as would be expected in warmer weather. Fig. 8 represents the results of one such survey.[19]

When water vapor is allowed to enter a wall and condensation occurs on its outer cold elements, it appears as frost or liquid. If the weather temperature rises frequently, frost melts and becoming liquid, is likely to penetrate capillary materials like wood, or run down when the surface is non-absorbing or is already saturated with water. In weather that is continuously cold for a long period, the frost may build back into a cavity or fibrous insulation and, when it reaches a warmer plane, will run to lower, cooler levels where it forms a mass of ice. Water seepage to the weather side may occur harmlessly in masonry walls when the weather is above freezing but water seepage into the building must obviously be avoided. In typical frame construction with wood sheathing which has large water absorbing capacity, seepage is rare and occurs only after a long period of steady cold weather. More generally, moisture accumulates in wood sheathing and siding through the colder months and reaches a peak in late

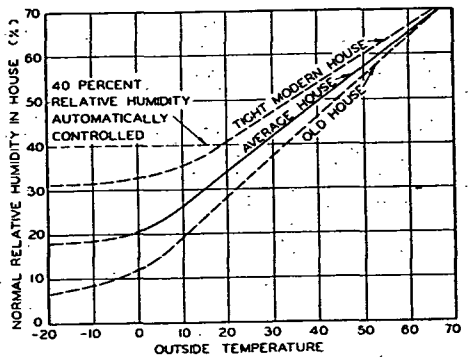

FIG. 8. RELATIVE HUMIDITY IN DWELLINGS

winter, after which the drying of spring and summer completes the annual cycle. The average winter temperature and its duration are factors in the condensation problem. In Fig. 9 the United States is divided into three condensation zones based on winter weather conditions.[20] Zone I roughly includes those areas where the design temperature is −20 F or colder; zone II those for which the design temperature is zero to −20 F, and zone III those at zero and warmer. Within each zone, similar degrees of condensation trouble are to be expected, and similar corrective measures apply.

In roofs, the condensation problem is much the same as in walls. The roof covering may be even more resistant to the escape of vapor than wall coverings such as paint; and while paint is likely to be ruptured by excessive moisture, no such relief occurs in roofs. Thus roofs furnish conspicuous examples of rapid decay in lumber.

In crawl spaces over uncovered damp ground, a large water evaporation sometimes occurs and causes condensation on the outer ends of floor joists and other members that are below the floor line and near to the outside. Water vapor from the crawl space may also enter walls, be transported by rising air in a stack effect, and even reach the attic by this route when the

wall structure permits. Ventilation, as discussed later in this chapter, is an important correction factor in these cases.

Insulation in a wall or roof reduces heat loss and lowers the temperature of the outer elements of the structure, thus increasing the possibility of condensation if the vapor path to the cold surface is not blocked. Since low vapor resistance is a characteristic of fibrous insulation, the needed vapor resistance must be provided by other means. It is to be noted that, in typical residential conditions, condensation does not occur in fibrous insulation itself, except when frost has formed on sheathing and gradually

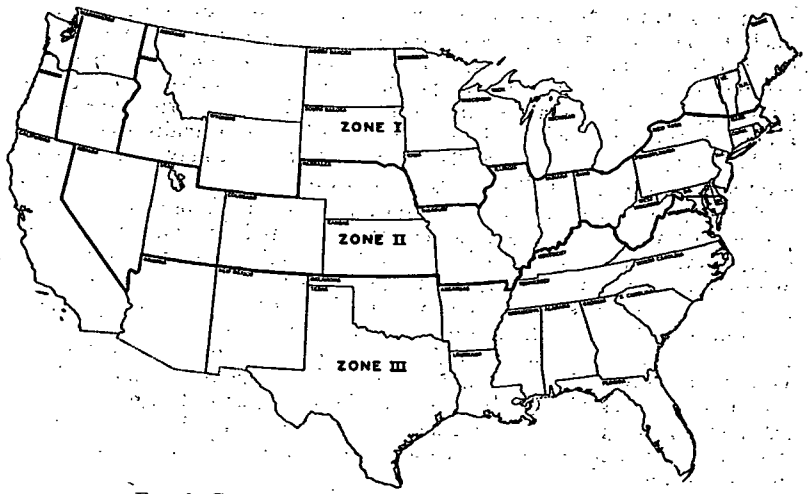

FIG. 9. CONDENSATION ZONES IN THE UNITED STATES
(Zones Include Areas with Design Temperatures about as follows: Zone I, −20 F and lower; Zone II, 0 F to − 20 F; and Zone III, above 0 F)

built backward among the fibers. Wet insulation may result from this condition or from liquid condensation seeping down from a higher level.

Control of Concealed Condensation

An excessive accumulation of moisture in walls (or roofs) can be prevented by one or more of the following measures: (1) provide a vapor barrier to limit vapor entrance into the wall, (2) ventilate the building to reduce vapor pressure therein, (3) ventilate the wall cavity to remove vapor that has entered.

1. *Vapor Barrier.* A vapor barrier is the principal and most obvious correction, but each measure is more effective if aided by the effect of another. In habitations, some ventilation of the living space, either incidental or planned, is necessary. Also, a small amont of cavity ventilation is essential in cases where the vapor inflow is not completely stopped and the moisture storing capacity of the outer wall elements is slight. This applies to some prefabricated designs using metal siding.

Vapor barrier sheets are often built into the wall near the warm surface. In wood frame walls they may be applied to the inside surface of the studs. They are sometimes attached to the warm side of the insulating materials,