BIA
Technical Notes on Brick Construction
Brick Industry Association 11490 Commerce Park Drive, Reston, Virginia 20191

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MOISTURE CONTROL IN BRICK AND TILE WALLS
CONDENSATION

INTRODUCTION

It is generally agreed that the durability of masonry depends primarily on its resistance to the penetration of moisture into the body of the masonry. The source of this moisture may be wind-driven rains or it may be from interior exposures resulting from various occupancies which create high humidities. These include, among others, air conditioning with humidity control, food processing and unventilated space heaters. Differences in humidity between inside and outside air resulting from these occupancies will cause vapor flow within the wall and, unless controlled, either by the use of properly placed vapor barriers or by ventilating, this vapor may condense within the wall under certain temperature conditions.

When wall surface temperatures are substantially below air temperatures, condensation may occur on the wall surface.

CONDENSATION ON WALL SURFACES

Atmospheric air is a mixture of dry air and water vapor. At a given temperature air is saturated when the space occupied by the mixture holds the maximum possible weight of water vapor at that temperature. The amount of water vapor necessary to saturate the air at constant pressure depends upon the temperature-the higher the temperature the more water vapor will be required. If saturated air at a temperature of 50 deg, for instance, is warmed to a temperature of 70 deg, the mixture is no longer saturated but will absorb additional water vapor. However, if unsaturated air is cooled at constant pressure, a temperature will be reached at which the air is saturated. This temperature is called the dew point and, if the mixture is cooled below the dew point, water will condense from the air. Dew which occurs in the early mornings during the warmer months in many localities is one of the most common examples of the effect of cooling unsaturated air to a temperature below the dew point or to a point where the water vapor which the air contains begins to condense.

The water vapor in air is called humidity, and relative humidity is the ratio of the amount of water vapor which a mixture contains to the amount required for saturation at a given temperature. Obviously, for a fixed amount of water vapor, the relative humidity will vary with the temperature, increasing as the temperature is lowered and decreasing as the temperature rises.

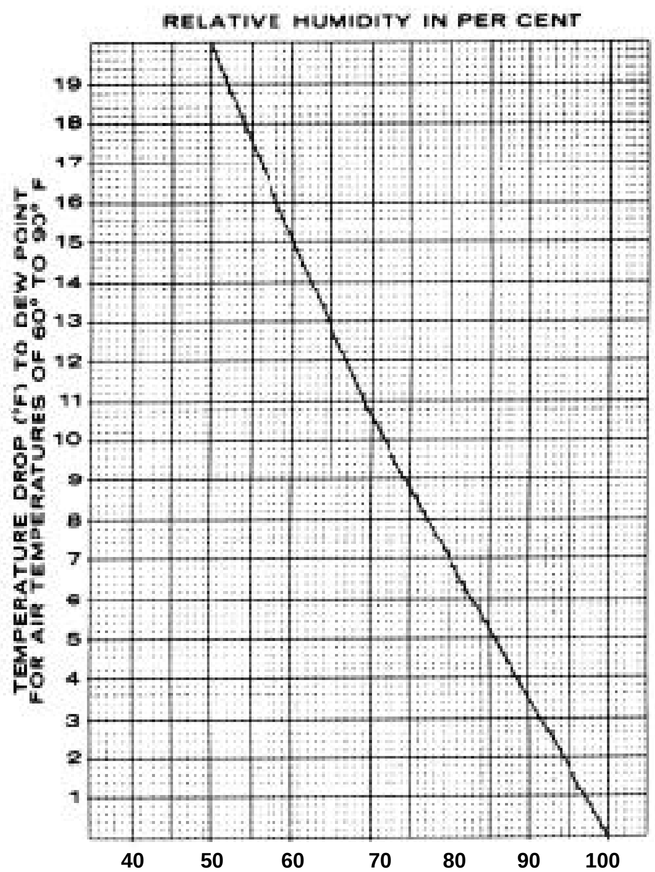

FIG. 1
Temperature Drop Curve for Relative Humidities from 50 Per Cent to 100 Per Cent

While the dew point depends upon the amount of water vapor in the air and is the temperature at which the water vapor present is sufficient for saturation, there is also a practically constant relation between dew point and relative humidity for a considerable range of temperatures; that is, for a relative humidity of 50 per cent, the difference between air temperature and dew point is approximately 20 deg for any air temperature from 60 deg to 90 deg. Similar relations hold for other relative humidities. A discussion of the reason for this relationship may be found in the ASHRAE *Guide and Data Book,*

*Originally published in February 1965, this *Technical Notes* has been reviewed and reissued.

