capacity 75 L/s (150 cfm).

Make-Up Air Required

- Minimum 75 - 40 = 35 L/s (70 cfm).
- Design calculation says that 6" duct needed.
- No make-up air heater specified.

Comments

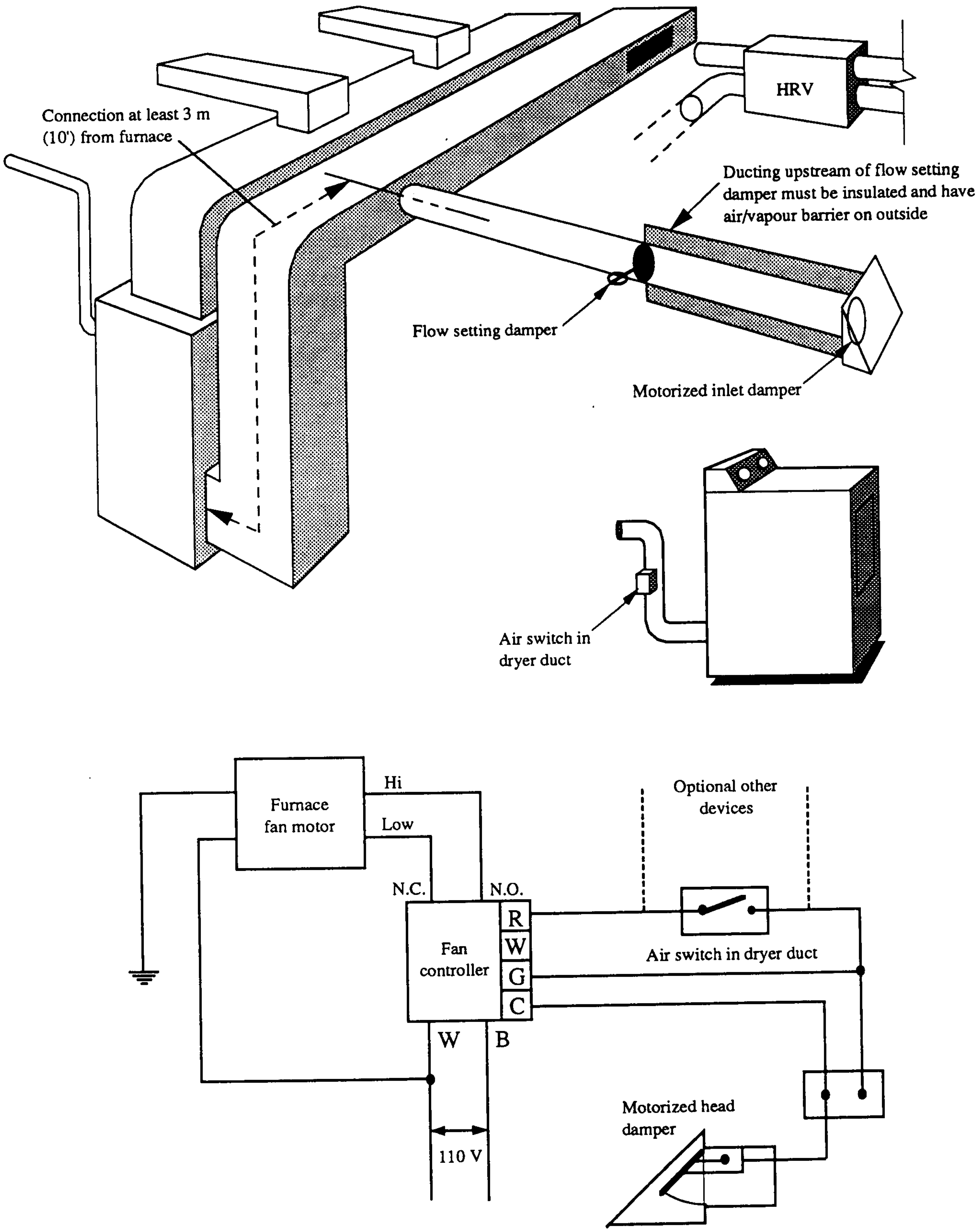
- Field testing may find that no make-up air inlet required, especially if dryer of known capacity.
- Motorized damper used to provide positive shut-off.
- Requires control to switch furnace to high speed when damper open.
- Suggest that system be installed as close as allowable (3 m) to furnace to get maximum suction force.
- Designer and installer of system and controls must know furnace system.
- With electric furnace return, air temperature can be lower than with a fuel-fired furnace, but comfort may require duct heater if make-up air volume greater than about 75 L/s (150 cfm).

