the generator. At the same time it reduces cooling water requirements.

Cooling water is required at two points in the cycle. The cooling water is circulated initially through the absorber (to remove the heat of absorption of the water into the solution)

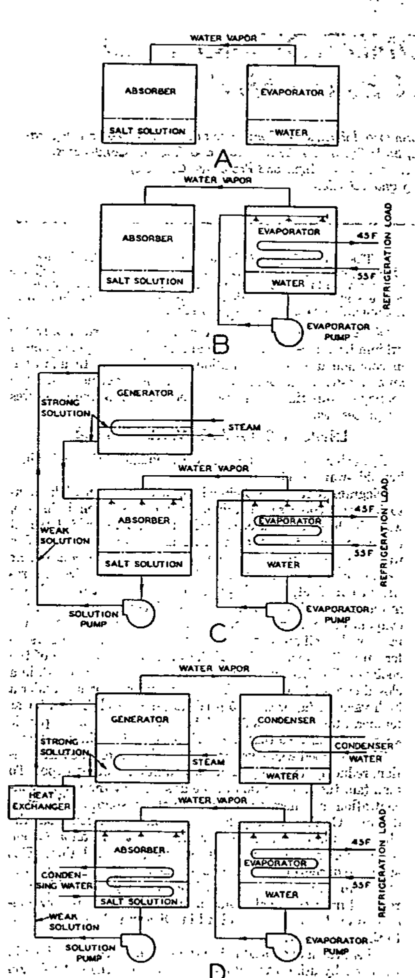

Fig. 1 .... Components of Lithium Bromide Absorption System

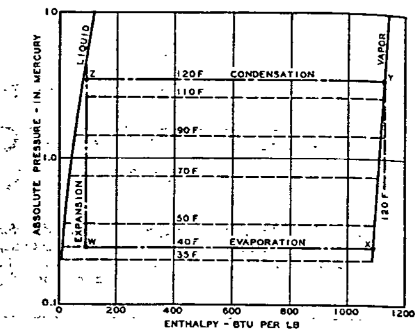

Fig. 2 .... Pressure-Enthalpy Diagram for Water

and then through the condenser (to remove the heat of the load and of the heat source). This cooling water may be supplied by a cooling tower or other suitable source.

A variation of this cycle is the use of a two-effect generator. Heat is supplied to a weak lithium bromide solution in the first effect generator. The solution boils, liberating water vapor and concentrating the solution. The partially concentrated lithium bromide then passes through a heat exchanger which serves as a second effect generator. The pressure in the second effect generator is lower than that of the first effect generator. At the reduced pressure, the solution boils at a temperature lower than that of the condensing vapor from the first effect generator. Chillers incorporating this principle are available.

A lithium bromide-water cycle[2] is shown in separate diagrams for water and lithium bromide in Figs. 2 and 3, respectively.

Since water is used as the refrigerant in the absorption machine, the pressure-enthalpy diagram for water is shown in Fig. 2. Line W-X shows that at 40 F evaporating temperature and 120 F condensing temperature, the net latent heat available for refrigeration is the enthalpy difference of the vaporized refrigerant water at 40 F (1079.3) saturated, and the condensed liquid at 120 F (87.9), or 991.4 Btu per lb of refrigerant water in circulation in the cycle.

Line Y-Z shows that the net heat rejected by the refrigerant water in condensing at 120 F condensing temperature, is the enthalpy difference between vapor superheated to 230 F and condensed water at 120 F or 1163.8 − 87.9 = 1075.9 Btu per lb.

Line Z-W shows that each pound of refrigerant water returning from the condenser to the cooler at constant enthalpy, partially vaporizes, thus becoming a mixture of approximately 93 percent water and 7 percent vapor by weight.

The absorption refrigeration cycle cannot be shown completely on a pressure-enthalpy diagram for water. Water vapor at point X in Fig. 2 is absorbed into a water solution of lithium bromide, and separated as superheated vapor from the solution at point Y. To complete the cycle, reference must be made to a water vapor pressure-solution temperature-solution concentration chart for a solution of lithium bromide and water.

When the concentration of lithium bromide in water is zero the *solution* is pure water. Temperature of the *solution* is the temperature of water, and its vapor pressure is that of

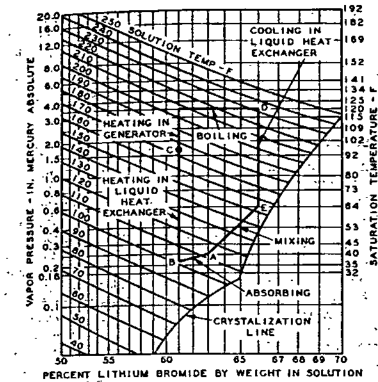

Fig. 3 .... Lithium Bromide Pressure-Temperature-Concentration Chart

water vapor. At zero concentration, the water temperature-vapor pressure relation agrees exactly with standard steam tables.

