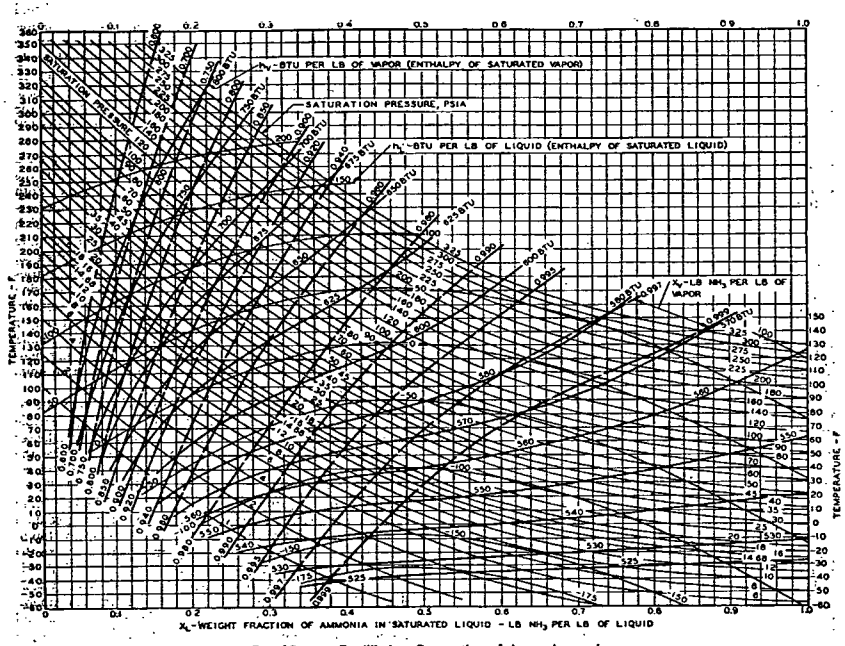


Fig. 19 .... Equilibrium Properties of Aqua Ammonia

2. Lithium bromide is not sufficiently soluble in water to permit the absorber to be air cooled.
3. The extremely low pressures in the system require large vapor conduits.

For systems where these disadvantages are not prohibitive, this combination can be used effectively.

A third system using dimethoxytetraethylene glycol as the absorbent, with methylene chloride as the refrigerant, was mentioned earlier and is typical of a whole group of such systems using the ether structure as a hydrogen bonding group. In addition to methylene chloride, other refrigerants such as the partially halogenated hydrocarbons[28] (Refrigerants 21, 22, etc.) have been investigated as refrigerants. In general, systems of this type suffer from two major disadvantages, namely, relatively low values of the CP and a lack of chemical stability. Consequently, practical machines are limited at this time to the ammonia-water system and the water-aqueous lithium bromide system.

Thermodynamic and Physical Data Required

One of the things that has hindered the search for new absorbent-refrigerant combinations is the lack of adequate data. Even for those systems which are in current use, the available data fail to cover the complete range of conditions and the designer has to depend on extrapolations.

The analysis of an absorption refrigeration cycle usually consists of a series of heat balances and material balances around the various components, as well as around the cycle as a whole. For such an analysis, the information required for the working fluids consists of equilibrium pressure-temperature-composition data for material balances, and enthalpy-temperature-composition data for both the liquid and vapor phases for heat balances. In addition to the cycle analysis, the designer will need data for density, viscosity, heat capacity, and thermal conductivity for both liquid and vapor phases for flow calculations, heat exchanger design, pump design, etc.

Ammonia-Water System Data

The available data for vapor-liquid equilibria and for enthalpy-temperature-composition for this system have been studied and recalculated by Scatchard *et al*,[29] in an attempt to combine the various fragments into a single compilation. Scatchard's results were then plotted on a single chart by Kohloss and Scott;[30] this chart is presented here as Fig. 19.

In 1960, the Institute of Gas Technology began a study, sponsored by the American Gas Association, to re-evaluate the ammonia-water system data and to obtain new experimental data to fill in some of the areas of the chart not previously studied. At present, this work is incomplete, but the Institute is planning to publish new results in the form of a bulletin. A discussion of the methods used and new data obtained in this investigation is given in Reference 31.

