horizontal on the Mollier Chart; in other words, the humidity ratio of the Supply Air must be the same as that of Inside Air.

Good practice is to limit the temperature of the Supply Air to 105 F. The condition line crosses the 105 F isotherm at 15.6 per cent saturation. The thermodynamic properties of the Supply Air are: $h = 33.91$ Btu per pound of dry air, and $W = 0.00787$ lb water per pound of dry air. Accordingly, the weight of dry air to be recirculated is $73{,}750 \div (33.91 - 25.38)$ minus $2590 = 6056$ lb per hour.

The dew-point temperature of the Supply Air is the same as that of Inside Air, namely, 50.8 F. A suitable conditioning process is to (see Fig. 9): (1-2) preheat the Ventilating Air to temperature t; (2-3) mix it adiabatically with Recirculated Air; (3-4) saturate the resulting mixture adiabatically with recirculated spray; (4-5) reheat to 105 F on the condition line. The temperature t must be chosen so that, after preheating, the wet-bulb of the Ventilating Air is 50.8 F.

The determination of the preheating temperature t using the data of Table 6, though straightforward, is somewhat tedious. Graphical solution using the Mollier Chart is easier. The answer 37.1 F is obtained by drawing the line A + B so that the length of A is in proportion to the length of B as the weight of Recirculated Air 6056 lb is to the weight of Ventilating Air 2590 lb, and where this line crosses (1-2) temperature t results. The data needed to calculate the quantities of heat required for preheating and subsequent reheating may now be assembled.

	Outside Air	*After Preheating*	*After Mixing*	*After Adiabatic Saturation*	*After Reheating*
t	0	37.1	60.2	50.8	105.0
h	0.67	9.59	20.65	20.69	33.91
W	0.00063	0.00063	0.00570	0.00787	0.00787

The quantity of heat required for preheating is $2590 \times (9.59 - 0.67) = 23{,}100$ Btu per hour; and that required for reheating is $8646 \times (33.91 - 20.69) = 114{,}300$ Btu per hour.

A trial balance for the energy accounting may be made. The Ventilating Air brings in energy 1730 Btu per hour; the heat added by the preheating coil is 23,100 Btu per hour; the energy supplied by the spray is $(6056 + 2590) \times (20.69 - 20.65) = 340$ Btu per hour; the heat added by the reheating coil is 114,300 Btu per hour; and the total is 139,470 Btu per hour. This is in substantial agreement with the stated requirements of the problem.

The Ventilating Air brings in water of amount 1.63 lb per hour; the spray adds $(6056 + 2590) \times (0.00787 - 0.00570) = 18.76$ lb per hour; and the total is 20.39 lb which is in agreement with the stated requirements.

STEADY FLOW ENERGY EQUATION

It was previously stated that, in steady flow, the energy convected by the fluid at any section is the sum of (*a*) kinetic energy due to velocity; (*b*) gravitational energy due to elevation; (*c*) enthalpy due to the condition of pressure, temperature and composition of the fluid. A more detailed discussion of item (*a*) is in order.

Kinetic Energy

There are reasons to believe that the so-called *velocity pressure* h_v read by a Pitot tube is simply the kinetic energy per unit volume of the fluid immediately upstream from the tube, as application of Bernoulli's Equation suggests. Thus (see Equation 3, Chapter 35).

$$V = 1097.3 \sqrt{\frac{h_v}{d}} \qquad (26)$$

where

V = velocity, feet per minute.
h_v = velocity pressure, inches of water at 60 F.
d = density of fluid, pounds per cubic foot.

In the case of flow through a duct, the velocity pressure is found to vary considerably over the section and a traverse has to be made. The cross-sectional area of the duct is divided into a number of equal concentric areas, and measuring stations are located at centroidal points in each area along two perpendicular diameters. Usually the ultimate object is to determine an *average* velocity $\overline{V}$ from which the weight of fluid crossing the section per unit time can be obtained on multiplying by the cross-sectional area of the duct and by the density of the fluid. This is obtained by simply averaging the square roots of all measured velocity pressures as follows:

$$\overline{V} = \frac{1097.3}{\sqrt{d}} \left(h_v^{1/2} \right)_{av} \qquad (27)$$

where

$\overline{V}$ = average velocity, feet per minute.
$(h_v^{1/2})_{av}$ = arithmetic average of the square roots of all measured velocity pressures, inches of water at 60 F.

But the item of present importance is the *average kinetic energy* convected with each pound of fluid. Consistently with the previous discussion, this can be shown to be

$$\overline{KE} = 0.006678\, v \frac{(h_v^{3/2})_{av}}{(h_v^{1/2})_{av}} \qquad (28)$$

where

$\overline{KE}$ = average kinetic energy, Btu per pound.
v = specific volume, cubic feet per pound.
$(h_v^{3/2})_{av}$ = arithmetic average of the 3/2-powers of all measured velocity pressures, inches of water at 60 F.

If the velocity pressure were uniform over the section, Equations 27 and 28 could be combined to give

$$\overline{KE} = \left(\frac{\overline{V}}{13{,}430} \right)^2 \qquad (29)$$

But, it is interesting to note that if the velocity varies *parabolically* from zero at the walls to maximum at the center as it does in the case of purely viscous flow in a circular duct, *then the average kinetic energy is twice that given by* Equation 29.

Example 20. If 2000 cfm of air flows through an 8 in. diameter circular duct, find the average kinetic energy per pound of air.

Solution. The cross-sectional area of the duct is 0.349 sq ft; hence the average flow velocity is 5730 fpm. If the velocity were uniform over the section, the average kinetic energy would be $(5730 \div 13{,}430)^2 = 0.182$ Btu per pound. But it is more likely that the actual distribution of velocity would approximate that characteristic of viscous flow; hence the average kinetic energy would be more nearly $2 \times 0.182 = 0.364$ Btu per pound.

Gravitational Energy

The potential energy due to elevation Z (feet) above any convenient datum is simply $Z \div 778.3$ Btu per pound of fluid. In the case of moist air,