AIR-SOURCE HEAT PUMPS

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ABSTRACT

This paper deals with Air-Source heat pumps draw heat from the autside air during the rating season and rejem heat outside during the summer cooling season.

1. INTRODUCTION

There are two types of air-source heat pumps. The most common is the air-to-air heat pump. It extracts heat from the air and then transfers heat to either the inside or outside of your home depending on the season. The other type is the air-to-water heat pump, which is used in homes with hydronic heat distribution systems. During the heating season, the heat pump takes heat from the outside air and then transfers it to the water in the hydronic distribution system. If cooling is provided during the summer, the process is reversed: the heat pump extracts heat from the water in the home's distribution system and "pumps" it outside to cool the house. These systems are rare, and many don't provide cooling; therefore, most of the following discussion focuses on air-to-air systems.

More recently, ductless mini-split heat pumps have been introduced to the Canadian market. They are ideal for retrofit in homes with hydronic or electric resistance baseboard heating. They are wall-mounted, free-air delivery units that can be installed in individual rooms of a house. Up to eight separate indoor wall-mounted units can be served by one outdoor section. Air-source heat pumps can be add-on, all-electric or bivalent. Add-on heat pumps are designed to be used with another source of supplementary heat, such as an oil, gas or electric furnace. All-electric air-source heat pumps come equipped with their own supplementary heating system in the form of electric-resistance heaters. Bivalent heat pumps are a special type, developed in Canada, that use a gas or propane fired burner to increase the temperature of the air entering the outdoor coil. This allows these units to operate at lower outdoor temperatures.

Air-source heat pumps have also been used in some home ventilation systems to recover heat from outgoing stale air and transfer it to incoming fresh air or to domestic hot water.

2. HOW DOES AN AIR-SOURCE HEAT PUMP WORK

An air-source heat pump has three cycles: the heating cycle, the cooling cycle and the defrost cycle.

The Heating cycle

During the heating cycle, heat is taken from outdoor air and "pumped" indoors.

- First, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the outdoor coil, which acts as the evaporator coil. The liquid refrigerant absorbs heat from the outdoor air and boils, becoming a low-temperature vapour.
- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid before the vapour enters the compressor. The vapour is then compressed, reducing its volume and causing it to heat up.
- Finally, the reversing valve sends the gas, which is now hot, to the indoor coil, which is the condenser. The heat from the hot gas is transferred to the indoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device and the cycle is repeated. The indoor coil is located in the ductwork, close to the furnace.

The ability of the heat pump to transfer heat from the outside air to the house depends on the outdoor temperature. As this temperature drops, the ability of the heat pump to absorb heat also drops. At the outdoor ambient balance point temperature, the heat pump's heating capacity is equal to the heat loss of the house.

At the outdoor ambient balance point temperature, the heat pump's heating capacity is equal to the heat loss of the house. Below this outdoor ambient temperature, the heat pump can supply only part of the heat required to keep the living space comfortable, and supplementary heat is required. When the heat pump is operating in the heating mode without any supplementary heat, the air leaving it will be cooler than air heated by a normal furnace. Furnaces generally deliver air to the living space at between 55°C and 60°C. Heat pumps provide air in larger quantities at about 25°C to 45°C and tend to operate for longer periods.

The Cooling cycle

The cycle described above is reversed to cool the house during the summer. The unit takes heat out of the indoor air and rejects it outside.

- As in the heating cycle, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the indoor coil, which acts as the evaporator. The liquid refrigerant absorbs heat from the indoor air and boils, becoming a low-temperature vapour.
- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid, and then to the compressor. The vapour is then compressed, reducing its volume and causing it to heat up.
- Finally, the gas, which is now hot, passes through the reversing valve to the outdoor coil, which acts as the condenser. The heat from the hot gas is transferred to the outdoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device, and the cycle is repeated.

During the cooling cycle, the heat pump also dehumidifies the indoor air. Moisture in the air passing over the indoor coil condenses on the coil's surface and is collected in a pan at the bottom of the coil. A condensate drain connects this pan to the house drain.

The Defrost cycle

If the outdoor temperature falls to near or below freezing when the heat pump is operating in the heating mode, moisture in the air passing over the outside coil will condense and freeze on it. The amount of frost buildup depends on the outdoor temperature and the amount of moisture in the air. This frost buildup decreases the efficiency of the coil by reducing its ability to transfer heat to the refrigerant. At some point, the frost must be removed. To do this, the heat pump will switch into the defrost mode.

