50 per cent saturation) in the direction given by the protractor for a specific enthalpy of 3.06 Btu/lb$_w$.

If air is saturated adiabatically with spray water which is recirculated, the water will ultimately assume a temperature such that the air is brought to saturation at exactly the same temperature; that is, the water will assume the thermodynamic wet-bulb temperature of the air.

Example 11. Air at 75 F and 60 per cent saturation is saturated adiabatically with recirculated spray water. Find the resulting temperature and the weight of water added per pound of dry air.

Solution. In view of the foregoing remarks the solution of this example reduces to the determination of the thermodynamic wet-bulb temperature of the air. Its humidity ratio is $0.60 \times 0.01882 = 0.01129$; its enthalpy is $18.018 + 0.60 \times 20.59 = 30.372$; Equation 7 defining thermodynamic wet-bulb temperature becomes

$$h_s^* - (W_s^* - 0.01129)h_w^* = 30.372$$

At 65 F the value of the lefthand member is 29.995; at 66 F its value is 30.746; by interpolation the thermodynamic wet-bulb temperature is 65.51 F where the humidity

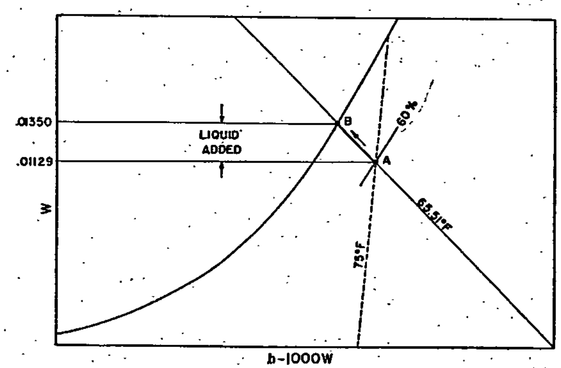

Fig. 8. Illustration of Use of Goff Diagram in Solution of Example 11

ratio at saturation is 0.01350; consequently the weight of water added is $0.01350 - 0.01129 = 0.00221$ lb per pound of dry air.

On the Goff Diagram, Fig. 8, the process is represented by the line AB which is a segment of the 65.51 F thermodynamic wet-bulb line. The difference between the ordinates at B and at A is the weight of water added per pound of dry air.

Cooling Load

The problem of calculating the cooling load for an air conditioned space usually reduces to the determination of the quantity of *inside air* that must be withdrawn and the condition to which it must be brought by suitable processing so that its return to the conditioned space will have the net effect of removing given amounts of energy and water from the space.

Let M denote the weight of dry air withdrawn with *inside air* per hour. With it will be withdrawn energy of amount Mh_1 and water of amount MW_1 per hour, where h_1 and W_1 denote the enthalpy and humidity ratio of the *inside air*, respectively. The weight of dry air returned with the *conditioned air* will necessarily be the same as that withdrawn with the *inside air*, but with it must be returned a smaller quantity of energy Mh and a smaller quantity of water MW. Let ΔQ and ΔW denote the given

amounts of energy and water to be removed from the conditioned space per hour; then

$$Mh = Mh_1 - \Delta Q$$
$$MW = MW_1 - \Delta W$$

Eliminating M and letting q denote the ratio of energy removed to water removed, that is, $q = \Delta Q/\Delta W$,

$$\frac{h - h_1}{W - W_1} = q \quad (11)$$

according to which: *all possible states for the conditioned air lie on a straight line on the Goff Diagram passing through the state point of the inside air in the direction specified by the numerical value of the ratio q.* This line is called the *condition line* for the given problem. If the condition line crosses the saturation curve, the point of intersection is called the *apparatus dew-point* for the given problem.

The protractor of the Goff Diagram facilitates the drawing of the condition line and the locating of the apparatus dew-point. For this purpose the numerical value of the ratio q is to be regarded as a value of the *specific enthalpy of water added, Btu per pound.*

Example 12. A condition of 80 F dry-bulb, and 67 F thermodynamic wet-bulb, is to be maintained in a clothing store, outside conditions being 95 F dry-bulb, and 75 F thermodynamic wet-bulb. The energy gain from normal heat transmission is estimated at 16,000 Btu per hour, that from solar radiation at 48,000 Btu per hour. The energy generated by lights, fans, etc. is estimated at 13,900 Btu per hour. The ventilation requirement is 30,000 cu ft per hour. The number of occupants is 50. Find the apparatus dew-point.

Solution. The properties of *inside air* and *outside air* are readily calculated from the data in Table 1, see especially Example 2.

		Inside Air	Outside Air
μ	=	0.5024	0.3848
h	=	31.514	38.408
W	=	0.01122	0.01413
v	=	—	14.296

The weight of dry air entering with the *ventilating air* is 30,000/14.296 = 2098.5 lb per hour which brings with it energy of amount $2098.5 \times 38.408 = 80.595$ Btu per hour and water of amount $2098.5 \times 0.01413 = 29.659$ lb per hour.

The weight of dry air displaced from the store by the *ventilating air* is 2098.5 lb per hour which takes with it energy of amount $2098.5 \times 31.514 = 66,132$ Btu per hour and water of amount $2098.5 \times 0.01122 = 23.541$ lb per hour.

Each occupant may be regarded as a normal person standing at rest and evaporating (1386 grains) 0.198 lb of water per hour (value obtained by interpolation between Curves D and C Fig. 7, Chapter 12) at about 79 F. From this source there is water of amount $50 \times 0.198 = 9.90$ lb per hour and energy of amount $9.90 \times 1095.7 = 10,847$ Btu per hour added to the conditioned space. In addition each occupant loses 225 Btu per hour by conduction, convection, and radiation, making a total for 50 persons of 11,300 Btu per hour.

The net energy gain is $16,000 + 48,000 + 13,900 + 80,595 - 66,132 + 10,847 + 11,300 = 114,510$ Btu per hour. The net water gain is $29.659 - 23.541 + 9.90 = 16.018$ lb per hour. Accordingly the direction of the condition line is fixed by the ratio, $q = 114,510 \div 16.018 = 7148.8$ Btu per pound of water.

On the Goff Diagram, Fig. 9, the direction of the condition line is given by the protractor for a *specific enthalpy of water added* of 7148.8 Btu per pound. The line itself passes through the state point of the inside air and intersects the saturation curve at the apparatus dew-point.

According to Equation 11 the enthalpy h_s and humidity ratio W_s at the apparatus dew-point must satisfy the equation

$$7148.8W_s - h_s = 7148.8 \times 0.01122 - 31.514 = 48.681$$