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Air-Source Heat Pumps

There are two common types of heat pumps: air-source heat pumps and geothermal heat pumps (GHPs). Either one can keep your home warm in the winter and cool in the summer. An air-source heat pump pulls its heat indoors from the outdoor air in the winter and from the indoor air in the summer. A GHP extracts heat from the indoor air when it's hot outside, but when it's cold outside, it draws heat into a home from the ground, which maintains a nearly constant temperature of 50˚ to 60˚F. This fact sheet focuses on air-source heat pumps, which comprise the majority of all residential heat pump applications.

An air-source heat pump can provide efficient heating and cooling for your home, especially if you live in a warm climate. When properly installed, an air-source heat pump can deliver one-and-a-half to three times more heat energy to a home compared to the electrical energy it consumes. This is possible because a heat pump moves heat rather than converting it from a fuel, like in combustion heating systems.

How They Work

You might be wondering how an air-source heat pump uses the outdoor winter air to heat a home. Believe it or not: heat can be harvested from cold outdoor air

Sara Farrar, NREL/PIX05420

This home in Austin, Texas, features an air-source heat pump.

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down to about 40°F. And this can be accomplished through a process you're probably already familiar with—refrigeration.

Basically, a heat pump's refrigeration system consists of a compressor, and two coils made of copper tubing, which are surrounded by aluminum fins to aid heat transfer. The coils look much like the radiator in your car. Like in a refrigerator or air-conditioner, refrigerant flows continuously through pipes, back and forth from the outdoor coils. In the heating mode, liquid refrigerant extracts heat from the outside coils and air, and moves it inside as it evaporates into a gas. The indoor coils transfer heat from the refrigerant as it condenses back into a liquid (see Fig. 1 below). A reversing valve, near the compressor, can change the direction of the refrigerant flow for cooling as well as for defrosting the outdoor coils in winter (see Fig. 2 on page 3).

When outdoor temperatures fall below 40°F, a less-efficient panel of electric resistance coils, similar to those in your toaster, kicks in to provide indoor heating. This is why air-source heat pumps aren't always very efficient for heating in areas with cold winters. Fuel-burning furnaces generally can provide a more economical way to heat homes in cooler U.S. climates.

Types of Air-Source Heat Pumps

You can use a central heat pump to heat and cool a whole house. Most central heat pumps are split-systems—that is, they each have one coil indoors and one outdoors (see Fig. 1 below). Supply and return ducts connect to a central fan, which is located indoors. The fan, often called an air handler or blower, circulates air throughout the house. The fan also usually contains electric resistance coils (some units now have a gas-fired furnace option). The heated or cooled air circulates from the fan to the supply ducts, and openings in the home called supply registers. Return registers and ductwork return the air to the fan to be heated.

Some heat pumps are packaged systems. These usually have both coils and the fan outdoors. Heated or cooled air is delivered to the interior from ductwork that protrudes through a wall or roof.

Another packaged system is the ductless room heat pump. These pumps will efficiently heat or cool a room or small house with an open floor plan. They are much more common for apartments and motel rooms than homes. They can be installed in a window or through a hole in the wall—wall installations being preferable for appearances sake. Through-the-wall