- First, the reversing valve switches the device to the cooling mode. This sends hot gas to the outdoor coil to melt the frost. At the same time the outdoor fan, which normally blows cold air over the coil, is shut off in order to reduce the amount of heat needed to melt the frost.
- While this is happening, the heat pump is cooling the air in the ductwork. The heating system would normally warm this air as it is distributed throughout the house.

One of two methods is used to determine when the unit goes into defrost mode. Demand-frost controls monitor airflow, refrigerant pressure, air or coil temperature and pressure differential across the outdoor coil to detect frost accumulation on the outdoor coil. Time-temperature defrost is started and ended by a preset interval timer or a temperature sensor located on the outside coil. The cycle can be initiated every 30, 60 or 90 minutes, depending on the climate and the design of the system. Unnecessary defrost cycles reduce the seasonal performance of the heat pump. As a result, the demand-frost method is generally more efficient since it starts the defrost cycle only when it is required.

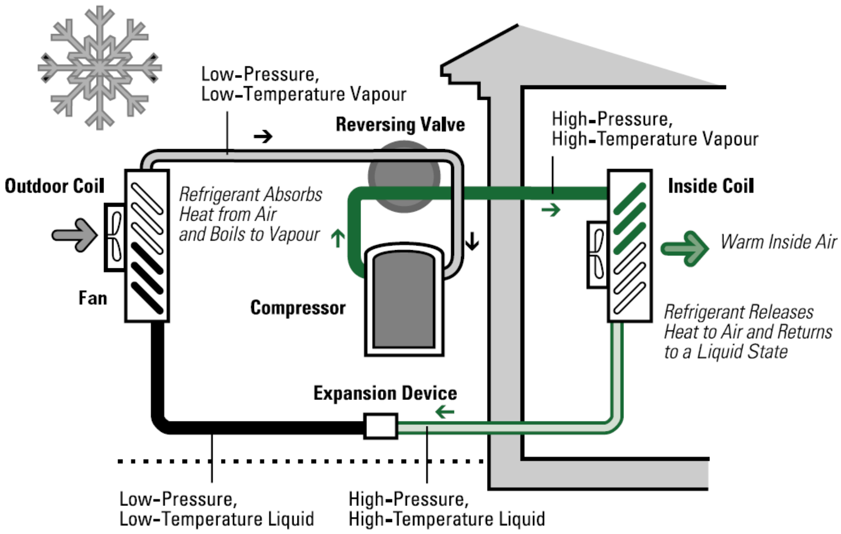

Fig.1. Components of an Air-Source Heat Pump (Heating Cycle)

Fig.2. Components of an Air-Source Heat Pump (Cooling Cycle)

3. PARTS OF THE SYSTEM

The components of an air-source heat pump are shown in Figure 1 and Figure 2. In addition to the indoor and outdoor coils, the reversing valve, the expansion device, the compressor, and the piping, the system has fans that blow air over the coils and a supplementary heat source. The compressor can be located indoors or outdoors. If the heat pump is all-electric, supplementary heat will be supplied by a series of resistance heaters located in the main air-circulation space or plenum downstream of the heat pump indoor coil. If the heat pump is an add-on unit (see Figure 3), the supplementary heat will be supplied by a furnace. The furnace may be electric, oil, natural gas or propane. The indoor coil of the heat pump is located in the air plenum, usually just above the furnace. See the section titled "Supplementary Heating Systems," on page 46, for a description of the operation of a heat pump and furnace combination. In the case of a ductless mini-split heat pump, supplementary heat can be provided by the existing hydronic or electric resistance baseboard heaters.

Fig.3. Add-On Heat Pump

4. ENERGY EFFICIENCY CONSIDERATIONS

The annual cooling efficiency (SEER) and heating efficiency (HSPF) of an air-source heat pump are affected by the manufacturer’s choice of features. At the time of this publication, the SEER of air-source heat pumps ranged from a minimum of 10 to a maximum of about 17. The HSPF for the same units ranged from a minimum of 5.9 to a maximum of 8.6, for a Region V climate as required in CSA C656. Region V has a climate similar to that of Ottawa. The minimum efficiency levels above are currently regulated in a number of jurisdictions. New minimum efficiency requirements are scheduled to come into effect across Canada in 2006. The minimum SEER will likely be 13, and the minimum HSPF will be 6.7. These levels represent a significant improvement over the average sales-weighted efficiency from only a few years ago. More efficient compressors, larger heat exchanger surfaces, improved refrigerant flow and other controls are largely responsible for these gains. New developments in compressors, motors and controls will push the limits of efficiency even higher.

