Johns Manville

Vapor Retarders

1.0 Vapor Retarders

1.1 Roof structures have recently come under greater scrutiny in controlling the flow of energy into and out of buildings, because the roof area is a large portion of the exterior building surface. The preservation of the thermal efficiency of the roof insulation is also becoming more important and therefore designers should give careful consideration to the use and proper design of vapor retarders in the roofing system.

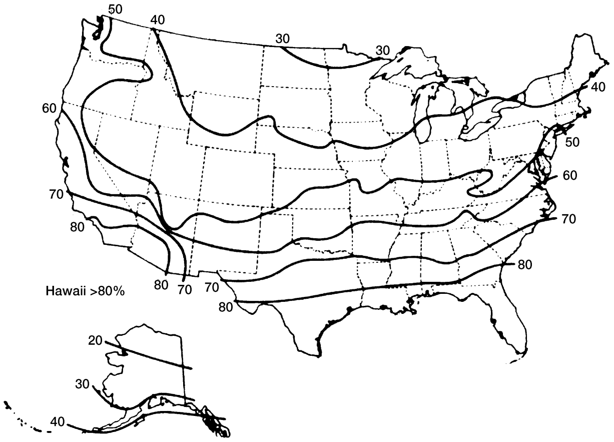
1.2 The need for a vapor retarder should be determined by the architect and/or engineer in accordance with current engineering practices and vapor theory, based on data provided by the building owner. The owner must provide the designer with information as to the present and future planned use of the structure. A JM Technical Service Specialist can assist the designer, architect or engineer by providing advice and technical guidance on vapor retarders.

1.3 In general, any time that condensation can occur, the designer should consider designing a vapor retarder into the roof system. Because the potential for condensation is related to a number of factors, it is very difficult to give hard and fast rules when and where to install a vapor retarder. There are two guidelines or "rules of thumb" that are used to help determine if the designer should investigate, with actual calculations, if a vapor retarder should be used.

1.4 The older and more established "rule of thumb" says that if any of the following conditions exist, a vapor retarder should be strongly considered.

A. Structures in areas where the January mean temperature is 40°F (4°C) or less.
B. Structures which are humidified or where operations generate a considerable amount of moisture and humidity (in excess of 45% R.H.), such as paper and textile mills, laundries, bakeries, locker rooms, etc.
C. Structures that are roofed, enclosed and heated, when subsequent interior construction activities generate large quantities of moisture.
D. Other situations that require a vapor retarder which the designer should consider.

1.5 A new and more analytical "rule of thumb" has been developed by Mr. Wayne Tobiasson of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). He has developed a map of indoor relative humidities at 68°F (20°C). Buildings which have an indoor relative humidity above these figures should be considered for the inclusion of a vapor retarder. His article "Vents and Vapor Retarders for Roofs" (available as Miscellaneous Paper MP-2246 from CRREL, Hanover, NH) contains more details and charts to convert to indoor temperatures other than 68°F (20°C). When estimating an indoor relative humidity during the design phase, it should be noted that human occupied spaces very often have relative humidities near 50%.



1.6 As with any "rule of thumb," the information above should only be used as a guideline. Specific building requirements should be confirmed with an actual analysis. There are many other issues that must be considered, such as the presence of a swimming pool or other high-humidity-producing operations. These would include cooking, washing, or unusually high humidity during the first months due to construction moisture. Construction moisture within a building that is being finished late in the season can be a problem. Operations such as the pouring of concrete will add large amounts of moisture to the air in a building, which can cause condensation in a roof system that does not have a vapor retarder. This condensation can drip back into the building and give the appearance of a roof leak. These are called "phantom leaks," because they do not correspond to a rain nor are they in the same place all the time.

1.7 Information is given below on the mechanism and causes of condensation, as well as how to design an effective vapor retarder.