Options

- Parallel air switches can be provided for other exhaust devices.

Component Costs

• Motorized hood damper	100
• Controls	70



Example 3
Duct to Furnace Return Air

Example System 4
Controlled Passive Duct to Tempering Space

General Application

- Allowable but not recommended.
- Limited capacity — 8" duct only good for about 50 L/s (100 cfm).

Example Shown

House with
- Estimated Leakage Flow through envelope at 5 Pa — 40 L/s.
- Fireplace.
- Exhaust Devices:
  - Dryer — assumed capacity 75 L/s (150 cfm).

Make-Up Air Required

- Minimum 75 - 40 = 35 L/s (70 cfm).
- 8" duct needed.

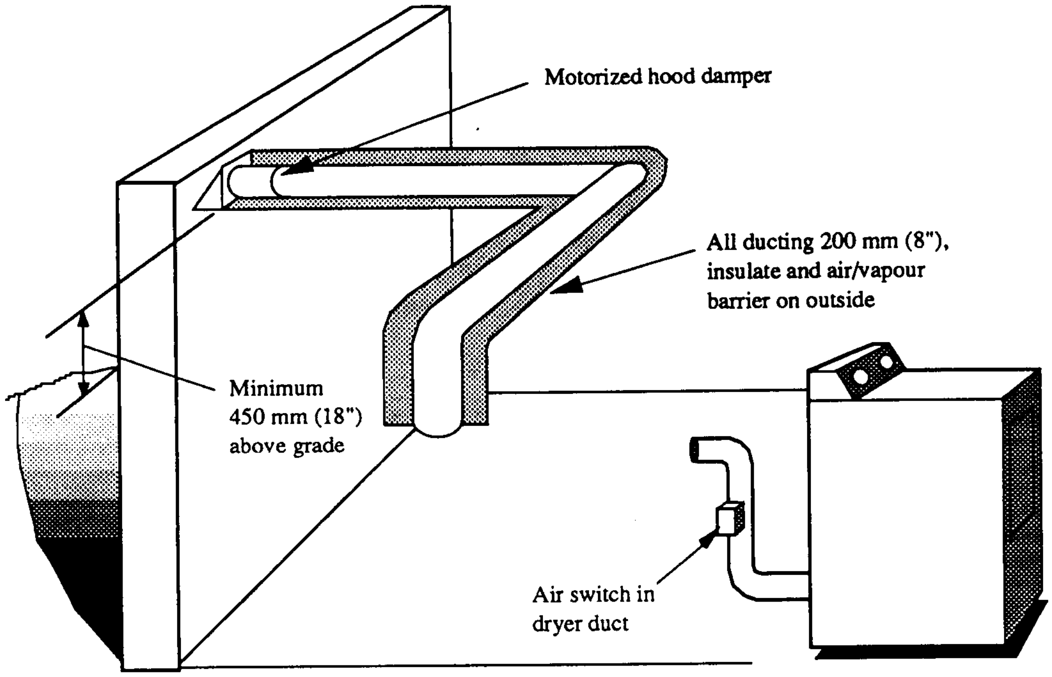
Comments

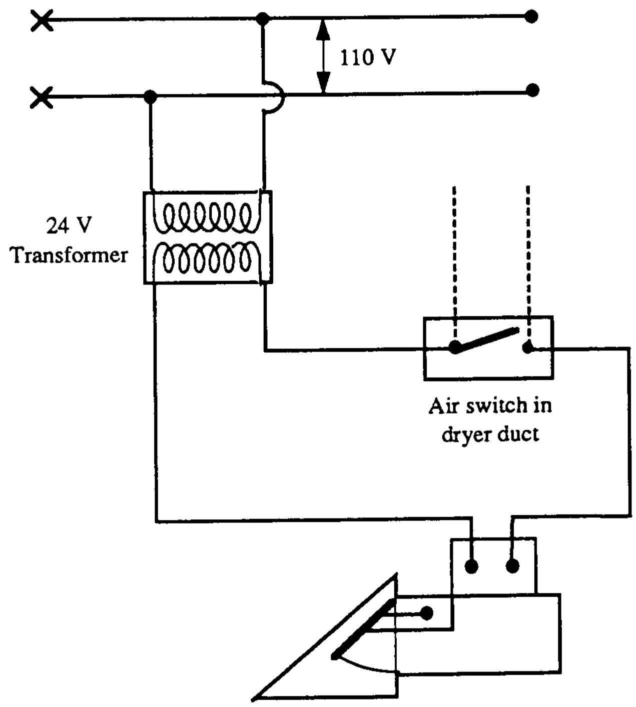
- Least recommended approach.
- Field testing may find that no make-up air inlet required, especially if dryer of known capacity.
- Capacity of approach limited by duct size — probably only good for dealing with dryer.
- Motorized damper used to provide positive shut-off.
- Electric duct heater cannot be used because flow cannot be proven.

