back pressures, causing liquid floodback to the compressor. In some cases suction line accumulators or charge-control devices are employed to minimize this effect.

A *refrigerant receiver* is commonly used, as in other types of refrigeration systems, to provide a storage place for liquid refrigerant. It is particularly useful in a heat pump in order to take care of the unequal refrigerant requirements between heating and cooling.

Control Components

Heat pump control systems and components are of the same general type used in other types of heating and cooling equipment. Reference should be made to Chapter 43.

Practically all heat pumps for residential heating and cooling are controlled automatically from the temperature of the conditioned space. *Room air thermostats* are usually of the type that combine the control of both the heating and cooling function, the selection of function either being accomplished automatically in response to air temperature or manually by a selector switch. When supplementary heaters are employed, usually electric resistance heaters, it is common to control them with the second stage of a two-stage heating control. This restricts their usage to makeup of the difference between the heating requirement and the heat-pump capacity (see Fig. 6). To avoid unnecessary usage and excessive electrical demand, particularly when the thermostat setting is raised suddenly, it is customary to use one or more outdoor thermostats to limit the amount of resistance heat used at the higher outdoor temperatures.

In residential heat pump applications, night-set-back, common with fuel-fired systems, is not ordinarily employed because substantial excess capacity is required for warm-up and because possible operating cost savings, if any, are deemed to be small.

On the larger type systems, a proportional action type of control is sometimes used for controlling compressor and supplementary stages in steps.

A variety of *defrosting control* schemes have been used to sense the need for defrosting air-source heat pumps and to initiate and terminate the defrost cycle.

A timer is sometimes used and set to cause defrosting at predetermined intervals for instance, about every two hours. After initiation of the defrost cycle defrosting can be terminated either by the use of a control sensing the coil pressure or a thermostat located so as to measure the temperature of the liquid refrigerant in the outdoor coil. When the temperature (or corresponding saturation pressure) of the liquid leaving the outdoor coil rises to about 40 F the completion of defrosting is assured. Termination of defrosting may also be obtained by a second time interval control.

Another method of starting the defrost cycle is to use a pressure control which reacts to the air pressure drop across the coil. Under conditions of frost accumulation the air flow will be reduced and the increased pressure drop across the coil will initiate the defrost cycle. Again the preferred method of terminating the defrost cycle is to use a refrigerant temperature control measuring the temperature of the liquid refrigerant in the coil.

A third method for defrosting involves a temperature differential control in which two temperature sensing elements are used; one responsive to the outdoor-air temperature and the other responsive to the temperature of the refrigerant in the coil. As frost accumulates, the differential between outdoor temperature and refrigerant temperature will increase, causing a defrost cycle to be initiated. The system will be restored to operation when the refrigerant temperature in the coil reaches a specified temperature indicating that defrosting has been completed. When the outdoor-air temperature decreases, the differential between outdoor-air temperature and refrigerant temperature decreases, causing the defrost cycle to be initiated sooner, unless compensation is provided.

Other Components

Supplementary *resistance heaters*, commonly used with many unitary type heat pumps may be incorporated either within the unit or external to it. They may take any of the forms discussed in Chapter 17. When installed in the distribution ductwork, they are frequently controlled to temper the air during defrosting operation on units employing *reverse-cycle* defrost.

APPLICATION

Criteria for Feasibility

Factors to be considered in determining the practicability of employing a heat pump include the following:

1. Presence of a cooling load.
2. Relative amounts of heating and cooling.
3. Availability of suitable heat source and sink.
4. Equipment requirements and installed cost.
5. Operating cost.

These criteria may be applied whether the equipment to be considered is of the factory-built, unitary type or the field-assembled type. In fact, an analysis of these factors, in addition to determining feasibility of the heat pump for a particular application, should also be useful for choosing the equipment type.

Unless there is a need for cooling, heating with a heat pump is ordinarily not economically feasible. Under certain circumstances this may not be true, but usually a heat-pump system will have a higher first cost than a fuel-fired heating system.

With the almost universal need for comfort cooling, particularly in commercial establishments, but also to an increasing extent in residences, the feasibility of a heat pump becomes more favorable. Only a portion of the required equipment will then have to compete with a separate heating system. In fact, in large buildings, the existence of simultaneous heating and cooling loads in different zones for a large portion of the time is often uniquely suited to a heat-pump system.

The relative amounts of heating and cooling required may greatly influence the first cost and the suitability of a heat pump. In the usual case the size of the heating load is the predominating factor, particularly with structures in colder climates having low internal heat gain. The application of insulation and adequate sealing against unwanted air infiltration reduces the ratio of the heating to cooling loads.

The availability of a suitable heat source and sink generally involves making the optimum selection from the standpoint of overall economics. Factors to be considered were presented earlier in this chapter in the section Heat Sources and Sinks.

The heat source selected will usually also serve as a heat sink. It should be recognized that in applications requiring heating and cooling in different zones simultaneously, the heat source or sink need only handle the net heat input or output of the system.

To *estimate the equipment requirements and installed cost* it is necessary to make at least a tentative equipment selection. Before this can be done it will, first be necessary to determine the heating and cooling loads. For small structures this generally entails only the calculation of the peak heating and cooling loads. For larger buildings, a more detailed analysis may be required in order to take into account the loads at other than the design conditions, the time periods at which loads occur, ventilation schedule, variations in loads due to internal heat gains from lights, equipment and occupancy, and simultaneous heating and cooling loads in different zones.