1.8 The air inside an occupied building is a mixture of dry air and water vapor. The water vapor can be thought of as steam at very low pressure and it behaves like a gas. Its pressure forces it to move to areas of lower vapor pressures. This gas cannot be seen except when saturated conditions occur and then it appears as fog. The quantity of water vapor in the air depends on the rate that moisture is released in the building and the relative resistance to moisture vapor transmission of the building shell.

1.9 If the building is relatively "sealed" so vapor cannot escape to the outside, the water vapor content of the inside air will increase and may finally reach a point where condensation will occur on cool surfaces such as on outside walls, windows, the underside of the roof deck or within the roof system. Condensation of liquid water from water vapor will occur whenever the temperature of a surface is at or below the dew point of the air-water vapor mixture in the building.

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1.10 The water vapor tends to equalize by moving from warmer, more humid space to cooler, less humid space. In most regions of the United States, water vapor within a building typically moves upward during the winter months, from the heated, more humid interior up through the roofing system, toward the colder, drier exterior. As the water vapor moves through the roofing system, it will condense and change to water if it reaches its dew point (the point at which it reaches a relative humidity of 100%). This movement is reversed in an air-conditioned building in humid summer conditions.

1.11 An important distinction should be made in regard to condensation as there are two different types of condensation with which we must be concerned when designing a roof structure.

1.12 Surface condensation on interior surfaces of a building occurs if the interior ceiling or bottom of a roof deck is cold enough to cause the interior air to reach its dew point. This type of condensation cannot be prevented by use of a vapor retarder. This condensation can only be avoided by use of an adequate amount of thermal insulation or by proper dehumidification of the interior of the building.

1.13 The condensation which occurs within the roofing system, however, is a more serious concern. Nearly every structural roof deck is porous to some degree, or has joints open to water vapor migration, and it is possible for condensation to occur in the roof insulation layer or on the bottom of the roofing membrane.

1.14 There is a thermal gradient within the roof system, graduating from warm on the inside to cool on the outside in winter and the reverse in air-conditioned buildings in the summer.

1.15 This condensation may occur as liquid water or frost, depending on the outside temperature. In either case, it will eventually saturate the insulation and reduce its thermal efficiency, and possibly its structural integrity. It may also flow back into the building and appear as a roof leak.

1.16 The only way to prevent the condition just described is to stop the water vapor from reaching the dew point. If a good vapor retarder is placed on the warm side of sufficient insulation R-value, the possibility of surface or internal condensation is minimized.

1.17 The effectiveness of a vapor retarder is measured by its "perm" rating. The porosity of a material to the passage of water vapor is measured in perms. This is defined as the number of grains of water vapor that will pass through one square foot of the material in an hour when the vapor pressure differential between the two sides is equal to 1 inch of mercury (0.49 psi).

1.18 To be classified as a vapor retarder, a material should have a permeance of less than 0.5 perms.

Material	Perm Rating*
Bituminous built-up membrane	0.0
2 ply fiber glass and asphalt	0.0
45 mil (1.1 mm) EPDM	0.04
60 mil (1.5 mm) EPDM	0.03
Aluminum foil (no holes, no laps)	0.0
4 mil (0.10 mm) polyethylene	0.08
6 mil (0.15 mm) polyethylene	0.06
4 mil (0.10 mm) polyvinyl chloride (PVC)	greater than 0.8
Kraft paper laminates	less than 0.3
No. 15 asphalt-saturated felt	1.0
No. 43 asphalt-saturated and coated felt	0.3
Steel deck (discounting seams)	0.0
Steel deck (including seams)	greater than 1.0
Structural concrete deck (no cracks)	about 0.5
Plywood, ¼" (6 mm) thick, exterior glue	0.7
Gypsum wall board, ⅜" (9.5 mm) thick	50.0

*grains/hr·sq ft·inch mercury

1.19 Vapor retarders protect roof insulation and membranes against moisture attack that is a result of condensation. However, vapor retarders will not protect roof systems from entrapped moisture due to the installation of damp or wet insulation, or due to leaks in the roof membrane or flashings. Any condition which allows entry of surface water contributes to loss of thermal efficiency and possible premature failure of the roof insulation and roof membrane.