Options

Component Costs

• Motorized hood damper	100
• Controls	25





Example 4
Passive Duct to a Heated Tempering Space

Example System 5
Combined Make-Up Air/Combustion Air Passive Duct

General Application

- Deals only with heating and DHW appliances; does not deal with a fireplace.
- Largest damper available 9" — only good for about 55 L/s (110 cfm) of make-up air, and 15 L/s of combustion air.

Example Shown

House with
- Estimated Leakage Flow through envelope at -5 Pa — 40 L/s.
- Forced air, induced draft, gas furnace.
- Induced draft, gas DHW.
- Exhaust Devices:
  - Dryer — assumed capacity 75 L/s (150 cfm).

Make-Up Air Required

- Minimum 75 - 40 = 35 L/s. Allow another 15 L/s for combustion air. Total 50 L/s (100 cfm).
- 8" duct needed.

Comments

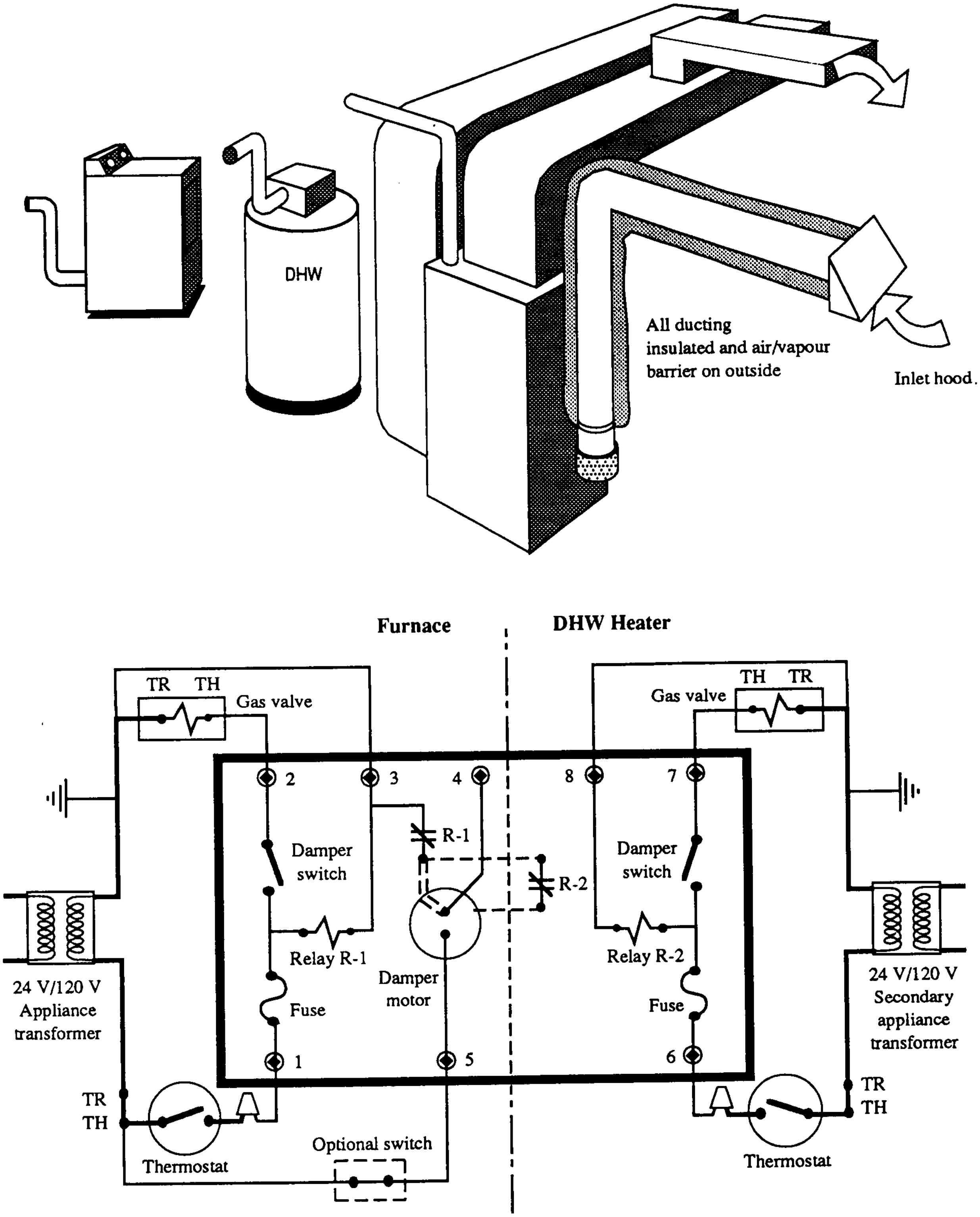
- CGA approved combustion air damper supplies both make-up and combustion air.
- Control diagram shown suitable for many appliances, but verify with appliance or damper manufacturer.

