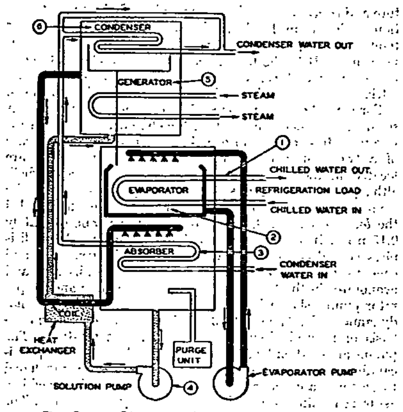


Fig. 5 .... Diagram of Lithium Bromide-Water Absorption System

A simple expression for the CP of an ideal absorption cycle is:

$$(CP) = \frac{T_1(T_4 - T_3)}{T_4(T_2 - T_1)} \qquad (1)$$

where

T_1 = evaporator temperature, Rankine.
T_2 = condenser temperature, Rankine.
T_3 = absorber temperature, Rankine.
T_4 = generator temperature, Rankine.

Actual cycles are never as efficient as the ideal cycle. Every difference between the actual and ideal cycle produces a thermodynamic loss. As a result, the (CP) of actual absorption cycles is generally less than one, no matter how efficiently they are carried out nor how small the temperature difference between the evaporator and the condenser and absorber may be. It should be noted, however, that the (CP) falls off slowly as these temperature differences are increased. This assists in maintaining high part-load efficiencies. These characteristics are very different from those of compression systems.

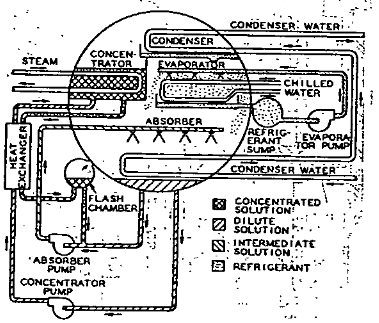


Fig. 6 .... Diagram of One-Shell Lithium Bromide Cycle Water Chiller.

Influence of Condenser Water Temperatures

An analysis of the cycle shows that unit efficiency improves with a reduction in condenser water temperature. The condensing temperature is almost a direct function of the condenser water temperature; hence, an increase in the condenser water temperature will result in an almost identical increase in the condensing temperature. With a fixed evaporator temperature, an increase in the condensing temperature will result in a higher temperature condensate having a greater enthalpy. This condensate, upon its return to the evaporator, has a reduced refrigerating effect. The net result of an increase in condenser water temperature is a reduction in capacity, and an increase in the energy input requirements.

If the condenser water temperature continues to rise, the capacity of the unit continues to decrease. Since the lithium bromide unit is operating under a high vacuum, no pressures higher than atmospheric can develop. This eliminates the need for a high head-pressure safety cut-out. Absorption machines using the lithium bromide-water cycle can continue to produce some refrigeration even with unusually high cooling water temperatures.

On the other hand, if the temperature of the condenser water should decrease, the capacity of the unit would increase. It is desirable to limit variations in capacity resulting from variations in the temperature of the entering condenser water, as may exist with a cooling tower. The installation of an automatic 3-way valve between the cooling tower and the condenser is recommended. This valve will either recirculate

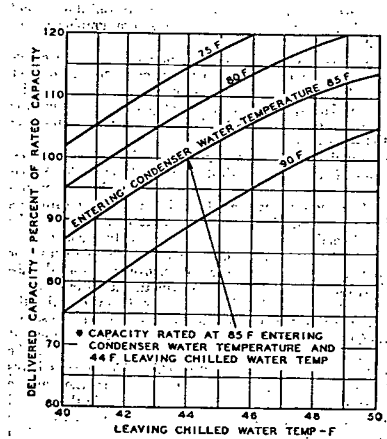


Fig. 7 .... Performance Characteristics of Lithium Bromide Cycle Water Chiller

condenser water, mix condenser and cooling tower water, or deliver 100 percent tower water, to hold the water temperature within design limits.

In the modern lithium bromide absorption system, the condenser water flow rate is held constant throughout the entire operating range of the chiller. Fig. 7 shows the performance of a typical lithium bromide cycle water chiller with respect to condenser cooling water temperatures.

Influence of Chilled Water Temperature

Further analysis of the lithium bromide-water cycle also reveals the advantage of maintaining the chilled water temperature as high as the load will permit. The chilled water temperature follows evaporator temperature very closely; hence, an increase in the required temperature of the chilled water requires an almost identical increase in the evaporator temperature. With a fixed condenser temperature, the enthalpy of the refrigerant to the evaporator remains unchanged. If the evaporator temperature rises, the leaving enthalpy increases, thereby increasing the refrigerating effect. This results in an increase in the refrigerating capacity of the unit, and at the same time a reduction of energy input requirements.

