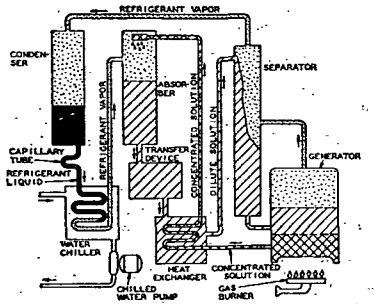

Fig. 9 .... Diagram of Direct-Fired Ammonia-Water Cycle Water Chiller

cooling the liquid ammonia from the condenser with the cool refrigerant vapor from the evaporator. This increases the refrigerating capacity of each pound of refrigerant at no cost except that of slightly warmer cooling water leaving the absorber. Not all the auxiliaries described are used in every application. Consideration must be given to the efficiency improvement vs cost of auxiliaries. There is a combination which will yield the best economic balance of initial costs to operating expenses.

The arrangement of components in a 3-ton direct-fired, air-cooled water chiller is shown schematically in Fig. 9.

Influence of Condenser Temperatures

Analysis of the ammonia-water cycle shows that unit efficiency improves with a reduction in the condenser temperature. A fuller discussion of this point appears in the previous section on lithium bromide-water cycle absorption units.

Fig. 10 shows the performance of an ammonia-water cycle unit.

Influence of Chilled Water Temperatures

Further analysis of the ammonia-water cycle shows the advantage of maintaining the chilled water temperature as high as the load will permit. The previous section on the lithium bromide cycle includes an appropriate discussion.

Chilled water temperatures suitable for any air-conditioning application are available from ammonia-water cycle units. (See Fig. 10.)

By extending the pressure through which the cycle operates the ammonia-water cycle may be used to produce very low temperatures (−50 F) for industrial and process applications. This low temperature system is sometimes used as an ammonia recovery unit in chemical process work.

Influence of Temperature of the Heat Source

The smaller sizes of ammonia-water cycle absorption equipment in use are operated *on-off*. The temperature of the heat source is immaterial in this type of operation; the unit merely runs a greater or lesser portion of the time, depending upon the load. Direct firing is ideal for applications of this type, generally used in residences.

Low temperature ammonia-water cycle equipment for industrial work generally use waste heat (steam). The temperature of the heat source is used here to control the output of the unit. A discussion of this may be found in the previous section on the lithium bromide-water cycle.

BASIC ABSORPTION EQUIPMENT

The components of absorption systems are, in effect, stationary heat exchangers; the only moving parts on such units may be the solution, refrigerant, and chilled water pumps. These basic components may be arranged into a number of shells, depending upon the requirements of the situation. Units are available having one or more shells and auxiliary vessels.

Evaporators and Coolers

Evaporators perform the same function and in a similar manner in an absorption unit as they do in a compression unit: they transfer heat from the material to be cooled (water, air, or brine) to the refrigerant. There are two basic types of evaporators: dry and flooded. In the dry evaporator the refrigerant is completely vaporized as it passes through; in the flooded evaporator only a portion of the refrigerant is evaporated. A surge tank is required to separate the vapor from the liquid. The liquid is returned to the evaporator, while the vapor continues on in the cycle. In an absorption unit, the absorber attracts only refrigerant vapor, in effect, operating the evaporator as a dry evaporator. If an abnormal condition should cause liquid refrigerant to be carried over to the absorber, no physical harm would be done; the unit capacity would be reduced temporarily until the absorber solution could be restored to the proper concentration. It makes no difference to the operation of the evaporator whether the refrigerant is inside or outside the coil.

The evaporator and the cooler are one and the same component. The heat required to evaporate the refrigerant is obtained by cooling the material on the other side of the coil or tube. Coolers used with absorption units may be used as: (1) direct air coolers, and (2) water chillers.

1. *Air coolers.* When direct air cooling is utilized, the refrigerant is inside the coil and the air passes over the coil. Cooling and dehumidification are a function of the coil geometry and the temperatures of the air and coil. The coil surface may be smooth or finned. Smooth-surfaced coils require greater surface than the finned coil. The finned coil causes a greater pressure drop. The fins, in addition, must be placed far enough apart to prevent retention of moisture which is condensed from the air.

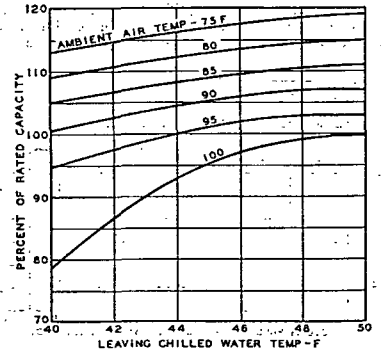

Fig. 10 ..... Performance Characteristics of an Ammonia-Water Cycle Water Chiller

2. *Water chiller.* When the machine is designed as a water chiller, the refrigerant is outside the coil, and the water to be chilled is inside the coil. The coil may be submerged in the refrigerant or the refrigerant may be sprayed over the coils in a thin film. A system chilled water pump, separate from the absorption machine, is required to circulate the chilled water through the evaporator coils, and thence to the remainder of the air conditioning system.

