Heat Pumps:
What are they and why should we use them?

Submitted by:

Bruce Privett

To:

Professor Dan Mielke

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Abstract

In this research paper I broadly covered the subject of heat pumps. I wrote about air-source heat pumps and water-source heat pumps. I identified what the basic components of heat pump systems are as well as the sources of power to drive these systems. I gave a brief explanation of coefficient of performance and how the two types compare in that aspect. I identified the relative cost of each. Finally, I gave a brief summary regarding heat pumps and made concluding remarks.

Introduction – What is a heat pump?

I. Basic components of heat pumps
II. Basic styles of heat pumps
  -Air source
    - air-to-air
    - air-to-liquid
  -Liquid source
    -liquid-to-air
    -liquid-to-liquid
III. Energy sources for heat pumps
  - Grid power
  - Combustion-generated electricity
  - Alternative Energy Sources
    - direct-drive hydraulics
    - hydroelectric
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IV. Coefficient of performance vs. installation cost
  - Air source systems
  - Liquid source systems

Summary

Conclusion

Introduction

The purpose of this presentation is to introduce the reader to the concept of heat pumps and provide a general understanding of their function. I will describe the basic components as well as the basic styles of heat pumps that are used. A general description of the energy sources used to power these systems will be followed by a comparison of the efficiency of the types of units discussed. Finally, I will discuss my feelings about the importance of these systems.

In short, a heat pump is a device that gathers heat energy from a source and transfers it to another location. It has a reversible cycle and can, therefore, be used to heat or cool. In the heating application this energy is gathered from a source outside a building and discharges it inside where it is desired. During a cooling cycle, heat energy is transferred from within the structure to the outside where it can be discharged or used as a heat source. It functions the same as an air conditioner during cooling.

This concept is not new or even recent- it was conceived of long ago. “The basic principle of heat pump operation was first proposed by Nicholas Carnot in 1824 and furthered by Lord Kelvin in 1852”(Sutphin, S.E.1987). With the ever-increasing energy demands and astronomical prices for fossil fuels the world faces today, heat pump technology is a logical place to focus our attention.

I. Basic components of heat pumps.

Heat pumps consist of nine basic components: the compressor, two heat exchange coils, an expansion device, fans or pumps with each coil, a suction accumulator for the

refrigerant, a four-way valve, a low temperature refrigerant, a resistance heater and a control system (McGuigan, D.year unknown).

"The compressor compresses the refrigerant to increase its temperature"(McGuigan). One heat exchanger coil serves as the condenser, while the other is the evaporator (McGuigan). Compressors are normally electrically driven.

The expansion device allows the refrigerant to expand, which causes a pressure drop and results in cooling of the refrigerant liquid (McGuigan). It can be either a capillary tube type or a thermostatic expansion valve or TXV.

Either a fan or a pump is used in conjunction with each heat exchanger coil (McGuigan). If the exchange is from a coil to air, then a fan is used and if the exchange is made in a coil to a liquid, a pump is used to circulate that liquid (Mcguigan).

A suction accumulator is a reservoir that prevents liquid from entering and damaging the compressor.

A four- way valve or reversing valve is a key component of the heat pump. "There are three connection tubes on one side of the tube and one on the other. These tubes connect the valve to the suction and discharge of the compressor as well as the vapor line connections of the heat exchangers"(Miles, L.1994). This valve can reverse the direction of the refrigerant flow to accomplish either heating or cooling.

A low temperature refrigerant is used with a heat pump. "The low boiling temperature increases the heat absorption ability of the refrigerant as it changes state from a vapor to a gas"(McGuigan). There are multiple refrigerants that would work well for this application.

A an electric resistance heater either adds supplemental heat when the unit cannot keep up with the load or deices the condenser coil in the defrost cycle (McGuigan).

Like any heating or cooling appliance, heat pumps require control systems and the associated mounting components.

II. Basic styles of heat pumps

There are four basic styles of heat pumps that fall into two main categories: Air source heat pumps and water source heat pumps. If the heat energy comes from ambient air, it is an air source. When the energy is transferred from a water supply it is a water source heat pump.

Air-Source Heat Pumps:

"An air-source heat pump, as the name implies, utilizes the outside air as a heat source. Because the outside air is free and readily available, the air-source heat pump is by far the most popular of the two types of heat pumps..."(Sutphin).

Air-to-Air – in this configuration, air is pushed or pulled over a coil by a fan where it boils off the refrigerant inside. This vaporized refrigerant is compressed by a compressor and discharged into the second coil where the heat is rejected as fan-driven air flows over the coil. In the cooling mode, this is called air conditioning. In the reverse cycle, we call it a heat pump.

Air to Liquid- air is drawn or driven over a coil by a fan where it boils off refrigerant that passes through a refrigerant to liquid heat exchanger that heats water (Miles). This cycle is usually not reversed. It is used to heat domestic hot water, swimming pools and etcetera.

