EEM-00259

Permeability of Common Building Material to Water Vapor

WHAT IS A PERM RATING?

If a material has a perm rating of 1.0, we know that in 1 hour, when the vapor pressure difference between the cold side and the warm side of the material is equal to 1 inch of mercury (1" Hg), 1 grain of water vapor will pass through 1 square foot of the material. One grain of water is equal to 1/7000 of a pound.

Vapor pressures depend on the temperature and relative humidity (RH) of the air — as temperature and RH go up, vapor pressure gets higher. The greater the vapor pressure differential across or through a material, the greater the tendency for water vapor to migrate from the high pressure side to the low pressure side.

EFFECT OF MATERIAL THICKNESS

The perm ratings given are for stated thicknesses of materials. Generally, doubling material thickness halves water vapor transmission: if 1 inch of a material has a perm rating of 2.0, then for 2 inches, the perm rating would be 1.0. With paints, however, adding a second coat more than halves the water vapor transmission.

ALASKAN VAPOR BARRIERS

Because of Alaska's wintertime vapor pressure differentials, and the lengths of the cold spells, the ideal vapor barrier has a perm rating approaching 0.0. The most widely used vapor barrier is 6 mil polyethylene, which has a perm rating of 0.06. Given the combination of high RH indoors, and very cold weather outside, measurable amounts of water vapor will pass through 6 mil polyethylene. For high moisture buildings, such as those housing swimming pools or Jacuzzis, 10 mil polyethylene is often specified. In practice, however, it is not usually the perm rating of the water vapor barrier which determines how much water will pass into the insulation, but the quality of the vapor barrier installation. A carefully installed, well sealed 4 mil polyethylene vapor barrier is much to be preferred to a 6 mil VB with unsealed seams, gaps, tears at electrical boxes and unsealed attic scuttle openings.

QUALITY OF DATA

Perm ratings are established by testing, but several different test methods are used, and different tests on the same materials yield different results. For this reason, published perm ratings are not to be regarded as the truth, but as a design guide. When the vapor barrier performance of a material is critical to an installation, it is best to rely on manufacturer's specifications, or conduct an independent test. For an enlightening discussion of this issue, see The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE's) *1985 Handbook of Fundamentals.*

A SAMPLE CALCULATION

For demonstration purposes, we shall now assume a set of conditions and make a calculation concerning the amount of water vapor which will migrate through a vapor barrier. The relevant formula is:

WVT = A x T x delta P x perms

WVT stands for **"water vapor transmission."** Unit of measurement: grains. One pound equals 7000 grains.

A means **"area."** Unit of measurement: square feet (ft^2). We will assume that this is a two story house, 24' wide by 40' long by 17' high. Area of the vapor barrier, then, is about **3900** ft^2, allowing 10% of floor area for doors and windows.

T means **"time."** Unit of measurement: hours. We will perform this calculation for the month of January, which has **744** hours.

Delta P means **"difference in vapor pressure between inside and outside."** Unit of measurement: inches of mercury (" Hg). In order to derive this number, we must assume a temperature and a relative humidity (RH) for both inside and out. Let the inside temperature be 70°, and the outside -10°, which is about average for January in Fairbanks. Let the inside RH be 40%, and the outside be 70%. The Table of Vapor Pressures gives figures for saturated air (100% RH); to get the vapor pressure at an RH less than 100%, you multiply by the percent RH. In this case, (.7392 x 40%) - (.022 x 70%) = **.2803** " Hg.

Perms means **"perm rating."** Unit of measurement: grains of water vapor per hour per square foot per inch of mercury vapor pressure differential (gr/ft^2/hr/" Hg). We will assume that the average perm rating of the installation (including unpatched tears, nailholes, etc.) is 0.1 perms.

With these assumptions, then:

WVT = A x T x Delta P x Perms
3900 x 744 x .2803 x 0.1 = 81332

grains of water. This is 11.6 pounds, or about 1.4 gallons.

