steam consumption in pounds per hour per ton of refrigeration increases rapidly as the booster steam pressure is lowered. For example, the lowering of the booster steam pressure from 200 to 90 psig results in an increase in steam consumption of approximately 5 percent, whereas a further decrease in booster steam pressure to 10 psig increases steam consumption by approximately 72 percent over that required at 200 psig.

The capacity of a steam-jet system is usually controlled by controlling the number of boosters in use since the unit usually has several boosters operating on the same evaporator. Usually one booster is automatically controlled, whereas the others are manually operated. The capacity is dependent, as for all compressors, upon the evaporator temperature, or in other words, the suction pressure. For example, the capacity is lowered approximately 17 percent if the evaporator or chilled water temperature is lowered from 50 to 45 F. The capacity therefore can be controlled to some extent by regulating the evaporator temperature.

The Absorption System

The absorption and mechanical compression cycles have in common the vaporizing and condensing of a liquid, but differ in that one has a compressor unit and the other an absorber-generator unit for producing the necessary pressure difference between vaporizing and condensing levels. Both cycles require energy for operation: mechanical energy for the compression cycle; heat for generation in the absorption cycle.

Thermodynamic analysis of absorption cycles is relatively complex and requires the use either of tables or graphs showing the equilibrium relationships and thermodynamic properties of the refrigerant-absorbent combination. Data of this kind are given in the first book in the bibliography. A discussion of various absorbents is given in the sixth book. Thermodynamically, the effectiveness of a refrigerant-absorbent combination increases directly with its negative deviation from Raoult's Law.

Fig. 7 shows a typical absorption cycle flow diagram. Cooling water first goes through the absorber (where it extracts the heat of absorption which is liberated by the refrigerant vapor as it goes into solution), then through the condenser, and finally through the rectifier. Refrigerant from the evaporator enters the absorber where it goes into solution in the absorbent; the high concentration solution is then pumped to the generator where heat is supplied; the refrigerant (with some absorbent vapor) leaves for the rectifier and the warm low concentration solution is returned to the absorber. In the rectifier selective condensation occurs, the concentration of the absorbent in the condensate being much greater than its concentration in the entering vapor mixture; rectifier condensate is dripped back to the generator.

Operating Cycle. The components of one form of lithium bromide water absorption system are illustrated in Fig. 8.

Diagram A shows two closed vessels, with salt (lithium bromide) solution in one and water in the other. The salt solution in the absorber has affinity for water vapor and evaporates some of the water. The water that remains in the evaporator is thus cooled by evaporation, thereby producing a refrigeration effect.

Since these two vessels operate under a high vacuum, chilled water temperatures down to 38 F may be obtained. To utilize the refrigeration effect, a coil is placed inside the evaporator as shown in diagram B. A pump circulates water from the evaporator tank to a spray header to wet the surface of the coil. The evaporation and cooling effect of the spray on the coil surface chills the water as it is circulated through the coil in a closed circuit to a refrigeration load.

