

= 80,300 Btu per hour and water of amount $2099 \times 0.01402 = 29.43$ lb per hour. An equal weight of dry air must be displaced from the store.

The thermodynamic properties of Inside Air are: $h_1 = 31.41$ Btu per pound dry air, and $W_1 = 0.01115$ lb water per pound dry air. Therefore, the energy leaving the store with the Inside Air displaced by the Ventilating Air is $2099 \times 31.41 = 65,900$ Btu per hour; the weight of water leaving is $2099 \times 0.01115 = 23.41$ lb per hour.

Each occupant may be regarded as a *normal person standing at rest* and therefore evaporating 0.198 lb of water per hour at about 79 F (Table 3, Chapter 2). Therefore the energy added to the store by such evaporation is $50 \times 0.198 \times 1096.2$ (enthalpy of saturated vapor at 79 F, Table 8) = 11,000 Btu per hour, the weight of water added being $50 \times 0.198 = 9.90$ lb per hour. In addition each person loses 225 Btu of heat per hour by conduction, convection and radiation, making a total for 50 persons of 11,300 Btu per hour.

An energy balance shows a net gain of $16,000 + 48,000 + 13,900 + 80,300 - 65,900 + 11,000 + 11,300 = 114,600$ Btu per hour. A water balance shows a net gain of $29.43 - 23.41 + 9.90 = 15.92$ lb per hour. The slope of the condition line is determined by the ratio $q = 114,600 \div 15.92 = 7205$ Btu per pound of water. The temperature at which the condition line crosses the saturation curve is 58.02 F which is, therefore, the apparatus dew-point. This temperature is found by solving Equation 25,

$$\frac{31.41 - h_s}{0.01115 - W_s} = 7205$$

The fact that a trial-by-error solution is required is not a serious complication.

In order to calculate the cooling load it will be assumed that the air conditioning process consists of cooling and separating. The thermodynamic properties entering the calculations are:

	Inside Air	After Cooling	After Separating
t	80.0	58.02	58.02
W	0.01115	0.01115	0.01027
h	31.41	25.086	25.063

It follows that the refrigeration required is $31.41 - 25.086 = 6.324$ Btu per pound dry air. But the weight of dry air involved is $114,600 \div (31.41 - 25.063) = 18,056$ pounds per hour; hence the total refrigeration required, namely, the cooling load, is $18,056 \times 6.324 = 114,185$ Btu per hour, or $114,185 \div 12,000$ (Btu extracted per hour per ton of refrigeration) = 9.49 tons.

The weight of water removed is $18,056 \times (0.01115 - 0.01027) = 15.92$ lb per hour as required. This water is removed as liquid at 58.02 F and therefore removes energy of amount 15.92×26.1 (specific enthalpy of liquid water at 58.02 F, Table 6) = 415 Btu per hour. This plus the refrigeration accounts for the total removal of 114,600 Btu per hour as required.

In practice the point at which the condition line crosses the saturation curve may dictate an excessive number of air changes. If so, it may be necessary to cool to a lower temperature. But, if the requirements of the problem are to be exactly met both as regards removal of energy and removal of water, the mixture returned to the conditioned space must then contain a certain amount of liquid. In other words, its state point must lie on the condition line.

It may be that the condition line does not cross the saturation curve at all, in which case the apparatus dew-point as defined previously does not exist. In this case the actual dew-point of the apparatus can be set at any temperature provided the air is then reheated to a point on the condition line before being returned to the conditioned space.

In actual practice it is rarely possible to obtain complete saturation at the dew-point temperature at which the apparatus is set. This may be due to insufficient contact; or a portion of the air may be deliberately

by-passed. But either is equivalent to reheating and, if the final condition still lies on the condition line, the requirements of the problem can be exactly met.

Heating Load

The idea of the condition line is also useful in calculating heating load problems. Its use is best illustrated by means of an illustrative example.

Example 20. The clothing store of Example 19 is to be maintained at 70 F dry-bulb, 50 per cent saturation in winter, with outside design conditions being 0 F dry-bulb, 80 per cent saturation. In order to avoid window condensation with the given inside and outside conditions, double doors and windows are provided. Show windows are sealed. The ventilation requirements of 10 cfm per person for 50 persons, or 30,000 cfh, will build up a slight pressure. For these three reasons, infiltration is reduced to a negligible amount. The normal heat transmission through walls, partition, floor, roof, glass, and doors is estimated at 73,750 Btu per hour. Considerable energy is gained from lights and occupants, but only after the store is raised to the proper conditions; hence this item should be disregarded in figuring the maximum heating load. Analyze the problem as shown in Fig. 9.

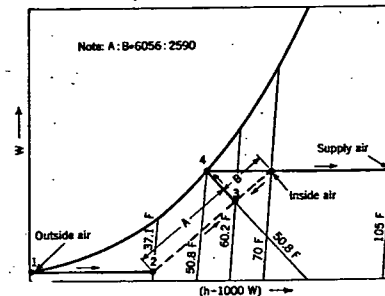


FIG. 9. DIAGRAM ILLUSTRATING EXAMPLE 20

Solution. The thermodynamic properties of Outside Air are: $v = 11.59$ cu ft per pound of dry air, $h = 0.67$ Btu per pound of dry air, and $W = 0.00063$ lb water per pound of dry air. Accordingly, the Ventilating Air introduces dry air of amount $30,000 \div 11.59 = 2590$ lb per hour, energy of amount $2590 \times 0.67 = 1,730$ Btu per hour, and water of amount $2590 \times 0.00063 = 1.63$ lb per hour. Since infiltration is negligible, none of the Ventilating Air will be admitted directly to the store, but will enter with the Supply Air after having been processed in the air conditioning apparatus. Nevertheless, it displaces an equal weight of dry air from the store.

The thermodynamic properties of Inside Air are: $v = 13.51$ cu ft per pound of dry air, $h = 25.38$ Btu per pound of dry air, and $W = 0.00787$ lb water per pound of dry air. Accordingly, the Ventilating Air displaces energy of amount $2590 \times 25.38 = 65,730$ Btu per hour, and water of amount $2590 \times 0.00787 = 20.38$ lb per hour.

Using these data, it appears that the total energy to be added to the store is $73,750 + 65,730 = 139,480$ Btu per hour while the total water to be added is 20.38 lb per hour. But it would be a mistake to determine the condition line by the ratio of these two quantities, since the dry air returned with the Supply Air exceeds that recirculated from the store by the amount introduced with the Ventilating Air. It is correct, however, to lump the Recirculated Air and the Displaced Air together, since both leave the store under the conditions of Inside Air. Then the Supply Air must return more energy to the store than both of these remove by an amount equivalent to the normal heat transmission or 73,750 Btu per hour, and more water by amount zero. The ratio of these two quantities determines the condition line. Since the ratio is infinite, the condition line is