satisfactory. There are cases, however, in residential construction where a one perm barrier would not be adequate and there are also many industrial applications in which a very much higher vapor resistance is required. In any event, the choice of an adequate barrier implies that its permeance be definitely established. The usually accepted test procedure for this purpose is a dry method at a temperature of 70 F to 80 F. If obtainable at reasonable cost (including good application), a barrier better than required should be chosen for any construction. Despite the theoretical possibility of safely discharging some vapor through a wall, a higher than minimum permeance is not preferred.

An exact statement showing which buildings require a vapor barrier is not readily formulated. However, in view of the distressing results its

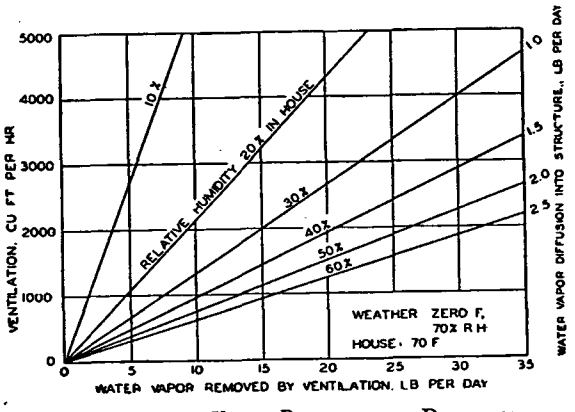

FIG. 7. WATER VAPOR BALANCE IN A DWELLING

(Vapor Barrier, 1 perm; Wall and Ceiling Area 2000 sq ft Insulated)

omission may bring, it is tentatively recommended that the walls of every well constructed modern dwelling include a vapor barrier when the construction includes any material that would be damaged by moisture or its freezing. This applies to all condensation zones in Fig. 6 when the *U* value for the wall is lower than 0.25 Btu per (sq ft) (hr) (F deg), and it applies in Zone I and Zone II to walls of higher transmittance.

In applying vapor resistance to a wall, there are certain fundamental principles which should be followed. First, the vapor barrier should be placed as near to the warm surface of the wall as practicable. Second, it should be continuous with no direct openings through the barrier. Good workmanship and application are very important. Workmanship that leaves two openings through the barrier, or around its margin, at different levels, connecting air spaces at only slightly different temperatures, leaves a path for thermosyphon air rotation which will transport large amounts of water vapor from the warmer space to the colder. If a membrane barrier is used back of the plaster or interior finish, its joints should be made over some solid framing member, and not between the studs or in similar places. Usually a two-inch lap over a framing member will make a sufficiently tight joint when the interior finish is applied. Such a lap, however, without backing would not be adequate. Barriers attached to the warm side of

insulation should form a continuous unbroken membrane over the entire insulated area. Edges should be lapped over framing members; ends of strips should be fastened by lapping over plates or headers. All openings for electrical fixtures and joints around window and door casings should be carefully sealed. Holes accidentally made in the barrier should be sealed.

2. *Ventilation of Living Space.* The second measure listed for the control of concealed condensation is ventilation of the house. This measure is obviously necessary as an accompaniment to a vapor barrier since, if the barrier blocks entrance into the walls, the water vapor must be removed

TABLE 3. RECOMMENDED GOOD PRACTICE[14]-LOFT AND ATTIC VENTILATION[a]

FLAT ROOF—SLOPE LESS THAN 3 INCHES IN 12 INCHES
Condensation Zone I[c]: Total net area of ventilation should be 1/300th[b] distributed uniformly at the eaves *plus* a vapor barrier in the top story ceiling. Free circulation must be provided through all spaces. Condensation Zone II and III: Same as for Zone I.
GABLE ROOF—SLOPE OVER 3 INCHES IN 12 INCHES
Condensation Zone I: Total net area of at least 2 louvers on opposite sides located near the ridge to be 1/300th[b] *plus* a vapor barrier in the top story ceiling. Condensation Zone II: Same ventilation as for Zone I. A vapor barrier is not considered necessary. Condensation Zone III: Same as for Zone II.
HIP ROOF
Condensation Zone I: Total net area of ventilation should be 1/300th[b] with 1/600th[b] distributed uniformly at the eaves *and* 1/600th[b] located at the ridge with all spaces interconnected. A vapor barrier should also be used in the top story ceiling. Condensation Zone II: Same ventilation as for Zone I. A vapor barrier is not considered necessary. Condensation Zone III: Same as for Zone II.
GABLE OR HIP ROOF—WITH OCCUPANCY CONTEMPLATED
Condensation Zone I: Total net area of ventilation shoud be 1/300th[b] with 1/600th[b] distributed uniformly at the eaves *and* 1/600th[b] located at the ridge with all spaces interconnected. A vapor barrier should also be used on the warm side of the top full story ceiling, the dwarf walls, the sloping part of the roof, and the attic story ceiling. Condensation Zone II: Same as for Zone I. Condensation Zone III: Same as for Zone I except that a vapor barrier is not considered necessary if insulation is omitted.

[a] It is recognized that in many areas increased ventilation may be desirable for summer comfort. For winter comfort, insulation is recommended between a living space and a loft or attic ventilated at these rates.

[b] Refers to area enclosed within building lines at eave level.

[c] The zone numbers refer to Fig. 6.

by other means. No great volume of air change is necessary, however, and normal infiltration alone is frequently all that is required in winter weather.

The effectiveness of ventilation is shown in Fig. 7, which also shows the small amount of water vapor escaping into the barrier-equipped, well-insulated walls and ceilings (2000 sq ft) of a typical small dwelling, the floor being neglected. Evidently, ventilation of 2000 cu ft per hr will remove 21 lbs of vapor per day with the relative humidity at 40 percent, while at the same time 1.5 lbs escapes into the structure. The total vapor production (22.5 lb) is a typical amount. Double glass will be barely safe from visible condensation as will be seen in Fig. 4. By reference to Chapter 6, 2000 cu ft per hr appears to be near the minimum for odor control, and ventilation would have to be higher when cooking is done. By reference to Chapter 11, it appears that usual infiltration will normally supply the necessary air change, but that supplementary ventilation may be neces-