approximately equal. Above this temperature, the single stage is more efficient, but below this point the two-stage usually delivers more heat per kilowatt input. Whether these improvements in efficiency will outweigh the disadvantages of the higher initial cost of staging will depend upon the requirements of a particular installation.

Further information on multi-stage systems will be found in Chapter 1 of the 1961 Guide And Data Book and Chapter 73 of this volume.

Centrifugal compressors for larger capacity applications are primarily used on water-source heat pumps, but are finding some applications on air-source systems, particularly those employing the reclaiming cycle (Fig. 4). They are readily applicable to this type of application, since the suction temperatures can usually be relatively constant at approximately 37–39 F with a condensing temperature generally below 130 F. Multistaging of the centrifugal machines, similar to that described for the reciprocating units, must be employed when low temperature outdoor air is used as the heat source. Centrifugal assemblies invariably employ water as the heat transfer fluid on both the high- and low-sides of the refrigerating machine. When the chiller is exposed to temperatures below 30 F, an antifreeze liquid or brine such as trichloroethylene with a suitable viscosity, corrosiveness and first cost is required.

Compressor Floodback Protection

On the more recent air source-sink, central plant type of installations, a suction line separator, similar to that shown in Fig. 6, has been used successfully. This separator, in combination with a liquid-gas heat exchanger, is a protection against migration and harmful liquid floodbacks to the compressor. The solenoid valve should be wired to open when the compressor is operating and the hand valve adjusted to provide an acceptable bleed rate into the suction line. Similarly, a separator is generally used on the compressor discharge to permit return of the oil directly to the compressor crankcase.

Liquid Subcooling Coils

Generally a refrigerant subcooling coil can be added to the heat pump cycle, as illustrated by Fig. 7, in order to preheat the ventilation air during the heating cycle and, at the same time, lower the temperature of the liquid refrigerant. Depending upon the refrigerant circulation rate and the quantity and temperature of ventilation air, the heating capacity can be increased as much as 15 to 20 percent, as indicated by Fig. 8.

Similarly, a well water coil can be incorporated in the water-to-water systems (Fig. 1) to either preheat or precool

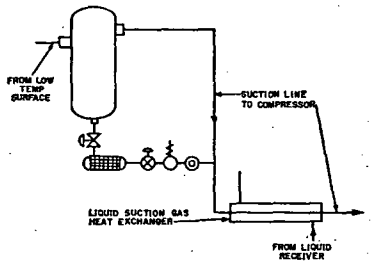
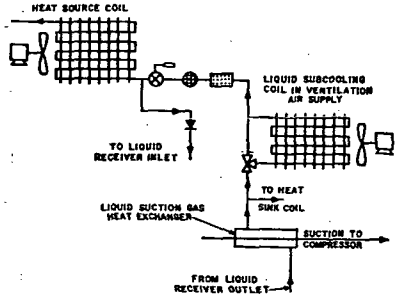


Fig. 6 .... Suction Line Separator for Protection Against Liquid



* To increase heating effect and improve coefficient of performance on heating cycle.

Fig. 7 .... Liquid Subcooling Coil in Ventilation Air Supply*

the ventilation air, depending on the operating cycle, and thereby improve the performance factor. Means must be provided to prevent freezing of the water within the coil when exposed to ventilation air temperatures below 32 F.

Defrosting of Heat Source Coils

Frost will begin to accumulate rather heavily on outdoor heat source coils when the temperature reaches approximately 40 F, but will lessen somewhat with the simultaneous decrease in outdoor temperature and moisture content.

Automatic defrosting may be accomplished without causing discomfort to the occupants, by using hot gas particularly in the indirect systems, because of the relatively short defrosting cycle (usually less than 10 min) and the thermal storage of the conditioned space. Actually in most cycles the defrost cycle consists of changing the equipment to the cooling cycle in which case the outdoor coil becomes the condenser, and the indoor coil becomes the evaporator. In instances where discomfort may be experienced, due to the type of distribution, the supplemental heating can be used to offset the cooling effect.

The most common methods of controlling the frost accumulation on an outdoor heat-source surface are:

1. *Refrigerant-Air Temperature Differential.* Because the suction temperature decreases with frost accumulation, the increase in the differential between the entering outdoor air and the suction temperature, is an indication of the frost buildup. A temperature differential control is used to initiate the defrost cycle.

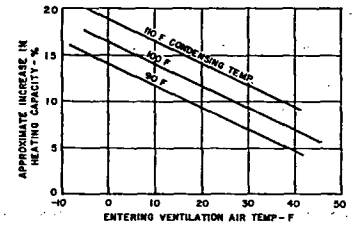


Fig. 8 .... Anticipated Increase in Heating Capacity Resulting from Use of Liquid Subcooling Coil (Fig. 7)

2. *Air Pressure Differential Across Coil.* The frost accumulation will also increase the air resistance across the heat absorbing surface. Therefore, by means of an air pressure differential switch, the defrost cycle can be initiated at a predetermined value.