Lithium bromide is a neutral salt, soluble in water. When the weight concentration of the solution is zero, solution vapor pressure remains water vapor pressure. With lithium bromide in the solution, the vapor pressure of the solution is reduced. To obtain equal vapor pressures from pure water and from a lithium bromide solution, the pure water would have to be at a lower temperature than the lithium bromide solution. This difference in temperature may be called *dew-point depression.* These relationships are shown graphically in Fig. 3.

The dew-point depression thus obtainable can be calculated. For example: the vapor pressure of a 100 F, 60 percent by weight, concentration lithium bromide solution is 0.23 in. Hg (see Fig. 3); the temperature of pure water having the same vapor pressure is 38 F. Thus, the dew-point depression is 100 − 38 = 62 F.

Continuing the refrigeration cycle, refrigerant water vapor at point X (Fig. 2) is absorbed along line A-B (Fig. 3). As it is absorbed, it reverts to liquid water, giving up its heat of condensation and diluting the lithium bromide solution from its original concentration A to concentration B. Because the heat of condensation would raise the solution temperature and stop the absorption process by raising the solution vapor pressure, cooling water is used to remove heat from the absorber, thus preventing rise of the solution temperature.

The solution at reduced concentration B now contains the refrigerant water. This solution is pumped from the absorber through the heat exchanger to the generator, entering at temperature and concentration C. In the generator, the solution is heated and then boiled. This boiling process drives off refrigerant water vapor and leaves the solution at the higher concentration D. The refrigerant again in the form of water vapor, flows to the condenser, point Y (Fig. 2).

The solution at the elevated temperature and concentration D, returns by gravity to the absorber, gives up heat in the liquid heat exchanger and enters the absorber at temperature and concentration E. The heat given up by the hot solution, cooling from the elevated temperature at D to the lower temperature E, heats the weak solution from the low temperature at B to the higher temperature C. The solution at temperature and concentration A, which does the actual refrigerant absorbing is obtained by mixing solutions E and B.

For simplification, the cycle is shown operating with four separate chambers. In practice, the chambers may be incorporated into two shells or even into a single shell. In the case of a two-shell machine, the generator and condenser are located in the upper shell (called the *high pressure* shell, although the pressure is approximately 1 psia), and the evaporator and absorber are located in the lower shell (called the *low pressure* shell, where the pressure is approximately 0.15 psia). In the case of a single-shell machine, the shell is physically divided into two zones, with the generator and condenser in the *high pressure* zone, and the absorber and evaporator in the *low pressure* zone. The solution and evaporator pumps shown in Fig. 1 are not a part of the thermodynamic cycle. The small (3 to 25 ton) units operate on the basis of natural circulation of the various solutions. The pumps are used on large equipment only to reduce the physical dimensions of the machines. A purging device is included to remove any noncondensable gases from the machine, assuring maximum capacity and efficiency at all times. The arrangement of components in a 3-ton direct-fired air conditioner is shown in Fig. 4. The arrangement of components in large tonnage indirect-fired, two-shell and single-shell water chillers is shown in Figs. 5 and 6.

Coefficient of Performance

The coefficient of performance (CP) has long been used to permit evaluation of the effectiveness of a refrigeration cycle. It is defined as the ratio of refrigerating effect (output) to the heat equivalent of the input. In the case of an absorption cycle, it can be measured as the ratio of the heat absorbed in the evaporator to the heat absorbed in the generator.

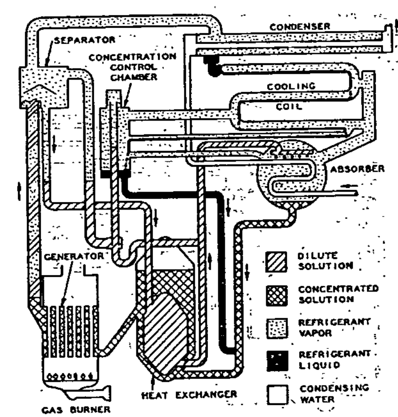

Fig. 4 .... Diagram of Direct-Fired Lithium Bromide Cycle Air Conditioner