1.20 Vapor retarders must always be placed on the warm side of the insulation. JM FP-10 One-Way Roof Vents, compatible with the membrane used, may be helpful in venting a roof system whether or not a vapor retarder is used. The primary function of these vents is to relieve vapor pressure within the roofing system. It should be noted, however, that the installation of roof vents is not a practical method of drying out wet roof insulation.

1.21 These vents can also be used to relieve the moisture pressure in roof systems applied over non-cellular lightweight fills or old wet decks, reducing the possibility of moisture problems within the system.

1.22 Another system of venting the roof construction is to incorporate a venting base sheet with an insulation overlay. JM Ventsulation Felt is a coated felt with the bottom embossed or patterned in such a way as to provide channels for moisture vapor to travel to the outer edges of the building or to roof vents.

1.23 The addition of a vapor retarder to a roof system assembly on a steel deck typically requires double layer insulation with the vapor retarder sandwiched in between the two layers. The first layer is a minimum thickness base sufficient to span the flutes of the deck and to receive the vapor retarder membrane.

The second layer provides the primary insulation for the system.

1.24 The trend toward high thermal roof insulation has accentuated the need to protect the insulation with an adequate vapor retarder.

2.0 Design of Vapor Retarders

2.1 When a vapor retarder is part of the insulation system, it is imperative to know how to determine the temperature of the vapor retarder or any surface within the roof system to prevent condensation from forming within the system. The temperature of the vapor retarder is a function of the inside and outside air temperature, and the thermal resistance of the insulation system. The following is the formula for obtaining the vapor retarder temperature.

$$T_x = T_i - \frac{R_x}{R_t}(T_i - T_o)$$

where:

T_x = Temperature at vapor retarder.
T_i = Design temperature of inside air.
T_o = ASHRAE winter design temperature of outside air.
R_x = Sum of all resistances from inside to the vapor retarder.
R_t = Sum of the total thermal resistances of the roof/ceiling structure, including air films.

2.2 The dew point temperature can be found on the psychometric table, if the indoor temperature and the relative humidity of the inside air are known. It is imperative that the vapor retarder temperature be warmer than the dew point to prevent condensation at the vapor retarder. If this is not the case, more insulation must be installed above the vapor retarder. The additional resistance is added to the R_t in the formula to obtain a new vapor retarder temperature.

2.3 Example: The indoor conditions of a conventional building are 75°F (24°C) (T_i) and 60% relative humidity. The ASHRAE winter design temperature is -20°F (-29°C) (T_o) for outside air. The roof construction and resistances for each component is as follows:

	Total System Resistances (R_t)	**Resistances To Vapor Retarder (R_x)**
Inside Air Film	0.61	0.61
Steel Deck	0.00	0.00
Vapor Retarder	0.12	—
¾" (19 mm) Fesco	2.08	—
Roof Membrane	0.33	—
Outside Air Film	0.17	—
	3.31	0.61

5.2.4 Determine the temperature at the vapor retarder surface:

$$T_x = T_i - \frac{R_x}{R_t}(T_i - T_o)$$

$$= 75 - \frac{0.61}{3.31}(75 - (-20))$$

$$= 75 - \frac{0.61}{3.31}(95)$$

$$= 75 - 17.51$$

$$T_x = 57.49°F\ (14.16°C)$$

5.2.5 The dew point temperature for 75°F (24°C) and 60% relative humidity is 60°F (16°C) as found on the chart on page 5-4. Therefore, the vapor retarder surface Temperature (Tx) is colder than the condensation temperature (57°F vs. 60°F [14°C vs. 16°C]) and moisture will condense on the vapor retarder.

5.2.6 To correct this condition, additional insulation should be added above the vapor retarder, to make the vapor retarder warmer than the dew point or condensation temperature.

