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

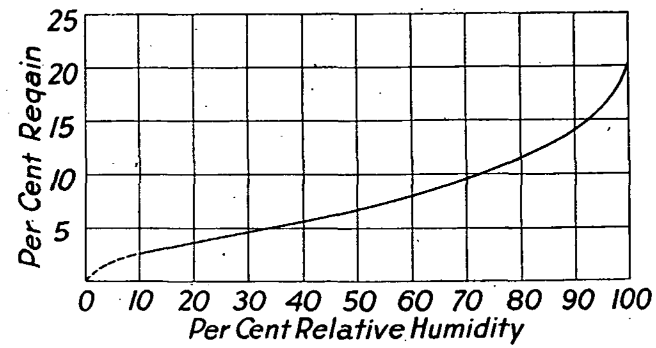

FIG. 3. REGAIN CHART FOR COTTON (SEA ISLAND) AND PAPER (CELLULOSE) AT 70 DEG.

the conductivity of the surface in contact with the air would be increased approximately 50 per cent.

Hygroscopic Properties of Materials

Hygroscopic materials are those which readily absorb or give off moisture to the surrounding air.

Air conditioning in many industries is largely concerned with the control of this hygroscopic moisture. The moisture content of a hygroscopic material when in equilibrium depends upon the relative humidity of the surrounding air, but varies widely for different materials.

The moisture content also varies to some extent for different temperatures at the same relative humidity. The content of hygroscopic moisture is sometimes termed *regain* and is expressed in parts of water per 100 parts of dry material. The curve (Fig. 3) shows the effect of moisture content upon the rate of drying of cotton and paper, with an air temperature of 70 deg. fahr. dry-bulb.

If the material contains moisture in excess of the *regain* corresponding to any relative humidity, then it will give up moisture to the air with the absorption of heat and there will be a resultant cooling effect equal to that of evaporation. On the other hand, if the hygroscopic material contains moisture below that of the corresponding atmosphere, it will absorb moisture from the air with a release of heat which corresponds to the latent heat given off if a corresponding quantity of water vapor were condensed.