Condensers

Condensers for liquefying the refrigerant are of three types: (1) air-cooled, (2) water-cooled, and (3) evaporative. These three categories are identical to those used in other refrigeration systems.

1. *Air-cooled.* Air-cooled condensers first became popular on self-contained room air conditioners; and they are now used exclusively on this type of equipment.

The conventional air-cooled condenser is a fin-tube coil across which a fan blows air. The hot refrigerant from the generator enters the coil at the top, is condensed, and flows to a receiver or accumulator. Air-cooled condensers require a well ventilated, unobstructed location to obtain a constant supply of ambient air.

The principal advantages of air-cooled condensers are simplicity, and low operating and maintenance costs.

2. *Water-cooled.* Where an adequate supply of suitable water is available and its cost is not prohibitive, and where there are no legal restrictions against its use, the water-cooled condenser is preferred because of its superior performance. The temperatures of ground water and city water are, in general, too low to be used directly with absorption equipment since manufacturers specify minimum entering condenser water temperatures. Cooling water from the condenser discharge may be blended with the incoming water to maintain the water temperature to the absorber above the specified minimum.

An increased recognition of the growing water shortage in the United States has led to increased restrictions on the use of city water for air conditioning and refrigeration purposes. As a result, cooling towers are in almost universal use with water cooled condensers. Absorption air conditioning equipment has twice the heat rejection of compression type equipment, but does *not* require a tower twice as big.

A greater temperature rise in the condenser water temperature is economically feasible in absorption air-conditioning units. The attendant higher temperature of the water entering the tower results in a higher heat dissipation rate for a given tower.

The temperature of cooling water leaving the tower is a direct function of wet-bulb temperature. Because the maximum load on the system may coincide with maximum wet-bulb temperature, the air conditioning unit may, at such times, operate under adverse conditions, with a reduced efficiency. In many areas, this combination of adverse conditions occurs for only about 5 percent of the entire cooling period, and can be disregarded as an important factor in establishing yearly operating costs. Cooling towers are more completely discussed in Chapter 46.

3. *Evaporative.* The evaporative condenser, provides another means of conserving water. It is, in effect, a combined condenser and cooling tower in a single unit. A fan draws air across the condenser coil which is kept wet by a water spray.

The evaporative condenser requires a well ventilated, unobstructed location to obtain a constant supply of air. Its performance characteristics are similar to those of cooling towers. Chapter 42 contains additional information on evaporative condensers.

Absorbers

The absorber is a surface contact vessel where the refrigerant vapor can come into contact with, and be absorbed by, the concentrated absorbent. Heat is released in the process, and cooling coils are placed in the absorber to remove this heat of solution. Absorbers are of two types: (1) submerged coils, where the cooling coils are submerged in the mass of absorbent, or (2) spray or film distribution, where the absorbent solution is distributed over the cooling coils in a thin film or spray. The diluted absorbent collects in the absorber sump. In small units, gravity circulates this dilute solution to the generator; in large units, a solution pump is used.

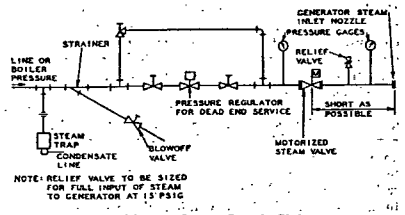

Fig. 11 .... Steam Supply Piping

Generators

Generators are heat exchangers using the heat to boil the refrigerant out of the dilute solution, to re-concentrate it. Generators may be of two types: directly or indirectly heated. Directly heated generators burn fuel within the unit to produce the required heat; the flue gases pass through tubes in the generator to boil the dilute solution. Indirectly heated generators use steam, hot water, or hot gases to boil the solution. The steam or hot water may be waste from other processes, or it may be produced in a companion low pressure boiler.

The generator may be designed to operate with submerged coils or tubes or with spray or film distribution, just as does the absorber.

When the generator is directly heated, provision must be made for gas and flue connections. If the unit is installed indoors, provisions must also be made for combustion air. Refer to ASA Standard Z21.30-1964, *Installation of Gas Appliances and Gas Piping*.

When the generator is indirectly heated, the supply piping, steam or water, should be designed in accordance with good piping practice. When steam supply pressure is above 12 psig, a pressure reducing station suitable for dead-end service should be installed. Fig. 11 shows an arrangement of the fittings generally used on a steam supply line; in addition, a second steam trap should be placed in the condensate line from the condenser. In high temperature water applications, the water flow control valve may be installed either at the inlet or outlet of the generator.

Control of Generator and Absorber

Smaller unitary machines, which are direct fired, meet load variations through on-off operation or by step-input through self-contained water temperature controls. As design chilled water temperature is approached, automatic gas controls switch to lowered input settings to match capacity. Large machines meet load variations by varying the rate of reconcentration of absorbent solution. A thermostat located in the chilled water line leaving the evaporator senses load changes through changes in the water temperature. This thermostat controls either: (1) an automatic steam valve that varies steam flow to the generator, (2) an automatic solution valve that varies the rate of flow of dilute solution to the generator, or (3) the rate of flow of dilute solution to the generator and an automatic steam valve. When a decrease in load causes a drop in the leaving chilled water temperature: