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Heat Pumps—How They Work, How They're Rated

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How Does A Heat Pump Work?

Heat energy will flow naturally from a warm area to a cooler one. For example, heat flows from a warm house to the cold outdoors or from a warm kitchen into a cold refrigerator compartment.

In contrast, a heat pump works **against** this natural flow by using a refrigerant* to transfer heat from a cool area to a warmer one. To accomplish this, the heat pump uses two coils. One coil contains a low-pressure liquid that is cooler than the air being heated, and a second coil contains a high pressure vapor that is hotter than the surrounding air.

As an example, trace the refrigerant flow through the system of a heat pump set by the thermostat on "heat". (See Figure 1)

The compressor will compress the refrigerant vapor and raise both the temperature and pressure. Compressed vapor flows through tubing to a reversing (4-way) valve that will direct the refrigerant to one of the coils as determined by the thermostat setting. In the heating mode, the coil used will be the so-called indoor coil (air-to-air split system) or the coil through which the house-return air passes. Since the coil is warmer than the transient return air, the coil gives up heat and in turn warms the return air. The now warmer return air becomes supply air and is ducted to the rooms being heated.

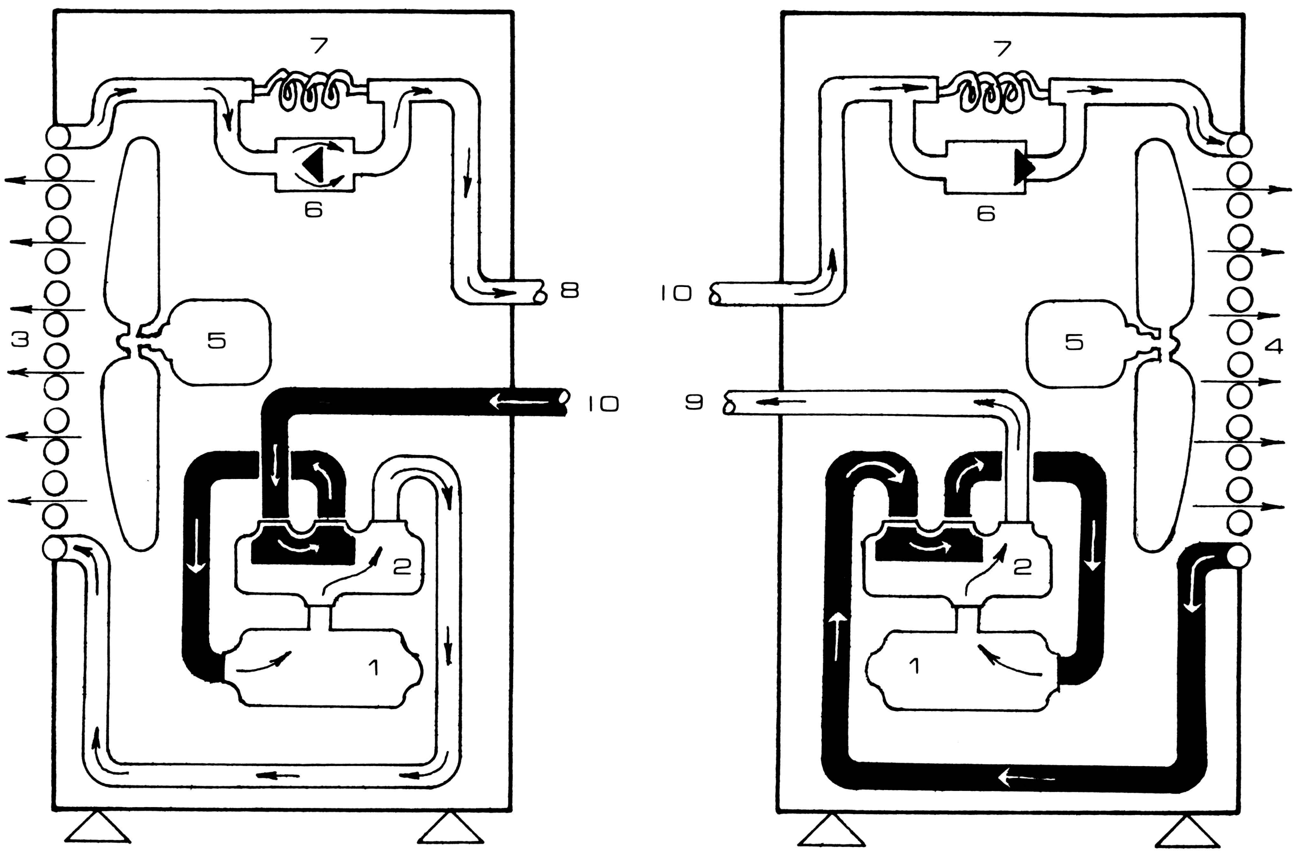
After giving up most of its heat, the now cooler refrigerant in the indoor coil condenses—that is, turns to a liquid—and moves on through the system towards the outdoor (evaporator) coil. After passing through the expansion valve (which may be just a length of tubing), a low temperature, low pressure mixture of vapor and liquid arrives at the outdoor coil. When a fan blows air across this coil, the cooler refrigerant absorbs heat from the air, the refrigerant "boils," and changes state to a vapor. The low temperature, low-pressure vapor returns to the compressor where the cycle begins again.