TABLE 1 VAPOR PRESSURES FOR SATURATED AIR

°F	in Hg	°F	in Hg	°F	in Hg	°F	in Hg
-65	.0007	15	.0806	43	.2782	71	.7648
-60	.0010	16	.0847	44	.2891	72	.7912
-55	.0014	17	.0889	45	.3004	73	.8183
-50	.0020	18	.0933	46	.3120	74	.8462
-45	.0028	19	.0979	47	.3240	75	.8750
-40	.0039	20	.1028	48	.3364	76	.9046
-35	.0052	21	.1078	49	.3493	77	.9352
-30	.0070	22	.1131	50	.3626	78	.9666
-25	.0094	23	.1186	51	.3764	79	.9989
-20	.0126	24	.1243	52	.3906	80	1.032
-15	.0167	25	.1303	53	.4052	81	1.066
-10	.0220	26	.1366	54	.4203	82	1.102
-5	.0289	27	.1432	55	.4359	83	1.138
0	.0377	28	.1500	56	.4520	84	1.175
1	.0397	29	.1571	57	.4686	85	1.213
2	.0419	30	.1645	58	.4858	86	1.253
3	.0441	31	.1723	59	.5035	87	1.293
4	.0464	32	.1803	60	.5218	88	1.335
5	.0488	33	.1878	61	.5407	89	1.378
6	.0514	34	.1955	62	.5601	90	1.422
7	.0542	35	.2035	63	.5802	91	1.467
8	.0570	36	.2118	64	.6009	92	1.513
9	.0599	37	.2203	65	.6222	93	1.561
10	.0629	38	.2292	66	.6442	94	1.610
11	.0661	39	.2383	67	.6669	95	1.660
12	.0695	40	.2478	68	.6903	96	1.712
13	.0730	41	.2576	69	.7144	97	1.765
14	.0767	42	.2677	70	.7392	98	1.819

TABLE 2 PROPERTIES OF WEATHER BARRIERS AND BUILDING PAPERS

Product Name	Tyvek housewrap, Dupont Company	Airtight-Wrap Presec, Inc.	Rufco-Wrap Raven Industries	Tu-Tuf Air Seal, STO-COTE Products	Barricade Building Wrap-Simplex	Conventional 15-lb asphalt-impregnated building felt
Type Product	Single bonded Polyethylene	Micro-perforated cross-laminated high-density polyethylene film			Spun-Bonded polyester	
	(1)	(2,3,4)			(5)	(6)
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Permeance (**perms**) ASTM E-96						
Method A	94	{15.2}	{15.2}	21.8	25.4	[5.6]
Method B	103	{17.3}	{17.3}	26.4	47.9	
Thickness (**mils**)	6.1	3	3	3.4	6	37.4
Weight (**lb/1,000 ft^2**)	8.81	12.7	12.7	12	136.1	150
Available dimensions (**ft**)	9x195 3x160	9x195 4.5x195	9x195 4.5x195	9x195 4.5x195 8x195	3x195 4.5x195	3 rolls (3x100)
Tensile strength, (**lbs**) ASTM D-1882						
Length	43.2	57.2	57.2	57.2	N.A.	N.A.
Width	64	60.4	60.4	60.4		
Tear resistance (**lbs**) ASTM D-827						
Length	32.5	[36.0]	[36.0]	[36.0]	[5.2]	[24.8]
Width	24.8	[36.0]	[36.0]	[36.0]	[14.6]	[20.7]
Air porosity (**seconds**) Gurley porosity TAPPI-T460	17.6	[8.7]	[8.7]	[8.7]	10.5	[14.3]
Water resistance (**cm**) AATCC Method 127	99.3	11	11	11	[35.8]	[41.8]

NOTES:

