Heat Pumps: An alternative Way to Heat Homes

Outcomes:

1. Identify different approaches taken to solve the problem of heating homes during cold times of the year (109-7)
2. Make informed decision about the various technologies used to hear our homes, taking into account potential advantages and disadvantages (110-7, 113-8)
3. Provide examples of how the technologies used to heat homes have improved over time (110-8)
4. Provide examples of how our understanding of evaporation and condensations of liquids resulted in the development of heat pumps (111-1)
5. Describe how various surfaces absorb radiant heat (308-6)

Introduction

Heating homes in Newfoundland and Labrador has long been a major concern. Historically, there have been three main sources of heat in this province. These are (1) wood, (2) oil, and (3) electricity. It takes a great deal of effort to stay comfortable during our cold damp winters. The effort made may be in labor (e.g. cutting, splitting and storing wood) or in dollars (e.g. increasing costs of oil or electricity). When building a new house, the choices of the type of heat source for that house has become a very important decision. To make this decision, there are many questions that should be considered about the traditional sources of heat. Some of these are:

Wood:

1. If I cut it myself, will there be places available in the future where I can cut it?
2. If I buy my wood, how expensive will it become?
3. Is there a long term supply of wood in my community?
4. Do I have the time needed to cut it up, store it to dry, and then put it in a shed?
5. Am I aware of the pollution created by burning wood?

Oil:

1. How expensive will it become in the future?
2. Will there be an ample supply in the future?
3. Do I have enough space in my house for the furnace and duct work?
4. Am I able to deal with a spill from the tank or fuel lines?
5. Am I comfortable with the green house gases that are produced?

Electricity:

1. How expensive will it become in the future?
2. What environmental damage results from its production?
3. Will there be enough in the future?
4. Is the source of the electricity environmentally friendly?

The decision of which heat source to install in a new house is not only a costly one, it is a decision that is often not easy to change in the future. For example, changing from oil to electricity (or vice versa) is very costly and, in some cases, is not possible due to how the house was constructed. As a result, the answers to these questions have long term implications for the house owner.

However, with recent scientific advancements, there are other options to the three "traditional" choices. One of these is the heat pump and is now becoming a very real and practical alternative. A heat pump is an electrical device that moves heat from one source, "concentrates" it, and transfers it to another location. This technology is very similar to that which is found in refrigerators and air-conditioners. In these devices, heat is removed from the fridge or room and transferred somewhere else. As you will see below, this type of heat pump works in the cooling mode only.

The Science Behind Heat Pumps

The heat pump is based on the following two scientific principles:

1. When a liquid is heated it will evaporate (becomes a gas) and when a gas condenses (becomes a liquid), it gives off heat. As you have learned, this is explained using the Particle Theory of Matter. As the particles in the liquid are heated, they have more kinetic energy and are able to move further apart. When particles gain enough kinetic energy, those at the surface can "break free" of the surrounding liquid particles and leave the liquid as a gas.
2. Changes in pressure can make a liquid evaporate, or gases condense, more easily. In other words, if the pressure on a liquid is reduced, the liquid will evaporate more easily. If a gas is put under more pressure, it will condense more easily. A common example of this is a propane tank or propane torch. Propane is placed in a tank under a pressure that causes it to be a liquid (if you shake the tank, you can hear or feel the liquid sloshing around inside). When you release the pressure on this liquid, such as when you open the tap or valve, the liquid evaporates and comes out as a gas. This happens because it is under high pressure inside the tank because the gas is "jammed" into a small space. When you open the valve, the pressure is much less because the gas is entering a much larger space.

These scientific principles are used to make a heat pump in the following way:

1. In the place where heat is to be removed, a liquid, called the refrigerant, is pumped through tubing under low pressure. The refrigerant is a liquid that has a very low boiling point (e.g. where water has a boiling point of 100 °C, the refrigerant might have a boiling point as low as 10 °C or lower).
2. As the refrigerant passes through the pipes, it absorbs heat energy from the surrounding environment and, because it has a very low boiling point, it evaporates (becomes a gas). At this point, the gas is under low pressure.
3. This low pressure gas is then pumped and compressed (put under high pressure) into a second area where it releases the heat energy it absorbed. The heat energy that is released can then be used to heat air or water. The warm air or water is then transferred to the location that is to be heated (e.g. a room in a house).
4. The compressed refrigerant is then passed through an expansion valve that reduces its pressure. At this point the gas reverts back into a liquid refrigerant and the process repeats itself.

To cool an area, the process is reversed. Because it is fully reversible, a large heat pump is capable of heating or cooling our homes, offices and schools depending on the outside temperature.