Fundamentals and Equipment Volume, 1963, published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

In Fig. 1, the difference in temperature between the air and the dew point (temperature drop) is plotted for relative humidities from 50 per cent to 100 per cent. It will be noted from this curve that for relative humidities above 80 per cent a drop in temperature of 6.8 deg or over will cause condensation. These high humidities usually occur during the summer when the difference in temperature between the air on opposite sides of a wall is small, probably 10 deg or less. For walls below grade, the temperature difference of the two sides of the wall may amount to 20 deg or more.

If condensation occurs, it may be eliminated by:

1. Reducing the humidity of the air. This may be accomplished by adequate ventilation if the high humidity is caused by conditions inside the building.
2. Increasing the temperature of the surface upon which the condensation occurs. Probably the simplest means of increasing the surface temperature is to increase the movement of air over the surface.
3. Increasing the heat resistance of the wall. This is usually done by the addition of an air space or insulation back of the interior finish.

The temperature gradient or temperature drop through a composite wall is directly proportional to the resistance of the various elements, including surface resistances; that is, if the total resistance of a wall is 8.0 and the resistance of one element is 2.0, the temperature drop across this element will be 2/8 of the air temperature difference on the warm and cold sides of the wall.

Table 1 gives the difference in temperature between the inside surface of various types of walls and the inside air temperature for differences between inside and outside air, ranging from 10 deg to 70 deg Fahr. These figures are based upon the conductivities and conductances of materials listed in Tables 1, 3 and 4 of *Technical Notes* 4, "Heat Transmission Coefficients of Brick and Tile Walls".

From Table 1, it may be noted that, for a difference in temperature between inside and outside air of 70 deg, the inside surface temperature of an exposed brick-and-brick cavity wall is 16 deg below the temperature of the inside air. Referring to the curve, Fig. 1, a temperature drop of 16 deg will cause condensation for relative humidities of 58 per cent or over. The temperature drop for a vermiculite insulated brick-and-brick cavity wall, exposed, is 6 1/2 deg for which relative humidities must be 81 per cent or over to cause condensation.

Table 1 may be used in connection with the "temperature drop" curve to select a type of wall construction which will be free from condensation

TABLE 1
Difference in Temperature Between Air and Inside Wall Surface for Various Total Differences in Temperature Between Inside Air and Outside Air

Wall Construction	Difference in Temperature Between Inside and Outside Air, deg Fahr						
	10	20	30	40	50	60	70
4-in. brick and 4-in. tile, furred and plastered.....	2	3 1/2	5	7	9	10	12
"SCR brick,"[1] furred and plastered.......	2	5	7	10	12	14	17
8-in. tile (3-cell), furred and plastered.....	1 1/2	3	4 1/2	6	7	8 1/2	10
10-in. brick and brick cavity, exposed.....	2 1/2	4 1/2	7	9	11	13 1/2	16
10-in. brick and tile cavity, plastered.....	1 1/2	3	4 1/2	6	7	8 1/2	10
10-in. brick and brick cavity, vermiculite insulated, exposed.....	1	2	3	4	5	6	6 1/2
10-in. brick and tile cavity, vermiculite insulated, plastered.....	1	2	2 1/2	3 1/2	4	5	6

Note: Plaster: gypsum and aggregate.
Lath: 3/8 in. gypsum.