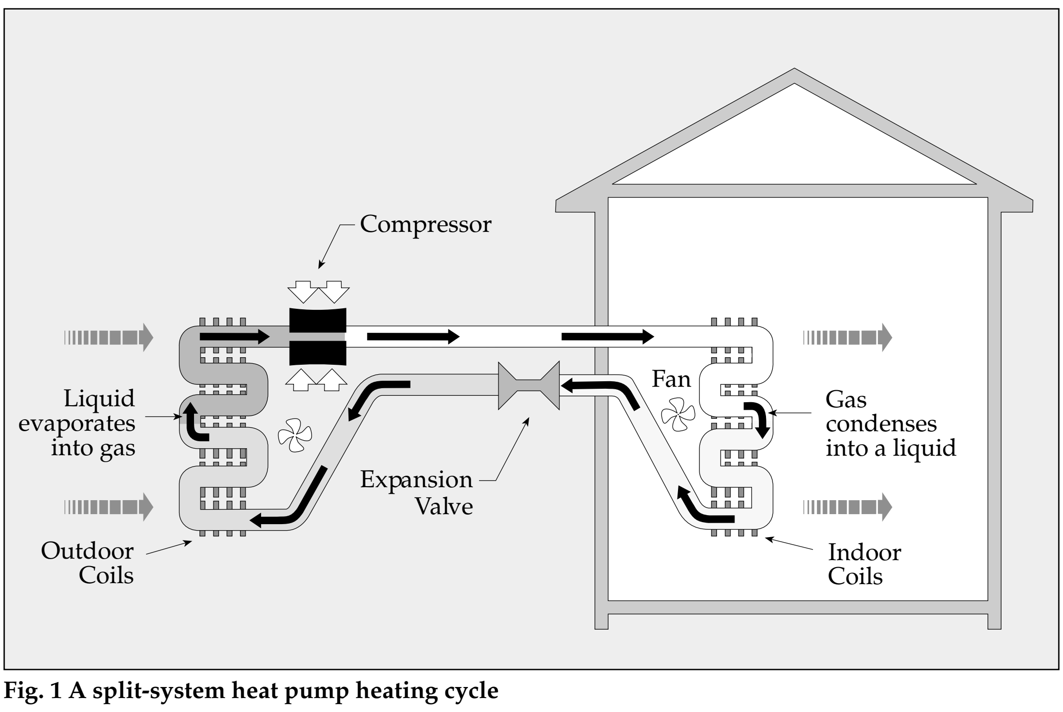

Fig. 1 A split-system heat pump heating cycle

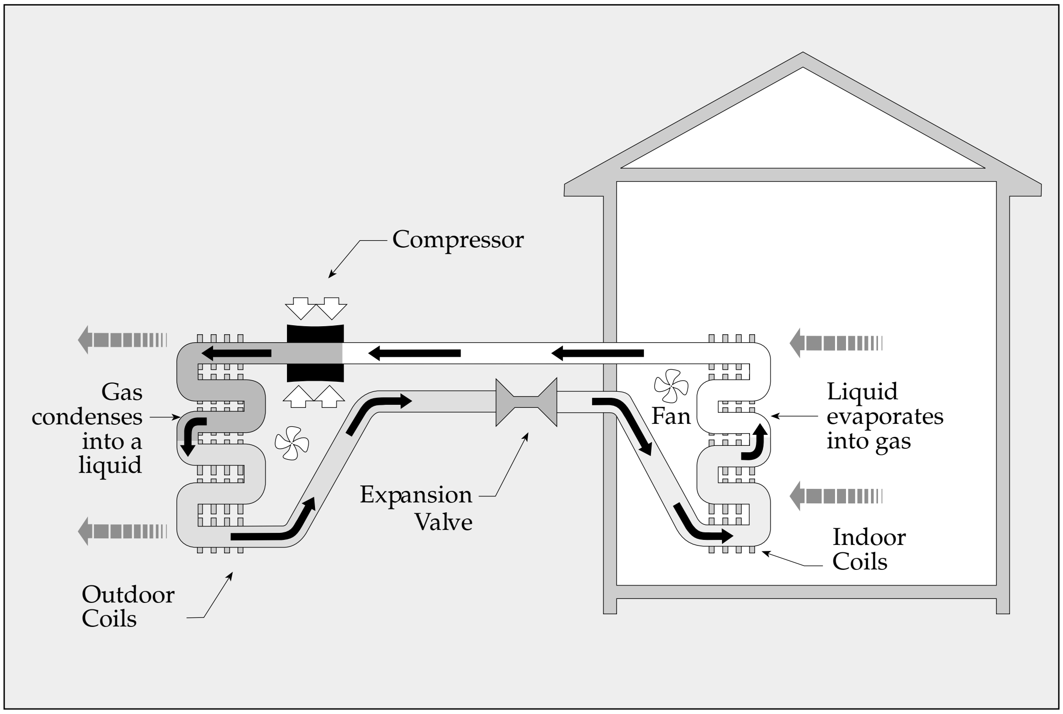

Fig. 2 A split-system heat pump cooling cycle

When selecting a new heat pump, it's important that you determine the proper size needed for your home.

installations, however, sometimes aren't well insulated from inside to outside and can have infiltration problems. When used, mini-split systems can solve these problems.