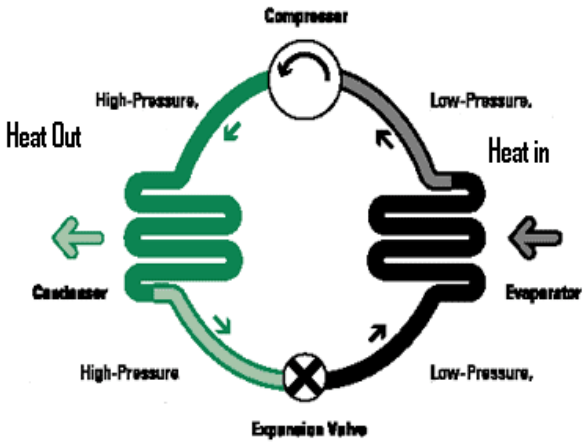

Figure 1: The basic heat pump cycle

You might wonder how this works during the cold winter months. You might ask "where is the source of heat when it's -18°C outside?" As you have learned in this unit, all matter contains energy until it reaches absolute zero (-273 °C). So, even at -18 °C, both the ground and the air are sources of heat. Furthermore, once you go below the deepest penetration of frost, the ground is at a comfortable 16°C (and will get even warmer as you go deeper). So, even on the coldest days, the air always contains heat. In fact, while it might not feel like it as you stand there shivering, air at -18°C contains about 85% of the heat it contained at 21°C!

Types of Heat Pumps

1. Air-Source Heat Pump

This type of heat pump uses the energy that is present in the air as a source of heat. Air-source heat pumps are most efficient when the outside air temperature is above -9 oC. Below this temperature, the commonly used refrigerants can not absorb enough energy from the air efficiently.

There are two types of air-source heat pumps:

(a) Air-to-Air

This type of heat pump removes heat from the air. If it is being used to heat a house, the heat is absorbed from the air outside then transferred to the air inside the house (see Figure 2). The fan, which is part of the heat collection mechanism (outside the house) pulls air across the pipes that contain the low pressure refrigerant. The refrigerant absorbs heat from the outside air and evaporates into a gas. This gas is then passed through the compressor and pumped inside the house and through a series of pipes and heats the surrounding structure. Inside the house, another fan, which is part of the distribution mechanism, pulls cool air from other parts of the house and forces it across the heated tubes that contain the high-pressure refrigerant. As the air passes over these tubes, it warms up. The fan continues to blow this warmed air into ductwork that carries it to the cooler parts of the house. This warm air heats the interior of the house.

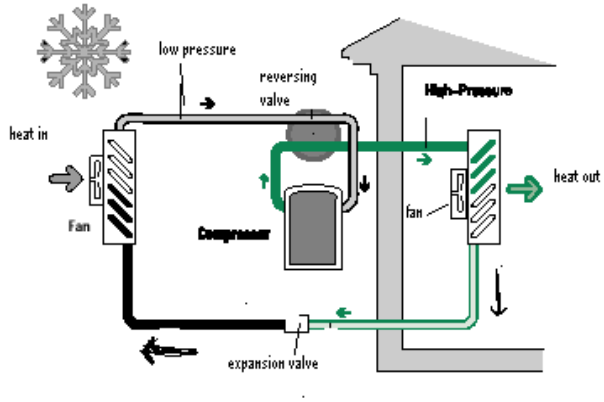

Figure 2: Heat pump in its Heating Cycle

To cool the house, the process is reversed and the refrigerant is pumped in the opposite direction (Figure 3). The fan pulls warm from inside the house, over the pipes that contain refrigerant under low pressure. The refrigerant absorbs the heat from this "inside air" and the heated refrigerant changes into a gas. As the "inside air" looses heat energy, it is cooled. The fan blows this cooler air into the ductwork and throughout the house. The cooler air cools the interior of the house. This gas passes through the compressor and enters the pipes outside the house. Here the fan blows outside air over the surface of the pipes and the outside air absorbs heat energy from the refrigerant. The gas condenses back into a liquid and is under low pressure. It is pumped back into the house and the cycle continues.

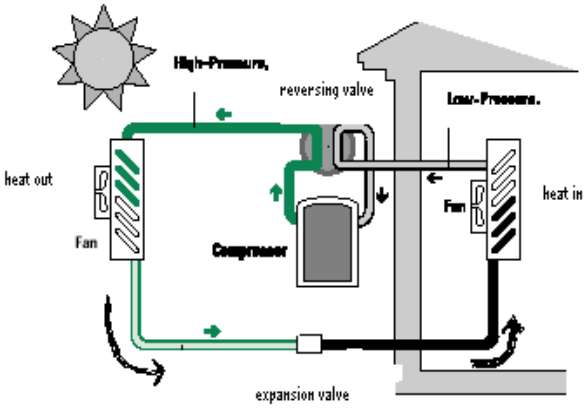

Figure 3: Heat pump in its Cooling Cycle

Notice the differences in the two cycles as displayed in Figures 2 and 3. These are:

i) the "heat in" mode is the reverse of the "heat out" mode
ii) the refrigerant is pumped in opposite directions. During the heating mode, it goes inside the building, while in the cooling mode, it goes outside the building.