[1]Reg. U.S. Pat. Off., SCPI

CONDENSATION WITHIN WALLS

The National Bureau of Standards Report, BMS63, *Moisture Condensation in Building Walls*, contains a method for calculating potential condensation if the temperature and vapor-resistant gradients of the wall are known. The following summarizes the discussion and method outlined in the report:

A definite volume of air held at a fixed temperature can contain permanently no more than a definite amount of water in the form of vapor. This limiting quantity of water per given volume is termed "moisture content at saturation". If the air contains a greater proportion of moisture than this at the particular temperature, the water will start condensing on the surfaces of the container or even on the dust particles in the air which then fall out in a fine mist. The ratio of the actual moisture content to the saturation moisture content for the particular temperature is termed "relative humidity". It is customarily expressed in per cent.

The concentration of water vapor may also be stated by giving its pressure. If water vapor is present, part of the atmospheric pressure is maintained by the water vapor and the remainder of the pressure by the other constituents of the atmosphere. At a particular temperature and at saturation, the water vapor exerts a definite pressure.

Data on saturated vapor pressures are listed in tables of the *ASHRAE Guide and Data Book* and Table 2 gives saturated vapor pressures for various temperatures as included in the 1963 edition. As may be noted, the variation of vapor pressure with temperature is not constant but increases rapidly with increased temperature.

TABLE 2
Saturated Vapor Pressures

Fahrenheit Temperature	Vapor Pressure, in. Hg
-10	0.0220
0	0.0376
10	0.0629
15	0.0806
20	0.1027
24	0.1243
30	0.1645
40	0.2477
50	0.3624
60	0.5216
70	0.7392
75	0.8750
80	1.0323
90	1.4219
100	1.9333

The ratio of the actual pressure of the water vapor to the saturation pressure of the water vapor for the particular temperature is also termed relative humidity. Its value when defined thus is essentially the same as that given previously.

When a given mixture of air and water vapor is cooled without loss of moisture, a temperature is eventually reached where the air becomes saturated with water vapor and condensation can occur. The temperature then existing is called the dew point.

When a vapor-pressure differential exists, water vapor will move toward the lower pressure independently of air. This vapor movement through common building materials is at a relatively high rate for common pressure differentials. When vapor passes through pores of homogeneous walls, which are warm on one side and cold on the other, it may reach its dew point and condense into water within the wall; but, if the flow of vapor is impeded by a highly vapor-resistant material on the warm side of the wall, the vapor cannot reach that point in the wall at which the temperature is low enough to cause condensation.

Permeability to water vapor travel is known as permeance which is defined as "the ratio of water vapor flow to the vapor-pressure difference between the surfaces". Permeance is measured in perms. A perm is equal to 1 grain per sq ft per hr per in. of mercury vapor-pressure difference. A perm-inch is the permeance of 1-in. thickness of a homogeneous material. The reciprocal of permeance is called vapor resistance.

Differences in vapor pressure through different parts of the wall from inside to outside distribute themselves in proportion to the vapor resistance of the respective parts; that is, the fraction of the total vapor-pressure drop from inside to outside occurring between the air indoors and some chosen point within the wall is the same as that fraction of the total vapor resistance of the wall occurring between the air indoors and the chosen point.

In this it is analogous to heat flow, in which differences in temperature through different parts of the wall from warm to cold side are proportional to the thermal resistance of these parts.