1. Extrapolated from, "Wrap Wars," Alex Wilson, *New England Builder,* August 1987.
2. Values in brackets, [ ], obtained from DuPont literature on Tyvek.
3. Values in brackets, { }, low because film installed backwards (worst-case situation).
4. All other values obtained from company literature or personal communication with company.
5. Perm: Vapor transmission rate of 1 grain of water vapor/ft^2/hr/in. of mercury pressure difference.
6. The data are provided to permit comparison of material and selection of air-vapor barrier or weather barrier materials.
7. Exact values should be obtained from the manufacturer of material.
8. A continuous air-vapor barrier is usually placed on the warm side of the shell before the gypsum board (drywall) is placed.
9. The air-vapor barrier should have a permeance of less than 1 perm.
10. The weather barrier should have a high permeance, a low water resistance, a high air porosity, high tensile strength, and high tear resistance.
11. The compilation is from a number of sources; values from dry-cup and wet-cup methods were usually obtained from investigations using ASTM E96 and C355. Other values were obtained using techniques such as two-temperature, special cell, and air velocity.

Source: Axel R. Carlson, Professor Emeritus, University of Alaska Fairbanks, Fairbanks, Alaska, 9/3/87.

TABLE 3 WATER VAPOR PERMEANCE OF CONSTRUCTION MATERIALS

Material	Thickness (in.)	Permeance (perm)	Permeability (perm/in.)
MATERIALS USED IN CONSTRUCTION			
Concrete, 1:2:4 mix	4	1.25	3.2
Brick masonry	4	0.8	
Concrete block, cored limestone aggregate	8	2.4	
Tile masonry, glazed	4	0.12	
Asbestos cement board	0.12	4-8	
with oil base finish	0.12	0.3-0.5	
Plaster on metal lath	0.75	15	
Plaster on wood lath	0.75	11	
Plaster on plain gypsum lath, with studs	0.75	20	
Gypsum wall board, plain	0.375	50	
Gypsum sheathing, asphalt impregnated	0.5		20
Structural insulating board, sheathing quality	0.5		20-50
Structural insulating board, interior uncoated	0.5	50-90	
Hardboard, standard	0.125	11	
Hardboard, tempered	0.125	5	
Roofing, built up, hot mopped		0	
Wood, sugar pine			0.4-5.4
Plywood, Douglas Fir, exterior glue	0.25	0.7	
Plywood, Douglas Fir, interior glue	0.25	1.9	
Acrylic, glass fiber reinforced sheet	0.056	0.12	
Polyester, glass fiber reinforced sheet	0.048	0.05	
THERMAL INSULATIONS			
Air still			120
Cellular glass			0
Mineral wool, unprotected			116
Expanded polyurethane, R-ll, board stock			0.4-1.6
Expanded polystyrene, extruded			1.2
Expanded polystyrene, bead			2.0-5.8
Phenolic foam, covering removed			26
Unicellular synthetic flexible rubber foam			0.02-0.15
PLASTIC AND METAL FOILS AND FILMS			
Aluminum foil	0.001	0	
Aluminum foil	0.00035	0.05	
Polyethylene	0.002	0.16	
Polyethylene	0.004	0.08	
Polyethylene	0.006	0.06	
Polyethylene	0.008	0.04	
Polyethylene	0.010	0.03	
Polyvinyl chloride, unplasticized	0.002	0.68	
Polyvinyl chloride, plasticized	0.004	0.8-1.4	
Polyester	0.001	0.73	
Polyester	0.0032	0.23	
Polyester	0.0076	0.08	
Cellulose acetate	0.01	4.6	
Cellulose acetate	0.0125	0.32	