3. *Time Control.* This method actuates the defrost cycle by means of a suitable timer at predetermined time periods, when the outdoor temperature is below 40 F. This cycle is based on the assumptions that the frost accumulation on the surface will generally be at a uniform rate and, consequently, can be satisfactorily defrosted at definite time intervals.

Draining of Heat Source and Sink Coils

The direct expansion type of indoor and outdoor heat transfer surfaces serve both as condensers and evaporators. Both surfaces, therefore, must have proper refrigerant distribution headers to serve as evaporators and have suitable refrigerant drainage while serving as condensers.

In the flooded type of system, the normal float control, to maintain the required refrigerant level, is generally used.

CONTROLS

The control system should be designed to provide flexible and effective heat pump operation. Capacity modulation, a convenient method of switching from heating to cooling, and automatic defrosting of the heat source surfaces should be provided.

Provisions should be made in the control system to prevent energising the supplemental electric heater until: (1) the heat pump system is unable to satisfy the heating requirement when operating at full capacity, and (2) the outdoor air is below a predetermined outdoor temperature. In this way the coincident electric kilowatt demand will be minimized with a resulting lower average power cost. In some installations, it may be necessary to energise the supplemental heat during the defrosting cycle in order to minimize any cooling effect within the structure, but this normally will not exceed the maximum coincident demand, during the heating cycle.

FACTORY BUILT UNITARY EQUIPMENT

The factory built unitary type of heat pump equipment is becoming available in an increasing number of capacities and designs. These units normally use air or well water as the heat source and sink, and air or water as the distribution fluid, as described in Chapter 58 of the 1961 Guide And Data Book. Also, in this design of equipment the direction of the refrigerant is changed by means of a 4-way valve to obtain heating and cooling.

Unitary heat pump equipment is almost universally used in residential and the smaller commercial and industrial installations. The multi-unit type of installations, where a number of smaller individual units with 5–10 tons of cooling capacity, for example, are particularly advantageous to obtain zoning and to provide simultaneous heating and cooling.

The application of this equipment is similar to the unitary cooling equipment described in Chapter 57 of the 1961 Guide And Data Book. The units are shipped from the factory as a complete preassembled unit, including internal wiring, controls, and piping. Only the ductwork, external power wiring, and condensate piping are required to complete the installation. For the split unit, however, it is also necessary to connect the refrigerant piping between the indoor and outdoor sections.

The main advantages of this type of installation are:

1. Equipment rooms can frequently be eliminated.
2. The unit (if an integral unit) can often be suspended from the ceiling to save valuable floor space.
3. The outdoor section (if a split model) can many times be located on the ground, adjacent to the building, or on the roof without detracting from building appearance for accessibility for maintenance and service.
4. The unit can be located in or immediately adjacent to the zone area being served, thereby reducing and simplifying the distribution system.
5. The system is extremely flexible and does not require preparation of complex drawings and control diagrams to obtain satisfactory installation.

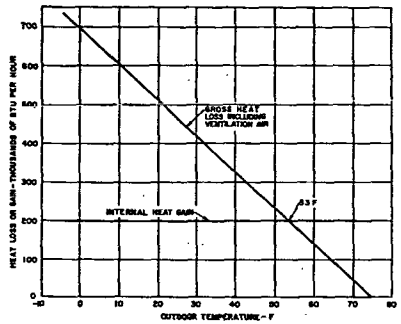


Fig. 9 .... Heat Loss and Heat Gain at Various Outdoor Temperatures for Exterior Zone of Typical Multi-story Office Building

HEAT RECLAIMING CYCLE

Figs. 1, 2, 3, and 4 show that the heat pump is readily adaptable to installations requiring simultaneous heating and cooling by transferring heat from the interior of a structure, for instance, where cooling is desired, to the exterior where heating is needed. This type of application frequently results in a considerable cost saving as compared with other designs, because of the resulting relatively high operating efficiency of the equipment under these conditions. An indication of the magnitude of the recoverable heat in a modern multi-story office building is given by Figs. 9, 10, and 11. Figs. 9 and 10 show the day gross heat loss and the internal heat gain of the

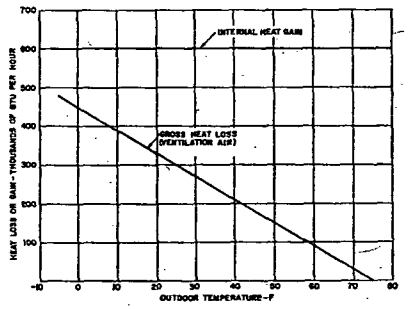


Fig. 10 .... Heat Loss and Heat Gain at Various Outdoor Temperatures for Interior Zone of Typical Multi-story Office Building