flows to the evaporator through an expansion valve which reduces its pressure and regulates its flow. The evaporator absorbs heat from a 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,

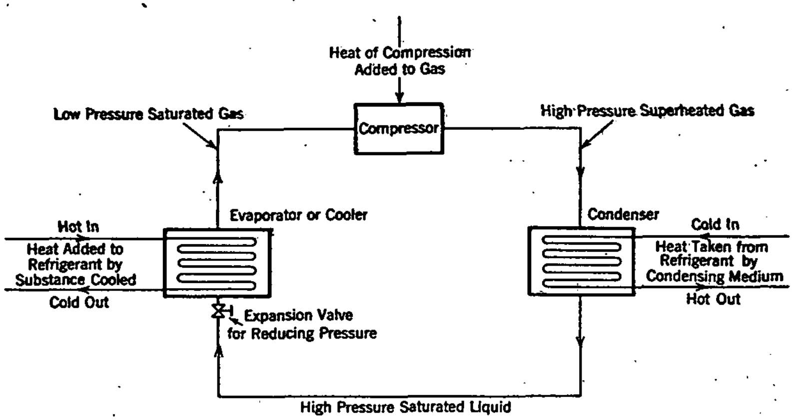

FIG. 1. MECHANICAL REFRIGERATION SYSTEM

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.

Considering the theoretical cycle, saturated vapor is drawn into the compressor at *a* and compressed at constant entropy (adiabatically) and 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 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 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 liquid is indicated by a dotted line close to and parallel to the ordinate.

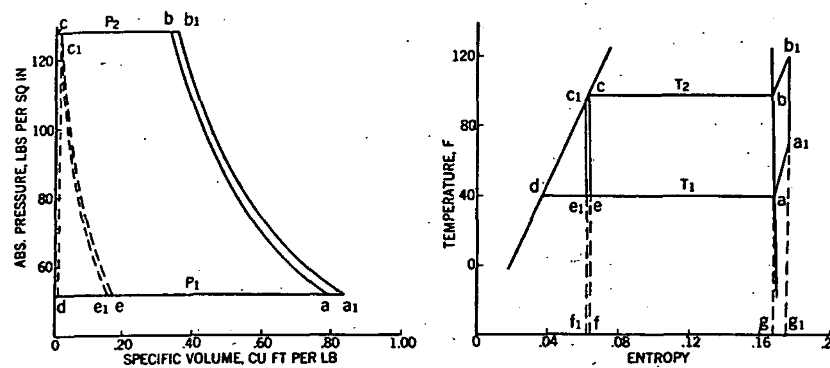

FIG. 2. THEORETICAL DICHLORODIFLUOROMETHANE (F_{12}) CYCLES

It is obvious that it is necessary to include the work of pumping the liquid as well as pumping the vapor as part of the refrigeration work.

Theoretical Work per Pound

The temperature-entropy and pressure-volume diagrams are based on one pound of the refrigerant. Likewise, the theoretical work and the refrigerating effects are conveniently based on a pound of refrigerant. The compression work per pound may be found by several methods.

The temperature-entropy method starts with state point *a*. Since the quality of *a* is known, the heat content of the vapor H_a is known, and also the entropy S_a. Since $S_a = S_b$ and with T_2 given, H_b can be determined. If W = work in foot-pounds per pound of refrigerant, then

$$W = (H_b - H_a) \times 778 \quad (1)$$

The pressure-volume method starts with state point *a*, whose pressure and specific volume are known. The work of compression is the adiabatic work of compression from P_1 to P_2, plus the work of expelling the vapor at constant pressure P_2 minus the external work of evaporation of the vapor to volume V_1 at pressure P_1.

$$W = \frac{n}{n-1} \times P_1V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1 \right] \quad (2)$$