Options

- Could have used sealed combustion appliances and eliminated need for make-up and combustion air.
- Control method could be adapted for a separate supply fan system.

Component Costs

• Hood	20
• Automatic combustion air damper	140



Example 5
Combined Make-up Air/Combustion Air System

Example System 6
Package Supply Fan System with Hydronic Coil

General Application

- Package can provide up to 95 L/s (200 cfm).
- Gas DHW system.

Example Shown

House with
- Estimated Leakage Flow through envelope at 5 Pa — 40 L/s.
- Fireplace.
- Forced air, induced draft, gas furnace.
- Induced draft, gas DHW.
- Exhaust Devices:
  - Dryer — known capacity 55 L/s (110 cfm);
  - Range hood — known capacity 60 L/s (120 cfm).

Make-Up Air Required

- Minimum 55 + 60 - 40 = 75 L/s (150 cfm).

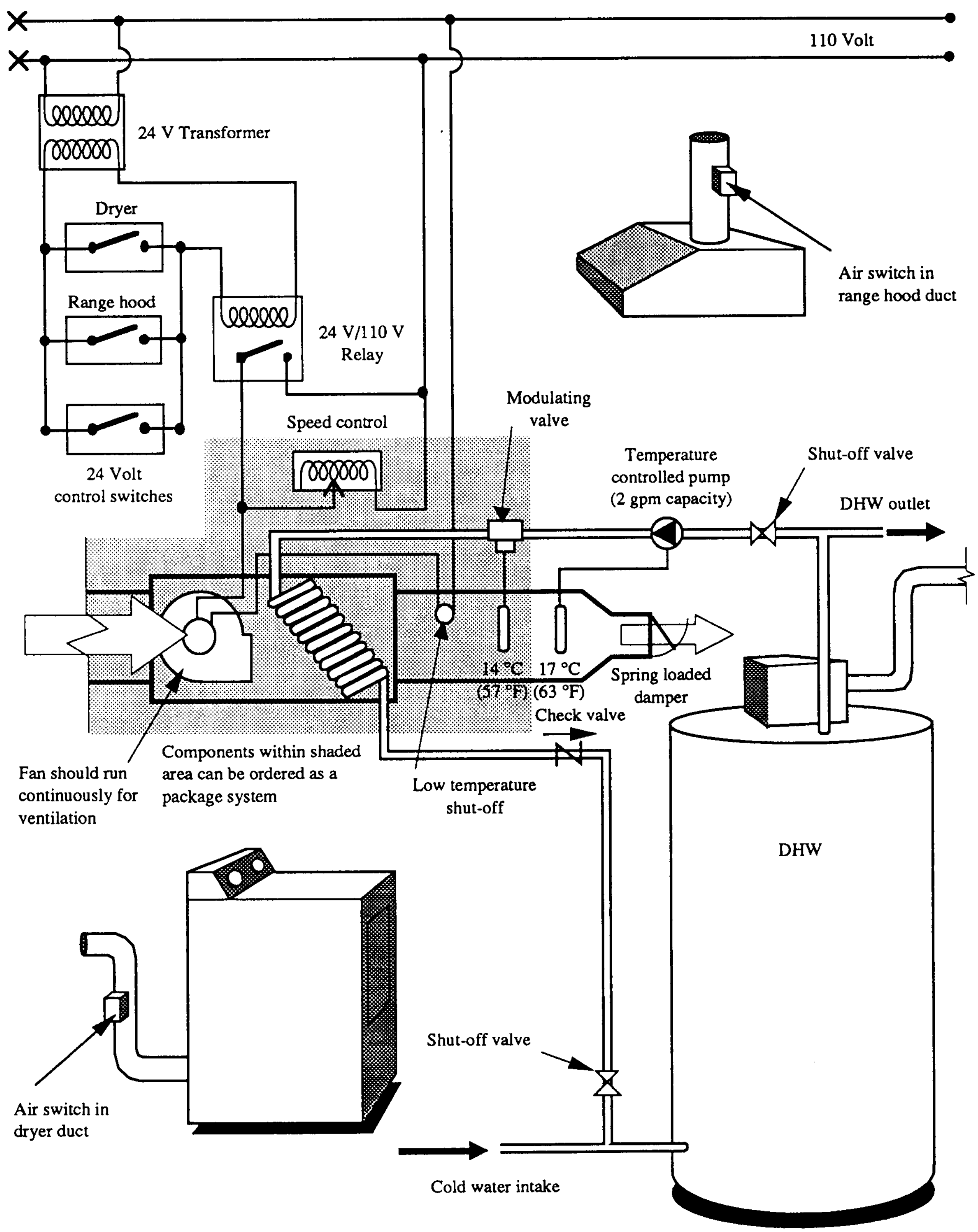
Comments

- In Ottawa climate, heat draw from DHW will be about 2 kW (about 7,000 BTU/hr). Gas DHW capacity is well above this.
- Field testing will probably allow reducing fan speed.
- Spring loaded damper used to provide positive shut-off.
- Some method of turning off circulating pump needed. Temperature control shown will require careful set up.
- Low temperature fan shut-off and modulation control needed for successful system.

Options

Component Costs

• Hood	20
• Fan coil package	550
• Spring loaded damper	40
• Circulating pump and control	100
• Controls	150



Example 6
Package Supply Fan System with Hydronic Coil

References

1. CAN/CSA-F326-M91 *Residential Mechanical Ventilation Systems*, published by the Canadian Standards Association, Rexdale, Ontario.

2. *Design Manual for Residential Mechanical Ventilation Systems*, Student Reference Manual, 1992, published by the Heating, Refrigeration and Air-Conditioning Institute of Canada, Etobicoke, Ontario.

3. Hoyme Manufacturing Inc., *Product Catalogue*, Camrose, Alberta.

