11.590 = 2588.4 lb per hour. This *ventilating air* is to be mixed adiabatically with *inside air* containing 7029.9 − 2588.4 = 4441.5 lb of dry air per hour; therefore, the humidity ratio of the mixture must be (2588.4 × 0.0006298 + 4441.5 × 0.007910) ÷ 7029.9 = 0.005229.

The condition line crosses the saturation curve at 50.86 F where the enthalpy is 20.782 and the humidity ratio is 0.007910. This is the state point to be reached by adiabatic saturation of the mixture of *ventilating air* and *inside air* with recirculated spray water. Accordingly, the state point of the mixture must lie on the 50.86 F thermodynamic wet-bulb line so that its enthalpy must have the value,

$$h = 20.782 - (0.007910 - 0.005229) \times 18.97 = 20.731$$

This requires that the enthalpy of the preheated *ventilating air* have the value,

$$h = (7029.9 \times 20.731 - 4441.5 \times 25.451) \div 2588.4 = 12.632$$

Since the humidity ratio of the preheated *ventilating air* is known to be 0.0006298, its temperature is readily found to be 49.75 F.

The quantity of heat required for preheating the *ventilating air* is 2588.4 × (12.632 − 0.668) = 30,968 Btu per hour; that to be added to the *supply air* is 7029.9 × (33.986 − 20.782) = 92,823 Btu per hour; the energy added with the spray water is 7029.9 × 18.97 × (0.007910 − 0.005229) = 357 Btu per hour; that introduced into the

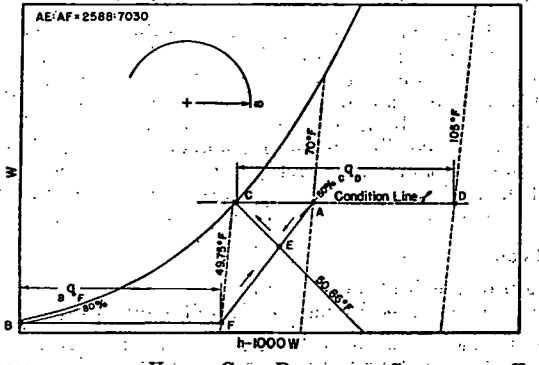

FIG. 11. ILLUSTRATION OF USE OF GOFF DIAGRAM IN SOLUTION OF EXAMPLE 14

system with the *ventilating air* is 2588.4 × 0.668 = 1729 Btu per hour; that carried out of the system with the *inside air* displaced by the *ventilating air* is 2588.4 × 25.451 = 65,877 Btu per hour; therefore, the net energy added to the system is 30,968 + 92,823 + 357 + 1729 − 65,877 = 60,000 Btu per hour as required.

On the Goff Diagram, Fig. 11, point A is the state point of the *inside air*. The condition line is horizontal so that point D is the state point of the *supply air*. The condition line crosses the saturation curve at point C so that the state point of the mixture of preheated *ventilating air* and *inside air* before adiabatic saturation with recirculated spray water must lie somewhere on the thermodynamic wet-bulb line through C. The state point of the *ventilating air* is point B, hence that of the preheated *ventilating air* must lie somewhere on the horizontal line through B. Its exact location is determined graphically by finding the straight line AF which is cut by the thermodynamic wet-bulb line through C into two segments such that AE:AF = 2588.4:7029.9. The length of the line BF is the quantity of heat required for preheating the *ventilating air* per pound of dry air; the length of the line CD is the quantity of heat to be added to the *supply air*, per pound of dry air.

WET-BULB TEMPERATURES BELOW 32F

A condition in which the water evaporating from the wick of a wet-bulb thermometer remains liquid at 32 F or lower is one of metastable equi-

librium and should therefore not be expected to occur in practice. The evidence that it does sometimes occur appears to be indirect and inconclusive. Stable equilibrium requires that the water freeze at 32 F or lower and is the condition to be expected in practice. On the Goff Diagram the lines of constant thermodynamic wet-bulb temperature have been drawn for stable equilibrium only. In other words it has been assumed that the water evaporating from the wick of the wet-bulb thermometer freezes when its temperature falls to 32 F or lower.

Example 15. Find the temperature at which dry air has a thermodynamic wet-bulb temperature of 32 F.

Solution. If it is assumed that the water evaporating from the wick of the wet-bulb thermometer remains liquid, the specific enthalpy of the dry air must have the value

$$h_a = 11.758 - 0.04 \times 0.003788 = 11.758$$

corresponding to which the temperature is 48.95 F. On the other hand if it is assumed that the water freezes, the specific enthalpy of the dry air must have the value,

$$h_a = 11.758 + 143.36 \times 0.003788 = 12.301$$

corresponding to which the temperature is 51.21 F. The second assumption is the assumption of stable equilibrium and should be expected to represent the actual situation.

The corresponding answer, namely 51.21 F, is the one given by the Goff Diagram at intersection of 32 F thermodynamic wet-bulb and 0 per cent saturation.

DALTON'S RULE

As stated in the introduction the thermodynamic properties of moist air have hitherto been obtained from those of dry air and water vapor separately by application of Dalton's Rule. Actual departures from the rule are due principally, but not entirely, to intermolecular forces; therefore, in order to apply the rule with any measure of consistency it is necessary to idealize the situation by assuming that the effects of such intermolecular forces are negligible and that both the dry air and the water vapor behave like perfect gases. Making this assumption, the volume v_T occupied by n_a mols of dry air at temperature T and pressure p_a is $v_T = n_a RT/p_a$ while that occupied by n_w mols of water vapor at the same temperature but at pressure p_w is $v_T = n_w RT/p_w$. According to Dalton's Rule, if the dry air and water vapor are mixed, each occupies the whole volume of the mixture at the temperature of the mixture and the pressure of the mixture is the sum of the individual pressures. Mathematically,

$$v_T = \frac{n_a RT}{p_a} = \frac{n_w RT}{p_w} = \frac{(n_a + n_w)RT}{p} \tag{12}$$

It follows from these equations that the so-called *partial* pressure of each constituent is its mol-fraction times the observed pressure of the mixture; thus, for water vapor,

$$p_w = \frac{n_w}{n_a + n_w} p \tag{13}$$

and similarly for dry air. Equation 13 may be regarded as the Dalton Rule, definition of partial pressure in terms of the observable terms n_a, n_w, p.

The humidity ratio W is the mol ratio n_w/n_a times the ratio of molecular