

volume) of about 5 percent. A decrease in capacity at low evaporator temperatures corresponding to low heat-source temperatures is also evident, as well as a decrease in power at low evaporator and condensing temperatures.

If the compressor has low clearance volume, e.g., 24 percent, then it is more suitable for low-temperature operation and will provide, for example, about 15 percent greater refrigerating capacity at an evaporator temperature of 0 F and a condenser temperature of 110 F. However, this compressor has somewhat more power demand under maximum cooling load conditions than does one of medium clearance.

It is obvious that more total heat capacity can be obtained at low outdoor temperatures by deliberately oversizing the compressor. When this is done, it may be necessary to provide some type of capacity reduction by means of two-speed motor drives, cylinder cutouts, or other methods.

The disadvantage of this arrangement is that the greater number of operating hours that occur at the higher suction temperatures must be served with the compressor in the unloaded condition which generally causes lower efficiency. Therefore, the annual operating cost will tend to rise. It is also true that the additional initial cost of the oversized compressor must be economically justified by the gain in heating capacity. One method proposed for increasing the heating output at low temperatures involves the use of staged compression, in which one compressor may pump from -20 F suction temperature to 40 F condensing temperature, and a second compressor compresses the vapor from 40 F to 120 F. In such an arrangement, it is possible to interconnect any two compressors so that they are in parallel, both pumping from approximately 45 F to 120 F at the normal cooling rating point, while at some predetermined outdoor temperature on heating they are reconnected so that they pump in staged relationship.

Fig. 7 shows the performance of such a pair of compressors for compressors of both medium and low clearance volume. It is apparent that at low suction temperatures the reconnection into a staged relationship does provide some added capacity. It should also be understood that the motor selection involved must be based upon the maximum loading conditions for summer operation, even though the low stage compressor has a greatly reduced power requirement under the heating condition.

The coefficient of performance will be approximately the same whether the compressors are coupled in parallel or compound-staged at any set of operating conditions, depending somewhat on the motor characteristics when lightly loaded.

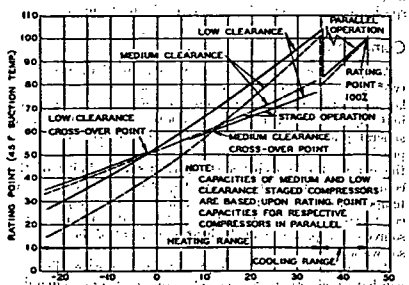


Fig. 7. . . . Comparison of Parallel and Staged Operation

A rotary compressor has characteristics similar to a reciprocating compressor except that it has low clearance and high volumetric efficiency. From this standpoint it is well suited to heat-pump service, providing about 30 percent greater capacity at 0 F - 110 F lift than a medium-clearance reciprocating compressor. However, this characteristic also tends to increase the power demand at the maximum cooling load conditions. At present, reciprocating compressors are most widely used for heat pumps, with rotary compressors being restricted to the first stage of a staged-compression system and not used during the cooling cycle.

Heat Transfer Components

Refrigerant-to-air and refrigerant-to-water heat exchangers, as previously described in the section Heat Sources and Sinks, are similar to heat exchangers used in current air-conditioning practice. A refrigerant subcooler coil may be employed in conjunction with an indoor air coil, or, on systems with a ventilation air supply, to preheat ventilation air. A substantial gain in capacity and coefficient of performance can result.

Refrigeration Components

Refrigerant piping, receivers, expansion devices, and refrigeration accessories in heat pumps are usually the same as those used in other types of refrigeration and air-conditioning systems.

A reversing valve is used to change the system from the cooling to the heating operation. This change-over requires the use of a valve, or valves, in the refrigerant circuit, except where the change is accomplished in fluid circuits external to the refrigerant circuit (see Table 1). Reversing valves are usually pilot-operated by means of solenoid valves which admit head and suction pressures to move the operating elements.

Expansion devices for controlling the refrigerant flow are normally thermostatic expansion valves as described in Chapter 45. If the circuiting is arranged so that the refrigerant line upon which the control bulb is placed can become the compressor discharge line, the resulting pressure developed in the power element of the valve may be excessive, requiring the use of a special control charge or pressure-limiting element. When a thermostatic expansion valve is applied to an outdoor air coil, a special cross-charge is desirable to limit the superheat at low temperatures and thereby obtain better utilization of the coil.

When an expansion valve is attached to a coil that is operated as a condenser, a bypass with a check valve is normally provided as indicated in Table 1.

On small factory-built systems, capillary tubes are normally used as expansion devices. While a single capillary tube on both heating and cooling is sometimes employed, better efficiency and performance can be obtained by using a more restrictive capillary tube for heating than for cooling. This may be accomplished by using two capillary tubes in either a series or parallel arrangement with a check valve to bypass one, for cooling or to block one for heating, respectively.

On an air-source heat pump that must operate over a wide range of evaporating temperatures, a capillary tube will tend to pass refrigerant at an excessive rate at low 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, which is commonly used to provide a storage place for liquid refrigerant, is particularly useful in a heat pump-to-take care of the unequal refrigerant requirements of heating and cooling.

Heat Pumps

Control Components

Heat pump control systems and components are of the same general type used in other types of heating and cooling equipment. (See Chapter 13.)

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 being accomplished either automatically in response to air temperature or manually by a selector switch. When supplementary heaters usually electric resistance heaters, are employed, 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 minimize the effect of the differential between stages, outdoor anticipation is sometimes used. 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.

Another method of controlling the heat pump and supplementary heaters is to use a room thermostat in conjunction with a sequencing controller which operates as a function of thermostat load.

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 any possible savings in operating cost would 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, e.g., 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 means 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 21 of the 1964 GUIDE AND DATA BOOK. When installed in the distribution ductwork, they are frequently controlled to temper the air during defrosting operation on units employing reverse-cycle defrost.

HEAT STORAGE

The use of thermal storage in a heat-pump system can improve its performance characteristics. Installations of heat pumps with thermal storage have principally been made in a few large building systems.^{1,2,3,4}

All materials possess the property of thermal storage to a greater or lesser degree. In the case of a building, the structural materials are almost always in the process of either absorbing heat from or delivering heat to the interior space. This effect is more pronounced in cooling operation where greater air temperature variation is tolerated. Storage tends to reduce the rate of temperature change and helps in some measure to reduce the peak equipment requirements. In this sense every heating and cooling system can be said to involve heat storage in some degree.

Many attempts have been made, particularly in recent years, to increase the heat-storage effect by using special heat-storage materials as part of the heating or cooling system. The result has been a reduction in the size of the heating, or cooling equipment necessary to take care of peak demands.

In the case of the heat pump, a provision for heat storage can serve not only to reduce the size of the heat pump necessary for a given load, but also to provide a more desirable electrical load by shifting part of the load to the time of day when the cost of power is least. The off-peak electric hot water heater is a common example of such a heat-storage application.

In general, there are two types of heat-storage systems that have been employed, (1) sensible heat-storage systems and (2) latent heat-storage systems.⁵ Usually, the latter is actually a combination of the two, making use of some sensible heat storage in addition to the latent effect. Heat storage in a heat-pump system may be utilized on the high side, when heat is available at a temperature suitable for direct heating, or on the low side as an intermittent heat source at temperatures lower than the heated space.

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