4. *Fantech Product Catalogue* from Aeroflo Inc., Mississauga, Ontario.

5. Energy Savings Products Limited, *Product Catalogue*, Edmonton, Alberta.

6. Chromalox, Division of Dimplex North America Inc., *Product Catalogue*, Toronto, Ontario.

7. Honeywell, *Controls Catalogue*, numerous locations.

Notice to Homeowner

The use of strong exhaust fans in tight houses, like this R-2000 Home, can cause problems with the operation of the fuel-burning appliances and/or fireplace. The suction of the fan could cause some of the exhaust from the appliances to be sucked into the house rather than going out the chimney or vent.

This house has been provided with a “make-up air system” designed to prevent these problems. It has been designed to counteract the effect of a fan up to the capacity of _________ L/s (_________ cfm) which is enough to deal with most normal exhausting appliances, like a dryer.

As a homeowner or resident, it is important to recognize that the following actions could lead to a hazardous condition.

1. Installing an appliance with a fan larger than the design capacity noted above, without having the make-up air system upgraded. One type of appliance is of special concern — range top grills. These can have very powerful fans. Their installation and use requires special precautions.
2. Defeating the operation of the make-up air system by plugging up the inlet.
3. Letting operation of the make-up air system degrade through inadequate maintenance. As the homeowner, it is your responsibility to ensure that the required maintenance gets done.

Attached to this notice, you will find suggested maintenance requirements and the manufacturer's information for components of the make-up air system.

The organization most familiar with the specific system in your house is:

____

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____

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Telephone: ____________________