4. VAPOR RETARDERS

4.1 General
Evaluation of the need and specific requirements for vapor retarders within roof systems involves the study of water vapor transmission through building materials. The Moisture Control for Low-Slope Roof Assemblies, *Low-Slope Text* section (Section 2) of *The NRCA Roofing and Waterproofing Manual* includes a practical discussion of water vapor theory, the means of controlling water vapor transmission, and the use of vapor retarders within roof systems.

This chapter is devoted to explaining the applicable terms, fundamental concepts, and equations for determining the dew point temperature, the design temperature at a vapor retarder, and the need for a vapor retarder within roof systems.

4.2 Definitions

4.2.1 Dew Point Temperature
The temperature at which air becomes saturated with saturated vapor (100 percent relative humidity) and condensation begins to form is the dew point temperature. The English (inch•pound) unit of measurement is expressed as °F.

4.2.2 Permeability
Permeability is the time rate of vapor transmission through a flat material of unit thickness induced by vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions. The English (inch•pound) unit of measurement for permeability is gr/h•ft^2•(in. Hg/in.), which is commonly referred to as "perm•inch" units.

4.2.3 Permeance
Permeance is the time rate of vapor transmission through a flat material or construction induced by vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions. The English (inch•pound) unit of measurement for permeance is gr/h•ft^2•in. Hg, which is commonly referred to as "perm" units.

4.2.4 Relative Humidity
Relative humidity is the ratio of the pressure of water vapor present in air to the pressure of fully saturated water vapor at the same temperature. Relative humidity is expressed as a percentage.

4.3 Permeance and Permeability
Water vapor transmission through building materials is measured as a rate of permeance or permeability.

The permeance, or perm rating, of a material is a performance evaluation specific to a sample of material, and not a specific property of the material.

The permeability of a material is a specific physical property of the material. Permeability is the arithmetic product of the permeance and thickness of a material.

Permeance and permeability of building materials and construction are measured in accordance with methods established in ASTM Standard E 96 *Standard Test Methods for Water Vapor Transmission of Materials.*

The permeance or permeability of common building materials is as follows.

Typical Water Vapor Permeance and Permeability Values[1,2]		
Material	**Permeance (perm)**	**Permeability (perm•in)**
Common roof membrane materials:		
Asphalt (hot applied, 2 lbs/100 ft²)	0.5	
Asphalt (hot applied, 3.5 lbs/100 ft²)	0.1	
Built-up membrane (hot applied)	0.0	
No. 15 asphalt felt	1.0	
No. 15 tarred felt	1.0	
Roll roofing (saturated and coated)	0.05	
Common insulation materials:		
Expanded polystyrene insulation		2.0 - 5.8
Extruded polystyrene insulation		1.2
Plastic and metal films and foils:		
Aluminum foil (1 mil)	0.0	
Kraft paper and asphalt laminated, reinforced	0.3	
Polyethylene sheet (4 mil)	0.08	
Polyethylene sheet (6 mil)	0.06	
Other common construction materials:		
Brick masonry (4 in. thick)	0.8	
Concrete (1:2:4 mix)		3.2
Concrete block (with cores, 8 in. thick)	2.4	
Gypsum wall board (plain, 3/8 in. thick)	50	
Hardboard (standard, 1/8 in. thick)	11	
Metal roof deck (not considering laps and joints)	0.0	
Plaster on metal lath	15	
Plaster on wood lath	11	
Plywood (Douglas fir, exterior glue, 1/4 in. thick)	0.7	
Plywood (Douglas fir, interior glue, 1/4 in. thick)	1.9	
Wood, sugar pine		0.4 - 5.4

1. Table adapted from Table 9, *1993 ASHRAE Fundamentals Handbook,* pages 22.14-22.15.
2. This table permits comparisons of materials; however, in the selection of vapor retarder materials, exact values for permeance or permeability should be obtained from the manufacturer or from laboratory tests. The values shown indicate variations among mean values for materials that are similar but of different density, orientation, lot, or source. The values should not be used as design or specification data.

Some common building materials that are found to have relatively low permeance or permeability ratings when evaluated in a laboratory may be largely ineffective in controlling vapor migration when evaluated after field installation. For example, a metal roof deck panel has a permeance rating of 0.0 perm when evaluated under laboratory conditions without considering laps and seams. However, when considering an installed metal roof deck, taking into consideration laps and joints in the metal panels and fastener penetrations in the completed installation, the effective overall permeance is 1.0 perm or more.

4.4 Relative Humidity and Dew Point Temperature

The relative humidity of air is typically measured in the field using a sling psychrometer to measure dry bulb and wet bulb temperatures. Knowing these variables, the relative humidity can be determined using a psychometric chart. The use of electronic psychrometers has become more common, due largely to ease of use.

Dew point temperature is determined knowing the variables dry bulb temperature and relative humidity using a psychometric chart. A simplified version of a psychometric chart, a psychometric table, is provided in Item 4.7.2 and as Table 9.

Design values for relative humidity and dew point temperature are typically determined by the designer of the building's heating, ventilating and air conditioning system. These values are determined based upon anticipated maximum extreme conditions and are used in determining mechanical equipment sizing and requirements for building envelope thermal insulation and water vapor control.

When evaluating thermal insulation and water vapor control requirements for existing buildings, design values for relative humidity and dew point temperature can often be obtained from the original design drawings, equipment operation manuals, or, in some cases, the building's maintenance engineer.

