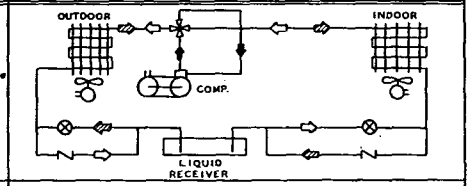
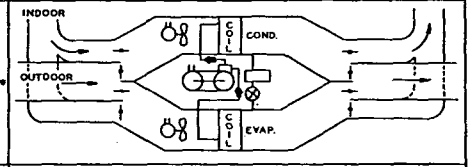
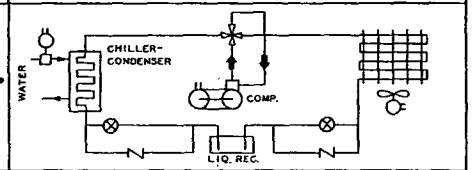
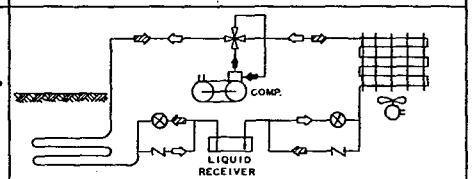
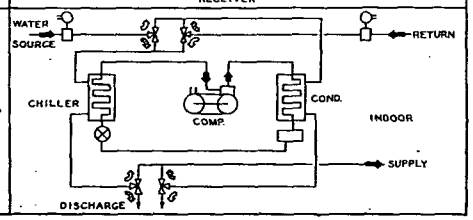
Table 1 .... Common Heat Pump Types

HEAT SOURCE AND SINK	DISTR. FLUID	THERMAL CYCLE	DIAGRAM (▨ HEATING ⇨ COOLING ➡ HEATING AND COOLING)
AIR	AIR	REFRIGERANT* CHANGEOVER	
AIR	AIR	AIR CHANGEOVER*	
WATER	AIR	REFRIGERANT* CHANGEOVER	
AIR	WATER		
EARTH	AIR	REFRIGERANT* CHANGEOVER	
WATER	WATER	WATER CHANGEOVER*	

* ALL SINGLE STAGE COMPRESSION

temperature heat may be required. The heat-pump cycle, in many instances, can be effective in the utilization of waste heat.[28]

In a number of processes, low-temperature heating and moderate refrigeration are required simultaneously. The concentration of fruit juices may be accomplished by a heat-pump system.

Fig. 1 illustrates the application of the heat-pump principle for drying. A large portion of the heat given off from the condenser while heating the stream of dry air is recovered by the evaporator from both the sensible and latent heat of the moisture-laden air downstream from the material being dried. This type of heat pump is expected to find particular application in the drying of tobacco and other agricultural products.

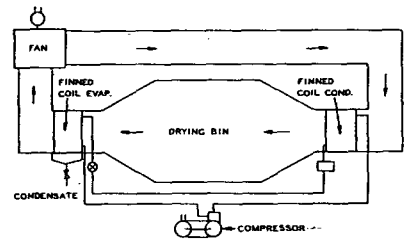


Fig. 1 .... Application of Heat Pump to Drying

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[18] and (d) the thermoelectric cycle.[17]

None of these cycles as heat pumps is currently practicable due to limitations in efficiency, cost or size.

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.

Air

Outdoor air offers a universal heat-source, heat-sink medium for the heat pump. Extended-surface, forced-convection heat-transfer coils are normally employed to transfer the heat between the air and the refrigerant. Typically these surfaces are 50 to 100 percent larger than the corresponding surface on the indoor side of heat pumps using air as the distributive medium. The volume of outdoor air handled is also usually greater in about the same proportions. The temperature difference during heating operation between the outdoor air and the evaporating refrigerant generally is in the range of from 10 to 25 F deg.

The performance of heating and cooling coils for air is given in more detail in Chapter 23.

When selecting or designing an air-source heat pump, two factors particularly must be taken into consideration; (1) the variation in temperature experienced in a given locality and (2) the formation of frost.

As the outdoor temperature goes downward, the heating capacity of an air-source heat pump decreases. Selecting the equipment for a given outdoor heating design temperature, therefore, is more critical than for a fuel-fired system. Consequently, care must be exercised to size the equipment for as low a balance point as is practically possible for heating without having excessive and unnecessary cooling capacity during the summer periods.

The procedure for finding this balance point, which is defined as the outdoor temperature at which the capacity matches the heating requirements, and for obtaining the most economical equipment selection, is given later in this chapter.

When the surface temperature of an outdoor air coil is 32 F or lower, frost may form and if allowed to continue, will interfere with heat transfer. Research has shown that with a nominal amount of frost deposit (typically about 2 to 3 lb per sq ft of coil face area) the heat transfer capacity of the coil is not substantially affected.[28] The number of defrosting operations will be influenced by the climate, the air-coil design and hours of operation. Experience has shown that little defrosting is generally required below 20 F and below 60 percent relative humidity.[29] This may be confirmed by psychrometric analysis using the principles given in Chapter 23. However, it should be noted that under very humid conditions when small suspended water droplets may be present in the air, the rate of frost deposit may be about three times as great as would be predicted from psychrometric theory. Under such conditions, a heat pump may require defrosting after as little as 20 minutes of operation. In applying an air-source heat pump, the effect of this condition on loss of available heating capacity should be taken into account.

Early application of air-source heat pumps followed commercial refrigeration practice involving relatively wide fin spacing; (i.e., 4 to 5 fins per inch) on the theory that this would permit faster defrosting. However, experience has proved that with effective hot gas defrosting much closer fin spacing can be tolerated and obtains the advantage of a reduction in the size and bulk of the system. In current practice a fin spacing of 8 to 10 per inch is widely used and some of the newer units have outdoor coils with as many as 13 fins per inch.

Water

Water may represent a satisfactory, and in many cases an ideal, heat source subject to the considerations listed in Table 2. Well water in particular is attractive from the standpoint of its relatively high and nearly constant temperature, generally being about 50 F in northern areas and 60 F and higher in the south. Information on well water availability, temperature, and chemical and physical analysis is generally available from U. S. Geological Survey offices located in many major cities.

Surface or stream water may be utilized, but under winter conditions of reduced temperature, the cooling spread between inlet and outlet must be limited to prevent freeze-up in the water chiller which is absorbing the heat. Some large