

that of the heat-power thermodynamic cycle governing the conversion between heat energy and mechanical work. It is derived from the Second Law of Thermodynamics (see Chapter 67, Terminology). The operating efficiency, or coefficient of performance (CP), of an elementary perfect refrigeration system for cooling and heating effects is given by Equations 1 and 2 respectively:

$$(CP) = \frac{T_c}{T_c - T_h} \quad (1)$$

where

T_c = evaporator temperature, Fahrenheit, absolute.
 T_h = condenser temperature, Fahrenheit, absolute.

With the ideal Carnot cycle operating as a heat pump, the coefficient of performance is

$$(CP) = \frac{T_h}{T_h - T_c} \quad (2)$$

In actual systems, the coefficients of performance are much lower and are defined in the following terms:

The *heating coefficient of performance*, $(CP)_h$, of an installed heat pump may be defined as the ratio of the total instantaneous useful heating effect produced by the heat-pump system at stated conditions, to the heat equivalent of the total energy input rate required to drive or operate the system. If total energy input of all auxiliaries such as fans and pumps is not included, it should be so stated.

The *cooling coefficient of performance*, $(CP)_c$, of an installed heat pump may be defined as the ratio of the instantaneous useful refrigeration effect produced by the heat-pump system at stated conditions, to the heat equivalent of the total energy input rate required to drive or operate the system.

The term *performance factor*, (PF), is similar to coefficient of performance, but is used when referring to values based on an extended period of time, such as a day, month, or season. The period of time covered should be given when using this term. If supplemental heat is involved, its effect should also be specified.

Heat Pump Types

Heat pumps for air-conditioning service may be classified according to (a) type of heat source and sink, (b) heating and cooling distribution fluid, (c) type of thermodynamic cycle, (d) type of building structure, and (e) size and configuration. The more common types are shown in Table 1.

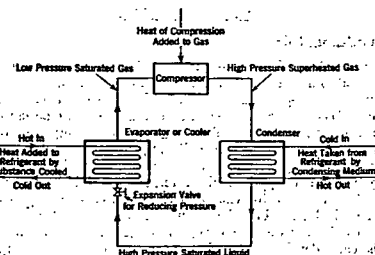


Fig. 1 ... Mechanical Refrigeration System

The air-to-air heat pump is the most common type. It is particularly suitable for factory-built unitary heat pumps, and has been widely used for residential and commercial applications. The first diagram in Table 1 is typical of the refrigeration circuit employed. In smaller unitary heat pumps, it is common to replace the expansion and check valves with a capillary tube for refrigerant control. A few installations have been made in which the forced-convection indoor heat transfer surface has been replaced by a radiant panel.

In air-to-air heat-pump systems, as shown in the second diagram of Table 1, the air circuits may be interchanged by means of dampers (motor-driven or manually operated), to obtain either heated or cooled air for the conditioned space. With this system one heat-exchanger coil is always the evaporator and the other is always the condenser. The conditioned air will pass over the evaporator during the cooling cycle and the outdoor air will pass over the condenser. The change from cooling to heating is accomplished, by positioning the dampers.

A water-to-air heat pump uses water as a heat source and sink, and uses air to transmit heat to or from the conditioned space.

Air-to-water heat pumps are commonly used in large buildings where zone control is necessary, and are also sometimes employed for the production of hot or cold water in industrial applications.

Earth-to-air heat pumps may employ direct expansion of the refrigerant in an embedded coil, as illustrated in Table 1, or they may be of the indirect type, described under the water-to-air type.

A water-to-water heat pump uses water as the heat source and sink for both cooling and heating operation. Heating-cooling changeover may be accomplished in the refrigerant circuit, but, in many cases, it is more convenient to perform the switching in the water circuits as illustrated in Table 1.

An earth-to-water heat pump (not shown in Table 1) may be like the earth-to-air type shown, except for the substitution of a refrigerant-water heat exchanger for the finned coil shown on the indoor side. It may also take a form similar to the water-to-water system shown, when a secondary-fluid ground coil is used.

Some heat pumps which use earth as the heat source and sink are essentially of the water-to-air type. An antifreeze solution is pumped through a circuit consisting of the chiller-condenser and a pipe coil embedded in the earth.

Other types of heat pumps in addition to those listed in Table 1 are possible. An example is one which utilizes solar energy as a source of heat; its refrigerant circuit may resemble the water-to-air, air-to-air, or other types, depending on the form of solar collector and the means of heating and cooling distribution employed.

Another variation is the use of more than one heat source. Some heat pumps have utilized air as the primary heat source, but are changed over to extract heat from water (e.g., from a well or storage tank) during periods of peak load. The use of solar energy requires another heat source during periods of insufficient solar radiation.

Other Refrigeration Cycles

Any thermodynamic cycle that is capable of producing a cooling effect may theoretically be used as a heat pump. Other than the ordinary vapor-compression cycle, possible cycles include: (a) the heat-operated absorption cycle, (b) the ejector cycle, (c) gas cycles, both open and closed, and (d) the thermoelectric cycle.

It is not currently practicable to use any of these cycles as heat pumps, due to limitations in efficiency, cost, or size.

Heat Pumps

HEAT SOURCES AND SINKS

Table 2 shows the principal media being used with heat pumps as a heat source for heating and as a heat sink for cooling. The most practical choice for a particular application will be influenced primarily by geographic location, climatic conditions, initial cost, availability, and type of structure. Various factors to be considered for each source are given in Table 2. A more detailed discussion of design and selection factors for each source and sink follows.

Table 1 ... Common Heat Pump Types

HEAT SOURCE AND SINK	DISTR. FLUID	THERMAL CYCLE	DIAGRAM
AIR	AIR	REFRIGERANT CHANGEOVER	OUTDOOR COOLING INDOOR HEATING
AIR	AIR	REFRIGERANT CHANGEOVER	INDOOR COOLING OUTDOOR HEATING
WATER	AIR	REFRIGERANT CHANGEOVER	CHILLER-CONDENSER COMP. LIQ. REC. INDOOR COOLING OUTDOOR HEATING
EARTH	AIR	REFRIGERANT CHANGEOVER	INDOOR COOLING OUTDOOR HEATING
WATER	WATER	WATER CHANGEOVER	WATER SOURCE RETURN SUPPLY DISCHARGE INDOOR COOLING