Selecting a Heat Pump

When selecting an air-source heat pump, consider the following three characteristics carefully: the energy efficiency rating, sizing, and the system's components.

Energy efficiency rating

In the United States, we rate a heat pump's energy efficiency by how many British thermal units (Btu) of heat it moves for each watt-hour of electrical energy it consumes. Every residential heat pump sold in this country has an EnergyGuide Label, which features the heat pump's heating and cooling efficiency performance rating, comparing it to other available makes and models.

The Heating Seasonal Performance Factor (HSPF) rates both the efficiency of the compressor and the electric-resistance elements. The HSPF gives the number of Btu harvested per watt-hour used. The most efficient heat pumps have an HSPF of between 8 and 10.

The Seasonal Energy Efficiency Ratio (SEER) rates a heat pump's cooling efficiency. In general, the higher the SEER, the higher the cost. However, the energy savings can return the higher initial investment several times during the heat pump's life. Replacing a 1970s vintage, central heat pump (SEER = 6) with a new unit (SEER=12) will use half the energy to provide the same amount of cooling, cutting air-conditioning costs in half. The most efficient heat pumps have SEERs of between 14 and 18.

You'll find the Energy Star® label—sponsored by the U.S Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA)—on heat pumps with an HSPF of at least 7 and a SEER of at least 12. Many new heat pumps exceed these ratings, but looking for this label is a good way to start shopping for one.

New Energy-Efficient Heat Pumps

The efficiency and performance of today's air-source heat pumps is one-and-a-half to two times greater than those available 30 years ago. This improvement in efficiency has resulted from technical advances and options such as:

- Thermostatic expansion valves for more precise control of the refrigerant flow to the indoor coil
- Variable speed blowers, which are more efficient and can compensate for some of the adverse effects of restricted ducts, dirty filters, and dirty coils
- Improved coil design
- Improved electric motor and two-speed compressor designs
- Copper tubing, grooved inside to increase surface area.

You and your contractor should discuss options that will help improve your home's comfort and the economy of your heat pump.

Sizing

When selecting a new heat pump, it's important that you determine the proper size needed for your home. Bigger is not better. Oversizing causes the heat pump to start and stop more frequently, which is less efficient and harder on the components than letting it run for longer cycles. A properly sized heat pump also will provide you with better comfort and humidity control than an oversized one.

The heating and cooling capacity of heat pumps is measured in Btu per hour. The cooling capacity is commonly expressed in "tons" of cooling capacity—each ton equaling 12,000 Btu per hour. Correct sizing procedures involve complex calculations, which are best performed by an experienced contractor, who uses sizing methods accepted by the heat pump industry. Don't employ a contractor who guesses the size of the heat pump needed. Rule-of-thumb sizing techniques are generally inaccurate, often resulting in higher than necessary purchase and annual energy costs.

System components

You and your contractor should discuss options that will help improve your home's comfort and the economy of your heat pump. Regarding ducts, for example, it's important to carefully consider their design and materials, as well as the proper amount of space they require. Check your home's blueprints to see if the architect and builder have planned adequate space for ducts and fans. Heating and cooling contractors complain that they often have to squeeze heating and cooling systems into spaces that are too small, resulting in constricted ducts and inadequate airflow.

Except for packaged systems, you'll also need to select the proper type of indoor coil for adequate summer moisture removal.

Installing a New Heat Pump

A heat pump's performance and energy efficiency not only depend on the selection and planning of the equipment but also on careful installation.

Consumers and home builders alike tend to accept the lowest bid for heating and air-conditioning work. This unfortunate choice can often leave a system lacking 10 to 30 percent in the materials and labor necessary to optimize heat-pump performance. Rather than just accepting the lowest bid, it's best to research the performance records of local contractors, and get involved in the planning and decision-making about your new heat pump system.