It is important to realize that actual relative humidity and dew point temperature values are constantly changing in normal building environments as the ambient temperature and/or water vapor pressure in the air change. Values for design relative humidity and design dew point temperature are theoretical constant values based upon design assumptions used for calculation purposes.

4.5 Need for Vapor Retarder

The use of vapor retarder membranes in low-slope roof systems has been widely debated in the roofing industry for years. A practical discussion of the need for vapor retarders based upon the environmental conditions at the building and the specific manner of roof system design and installation is included in the Moisture Control for Low-Slope Roof Assemblies, *Low-Slope Text* section (Section 2) of *The NRCA Roofing and Waterproofing Manual.*

There are at least three and possibly several others methods of determining the need for a vapor retarder membrane in low-slope roofs.

For many years NRCA has maintained that the use of a vapor retarder be considered in low-slope roof assemblies in accordance with simple guidelines. These guidelines are discussed under Item 4.7.4.1.

Research conducted by the U.S. Army Corp of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) also provides a method for determining the need for a vapor retarder membrane in low-slope roof assemblies. An explanation of the CRREL method is discussed under Item 4.7.4.2. NRCA recognizes CRREL's findings as viable, useful information for the roofing industry.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) also has criteria for determining the need for a vapor retarder membrane in roof assemblies. This methodology is explained briefly in Item 4.7.4.3. The ASHRAE criteria are considerably more conservative than the CRREL method or the NRCA simple guidelines.

NRCA considers the determination of whether a vapor retarder is necessary to be included in a low-slope roof assembly to be the responsibility of the designer of the roof system.

4.6 Vapor Retarder Design

If it is determined that a vapor retarder is necessary in a low-slope roof system, NRCA recommends that the vapor retarder membrane have a permeance rating less than 0.5 perms, preferably approaching 0.0 perms, to be considered an effective means of controlling water vapor transmission.

In order to prevent the formation of condensation on the bottom side of the vapor retarder, the temperature at the bottom side of the vapor retarder membrane must be warmer than the dew point temperature. Therefore, once it is determined that a vapor retarder membrane is to be used within a roof system, the design temperature at the bottom side of the vapor retarder must be calculated and the design dew point temperature determined. Then, to ensure that the temperature at the vapor retarder remains higher than the dew point temperature, sufficient insulation must be designed and installed above the vapor retarder to maintain the vapor retarder at a warm enough temperature to prevent condensation on the bottom side of the vapor retarder membrane.

In summary, the dew point temperature should occur within the insulation placed above the vapor retarder membrane in order to prevent condensation.

A practical discussion on the common materials and installation means for vapor retarder membranes used in roof systems is included in the Moisture Control for Low-Slope Roof Assemblies, *Low-Slope Text* section (Section 2) of *The NRCA Roofing and Waterproofing Manual.*

4.7 Calculation Methods

4.7.1 Determination of Design Temperature at the Vapor Retarder Level

4.7.1.1 Fundamental Equation

$$T_{vr} = T_i - \left[\left(\frac{\Sigma R_i}{\Sigma R} \right) (T_i - T_o) \right]$$

where:

T_{vr} = Temperature at the vapor retarder. English (inch•pound) units: °F.
T_i = Design inside (interior side) temperature. English (inch•pound) units: °F.
T_o = Design outside (exterior side) temperature. English (inch•pound) units: °F.
ΣR_i = Thermal resistance (R-value) of construction below (interior side) the vapor retarder. English (inch•pound) units: °F•ft²•h/Btu.
ΣR = Thermal resistance (R-value) of the overall roof construction. English (inch•pound) units: °F•ft²•h/Btu.

4.7.1.2 Example Calculation

4.7.1.2.1 Example
Situation: Determine the design temperature at the vapor retarder for a roof assembly that consists of a gravel-surfaced built-up membrane over two layers of insulation with a total thermal resistance (R-value) of 10.0 over a 5 inch (125mm) thick structural concrete deck (R = 0.25 °F•ft²•h/Btu). The design interior temperature (T_i) is 75°F and the design outside temperature is 0°F.

Solution: Determining the thermal resistance of the overall roof construction (ΣR) and thermal resistance of the construction below the vapor retarder level (ΣR_i):

Component	**ΣR**	**ΣRi**	
Outside air film (f_o)	0.17°F•ft²•h/Btu		from Table 6
Built-up membrane	0.33°F•ft²•h/Btu		from Table 1
Insulation	10.00°F•ft²•h/Btu		
Vapor retarder	negligible		from Table 1
5 in. structural concrete deck	0.25°F•ft²•h/Btu	0.25°F•ft²•h/Btu	
Inside air film (f_i)	0.61°F•ft²•h/Btu	0.61°F•ft²•h/Btu	from Table 6
ΣR =	11.36°F•ft²•h/Btu	ΣRi = 0.86°F ft²•h/Btu	

Then, determining design temperature at the vapor retarder level as follows:

$$T_{vr} = T_i - \left[\left(\frac{\Sigma R_i}{\Sigma R} \right) (T_i - T_o) \right]$$

$$= 75°F - \left[\left(\frac{0.86°F•ft^2•h/Btu}{11.36°F•ft^2•h/Btu} \right) (75°F - 0°F) \right]$$

$$= 69°F$$

4.7.2 Calculation of Dew Point Temperature

4.7.2.1 Fundamental Concepts

Dew point temperature is determined by knowing dry bulb (interior) temperature and relative humidity using the following simplified version of the ASHRAE Psychometric Chart.