5.2.7 If 1½" (38 mm) Fesco Board with an "R" of 4.17 is substituted for the ¾" (19 mm) layer, the following will result:

	Total System Resistances (R_t)	**Resistances To Vapor Retarder (R_x)**
(Rt from first example)	3.31	—
(R of ¾" [19 mm] Fesco)	-2.08	0.61
Difference	1.23	—
R of 1½" (38 mm) Fesco	+4.17	—
Total Resistance, R_t	5.40	—

2.8 Recalculate the temperature at the vapor retarder surface:

$$T_x = T_i - \frac{R_x}{R_t}(T_i - T_o)$$

$$= 75 - \frac{0.61}{5.4}(75 - (-20))$$

$$= 75 - \frac{0.61}{5.4}(95)$$

$$= 75 - 10.75$$

$$T_x = 64.25°F\ (17.91°C)$$

2.9 Therefore, the vapor retarder temperature (64°F [18°C]) is warmer than the condensation temperature (60°F [16°C]) with 1½" (38 mm) of Fesco.

2.10 Psychometric Table

Dew Point or Saturation Temperature (°F)

% Internal Relative Humidity															
100	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100
90	30	33	37	42	47	52	57	62	67	72	77	82	87	92	97
80	27	30	34	39	44	49	54	58	64	68	73	78	83	88	93
70	24	27	31	36	40	45	50	55	60	64	69	74	79	84	88
60	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
50	16	20	24	28	33	36	41	46	50	55	60	64	69	73	78
40	12	15	18	23	27	31	35	40	45	49	53	58	62	67	71
30	8	10	14	16	21	25	29	33	37	42	46	50	54	59	62
20	6	7	7	9	13	16	20	24	28	31	35	40	43	48	52
10	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34
	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100

Dry Bulb Temperature (°F)

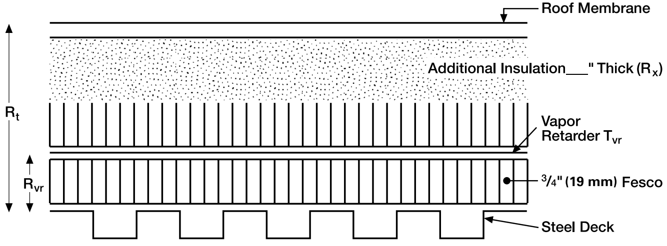
2.11 Typical Indoor Humidities in Winter:

Offices	30-50%
Hospitals	30-55%
Computer Rooms	40-50%
Department Stores	40-50%
Swimming Pools	50-60%
Textile Mills	50-85%

*This figure assumes the conditioning of interior air.

2.12 To carry this theory further, when a roof system construction is such that the vapor retarder is placed over a minimum layer of insulation, as shown below, the following calculations can be used to determine the thickness of insulation to establish the temperature at the vapor retarder to prevent condensation of vapor at or on the vapor retarder.

T_o = -20°F (-29°C)



T_i = 75°F (24°C) RH 60%

	Total System Resistances (R_t)	Resistances To Vapor Retarder (R_{vr})
Inside Air Film	0.61	0.61
Steel Deck	0.00	0.00
¾" (19 mm) Fesco	2.08	2.08
Vapor Retarder	0.12	—
*C-10 Fesco Foam (estimate)	10.00	—
BUR	0.33	—
Outside Air Film	0.17	—
Total "R"	13.31	2.69

* We know additional insulation is required above the vapor retarder, so we start our calculation by assuming C-10 Fesco Foam may be sufficient to prevent condensation at the vapor retarder (T_{vr}).

The following formula may be used to calculate the minimum "R" needed to prevent condensation.

$$R_x = R_{vr}\left(\frac{T_i - T_o}{T_i - T_{vr}} - 1\right) - R_e$$

where:

R_x = Insulation value needed above vapor retarder to prevent condensation.

R_{vr} = Thermal resistance to vapor retarder, i.e., "R" units below vapor retarder.

T_i = Inside design temperature.

T_o = Outside design temperature

T_{vr} = Temperature required at vapor retarder., i.e., 1 - 2 degrees above dew point.

R_e = Thermal resistance of existing construction above vapor retarder, not including R_x, (i.e., membrane and air film).