Table 2 .... Specific Volume of Aqua-Ammonia Solutions[a]

(Cu Ft per Lb of Subcooled or Saturated Liquid)

Temp, F	Weight Concentration Ammonia in Water											Temp, F
	0.00	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.00	
20	0.0160	0.0166	0.0172	0.0177	0.0182	0.0188	0.0196	0.0206	0.0218	0.0232	0.0247	20
40	0.0160	0.0167	0.0172	0.0178	0.0183	0.0190	0.0199	0.0209	0.0222	0.0236	0.0253	40
60	0.0160	0.0167	0.0173	0.0179	0.0185	0.0192	0.0201	0.0213	0.0226	0.0242	0.0260	60
80	0.0161	0.0168	0.0174	0.0180	0.0186	0.0195	0.0204	0.0216	0.0231	0.0248	0.0267	80
100	0.0161	0.0169	0.0175	0.0182	0.0189	0.0197	0.0208	0.0221	0.0236	0.0254	0.0275	100
120	0.0162	0.0170	0.0176	0.0184	0.0191	0.0200	0.0212	0.0226	0.0242	0.0262	0.0284	120
140	0.0163	0.0171	0.0178	0.0186	0.0194	0.0204	0.0216	0.0230	0.0249	0.0269	0.0294	140
160	0.0164	0.0172	0.0180	0.0188	0.0197	0.0207	0.0223	0.0237	0.0256	0.0279	0.0306	160
180	0.0165	0.0174	0.0182	0.0191	0.0200	0.0212	0.0226	0.0244	0.0265	0.0289	0.0320	180
200	0.0166	0.0175	0.0184	0.0193	0.0204	0.0216	0.0232	0.0252	0.0275	0.0304	0.0338	200
220	0.0168	0.0177	0.0186	0.0197	0.0210	0.0225	0.0242	0.0264	0.0288	0.0320	0.0361	220

[a] Prepared by B. H. Jennings and F. P. Shannon.

Data for the specific volume of aqueous ammonia solutions were determined by Jennings and Shannon and are presented in Table 2.

Water-Lithium Bromide System Data

Pressure-temperature-composition data for this system have been determined by Pennington[32]; these data have been plotted in Fig. 20.

The enthalpy-concentration charts for the water-lithium bromide system, Figs. 21 and 22, are included here by permission from Reference 33.

The specific gravity[34] of aqueous lithium bromide solutions is given at two temperatures in Fig. 23, and the specific heat[35] is plotted in Fig. 24. Viscosities[36] of aqueous solutions of lithium bromide solutions have been determined and are shown in Fig. 25.

Practical Cycles

It was stated earlier that the absorption cycle consisted of the four basic components: absorber, generator, condenser, and evaporator. However, it has been found necessary to add certain auxiliary components to the basic four for the purpose of improving the coefficient of performance. This auxiliary equipment does not change the basic cycle but simply improves the utilization of the heat energy.

Fig. 17 shows that there is a continuous circulation of absorbent from the generator to the absorber and back to the generator. Since the generator operates at a much higher temperature than does the absorber, the stream of hot absorbent leaving the generator represents a continuous loss of heat; the sensible heat content above the temperature of the returning stream of absorbent being dissipated by the absorber. The desirability of a simple liquid-liquid heat exchanger between these two absorbent streams is obvious. In systems involving a nonvolatile absorbent, this heat exchanger is generally the only auxiliary component used to improve the coefficient of performance of the basic cycle. Such a system is shown in Fig. 26, and is typical of the machines using water and lithium bromide.

Systems employing an absorbent having an appreciable vapor pressure require a rectifier in addition to the liquid-liquid heat exchanger. The ammonia-water system is the classic example. This rectifier is simply a distillation column, usually constructed as a part of the generator, which serves to decrease the concentration of absorbent vapor in the vapor stream going to the condenser. In order for the distillation column to function, a stream of reflux liquid must be supplied to the top of the rectifier. This reflux liquid may be a small portion of the liquid refrigerant produced in the condenser, but generally, a small reflux condenser is located between the rectifier and the main condenser in such a way that the condensate from the reflux condenser drains back to the rectifier. The amount of reflux liquid is controlled by limiting the quantity of heat removed from the reflux condenser. The details of the design, construction, and operation of the rectifier, or distillation column, can be found in any of the standard chemical engineering textbooks on unit operations, such as Reference 37.

A conventional system with liquid-liquid heat exchanger and rectifier is depicted schematically in Fig. 27.

Sometimes, a refrigerant precooler is used as an additional means for increasing the coefficient of performance. This device is simply a heat exchanger which serves to cool the liquid refrigerant by means of the cold vapor leaving the evaporator. This exchanger must be located in the refrigerant line on the high pressure side of the expansion device. The gain produced by this exchanger is small, however, and the saving in operating cost does not always justify the investment.

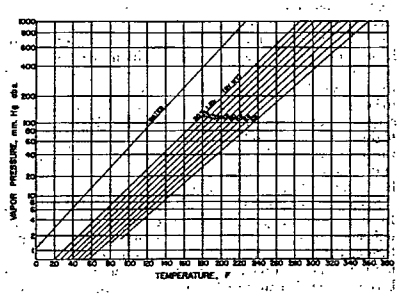


Fig. 20 .... Vapor Pressure of Aqueous Solutions of Lithium Bromide