TABLE 3 *(CONTINUED)*

Material		Permeance, (perms) Dry-cup	Wet-cup	Other
BUILDING PAPERS, FELTS, ROOFING PAPERS:	**Weight (lb/100 ft²)**			
Duplex sheet, asphalt laminated, aluminum foil, one side	8.6	0.002	0.176	
Saturated and coated roll roofing	65	0.05	0.24	
Kraft paper and asphalt laminated, reinforced 30-120-30	6.8	0.3	1.8	
Blanket thermal insulation back up paper, asphalt coated	6.2	0.4	0.06-4.2	
Asphalt-saturated but not coated sheathing paper	4.4	3.3	20.2	
Asphalt-saturated and coated vapor barrier paper	8.6	0.2-0.3	0.6	
15-lb asphalt felt	14	1	5.6	
15-lb tar felt	14	4	18.2	
Single-kraft, double	3.2	31	42	
LIQUID-APPLIED COATING MATERIALS	**Thickness (in.)**			
Commercial latex paints, dry film thickness				
Vapor retardant paint	0.0031			0.45
Primer sealer	0.0012			6.28
Vinyl acetate/acrylic primer	0.002			7.42
Vinyl-acrylic primer	0.0016			8.62
Semi-gloss vinyl-acrylic enamel	0.0024			6.61
Exterior acrylic house and trim	0.0017			5.47
Paint, 2-coats				
Asphalt paint on plywood			0.4	
Aluminum varnish on wood		0.3-0.5		
Enamels on smooth plaster			0.5-1.5	
Primers and sealers on interior insulation board			0.9-2.1	
Various primers plus 1-coat flat oil paint on plaster			1.6-3.0	
Flat paint on interior insulation board			4	
Water emulsion on interior insulation board			30.0-85.0	
Exterior paint 3-coats, on wood siding	**(oz/ft²)**			
White lead and oil		0.3-1.0		
White lead-zinc oxide		0.9		
Styrene-butadiene latex coating	2	11		
Polyvinyl acetate latex coating	4	5.5		
Chloro-sulfonated polyethylene mastic	3.5	1.7		
Chloro-sulfonated polyethylene mastic	7	0.06		
Asphalt cut-back mastic, 1/16 in., dry		0.14		
Asphalt cut-back mastic, 3/16 in., dry		0		
Hot melt asphalt	2	0.5		
Hot melt asphalt	3.5	0.1		

Notes:

1. Extrapolated from "Moisture in Building Construction," ASHRAE, 1985.
2. Tables give water transmission rates of representative materials.
3. Perm: Vapor transmission rate of 1 grain of water vapor/ft2/hr/in. of mercury pressure difference.
4. Exact values should be obtained from the manufacturer of material.
5. The air-vapor barrier should have a permeance of less than 1 perm.
6. The air barrier should have high permeance, low water resistance, high air porosity, high tensile strength, and high tear resistance.
7. The compilation is from a number of sources; values from dry-cup and wet-cup methods were usually obtained from investigations using ASTM E96 and C355. Other values were obtained using techniques such as two-temperature, special cell, and air velocity.

Source: Axel R. Carlson, Professor Emeritus, University of Alaska Fairbanks, Fairbanks, Alaska, 9/3/87

TABLE 4 PERMEANCE OF INTERIOR WALL COVERINGS

Treatment	Outside Temperature, °F	Relative Humidity %	Water Passing ml/h	Permeance perm	Variance
Control	-8.0	60	1.32	7.02	0.783
Control	-10.5	41	1.04	7.68	0.456
Cotton cloth	12.3	61	0.66	3.61	0.347
Sealer, 1-coat	-16.2	62	0.91	4.29	0.498
Sealer, 1-coat	5.8	63	0.78	4.03	0.145
Sealer, 2-coat	-17.3	61	0.54	2.78	0.082
Wall paper, conventional	-17.8	38	0.82	7.03	0.366
Vinyl paper	-24.0	66	0.15	0.73	0.189
Mean	-9.46	56	0.78	4.65	0.358

NOTES:
1. Extrapolated from, "Interior Wall Coverings For Moisture Control," James A. Lindley and Helen A. Lunde, Agricultural Engineering and Home Economics Departments, North Dakota State University, Fargo, North Dakota, 1987.

Source: Axel R. Carlson, Professor Emeritus, Cooperative Extension Service, University of Alaska Fairbanks, Fairbanks, Alaska, 9/21/87.

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