Liquid-Source Heat Pumps:

A liquid-source heat pump most commonly uses water that is pumped from a ground source and is injected back into the ground (Miles). This style of system, often called a geothermal heat pump, has been used since the 1940's(U.S. Dept. of Energy, E.E.R.E., 2000). "As with any heat pump, geothermal and water-source heat pumps are able to heat, cool and supply the house with hot water"(D.O.E., E.E.R.E.). In addition to well water, water sources include seawater as well as surface water from lakes, rivers and streams (McGuigan)

Liquid-to- Air- in this exchange, water is pumped through a refrigerant/water heat exchanger that can add energy to an air-cooled condenser during a heating cycle or remove energy from an air-exchange evaporator in a cooling mode, depending on the position of the refrigerant reversing valve (Miles).

Liquid-to-Liquid- this application involves pumping water from a source and through a liquid/refrigerant heat exchanger, which adds heat to the refrigerant, which then gives up the heat energy to domestic water or hydronic heating liquid through another heat exchanger (Miles). It can also be used to cool water such as for fish hatcheries (Miles).

III. Energy Sources For Heat Pumps

Grid power- the power that is supplied by the big power utilities is referred to as grid power and is delivered through large networks of electrical energy or grids. It is sold in units known as kilowatt-hours and the price of this supplied power is what we use as a basis for comparison for our alternative sources of energy. The price per kw/h is tied directly to the price of fossil fuels so when oil and gas prices rise, we pay more for

electricity. Since heat pumps utilize electric compressors, fans and pumps, the operating cost is increased as energy rates climb.

Combustion generated electricity- for off-grid consumer; this is more costly electricity than commercially supplied power. The efficiency of a heat pump system may help offset the higher cost of this form of independence.

Direct-drive hydraulics or watermill- the ideal alternative energy source cane drive a compressor directly from the waterwheel while a refrigerant/water heat exchanger can absorb heat from the water and heat a large building for virtually nothing after the installation (McGuigan).

Hydroelectric- generating electrical power from hydraulic pressure is a good long-term cost cutting strategy to power a heat pump system.

Solar panels- if a person has solar panels and is looking for efficiency, a heat pump system makes good sense. There are direct current compressors, pumps and fans that could drive a heat pump system.

Wind generated power- with enough wind a person could run a heat pump system off direct current and get the most from their energy.

IV. Coefficient of Performance vs. Installation cost

The term coefficient of performance is a formula we use to compare the amount of Btu's we pay for against the energy we gain. The formal is; COP=Btu's out/Btu's bought and it translates to Btu's per watt (Sutphin). A COP of 1 would mean straight electrical resistance energy and a COP of 3 would be three times better.

According to the U.S. Department of Energy, " Geothermal heat pumps (GHP's) use the constant temperature if the earth as the exchange medium in stead of the outside temperature. This allows the system to reach fairly high efficiencies (300-600%) on the coldest winter nights, compared to 175-250% for air source heat pumps on cool days". This means a COP of 3-6 for GHP's and 1.75-2.5 for air-source heat pumps. In other words, geothermal heat pumps have a higher coefficient of performance.

Naturally, a more efficient system has a higher cost of installation. "Even though the installation price of a geothermal system can be several times that of an air-source system of the same heating and cooling capacity, the additional costs will be returned to you in savings in 5-10 years"(D.O.E., E.E.R.E.). If you have the extra money to install the geothermal system it will be cheaper over the long run.

Summary- We have looked at the basic terms, components and concepts relating to heat pump systems. The space consumed in this report is only a tiny fraction of the vast body of knowledge relating to this topic. No subject is covered in detail yet is my hope that this small work will cause the reader to imagine a system that is designed to suit their particular need based on the resources they have available. This is, after all, a subject that is very much about the resourcefulness of Mankind.

In conclusion I want the reader to consider the wastefulness of the world we live in. Fossil fuels are being consumed at ever-increasing rates as we argue over how to get more and fight wars to control the supply. At the same time we ignore the viable energy opportunities all around us. We ignore systems and technologies that would make better

use of the fuels we have yet to consume. We overlook the mighty heat pump and its many useful applications. The day of the heat pump is upon us!

References

McGuigan, D., McGuigan, A. (year unknown). Heat Pumps: an effective heating &cooling alternative. Charlotte, Vermont: Garden Way Publishing

Miles, L. (1994). Heat pumps: theory and service. Albany, New York: Delmar

Sutphin, S.E. (1987). Residential heat pumps: installation and troubleshooting. Englewood Cliffs, N.J.: Prentice-Hall

United States Department of Energy-Energy Efficiency and Renewable Energy (2000,March). EERE consumer's guide: geothermal heat pumps. Retrieved April 8th, 2006 from http://www.eere.energy.gov/consumer/your_home/space_heating_cooling