minimum flow rates. Factors to be considered in selection are freedom from plugging, the effect on water elimination from the discharge air stream, and available pump characteristics.

Centrifugal pumps of moderate head are in general use. The water passages of such pumps makes them adaptable to handling of extraneous matter found in open recirculating systems.

Continuous bleed-off, with rates based on the condenser evaporation rate and the hardness of the make-up water, are necessary to prevent an increase in the concentration of solids and consequent precipitation of scale on the coil. Scale decreases the heat transmission through the coil surface and may reduce the air flow. A bleed line from the pump discharge or a means of removing a portion of the water draining from the coil may be used.

Air Flow

Although gravity circulation is possible, most evaporative condensers utilize forced circulation with a fan to either blow or draw air through the unit (see Fig. 26).

The draw-through type provides more even air distribution over the coil, but, unless the elimination of moisture is completely effective, the carryover of water particles will tend to deposit scale on the fan blades, thereby causing operational difficulties. The location of bearings and the materials used in the fan construction should be given consideration because of the high humidity of the leaving air stream.

Effective elimination of moisture from the leaving air stream is essential to prevent projection of mist which can deposit moisture on surrounding surfaces. This is accomplished by eliminator plates, which are closely spaced surfaces providing abrupt changes in air flow direction. Moisture particles are deposited on these surfaces and drained back to the sump.

If the air inlet is located near the sump, louvers may be required to prevent water from splashing out of the unit as it drains off the coil.

Heat Transfer Process

The temperature relationship between the refrigerant in the coil, the water temperature, and the air wet-bulb temperature at different points within the evaporative condenser is shown in Fig. 27. The heat transfer in an evaporative condenser occurs in two different processes.

Heat first flows from the condensing refrigerant through the coil surface and water film to the air-water interface. This heat flow depends upon the temperature difference and can be expressed as:

$$Q = UA\Delta t_m \qquad (5)$$

where

Q = heat flow, Btu per hour.
U = coefficient of heat transfer, Btu per (hour) (square foot) (Fahrenheit degree).
A = coil surface area, square feet.
Δt_m = mean effective temperature difference between refrigerant and air-water interface, Fahrenheit degrees.

Between the air-water interface and the air stream passing over the condenser, there is both a heat transfer and a mass transfer of water vapor. The mass transfer is accompanied by an evaporation of the water so that the latent heat of vaporization is supplied to this water.

As shown in Chapter 5, Mass Transfer, the sensible and latent transfer can be combined with the enthalpy potential as the driving force for both, such that:

$$Q = K_m A \Delta h_m \qquad (6)$$

where

Δh_m = mean effective enthalpy difference between the air stream enthalpy and the interface saturation state enthalpy.

Derivation of Equation 6 relies upon the validity of the Lewis relationship:

$$h_m/K_m = c_{pm} \qquad (7)$$

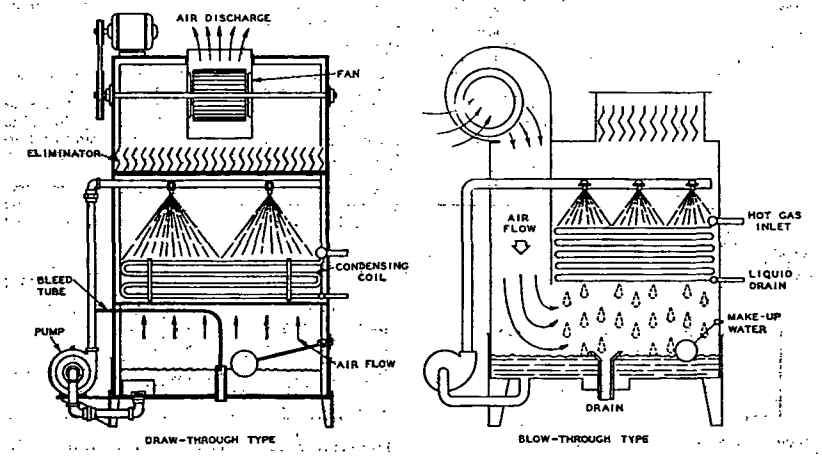

Fig. 26 .... Functional View of Evaporative Condenser

This relationship states that the ratio of the air side heat transfer coefficient h_a to the mass transfer coefficient K_m equals the humid specific heat of the air stream c_{pm} in Btu per (Fahrenheit degree) (pound of dry air). The Lewis relationship is used to compute mass transfer coefficients from a knowledge of the air film coefficients and the specific heat.