It is implicit in a feasibility study of this kind that the objective is to obtain a comparison between the cost of a heat-pump system and a combination air-conditioning and fuel-fired heating system. Therefore, in order to estimate the first cost of both systems, a preliminary design and selection of each must be made.

It does not necessarily follow that the system with the lowest first cost is the optimum choice. An excess of initial cost for any system may be justified by savings in operating cost or by other benefits derived.

The principal factors to be taken into account in estimating *operating cost* are given in the section Performance Characteristics. The application or feasibility study of a heat-pump system with regard to operating cost involves the comparison between it and alternative types of systems considered. Operating cost of fuel-fired systems may be estimated by the procedures given in Chapter 37.

Heating and Cooling Distribution

The distribution of the heating and cooling effect from a heat-pump system is an important application consideration, particularly because of the relatively low temperatures involved as compared to fuel-fired heating systems.

In a commercial-type structure, any system of distribution which is satisfactory for cooling will generally be satisfactory for heating with a heat pump. Conversely, any system satisfactory for heat distribution with a heat pump will be satisfactory for cooling, except, however, that panel systems will seldom have sufficient capacity to handle normal cooling loads satisfactorily.

Heat distribution in the space can be accomplished by forced air at high, medium, or low pressures; primary air with induction units; individual fan and coil units; a split system composed of forced air and panels; or panels alone. All these methods of heating, except panels alone, are as applicable to cooling as to heating.

The distribution from the heat pump to space units can be by use of water or air. Quantities circulated, pipe or duct sizes, transfer units, and other characteristics of the distribution system will resemble very closely standard practice for cooling systems.

Heating and cooling distribution in residential heat-pump systems generally follows the same principles as for summer cooling. Refer to Chapter 46. It has been found with residential air distribution systems, comfort may be achieved with the air volumes and temperatures encountered with heat pumps when proper attention is given to the number and location of air outlets.[a]

Design and Selection

Irrespective of the size and type of building and whether unitary or field-erected equipment is being considered, the first steps that should be performed are those described under Criteria for Feasibility. In applying unitary heat pumps, the manufacturers of these units ordinarily provide sufficient data and instructions for proper application. The typical procedure followed for both unitary and field-erected heat pumps is outlined below:

1. Determine heating and cooling loads. It is desirable also to determine the amount that loads may be reduced by additional insulation, sealing, and shading. Savings effected in equipment due to distribution and to operating costs may more than offset the added cost involved. In larger buildings, loads should be determined for the different conditions of operation including simultaneous heating and cooling.
2. Establish heat source and sink. See previous section on this subject.
3. Determine type of distribution system.
4. Choose major components: compressors, heat exchangers, and air handlers. For unitary equipment, establish equipment size, type, and make.
5. Establish design of refrigeration system.
6. Choose auxiliary equipment: fans, pumps, valves, etc.
7. Determine equipment location. Since the heat pump operates without fuel and combustion products, considerable flexibility is permitted in its location. A single-package unit, may be located in a basement, crawl space, attic, roof, garage, or carport, in the conditioned space, or out-of-doors. For remote-type, or split units, one section is generally located outdoors and the other in a convenient indoor location. Considerable flexibility in locating equipment of a field-erected heat pump in one or more areas is possible.

   Factors to be considered in equipment location are: (*a*) Accessibility to heat source and sink, (*b*) Convenient location with respect to indoor distribution system, usually duct work, (*c*) Availability of condensate drain, (*d*) Required accessibility and sufficient space for servicing, (*e*) Convenience to electric power wiring, (*f*) Suitability of structure for supporting weight of equipment, (*g*) Effect of noise and vibration transmission, and (*h*) Appearance.
8. Determine control system and components.
9. Estimate first cost and operating cost.

Illustrative Systems for Larger Buildings

Fig. 9 shows a system employing well water as a heat source and sink. In this particular case a heat exchanger is used between the well water circuit and the fluid circuit to transmit heat to the heat pump, heat exchangers, and the indoor conditioning coils. Although this requires an extra step of heat exchange, it avoids the necessity for pumping well water throughout the building and permits a high rate of flow in the building water circuit with resulting improvement in heat transfer. The use of a water preconditioning coil as shown to preheat, or precool, ventilation air often reduces the size of refrigeration capacity required as well as the cost of operation. It should be noted that both heated and cooled water can be furnished simultaneously to indoor-air-handling or remote-room units as may be required by the existence of heating and cooling loads in different zones at the same time.

For the system shown in Fig. 9, both the heating and cooling pumps are in operation regardless of whether the predominant demand is for heating or cooling.

If the predominant requirement is for heating, return water from the heating units is circulated through valve V-4 to the refrigerant condenser, where it picks up heat from the refrigerant, and then to the heating units. At the same time cooling water is circulated from the well water heat exchanger through the ventilating coil and valve V-2 to the chiller. Depending on the simultaneous cooling requirement, the chilled water either enters the cooling supply line or is returned directly to the heat exchanger. The proportion of the chilled water returned