When the heat pump is set by the thermostat on the "cool" cycle, the refrigerant flow is reversed which reverses the functions of the two coils. (See Figure 1.) What was the low-temperature outdoor coil is still outdoors (air-to-air pumps), but it is now high temperature. The formerly high temperature indoor coil (still located indoors) now becomes the cool coil in which refrigerant evaporates removing heat from the space being cooled.

COPs, SPFs, SEERs and Ratings

Through advertising, most major heat pump manufacturers attempt to create an almost "too-good-to-be-true" image of the heat pump. Unquestionably, a heat pump is the most efficient electric forced air heating system available. The electric power consumption *can be* up to 35 percent less than would be required by an electric furnace system sized to deliver the same amount of heat.[1] Of all conventional heating systems available today, heat pumps alone can return more heat than they consume. While conventional systems use energy to *create* heat, heat pumps use energy to *TRANSFER* and *INTENSIFY* heat that is already available in the surround-

*The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) defines a refrigerant as: "the fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and a low pressure of the fluid and rejects heat at a higher temperature and a higher pressure of the fluid, usually involving changes of state of the fluid" (liquid-to-vapor-to-liquid, etc.).



COOLING CYCLE **HEATING CYCLE**

1. Compressor
2. Reversing Valve
3. Condenser Coil
4. Evaporator Coil
5. Fan/Motor
6. Check Valve
7. Expansion Device
8. To Indoor (Evaporator) Coil*
9. To Indoor (Condenser) Coil*
10. From Indoor Coil

*Common Coil

■ Low Pressure Side

□ High Pressure Side

Fig. 1

ing environment. A heat pump uses energy only to run the fan and compressor motors.

Engineers speak of the efficiency of a heating device in terms of its coefficient of performance (COP). The COP is the ratio of energy output to the heat energy input. The COP figures dispensed by heat pump manufacturers are derived from standard testing procedures which measure COP at 70°F (21°C) inside temperature and 47° and 17°F (8.3 and-8.3C) outside temperature. A first-rate residential heat pump might have a published COP of 2.8 at 47 degrees and 1.9 at 17 degrees. Most are somewhat below that.[2]

As one might expect, COP data obtained under steady-state,* laboratory conditions is not

*Steady-state refers to the practice of continuously operating a piece of equipment under constant conditions.

necessarily equal to what one might find in the real world of a typical heat pump. While the COP of electric resistance heat (baseboard, ceiling cable, forced air) *at the heater* is generally considered 1.0 (you input 1 Btu, you get back 1 Btu), to extend this comparison to the heat pump is not valid. Heat pump COP values vary greatly with ambient (air) conditions while the COP of resistance systems is constant.

Recognizing this fact, current industry trend is to publish an integrated, annual COP known as the Seasonal Performance Factor or SPF. The SPF is an attempt to show the effects of climate on the performance of a heat pump. For a typical mid-Missouri *air-to-air installation*, most SPFs will be in the neighborhood of 1.65 to 2.0. This means that for each watt of electrical input, the consumer can expect to receive 1.65 to 2 watts of output.

Unfortunately, an *accurate* SPF figure for a heat pump installation is difficult to obtain. To simplify calculations, the following items are generally *not* considered:[3]

- The effect of cycling (on-off) operation is ignored in favor of a steady-state mode.
- Defrosting losses are neglected.*
- Decreased capacity due to frost accumulation is not recognized.*
- Beneficial results of solar radiation on outdoor equipment are not included (heating cycle).