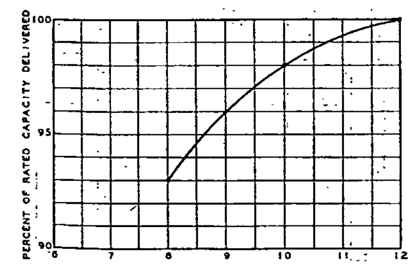
The chilled water temperatures may be dictated by the dehumidification requirements of the load. High chilled water temperature, if otherwise acceptable, will increase the capacity of the machine for sensible cooling, but will reduce the capacity of the machine for latent cooling.

If required, chilled water temperatures as low as 38 F can readily be produced in chillers using the lithium bromide-water cycle. Fig. 7 illustrates the performance of a typical lithium bromide-cycle water chiller with respect to chilled water temperatures.

Influence of Temperature of the Heat Source

The absorption cycle requires heat for operation. This heat may be supplied by direct firing, or it may be supplied indirectly by steam, hot water, or a number of other hot fluids. At any given load, the heat input requirement is fixed, without regard to the nature of the hot medium.

With a decrease in the temperature of the source, there is a decrease in the amount of refrigerant water vapor boiled out of the strong solution in the generator. This reduces the refrigerating capacity of the unit. Fig. 8 shows the performance of a typical lithium bromide cycle water chiller with respect to steam pressure. (Steam pressure is generally used to indicate steam conditions.) When the unit is to be operated on hot water, or other hot fluids, the manufacturer should be consulted for specific performance information.



* For Lithium Bromide Cycle Water Chiller

Fig. 8 .... Effect of Steam Pressure on Capacity*

Because direct-fired units are generally operated *on-off*, the temperature of the heat source is not significant with respect to capacity control. The unit will run a greater or lesser portion of the time, corresponding closely to the ratio of the actual load to the unit capacity. This kind of operation is primarily used in residential and small commercial applications.

AMMONIA-WATER CYCLE

Thermodynamically, the ammonia-water absorption cycle is identical to the lithium bromide cycle discussed earlier in this chapter. In the ammonia-water cycle, however, water plays a different role. Here it acts as the absorbent. Ammonia is the refrigerant, and consequently lower temperatures may be reached. The other principal operating difference between the two cycles is the pressure range in which the cycles operate. The lithium bromide-water cycle operates under a very high vacuum, while the ammonia-water cycle operates in a pressure range comparable to that of compression systems. Fig. 19 of Chapter 1 shows the properties of aqueous-ammonia solutions.

Although the major components of all absorption systems are the same, the characteristics of specific refrigerant-absorbent combinations may require auxiliary devices in order to improve the operating efficiency of the cycle. In the ammonia-water cycle, the volatility of water under the generator conditions is the major consideration.

The proportion of water in the ammonia-water vapor leaving the generator depends on the composition of the liquid and its temperature. In a simple cycle, no provision is made for removing water from the vapor before it enters the condenser. Hence, the water passes through the condenser to the evaporator and, being almost nonvolatile under evaporator conditions, it concentrates as evaporation proceeds, thus raising the boiling point of the remaining refrigerant. To keep such an evaporator operating, the accumulated water would have to be purged to the absorber, either continuously or periodically, as a liquid of high ammonia content.

Two devices commonly used to reduce the amount of water reaching the condenser and evaporator in the actual ammonia absorption cycle are the analyzer and the rectifier. The analyzer consists of a chamber through which the vapors leaving the generator pass in counterflow contact with the weak solution flowing to the generator. A bubble column, packing, or a series of baffle plates, may be used to make the vapor-liquid contact more effective. As the vapor passes upward through the analyzer it is enriched with ammonia, as well as cooled, and the solution is heated. Thus, the vapor going to the condenser is cooler and richer in ammonia, and the heat input required at the generator is decreased. The vapor flows from the analyzer into the rectifier. The rectifier is a heat exchanger set before the condenser (or it may be the inlet to the condenser) arranged in a manner to enable its condensate to drain to the analyzer or the generator. The warm refrigerant vapor from the analyzer is cooled by the weak solution flowing to the generator.

As in the case of the lithium bromide-water cycle, it is universal practice to conserve heat in the cycle by the use of a heat exchanger which uses the hot strong solution from the generator to preheat the weak solution from the absorber. This improves the cycle efficiency by reducing the heat input required. Less heat has to be carried away, reducing heat rejection requirements. Still further improvements in the efficiency of the operating cycle may be obtained by sub-