You can avoid most of the common comfort and performance problems from improper installation by following these guidelines:

- Make your home as energy-efficient as you can with proper insulation, energy-efficient windows, and an effective air barrier, etc. Then your contractor can install a smaller pump system with shorter duct lengths. In an energy-efficient home, it isn't necessary to run ducts all the way out to exterior walls to install registers near the exterior walls.
- Install the ducts inside your home's insulation and air barrier, if possible. Research shows that this strategy is a major energy saver.
- Insulate your ducts to R-8 if they must be located in an attic or crawl space beyond the home's air barrier and insulation.
- Locate the outdoor unit on the northside of your home if possible. If not, pick a shady spot. There should be no obstructions within 10 feet of the sides with openings and the top.
- Specify that the measured air leakage through your new ducts be less than 10 percent of your system's airflow. Air leakage of 5 percent or less is possible with careful workmanship.
- Tell your contractor that you want a return register in every room.
- Don't use building cavities as ducts. Building-cavity return ducts are notoriously leaky and often cause comfort, energy, and moisture problems.
- Pull on ductwork after installation to make sure it is fastened and sealed well. (Seal duct joints with mastic.)

Measurements of heat pump performance indicate that duct leakage waste 10 to 30 percent of the heating and/or cooling energy in a typical home.

Improving Performance

Poor installation, duct losses, and inadequate maintenance are more of a problem for heat pumps than for combustion furnaces. A growing body of evidence suggests that most heat pumps have significant installation or service problems that reduce performance and efficiency. According to a report on research funded by Energy Star, more than 50 percent of all heat pumps have significant problems with low airflow, leaky ducts, and incorrect refrigerant charge.

Increasing airflow in central heat pumps

The capacity and the efficiency of a heat pump depend upon adequate airflow. There should be about 400 to 500 cubic feet per minute (cfm) airflow for each ton of the heat pump's air-conditioning capacity. Efficiency and performance deteriorate if airflow is much less than 350 cfm per ton.

An ideal duct system has both a supply register and a return register for every room. Most homes, however, have only one or two return registers for the entire house. Air from other rooms must find its way back to these registers to be reheated or re-cooled. Obstructions in return air are a common air circulation problem, particularly from closed interior doors to rooms with no return-air register.

Blockage of supply or return air ducts and registers can pressurize or depressurize portions of the home, resulting in poor performance and increased air leakage through the building envelope. Restrictions to airflow have the greatest impact on the return-air side of the system, so repairs should start with the return ducts. Air from every supply register must have an unobstructed pathway back to a return register. You can install louvered grilles through walls or doors, ducts between rooms, and/or additional return ducts and registers to improve air circulation.

Technicians can increase the airflow by cleaning the evaporator coil, increasing fan speed, or enlarging the ducts—especially return ducts. Enlarging ducts may seem drastic but in some cases, might be the only remedy for poor comfort and high energy costs.

Air-sealing ducts

Measurements of heat pump performance indicate that duct leakage wastes 10 to 30 percent of the heating and/or cooling energy in a typical home. It's one of the most severe energy problems commonly found in homes because the leaking air is 20° to 70°F warmer than indoor air in winter and 15° to 30°F cooler in the summer.

Duct leakage may cause some minor comfort problems when ducts are located in conditioned areas. But when leaky ducts are located in an attic or crawl space, the energy loss is often large. Some of the worst duct leakage occurs at joints between the air handler, and the main supply and return air ducts.

Some main return ducts use plywood or fiberglass duct-board boxes. These boxes frequently leak because their joints are exposed to the duct system's highest air pressures. Heating and air-conditioning contractors often use wall, floor, and ceiling cavities as return ducts. These building-cavity return ducts are often accidentally connected to an attic, crawl space, or even the outdoors, creating serious air leakage. Fiberglass ducts and flex ducts are often installed improperly. These ducts may also deteriorate with age, leading to significant supply-duct leakage.

The best heating and cooling contractors have equipment to test for duct leakage. Testing helps locate duct leaks and indicates how much duct sealing is necessary. Do not use duct tape for sealing—its lifespan is very short, often less than 6 months.

Adjusting refrigerant charge

Room heat pumps and packaged heat pumps are charged with refrigerant at the factory. They are seldom incorrectly charged. Split-system heat pumps, on the other hand, are charged in the field, which can sometimes result in either too much or too little refrigerant.

