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 is generally in the range of from 10 to 25 deg.

The performance of heating and cooling coils for air is given in more detail in Chapters 34 and 35.

When selecting or designing an air-source heat pump, two factors in particular 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 down, the heating capacity of an air-source heat pump decreases. Selecting the equipment for a given outdoor heating design temperature, is therefore 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, 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.[11] The number of defrosting operations will be influenced by the climate, the air-coil design and the hours of operation. Experience has shown that little defrosting is generally required below 20 F and below 60 percent relative humidity.[12] This may be confirmed by psychrometric analysis using the principles given in Chapter 34. 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 will obtain 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; some of the newer units have outdoor coils with as many as 14 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 is particularly attractive because of its relatively high and nearly constant temperature, generally 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 reduced winter temperatures, 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 heat-pump systems have been in operation in Europe in areas where winter stream temperatures of about 35 F have permitted inlet-outlet temperature spreads of only 1 or 2 deg.

Under certain industrial circumstances, waste process water, such as spent warm water in laundries and warm condenser water, may be a source for specialized heat-pump operations.

Utilization of water during cooling operation generally follows conventional practice with water-cooled condensers.

Water-refrigerant heat exchangers generally take the form of direct-expansion water coolers, either of the shell-and-coil type or of the shell-and-tube type. They are circuited to permit use as a refrigerant condenser during the heating cycle and as a refrigerant evaporator during the cooling cycle.

Earth

Earth as a heat source and sink, by heat transfer through buried coils, has not been extensively used. This may be attributed to high installation expense, ground area requirements, and the difficulty and uncertainty of predicting performance.

Compositions of soil vary widely from wet clay to sandy soil, and have a predominant effect on thermal properties and attendant overall performance. The heat-transfer process in the soil is primarily one of bulk temperature change with time (e.g., transient heat flow). *Thermal diffusivity* α the ratio of thermal conductivity to the product of unit density and specific heat, $\alpha = k/\rho c$, is a dominant factor and is difficult to determine at different building sites. The moisture content likewise has an influence, since energy in the ground may also be transported via moisture travel in the soil.

In general, earth coils, usually arranged to be spaced horizontally at from 3 to 6 ft, are submerged from 3 to 6 ft below the surface. Though a lower depth might be preferred, excavation cost requires a compromise. Mean undisturbed ground temperatures generally follow the mean annual climatic temperature for any place.

Many individual studies involving theoretical as well as practical considerations have been conducted to determine earth heat transfer with respect to heat-pump possibilities. (References 13 through 25).

Solar

Although still largely in the research stage, the use of solar energy as a heat source, either on a primary basis or in combination with other sources, is attracting increasing interest.

The principal advantage of employing solar radiation as a heat-pump heat source is that, when available, it provides heat at a higher temperature level than other sources, thus resulting in an increase in coefficient of performance.[13] As compared to a solar heating system without a heat pump, the collector efficiency and capacity are materially increased due to the lower collector temperature required.

Research and development in the solar-source heat-pump field has been concerned with two basic types of systems, direct and indirect. In the direct system, refrigerant evaporator tubes are embodied in a solar collector, usually of the flat-plate type. Research has shown that when the collector has no glass cover plates the same collector surface can also

Table 2. Heat Pump Heat Sources and Sinks

Heat Source	Air	City Water	Well Water	Surface Water	Waste Water	Earth	Solar
Source classification	Primary	Primary or auxiliary	Primary	Primary	Primary or auxiliary	Primary or auxiliary	Auxiliary
Suitability as heat sink	Good	Good	Good	Good	Variable source	Usually poor	May be used to dissipate heat to air
Availability (location)	Universal	Cities	Uncertain	Rare	Limited	Extensive	Universal
Availability (time)	Continuous	Continuous—except local shortages	Continuous—unless well runs dry	Continuous	Variable	Continuous, temperature drops as heat is removed, slowly rises when pump stops	Intermittent, unpredictable, except over extended time
Expense (original)	Low, less than earth and water sources except city	Usually lowest	Variable, depending on cost of drilling a well	Low	Variable	High	High
Expense (operating)	Relatively low	High, usually prohibitive	Low to moderate	Relatively low	Low	Relatively moderate	Unexplored. Promising as auxiliary for reducing operating cost
Temperature (level)	Favorable 75-85% of time in most of United States	Usually satisfactory	Satisfactory	Satisfactory	Usually good	Initially good—drops with time and rate of heat withdrawal	Excellent
Temperature (variation)	Extreme	Variable with location (10 to 28 F deg)	Small	Moderate	Usually moderate	Large—less than for air, however	Extreme
Design information	Usually adequate	Usually adequate	Usually adequate	Usually adequate	Adequate if source is constant in supply and temperature	Inadequate	Practically available
Size of equipment	Large	Moderate	Moderate (except for well)	Moderate	Variable (usually moderate)	Moderate (except ground coils)	Particularly large
Adaptability to make production	Excellent, can be factory assembled and tested	Excellent	Excellent (except for well)	Excellent	Poor	Fair	Fair
Sources it may augment	Least heat available when demand greatest. Coil frosting requires extra capacity, alternate source, or standby heat. May require ductwork. Variable air temperature makes control difficult.	Scale on coils. Local use restrictions during shortages. Disposal. Water temperature may become too low to permit further heat removal.	Corrosion; scale may form on heat transfer surface. Disposal may require second well. Water location, temperature, composition usually unknown until well drilled. Well may run dry.	Water may cause scale, corrosion, and algae fouling	Usually scale forming or corrosive. Often insufficient supply. Very limited application, hence required individual design.	Limited by local geology and climate. Installation costs difficult to estimate. Requires considerable ground area, may damage lawns, gardens.	Probably will require heat storage equipment at either evaporator or condenser side.
Special problems							