Values for U can be calculated by the resistance concept from data on refrigerants condensing inside tubes, water sprayed over tubes, and tube conductivity. Because inadequate data are available on the first two items, U generally is determined experimentally.

Values for K_m generally are determined experimentally. A method of calculating K_m is given in Chapter 5.

Establishing U and K_m experimentally involves difficult interface temperature measurements. An indirect means is available. Referring to Fig. 28, plot the entering and leaving air specific enthalpy on a psychrometric chart and extend the line connecting them to intersect the saturation line. This establishes an average effective interface temperature t_{im}. U can now be determined from Equation 5 if it is assumed that:

$$\Delta t_m = t_{sm} - t_{im} \qquad (8)$$

where

t_{sm} = average saturated condensing temperature, Fahrenheit.
t_{im} = average effective interface temperature, Fahrenheit.
K_m = can be determined from Equation 6 if

$$\Delta h_m = h_{im} - h_{am} \qquad (9)$$

where

h_{im} = specific enthalpy of air at t_{im}, Btu per pound.
h_{am} = average specific enthalpy of air stream, Btu per pound.

A very complex heat transfer mechanism is involved. In addition to being sensitive to the normal variables of loading and mass flow, transfer rates are also sensitive to changes in entering air wet-bulb temperatures which affect water film temperature gradient and the accuracy of the calculated mean effective specific enthalpy difference.

Comparison of Atmospheric Heat Rejection Equipment

Heat may be rejected to the atmosphere from condensing refrigerant by an evaporative condenser, a water-cooled condenser, a combination of water-cooled condenser and cooling tower, or an air-cooled condenser.

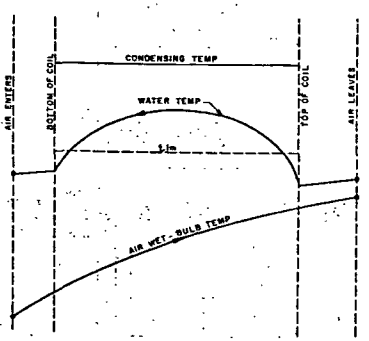

Fig. 27 .... Heat Transfer Diagram for an Evaporative Condenser

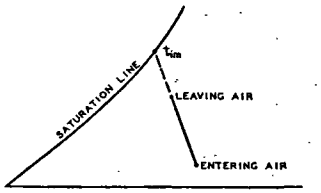

Fig. 28 .... Psychrometric Diagram for an Evaporative Condenser

When evaporation is part of the heat transfer process, ambient air has a high heat absorbing capacity. Therefore, by comparison with an air-cooled condenser, an evaporative condenser has a lower condensing temperature and compactness, due to lower requirements of coil surface and air flow.

While both the water-cooled condenser-cooling tower combination and the evaporative condenser operate with evaporation of water, there is an additional non-evaporative transfer of heat to the circulating water in the water-cooled condenser-cooling tower combination which raises its operating temperature levels and heat transfer surface requirements.

Ratings

Manufacturers customarily rate evaporative condensers in tons of refrigeration as a function of entering air wet-bulb and saturated condensing temperature. Ratings specify a model size, refrigerant, constant air flow, water flow, and suction pressure. Rating in terms of refrigeration effect is possible by specifying the operating conditions, and thus the heat rejection to the condenser. This effectively describes the refrigeration system of which the evaporative condenser is a part. This operating condition is likely to be based on the rating condition set up by ARI to establish the nominal capacity of a unit.

Fig. 29 shows typical generalized performance curves where the 100 percent value is the unit nominal capacity. These curves are usually drawn for a specific suction pressure. Performance at saturated suction pressures other than the constant rating value is determined by the use of correction factors which are sometimes supplied in a tabular form. Figs. 1, 2, or 3 may also be used to correct for suction pressures other than the base suction pressure used on rating curves similar to Fig. 29.

Accessory Coils

Some manufacturers produce subcooling and desuperheat coils.

A subcooling coil may be placed on the entering air side of the condensing coil to remove heat from condensed liquid refrigerant. This increases refrigeration system capacity and is useful in preventing flashing of refrigerant ahead of the expansion device if an evaporator location is elevated above the condenser. The design differs from that of the condensing coil due to the lower heat transfer rate on the refrigerant side.

A desuperheat coil may be placed on the leaving air side of the condensing coil to remove heat from superheated refrigerant vapor, prior to condensing. Its greatest value is in