t_{dp2} = dew-point of air leaving coil, Fahrenheit degrees.
t_r = average refrigerant temperature, Fahrenheit degrees.
t_s = average temperature of external surface of coil, Fahrenheit degrees.
Δt_m = mean temperature difference between fluid in coil and air passing over coil, Fahrenheit degrees.
NOTE: Δt_m is usually the logarithmic mean.
Δt_o = logarithmic mean temperature difference between air and coil surface.
U = overall coefficient of heat transfer, Btu per (hour) (square foot of external coil surface) (Fahrenheit degrees temperature difference between fluid in coil and air flowing over coil).
V = water velocity, feet per second.
Z = a constant for use in Equation 8 obtained by plotting on logarithmic coordinates G against values of f_o.
NOTE: Numerical subscripts refer to condition entering and leaving respectively.

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CHAPTER 36
REFRIGERATION

Refrigeration Theory: Definitions and Basic Concepts, Refrigerants, Vapor Compression Refrigeration Cycles, Clearance and Volumetric Efficiency, Complex Refrigeration Cycles, Air Cycle, Steam Jet, Absorption and Ice Systems, Heat Pump; Basic Refrigeration Equipment: Compression Machines, Condensers, Evaporators and Coolers; Refrigeration Controls, Piping and Accessories; Equipment Characteristics and Selection

WITH the increasing use of all-year comfort air conditioning installations, the importance of refrigeration to the air conditioning engineer has been greatly magnified. The details of equipment operation, maintenance and design remain problems for the refrigeration engineer, but the air conditioning engineer does retain a responsibility to the customer which requires on his part some knowledge of the different refrigeration cycles and the relative merits of each. In order to assist in meeting this need, the present chapter has been divided into four parts, the first covering the fundamental technical relationships which govern the selection and analysis of an operating cycle, the next two presenting brief discussions of basic refrigerating equipment and auxiliaries, and the last, information on selection criteria.

REFRIGERATION THEORY

Definitions and Basic Concepts

The *ton of refrigeration* is a quantity unit which originated in the days when harvested ice was the principal source of summer cooling. By definition the *ton* is the cooling effect realized when one ton of 32 F ice melts to water at 32 F; since the latent heat of fusion of ice is 144 Btu per pound, the *ton* represents a unit cooling effect of 144 × 2,000 = 288,000 Btu. In common practice the ton is usually considered a rate (rather than quantity) unit, and is taken as 288,000 Btu per day (24 hours), or 12,000 Btu per hour, or 200 Btu per minute. Thus for air conditioning calculations, the size of the requisite refrigeration machine, expressed in tons, can be obtained by dividing the heat gain of the structure, expressed in Btu per hour, by 12,000. In equation form:

$$H_t = (\text{Btu per hour heat gain}) \div 12{,}000 \quad (1)$$

where

H_t = load in tons.

The *working substance*, or *refrigerant*, is the fluid which carries heat through the refrigeration cycle from the evaporator, where heat enters the refrigerant, to the condenser where the heat is discharged to some cooling medium. The great majority of modern refrigeration systems use a liquefiable vapor as the working substance. By altering the pressure of the refrigerant its boiling temperature is changed, allowing the material to *boil* in the evaporator at a temperature sufficiently lower than that of the conditioned space, to insure maintenance of an effective heat transfer rate from