erant vapor between the moving elements and the case and delivers it to the condenser at the required pressure. The rolling together of the impellers as in the case of the gear compressor prevents the return of the refrigerant vapor to the low side of the system.

Steam jet compressors which are particularly adapted to large tonnage installations are simple, compact, have no moving parts and produce practically no vibration. However, they are not economical for water temperatures much below 40 F or where the cost of generating steam is higher than the cost of operation with other prime movers.

MECHANICAL REFRIGERATION

While the mechanical refrigeration systems differ in the methods used for compression of the refrigerant vapor, they are fundamentally similar.

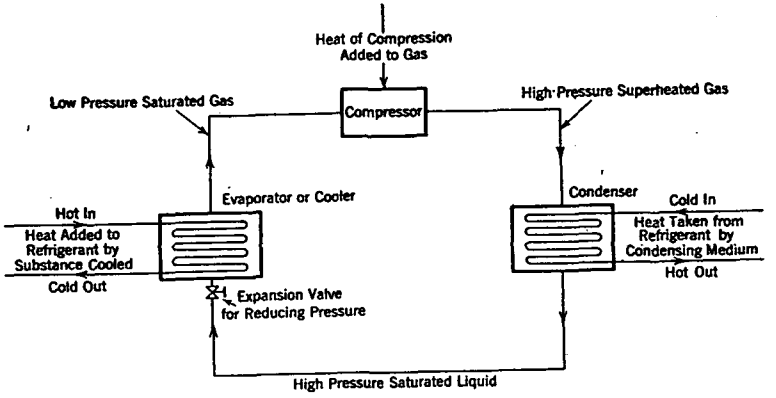


FIG. 1. MECHANICAL REFRIGERATION SYSTEM

Refrigerant vapor usually saturated or slightly superheated, is drawn into the compressor as diagrammed in Fig. 1. It is then compressed and discharged at a higher pressure to a condenser. The vapor is condensed as it contacts a heat transfer surface over which is flowing a cooling medium such as water, air or a combination of the two. The liquid refrigerant flows to the evaporator through an expansion valve which reduces its pressure and regulates its flow. In the evaporator the refrigerant absorbs heat from the medium which is to be cooled. When this medium is water or brine, the evaporator is known as a water or brine cooler and the refrigeration system, if used for air cooling, is known as an indirect system. When the medium cooled is air, the evaporator is known as a direct expansion cooler and the system is known as a direct expansion system.

Fundamentally, the function of the system is to absorb heat at one temperature and *pump* it to a higher temperature, where it may be removed by an available cooling medium. In order to conserve refrigerant, virtually all refrigeration systems are completely closed and the same refrigerant is recirculated.

Theoretical Mechanical Refrigeration Cycle

The complete mechanical refrigeration cycle may be illustrated on the temperature-entropy diagram, and also on the pressure-volume diagram, both of which are shown in Fig. 2.

In the theoretical cycle, saturated vapor is drawn into the compressor at a and compressed at constant entropy (adiabatically), and is then delivered to the condenser at b. Condensation occurs at constant temperature T_2 from b to c with a contraction from the vapor to the liquid volume. The line cd represents cooling from the temperature of the condenser to that of the evaporator by an external cooling means. At the same time, the pressure is lowered to P_1. Evaporation then occurs from d to a at temperature T_1, completing the work cycle $abcda$. Since no external means of cooling the refrigerant liquid is normally available, the

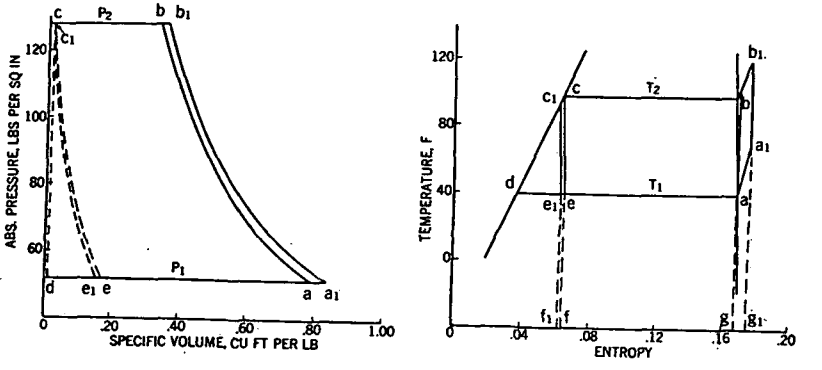


FIG. 2. THEORETICAL DICHLORODIFLUOROMETHANE (F_{12}) CYCLES

cooling is generally accomplished by evaporation of a portion of the refrigerant. Since the work of expansion is usually used up as friction in the expansion valve, this process is assumed to be carried on at constant total heat, as represented by the line ce on the temperature-entropy diagram. Thus the refrigerating effect is represented by an area $eagfe$. While the normal theoretical cycle starts with saturated vapor, operation is common at a condition of superheated vapor (as at a_1). Moreover, expansion may start either with a mixture of liquid and vapor or with a sub-cooled liquid, as at c_1, with expansion to e_1. It is obvious that this latter is desirable as it increases the refrigerating effect. Area $a_1b_1cdaa_1$ represents the work of such a superheated cycle, while the area $e_1a_1g_1f_1e_1$ represents the refrigerating effect of the cycle with superheated vapor and sub-cooled refrigerant liquid.

It will be noted on the pressure-volume diagram the volume of the saturated liquid is indicated by a dotted line close to and parallel to the ordinate.

In the discussions in this chapter a slight error is introduced by not including all of the work of pumping the liquid from the low to the high