The Air Refrigeration Cycle

Fundamentally, the air refrigeration cycle is essentially the same as the vapor cycle. The only important difference is that, since air does not change phase between the compressor and the expansion valve, it is necessary—and is also advantageous—to replace the expansion valve with an expanding engine. There is no temperature change in a perfect gas (and air approaches in behavior such a gas) during a constant enthalpy pressure reduction and hence an expansion valve of the usual type would be ineffective as a means of achieving low temperature in an air system. By utilizing an expander, however, the desired temperature drop is obtained, and, with it, a release of a considerable amount of energy as shaft work. In most air systems the expander and the compressor are so

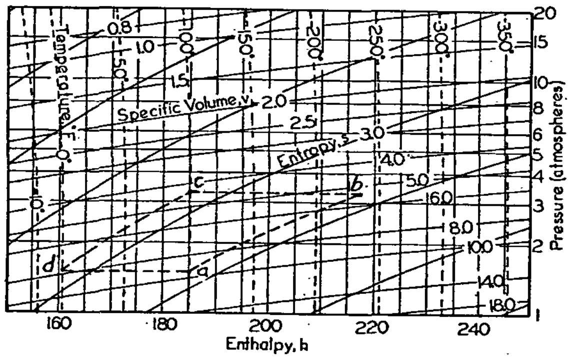

Fig. A. Pressure Enthalpy Diagram for Dry Air

connected that work coming from the expander is supplied to the compressor and the remaining compressor work requirements are then made up from some external energy source.

For vapor cycles work could also be obtained by using an expander in place of an expansion valve, but since material going to the expander would be in liquid form the amount of energy released during the pressure drop (and partial evaporation due to flash) would be relatively small and in most cases insufficient to justify the increased first cost and complexity of the expander.

Fig. A shows the most important working section of a pressure-enthalpy chart for dry air. A typical air cycle is shown by the heavy dashed lines forming the **abcd** area. Dry air at 100 F and 7 psig (1.5 atmospheres) enters the compressor at **a** with enthalpy of 185 Btu per pound and is compressed isentropically to the discharge point **b** where its pressure is 35 psig (3.3 atmospheres), enthalpy 218 Btu per pound and temperature 240 F. From **b** this hot, high pressure air passes through a cooler in which its temperature and enthalpy are reduced (at constant pressure) to the initial values; point **c** gives the state of the air leaving the cooler. If, now, this air were allowed to pass through an expansion valve its state at discharge would be **a** and no refrigerating effect would be available. Actually the air at **c** goes through an isentropic expander and leaves at state **d** with enthalpy and temperature of 161 Btu per pound and 0 F.

The refrigerating effect for the cycle shown is enthalpy at **a** − enthalpy at **d** = 24 Btu per pound.

The work input to the compressor is 218 − 185 = 33 Btu per pound.

The work obtained from the expander is 185 − 161 = 24 Btu per pound.

The net work required for the cycle is then 33 − 24 = 9 Btu per pound of air per minute.

The coefficient of performance (cop) is 24/9 = 2.67.

The air circulating per ton of load is 200/24 = 8.3 lb per minute.

The power requirement is 9/42.42 = 0.21 hp per pound of air or 0.21 × 8.3 = 1.75 hp per ton.

The example given, based on isentropic compression and expansion, gives a simple and conservative method of checking an air cycle. In practice, better economy is obtained if the compression process approaches isothermal rather than isentropic; the expander preferably operates isentropically. To reduce the size of the expanding cylinder and to avoid frosting difficulties, the air system usually operates with a low

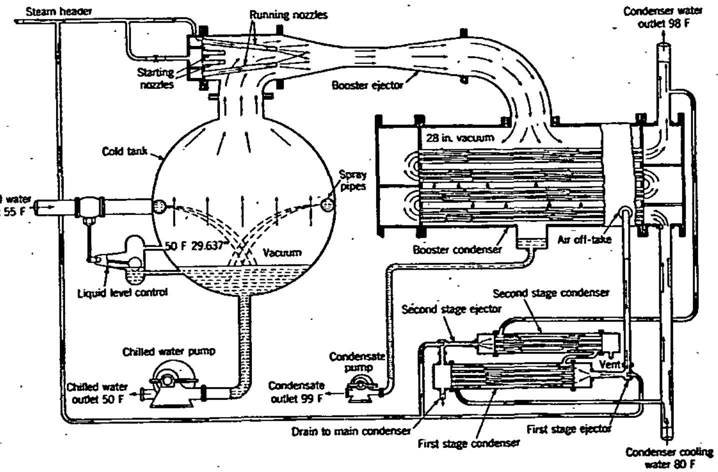

Fig. 2. Diagrammatic Arrangement of Steam Jet Vacuum Cooling Unit

pressure somewhat more than atmospheric. The usual compression ratio is about 4.

The principal advantage of the air system is that its refrigerant (air) is inexpensive and non-toxic. Serious disadvantages are size and cost of equipment and such a low coefficient of performance, that air refrigeration has no commercial importance today.

The Steam Jet System

The steam jet system under certain circumstances is desirable for use in air conditioning[1]. Steam supplies directly the power used for compressing the refrigerant, thus eliminating the losses connected with other methods of supplying energy. As the compression ratio between the evaporator and condenser under normal circumstances is large, the mechanical efficiency of the equipment is somewhat lower than that of the positive mechanical type compressor. The condensing water requirements are considerably greater, as both the refrigerant and the impelling steam must be condensed.

The steam jet system functions on the principle that water under high vacuum will vaporize at low temperatures. Steam jet boosters or com-