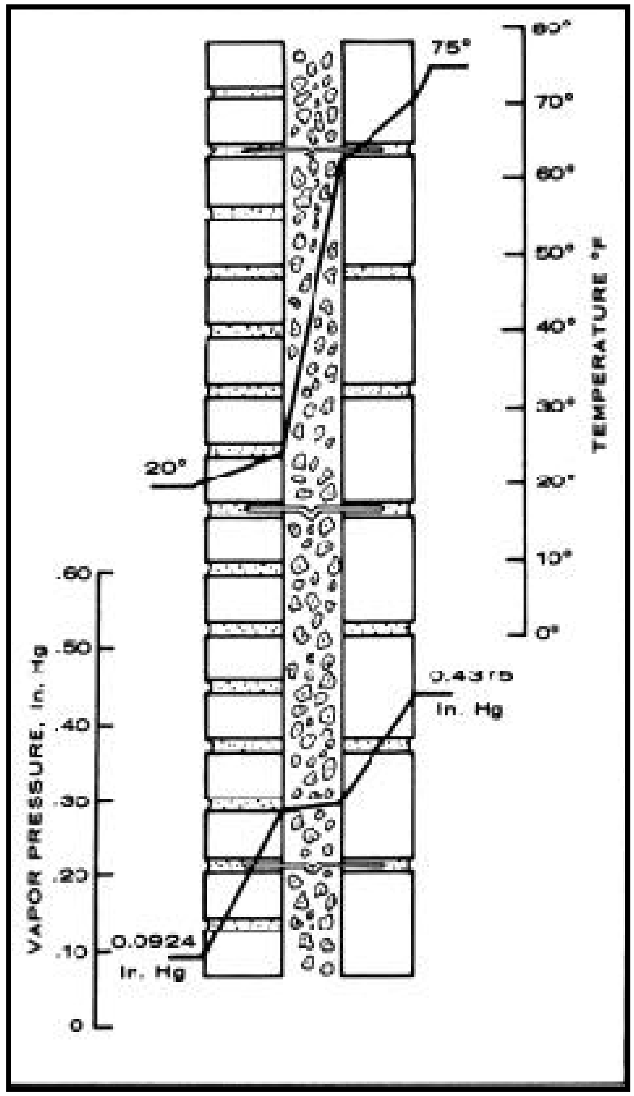

FIG.2
Temperature and Vapor Pressure Distribution
for a Brick and Tile Cavity Wall

As an example, assume a brick and tile, vermiculite insulated cavity wall, unplastered, exposed on the tile side to 75 deg Fahr, 50 per cent relative humidity, and on the brick side to 20 deg Fahr, 90 per cent relative humidity. The thermal resistances are:

Inside air	0.68
4-in. tile	1.11
2-in. vermiculite	5.56
4-in. brick	0.44
Outside air	0.17
R = 7.96	U = 0.125

The vapor resistances are:

4-in. tile	0.333
Insulation	0.008
4-in. brick	0.480
	0.821

The vapor pressure differential is 50 per cent of saturated vapor pressure at 75 deg (0.4375 in. Hg) minus 90 per cent of saturated vapor pressure at 20 deg (0.0924 in. Hg) equals 0.345 in. Hg. The temperature difference is 75 deg minus 20 deg equals 55 deg.

From the above resistances, the temperature gradient and vapor pressure gradient may be plotted as indicated in Fig. 2. As may be noted, the vapor pressure at the inside face of the brick wythe is 0.29 and the temperature at this point is 24 deg.

Referring to Table 2, the saturated vapor pressure at 24 deg is 0.124. Since the actual vapor pressure exceeds this amount, condensation might be expected to occur in the insulation just back of the outer wythe.

Vapor transmission tests, sponsored by the Structural Clay Products Research Foundation, a Division of Structural Clay Products Institute, were conducted on a wall similar to the above at Pennsylvania State University. The temperatures and humidities maintained during these tests were approximately the same as those assumed. Data obtained from the tests are included in the paper, *Review of Recent Research*, by C. B. Monk, Jr., published in the Proceedings of the BRI Conference on Insulated Masonry Cavity Walls, which was held in New York City in April 1960.

The results of the tests confirm the above calculations, since frost formed on the cavity face of the brick wythe. However, Mr. Monk states: "The major observation of the heat transfer data is the relative constant air-to-air conductance of the wall during the 18 days of steady state conditions, indicating no change in the thermal characteristics of the wall due to the frost observed at the end of the test."

From the vapor transmission tests, it is apparent that, insofar as condensation affects heat transfer, a vapor barrier is not required on the warm side of an insulated cavity wall, whose permeance is approximately equivalent to the wall tested when vapor pressure differentials are of the order of 1 in. of mercury. However, as previously indicated, water in a masonry wall may contribute to disintegration of masonry units and, where soluble salts are present in the masonry, it also contributes to efflorescence. For this reason, vapor barriers are recommended on the warm side of cavity walls with exterior wythes of glazed brick.