Split-system heat pumps that have the correct refrigerant charge and airflow usually perform very close to manufacturer's listed SEER and HSPF. Too much or too little refrigerant, however, reduces heat-pump performance and efficiency.

The difference between the energy consumption of a well-maintained heat pump and a neglected one ranges from 10 to 25 percent.

For satisfactory performance and efficiency, a split-system heat pump should be within a few ounces of the correct charge, specified by the manufacturer. When the charge is correct, specific refrigerant temperatures and pressures listed by the manufacturer will match temperatures and pressures measured by your service technician. Verify these measurements with the technician.

If the manufacturer's temperatures and pressure's don't match the measured ones, refrigerant should be added or withdrawn, according to standards specified by the EPA. Refrigeration systems should be leak-checked at installation and during each service call.

Manufacturer's say that a technician must measure airflow prior to checking refrigerant charge because the refrigerant measurements aren't accurate unless airflow is correct.

Operating a heat pump

Like combustion heating systems, you control heat pumps using thermostats.

If you leave and return at regular times everyday, you'll save money by using automatic thermostats, which minimize energy use during the times the home is unoccupied. However, choosing an automatic thermostat's reactivation time requires considering the duration of heat-pump operation necessary to restore a comfortable temperature. During the heating season, some homeowners also set their thermostats back 10°F, manually or automatically, when they leave home or go to bed.

A two-stage thermostat controls the heating. The first stage activates the refrigeration system. If it's too cold outside for the refrigeration system to counteract the home's heat loss, then the thermostat's second stage activates the electric resistance coils. An outdoor thermostat will prevent the less efficient electric resistance heat from coming on until the outdoor temperature falls below 40°F. An outdoor thermostat also will prevent auxiliary heat from activating when an automatic thermostat is warming the house after a setback period. Use setback thermostats that are only for heat pumps.

A defrost control tells the reversing valve when to send hot refrigerant outdoors to thaw the outdoor coil during the winter. During the 2-to-10-minute defrost cycle, auxiliary heat takes over, reducing the heat pump's overall efficiency up to 10 percent. The two most common types of defrost controls are time-temperature and demand-defrost. Time-temperature defrost controls activate defrost at regular time intervals for set time periods, whether there is ice on the outdoor coil or not. A demand-defrost control senses coil temperature or airflow through the coil, and only activates defrost if it detects the presence of ice. Obviously, choosing a heat pump with demand-defrost will pay a significant efficiency dividend.

For greater efficiency, don't locate a thermostat near a heat source or cold draft because they can cause a heat pump to operate erratically. This includes shading thermostats from direct sunlight. Also, do not turn the thermostat beyond the desired temperature. It will not make the heat pump heat or cool your home any faster. It will only waste energy. Residents who duel one another over the thermostat settings, moving it up and down to suit their different comfort levels, cause heat pumps to operate erratically and inefficiently.

Maintaining and Servicing

Heat-pump performance will deteriorate without regular maintenance and service. The difference between the energy consumption of a well-maintained heat pump and a severely neglected one ranges from 10 to 25 percent.

Regular Maintenance

Either the homeowner or service technician can perform the following routine maintenance tasks:

- Clean or replace filters regularly (every 2 to 6 months, depending on operating time and amount of dust in the environment).
- Clean outdoor coils as often as necessary (when dirt is visible on the outside of the coil).
- Remove plant life and debris from around the outdoor unit.

- Clean evaporator coil and condensate pan every 2 to 4 years.
- Clean the blower's fan blades.
- Clean supply and return registers and straighten their fins.

Professional Service

You should have a professional technician service your heat pump at least every year. The technician can:

- Inspect ducts, filters, blower, and indoor coil for dirt and other obstructions.
- Diagnose and seal duct leakage.
- Verify adequate airflow by measurement.
- Verify correct refrigerant charge by measurement.
- Check for refrigerant leaks.
- Inspect electric terminals, and if necessary, clean and tighten connections, and apply nonconductive coating.
- Lubricate motors, and inspect belts for tightness and wear.
- Verify correct electric control, making sure that heating is locked out when the thermostat calls for cooling and vice versa.
- Verify correct thermostat operation.

Resources

The following are sources of additional information on heat pumps. This list is not exhaustive, nor does the mention of any resource constitute a recommendation or endorsement.