In an actual operating cycle the salt solution is continu-

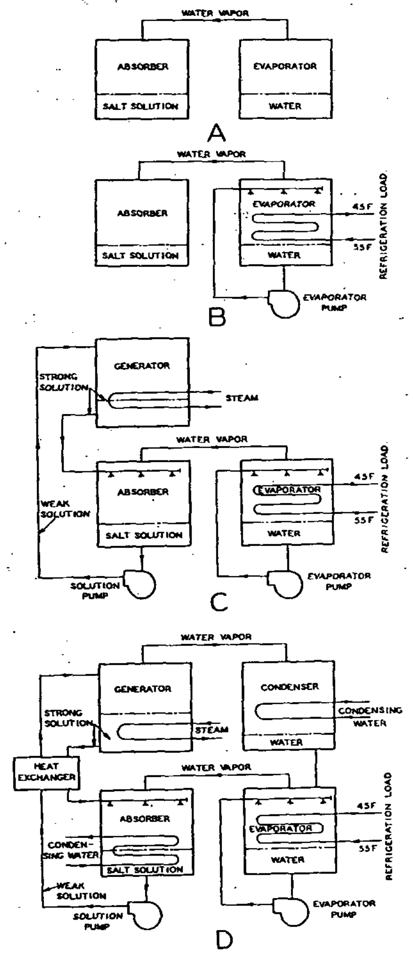

Fig. 8 .... Components of Lithium Bromide Absorption System

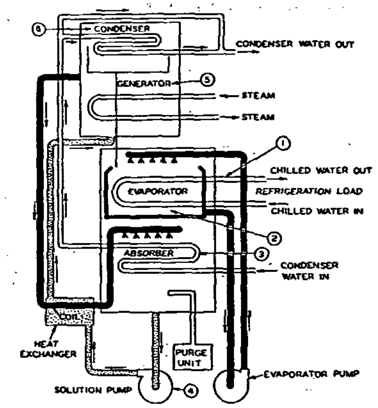

Fig. 9 .... Diagram of Lithium Bromide Water Absorption System

ally absorbing water vapor, thus diluting the solution and reducing its ability to absorb additional water vapor. To keep the salt solution in the absorber at the proper strength a generator is added to the system as shown in diagram C. The weak solution is pumped from the absorber to the generator where heat is used to boil off the excess water

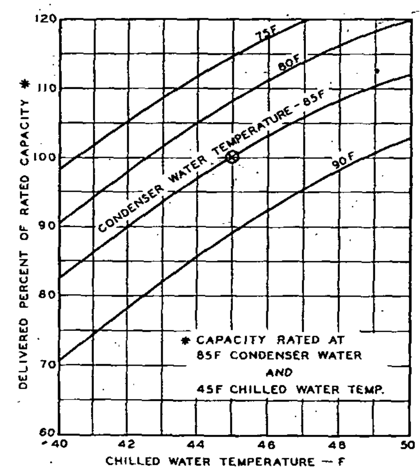

Fig. 10 .... Performance Characteristics of a Typical Lithium Bromide Absorption System

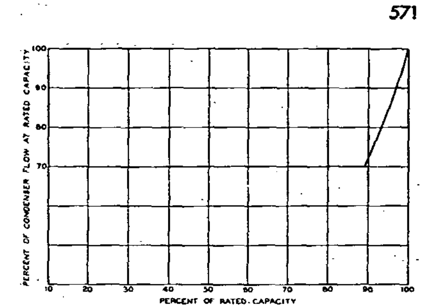

Fig. 11 .... Condenser Water Requirements for a Typical Lithium Bromide Absorption System

vapor. The reconcentrated salt solution is then returned to the absorber to continue the cycle.

The water vapor boiled off in the generator is condensed and returned to the evaporator. A heat exchanger is added to the system (diagram D) to conserve heat in the cycle by using the hot concentrated salt solution from the generator to preheat the cooler weak solution from the absorber. Condensing water from a cooling tower or other available source is circulated through coils in the absorber and condenser to remove waste heat from the refrigeration cycle.

For the sake of simplification, the cycle is shown as operating with four separate chambers. In actual practice, the condenser and generator are combined into a *high pressure* shell, with the absorber and evaporator located in a second shell. Fig. 9 schematically shows the arrangement. A purge unit is included to remove any non-condensables from the machine, thus assuring maximum efficiency and capacity at all times.

Coefficient of Performance. The coefficient of performance (CP) of an absorption system using lithium-bromide and water is approximately 0.6. The heat required can be obtained from steam, hot water or other heated liquids.

Absorption type equipment is fully automatic from full load to no load. The performance does not vary greatly between 20 percent of capacity and full load. The operating costs of absorption equipment are considered competitive with those of other forms of refrigeration. For a typical lithium-bromide-water system, Figs. 10, 11, and 12 illus-

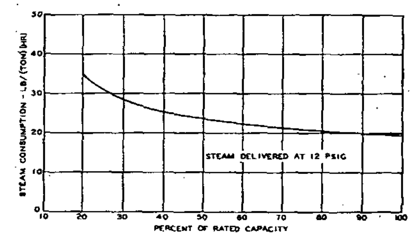

Fig. 12 .... Steam Requirements for a Typical Lithium Bromide Absorption System