(b) Air-to-water

This type of heat pump functions in exactly the same manner as the air-to-air heat pump with the exception that the energy transfer occurs between the air on the outside and water on the inside. For example, during the winter months, the heat pump removes heat from the outside air and transfers it to the water in pipes that are usually placed throughout the sub-floor (under the carpet, canvas or hardwood). This makes the floor warm which in turn heats the home. Or the water may run through a large metal structure called the radiator. The water inside the radiator heats the metal and the heat "radiates" into the room, heating the surrounding air.

2. <u>Ground Source Heat Pumps</u>

The ground-source heat pump takes heat energy from the ground outside the house, when in the heating mode, or deposits heat into the ground outside the house, when it is in the cooling mode.

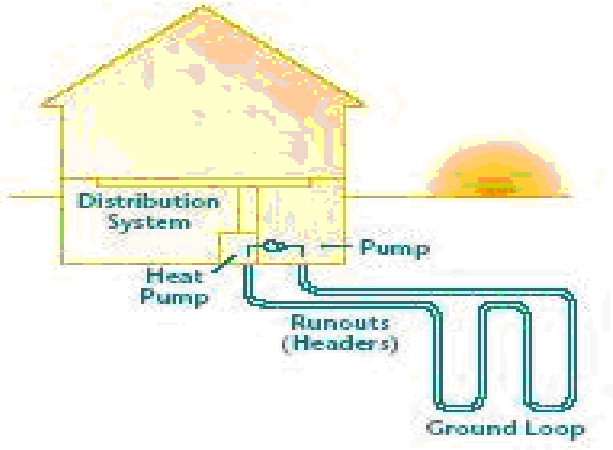

Figure 4: Ground source heat pump

The refrigerant is pumped through an underground piping system, and picks up heat in the heating cycle or gives up heat in the cooling cycle. The length and depth of the underground piping system depends on a number of factors. These are:

i) the size of the space to be cooled or heated

ii) the difference between the temperature inside the building and the outside temperature

iii) how well the space is insulated

Cost Comparisons

If the homebuilder is considering the installation of a heat pump as the heat source for the house, there are other questions that need to be considered. Three of the most important ones are: "Which type, air source or ground source is best for me?", "How much will it cost to install a heat pump?" and "Will it save me money on my heating bill?" The answer to the first question will depend on the general climate in the area. Since air source heat pumps are most efficient (i.e. most cost effective) where there is an average temperature range of -?? To +??, if the average temperature falls outside this range, the only real option is the ground source pump. It is difficult to answer the second question as there are many factors that influence the overall cost. Some of the factors that will influence the overall installation cost of a heat pump are: the size of the house, the configuration (bungalow, 2-storey, etc), where the house will be located (e.g. the more distant from the supplier, the more it will cost), the temperature range of the outside air, the type of soil that will need to be dug up, etc.

Often, it is the answer to the last question that most people will use to make their final decision. Figure 5 below provides a comparison of the costs involved to heat a 3000 sq. foot house, in a good location and an average temperature range (i.e. -15 °C to 25 °C).

Figure 5: Cost Comparison for Various Heat Sources

Heat Source	Installation Cost*	Average cost per month*	Yearly cost*	Cost in 10 years*
Electric heat	$2500	$300	$3600	$36,000
Oil furnace	$5000	$250	$3000	$30,000
Wood furnace	$5000	$130	$1560	$15,600
Air-Source pump	$12,000	$120	$1440	$14,400
Ground-Source pump	$25,000	$60	$720	$7200

Analysis

Careful comparison of the various heat sources available will point out pros and cons of each choice. The traditional sources for heating houses in Newfoundland and Labrador (Wood, Oil, and Electric) are cheaper to install but over the long term are more costly to operate. Also, in addition to the negative effects these traditional heat sources have on the environment, the operating costs for these may increase quickly as the supply is reduced. The alternative to the traditional heat sources is the heat pump. There are several positive features related to using heat pumps to heat our homes. These are:

i) they do not have any negative effects on the environment
ii) after they have been installed, they are cheaper to operate than the traditional sources of heat
iii) the operating costs will not change as they are not affected by limited supply or price increases.

So, with the positive effects on the environment along with the stable and relatively low operating costs, why don't more houses have heat pumps installed? The main reason is the upfront cost of installation. Even though a heat pump will save the homeowner money in the long run, the decision to add an extra $5000 to $20,000 on the cost of a new house is more than many people are able to afford or are willing to spend.

Conclusion

While there are many decisions that go into the planning and building of a house, the decision of which heat source to use is one that will have long term effects. This is a decision that is not made easily and each individual homebuilder has to carefully weight the pros and cons of each option to ensure they make the best decision to fit their lifestyle and budget.

Questions

1. What are the advantages/disadvantages of using a heat pump to heat your home?
2. Explain how a heat pump functions to cool a building rather than heat it?
3. Name three factors that can influence the overall cost of installing a heat pump?
4. What other household appliances use the same technology found in a heat pump?

5. How does an air source heat pump work to heat a home when the temperature of the air outside is -10 °C?
6. Describe the similarities and differences between air source and ground source heat pumps?
7. Using the table above, explain how using a ground source heat pump can actually save you money.