More advanced compressor designs by different manufacturers (advanced reciprocating, scroll, variable speed or two-speed compressors combined with current best heat exchanger and control designs) permit SEERs as high as 17 and HSPFs of up to 8.6 for Region V. Air-source heat pumps at the lower end of the efficiency range are characterized as having single-speed reciprocating compressors. Higher efficiency units generally incorporate scroll or advanced reciprocating compressors, with no other apparent design differences. Heat pumps with the highest SEERs and HSPFs invariably use variable- or two-speed scroll compressors.

5. INSTALLATION CONSIDERATIONS

In installing any kind of heat pump, it is most important that the contractor follow manufacturers' instructions carefully. The following are general guidelines that should be taken into consideration when installing an air-source heat pump:

- In houses with a natural gas, oil or wood furnace, the heat pump coil should be installed on the warm (downstream) side of the furnace.
- If a heat pump is added to an electric furnace, the heat pump coil can usually be placed on the cold (upstream) side of the furnace for greatest efficiency.
- The outdoor unit should be protected from high winds, which may reduce efficiency by causing defrost problems. At the same time, it should be placed in the open so that outdoor air is not recirculated through the coil.
- To prevent snow from blocking airflow over the coil and to permit defrost water drainage, the unit should be placed on a stand that raises it 30 to 60 cm (12 to 24 in.) above the ground. The stand should be anchored to a concrete pad, which in turn should sit on a bed of gravel to enhance drainage. Alternatively, the unit might be mounted from the wall of the house on a suitably constructed frame.
- It is advisable to locate the heat pump outside the dripline of the house (the area where water drips off the roof) to prevent ice and water from falling on it, which could reduce airflow or cause fan or motor damage.
- The pan under the inside coil must be connected to the house's interior floor drain, to ensure that the condensate that forms on the coil drains properly.
- The heat pump should be placed so that a serviceperson has enough room to work on the unit.
- Refrigerant lines should be as short and straight as possible. It is good practice to insulate the lines to minimize unwanted heat loss and to prevent condensation.
- Fans and compressors make noise. Locate the outdoor unit away from windows and adjacent buildings. Some units make additional noise when they vibrate. You can reduce this by selecting quiet equipment or by mounting the unit on a noise-absorbing base.
- Heat pump systems generally require larger duct sizes than other central heating systems, so existing ducting may have to be modified. For proper heat pump operation, airflow should be 50 to 60 litres per second (L/s) per kilowatt, or 400 to 450 cubic feet per minute (cfm) per ton, of cooling capacity.

The cost of installing an air-source heat pump varies depending on the type of system and the existing heating equipment. Costs will be higher if the ductwork has to be modified, or if you need to upgrade your electrical service to deal with the increased electrical load.

6. MAJOR BENEFITS OF AIR-SOURCE HEAT PUMPS

Efficiency

At 10°C, the coefficient of performance (COP) of airsource heat pumps is typically about 3.3. This means that 3.3 kilowatt hours (kWh) of heat are transferred for every kWh of electricity supplied to the heat pump. At –8.3°C, the COP is typically 2.3.

The COP decreases with temperature because it is more difficult to extract heat from cooler air. Figure 6 shows how the COP is affected by cooler air temperature. Note, however, that the heat pump compares favourably with electric resistance heating (COP of 1.0) even when the temperature falls to –15°C.

Air-source heat pumps will operate with heating seasonal performance factors (HSPFs) that vary from 6.7 to 10.0, depending on their location in Canada and their rated performance.

Energy Savings

You may be able to reduce your heating costs by up to 50 percent if you convert from an electric furnace to an allelectric air-source heat pump. Your actual savings will vary, depending on factors such as local climate, the efficiency of your current heating system, the cost of fuel and electricity, and the size and HSPF of the heat pump installed.

More advanced designs of air-source heat pumps can provide domestic water heating. Such systems are called "integrated" units because heating of domestic water has been integrated with a house space-conditioning system. Water heating can be provided with high efficiency in this way. Water heating bills can be reduced by 25 to 50 percent.

7. CONCLUSIONS

Proper maintenance is critical to ensure that your heat pump operates efficiently and has a long service life. You can do some of the simple maintenance yourself, but you may also want to have a competent service contractor do an annual inspection of your unit. The best time to service your unit is at the end of the cooling season, prior to the start of the next heating season.

4. REFERENCES

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