This wet-bulb or evaporation temperature is dependent upon the dry-bulb temperature and the moisture content, or upon the total heat of the air as indicated in the previous paragraph.

The effect of air velocity depends upon whether the flow of air is parallel to the surface or perpendicular to the surface elements. For a flow of air *parallel* to a horizontal surface

$$w = 0.093\left(1 - \frac{v}{230}\right)(e' - e) \quad \text{(approximately)} \tag{7}$$

where

w = pounds evaporated per square foot per hour.
v = velocity of atmosphere over surfaces in feet per minute.
e' = vapor pressure of the water corresponding to its temperature.
e = vapor pressure in the surrounding atmosphere.

For *transverse* flow, as across a tubular surface, the rate of evaporation is nearly doubled.

These relationships are indicated graphically on the chart, Fig. 2.

Since the difference in vapor pressures is substantially proportional to the difference between the wet and dry-bulb temperatures (*i.e.*, the wet-bulb depression) the rate of evaporation is also for case *two* substantially proportionate to the wet-bulb depression.

In case *two*, the rate of sensible heat transfer, from the air to the liquid to produce evaporation is substantially the same as the rate of heat transfer with the same type of surface, without moisture being present, but with the same temperature differences. In other words, the rate of heat transfer depends upon the temperature difference only, whether the surface is wet or not. For example, it has been shown that the rate of heat transfer with air flowing across staggered coils (transverse flow) may be represented by the formula:

$$U_t = \frac{1}{0.0447 + \frac{50.66}{v}} \tag{8}$$

where

U_t = heat transfer expressed in B.t.u per hour per square foot per degree difference in temperature between steam and air, for transverse flow.

At a velocity of 400 ft. per minute, $U_t = 5.8$, and at a velocity of 800 ft. per minute, $U_t = 9.3$.

Referring to Fig. 1, showing the rate of heat transmission by evaporation for different air velocities, it will be noted that for transverse flow there are 560 B.t.u. per hour per square foot transferred per inch difference of vapor pressure at a velocity of 400 ft. per minute and 910 B.t.u. per hour per square foot per inch difference in vapor pressure at a velocity of 800 ft. per minute. One inch of vapor pressure difference corresponds approximately to 95 deg. difference between the wet and dry bulb temperature. Dividing by 95, the value of 5.9 B.t.u. per square foot per degree difference in temperature is obtained for a velocity of 400 ft. per minute and 9.55 B.t.u. per square foot for a velocity of 800 ft. per minute.

It will be noted that for these two cases the heat transfer by evaporation per degree difference in temperature corresponds almost exactly with the heat transfer by convection coils. The similarity may be noted by comparing the formula for heat transfer in parallel flow where with

$$U_p = \frac{1}{0.026 + \frac{161}{v}} \tag{9}$$

the heat transfer by evaporation with parallel flow. The relationship will be seen to be very close in both cases and would indicate that the heat transfer by evaporation is actually brought about by a process of convection.

The difference in form of the two formulae may be due in part to errors in observation at the higher and lower velocities.

In cooling air and condensing out the moisture therefrom the heat transfer is considerably more rapid than when the air is dry and no moisture is condensed. In general the rate of heat transmission on the air side is increased an amount which is proportionate to the latent heat removed as compared with the sensible heat removed. That is, if the latent heat removed was 50 per cent of the sensible heat removed, then the conductivity of the surface in contact with the air would be increased approximately 50 per cent.

AIR CONDITIONING FOR INDUSTRIAL PROCESSES

Many materials take moisture from or give it up to the surrounding air depending upon its temperature and humidity. As moisture is absorbed the material will ordinarily become softer, more plastic and pliable. With a reversal of moisture flow comes a corresponding change in physical qualities. Economy requires that these physical qualities be maintained constant in order that high speed machinery may be permanently adjusted for the desired production.

When, for instance, looms were run by man power the conditions in a Lancastershire cellar were ideal for the manufacture of woolens and worsteds. Perhaps they would still be satisfactory with a single modern loom installed. But, if hundreds of these looms are crowded into a single room, the heat from the machinery—which may be sufficient to warm the building in severe weather—will raise the temperature and lower the relative humidity, thereby nullifying all advantages of climate. Thus, the development of the modern manufacturing plant has created a demand for industrial air conditioning which in turn has contributed its part to the process of development.

There are many industries which require a definite and unvaried humidity so that at some periods the normal quantity of moisture in the air must be increased, and at other times lowered. These include the confectionery, the artificial silk, and the printing and lithographing industries. Other industries require not only a constant relative humidity, but also a fairly uniform temperature. For example, the modern automatic wrapping machines used for wrapping chewing gum, food products, confectionery, and machine made cigarettes, require exact conditions of heat and moisture in order to function satisfactorily without frequent adjustments.