temperature it reaches 100 percent. That temperature is its dew-point. Evidently the vapor pressure which holds constant throughout this process is the saturation vapor pressure for the dew-point temperature. Cooling below the dew-point results in condensation of some of the vapor into liquid water (or frost at low temperatures) with a reduction of vapor pressure. As an example, air at 70 F and 40 percent relative humidity has a vapor pressure of $0.40 \times 0.73916 = 0.29566$ in. Hg, and may be cooled to 44.6 F with no change of vapor pressure. At 44.6 F the vapor becomes saturated, the relative humidity being 100 percent, and this temperature is the dew-point temperature at the start and also at any stage of the cooling. If the air contacts a surface colder than 44.6 F, condensation will occur on that surface. In fact, this removal of water vapor tends to reduce the dew-point of near-by air to the temperature of the cold surface. At a distance from the cold surface the dew-point temperature and the vapor pressure may be higher, when such a point is in the path of vapor movement from a vapor source to the point of condensation. Such movement of vapor may occur by diffusion without motion of the air, or by transportation if the air moves, the latter mechanism being generally more important in larger air spaces.

VISIBLE CONDENSATION

Just as moisture collects on the outer surface of a glass of cold water, so does it also condense on other cold materials. In winter, visible condensation may collect on cold closet walls and attic roofs and is commonly observed on frosted window panes. Although condensation, if liquid, may enter an unpainted surface as fast as it forms and thus be unseen, any condensation on a visible surface will for convenience here be called *visible condensation* to distinguish it from *concealed condensation*. Within residences and public buildings, visible condensation occurs in winter and may damage decorative finishes and window sash.

Interior visible condensation occurs when any surface is colder than the dewpoint of the near-by air. The temperature of any such surface—wall, roof, or glass—is dependent upon the air temperature inside and outside the building and the heat transfer coefficient U of the surface structure. Based on a value of 1.65 for the inside surface conductance, Fig. 1 shows the relative humidity in a room at 70 F when visible condensation will appear at various U-values. The curves for single and double glass at their usual U-values are included. It should be noted that U-values as commonly used are an average for a large area within which there may be spots, such as the studs in an insulated wall, where the transmittance is higher. The inside surface temperature of a wall will, in general, be lower at the bottom due to such things as stratification of inside air and the effects of air leakage and of convection in walls with air spaces. Since condensation seeks the coldest spot, values from Fig. 1 can be applied only with caution. As a result, the limit of relative humidity for a non-homogeneous wall is lower than might be inferred from its average U-value.

Normally, glass is the most likely spot in a heated room for appearance of condensation, but an uninsulated wall surface shielded from radiation by furniture, may be equally cold. In some cases where condensation is barely avoided, the surface, being but little warmer than the dew-point temperature, is exposed to moisture damage—such as swelling, mould or discoloration.

Visible condensation may occur also in summer. It is often seen on basement concrete walls and floors which are cooled by the earth and which,

being massive, tend to hold a constant temperature from day to day while the weather dew-point temperature rises. When no water vapor is released in the space, the dew-point tends to equal that of the outside (though it is likely to lag when there is slight ventilation). At times the dew-point temperature rises above the temperature of walls and floors and condensation results. If the basement is decorated the trouble may be serious. As an operating problem, the solution may be to reduce ventilation at times of high weather dew-point, to warm the walls, or to dehumidify the space. Warming the walls, a slow process at best, is generally accomplished in favorable climates by excess ventilation. In a climate having low temperature at night, it may be feasible to ventilate only at night and thus reduce the moisture content of hygroscopic materials which will then act as a desiccant to retard the dew-point rise during the day. In basement walls and floors insulation should be applied in the concrete or on its outside. Insulation placed on the inside of such walls eliminates visible

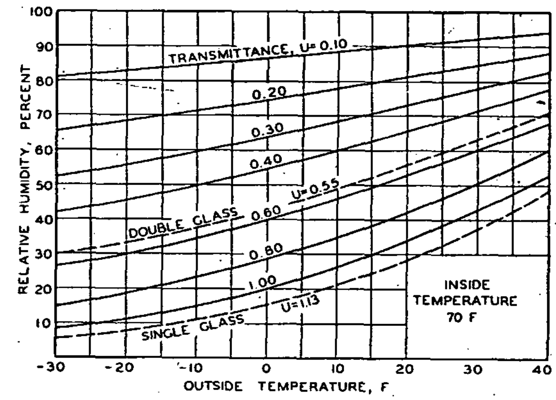

FIG. 1. RELATIVE HUMIDITY AT WHICH VISIBLE CONDENSATION WILL APPEAR ON INSIDE SURFACE

condensation but fosters concealed condensation. The control of the latter will be discussed. A practical and fully effective technique for such control has, however, not been developed. Usually, sub-surface dwellings should be designed for occupancy and should be dehumidified.

A similar situation is seen in dwellings with concrete floor slabs laid on the ground where such slabs are not a part of the heating system. In a northern climate where high dew-point temperatures occur in summer, condensation or very high relative humidity may damage rugs which are themselves contributors to the trouble since they reduce the floor slab temperature. Slab floors above grade are not so serious a problem as floor slabs on grade but their response to air temperature change is slow. Faster warming is accomplished by the removal of rugs and abundant ventilation at proper times. In their design, floor slabs should have as low specific heat and as high thermal resistance as is consistent with other requirements. Suitable insulation below the slab, especially well drained gravel, will help somewhat. A top surface cover of insulating value that is unaffected by water on its lower side would be desirable in the less favorable northern climates.

The avoidance of interior visible condensation is partly a construction