Ask an Energy Expert
DOE's Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
1-800-DOE-EREC (363-3732)
E-mail: doe.erec@nciinc.com
Online submittal form:
www.eren.doe.gov/menus/energyex.html
Consumer Energy Information Web site:
www.eren.doe.gov/consumerinfo/

Energy experts at EREC provide free general and technical information to the public on many topics and technologies pertaining to energy efficiency and renewable energy.

DOE's Energy Efficiency and Renewable Energy Network (EREN)
Web site: www.eren.doe.gov

Your comprehensive online resource for DOE's energy efficiency and renewable energy information.

Organizations

Air Conditioning Contractors of America (ACCA)
2800 Shirlington Rd., Suite 300
Arlington, VA 22206
Phone: (703) 575-4477
Fax: (703) 575-4449
E-mail: info@ms.acca.org
Web site: www.acca.org/

A national, trade association of heating, ventilation, air-conditioning, and refrigeration contractors.

Air-Conditioning and Refrigeration Institute (ARI)
4301 N. Fairfax Drive, Suite 425
Arlington, VA 22203
Phone: (703) 524-8800
Fax: (703) 528-3816
E-mail: ari@ari.org
Web site: www.ari.org/

A national trade association representing manufacturers of U.S. produced central air-conditioning and commercial refrigeration equipment.

Consortium for Energy Efficiency (CEE)
One State Street, Suite 1400
Boston, MA 02109-3507
Phone: (617) 589-3949
Fax: (617) 589-3948
Web site: www.ceeformt.org/

A national, nonprofit, benefits corporation that promotes the manufacture and purchase of energy-efficient products and services.

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Eastern Heating & Cooling Council (EH-CC)
20,000 Horizon Way, Suite 260
Mt. Laurel, NJ 08054
E-mail: info@eh-cc.org
Web site: www.eh-cc.org/

Educates consumers and contractors on properly designed and installed high-efficiency heating and cooling systems.

Energy Star®
DOE and EPA
Phone: (888) STAR-YES (782-7937)
E-mail: info@energystar.gov/
Web site: www.energystar.gov/

Provides lists of energy-efficient, Energy Star®-qualified products, including heat pumps.

Home Energy Magazine
2124 Kittredge Street, #95
Berkeley, CA 94704
Phone: (510) 524-5405
E-mail: contact@homeenergy.org,
Web site: www.homeenergy.org/

A source of information on reducing energy consumption in the home.

Web Sites

Heat Pumps
The Energy Outlet
Web site: www.energyoutlet.com/res/heatpump/

Heat Pumps for Heating and Cooling
DOE Office of Building Technology, State and Community Programs
Web site: www.eren.doe.gov/buildings/ee_heatpump.html

International Energy Agency Heat Pump Centre
Web site: www.heatpumpcentre.org/

Top-Rated Energy-Efficient Appliances
American Council for an Energy-Efficient Economy
Web site: www.aceee.org/consumerguide/2000enef.htm

Why Buy Energy-Efficient Appliances?
DOE Office of Codes and Standards
Web site: www.eren.doe.gov/buildings/consumer_information/

Further Reading

Consumer Guide to Home Energy Savings, Wilson A., Thorne J., Morrill J, American Council for an Energy-Efficient Economy (ACE^3), Washington, DC. Available from ACE^3 at (202)429-8873, ac3pubs@ix.netcom.com, or online at www.aceee.org.

Energy Savers: Tips on Saving Energy and Money at Home, DOE. Available from EREC (see Ask an Energy Expert above) or online in PDF and HTML at www.eren.doe.gov/consumerinfo/energy_savers/.

Geothermal Heat Pumps Make Sense for Homeowners, DOE Office of Geothermal Technologies, 1998. Available from EREC (see Ask an Energy Expert above) or online in PDF at www.eren.doe.gov/geothermal/pdf/26161b.pdf or in HTML at www.eren.doe.gov/erec/factsheets/ghp_homeowners.html.

Residential Energy: Cost Savings and Comfort for Existing Buildings , Krigger J., Saturn Resource Management, Helena, MT 2000. Available from Saturn at (406) 443-3433.