While efficiency rating numbers are most likely beneficial, they should be viewed with a certain amount of skepticism. As long as all manufacturers subscribe to the same testing and reporting procedure, then the rating numbers are an excellent comparative tool when equipment from different manufacturers is being evaluated. Whether the numbers are an accurate gauge of expected performance in a field situation remains speculative.

It was almost ten years ago that the letters EER began appearing on hang tags on some models of room air conditioners. Pioneered by the Association of Home Appliance Manufacturers, AHAM, the energy efficiency ratios (EERs) of its members' equipment were first published in 1973. Since that time the EER has become increasingly more recognizable by the public and is now accepted industry-wide as **the** method of rating or comparing air-conditioning equipment, both room and central systems.

The EER is easily calculated. Simply divide the Btu of cooling capacity by the power input** in watts. The resulting figure is a measure of a unit's cooling efficiency expressed in Btu's per hour per watt. The higher the number, the more efficient the unit. Stated another way, the higher the EER, the more cooling delivered per dollar spent on electricity.

Due to added manufacturing expenses, high EER units initially cost the consumer more. Whether the additional expense is justified is a decision the consumer must make.

On a state-wide average, Missourians can expect approximately 1070 hours of above 80°F (26.6°C) temperatures requiring some cooling.[4] For purposes of discussion, assume that electricity costs 6¢ per kilowatt hour and that a unit in question draws 4375 watts (4.375 KW). 1070 hours x 4.375 KW x 6¢ equals $280 per season cooling expense. Carrying the discussion a step farther, assume that another unit *of the same size* consumes 15 percent more electricity (has an EER 15 percent *lower* than the first unit). For the summer, the added expense of operating the less efficient unit is $280 x .15 or $42. The final step involves dividing the added cost of the more efficient (first) unit by $42 to arrive at the approximate number of summers required to pay for the higher priced system. Obviously, the above example assumes a constant electricity rate, a rather unlikely happening, making the payback period shorter with each rate increase.

As with a heat pump's SPF, the efficiency of air conditioning equipment is now being expressed in terms of Seasonal Energy Efficiency Ratios or SEER. SEER means the *total* delivered Btu's of cooling of a central air conditioner during its normal cooling season divided by the *total* electrical input in watt-hours during the same season.

The Air-Conditioning and Refrigeration Institute (ARI) is a trade association formed for the improvement of members who manufacture a variety of air treatment equipment. The ARI conducts testing procedures on manufacturer-submitted equipment which, if passed, is labeled with the Institute's distinctive certification symbol. Twice a year ARI publishes updated directories[5] listing by model number all of the equipment of a particular type successfully performing under ARI's standards. Copies of the Institute's

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*See Home Economics Guide GH5259, "Air-to-Air Heat Pumps for discussion on defrosting.

**For a heat pump system, power input includes the power required to operate all fans or blowers furnished with the model.

publications can be reviewed at libraries, or at firms working with air-conditioning or allied industries such as builders, contractors, or dealers. Copies of ARI directories are also available at a nominal charge direct from the Institute.

While not all manufacturers are ARI members, and some members decline to submit all of their product line, the ARI nonetheless performs a valuable regulatory function. The manufacturer of a model which fails to pass specified tests may either re-rate or withdraw the model from his line. If he chooses to do neither, his right to use the ARI certification symbol on *all* of his models is withdrawn and his name and listing is deleted from the directory.

When shopping for heating, ventilating, or air conditioning equipment, consumers are encouraged to look for the ARI seal.

References

1) Schunug, William. *The Heat Pump.* The Ohio State University, Cooperative Extension Service.
2) Smay, V. Elaine. "Heat Pumps", *Popular Science,* (July, 1978), p. 80-82, 132, 133.
3) Hanks, David J., "M/E Update, Heat Pumps." *Specifying Engineer,* (February, 1981), p. 81-85.
4) National Association of Home Builders Research Foundation, Inc., *Insulation Manual,* 1971. p. 30.
5) Air-Conditioning and Refrigeration Institute, *Directory of Certified Applied Air-Conditioning Products.* 1815 No. Fort Meyer Dr. Arlington, Virginia 22209, 1982.

For additional Heat Pump information see Home economics Guide Sheets GH5259, Air-To-Air Heat Pumps; and GH5258, Water-To-Air Heat Pumps.

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