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The water-vapor permeability of a variety of pulp, fiber, and felt materials was determined in accordance with ASTM Test Procedure C214-47T, which is now a part of ASTM Designation E96-53T.[2] The study was made on matched material, and both the dry and the wet method (procedures C and D of E96-53T)were used. Data covering comparable tests by both methods are limited, and the present report probably represents the most extensive coverage of materials now available.

As shown in table 1, the test methods yielded different mean vapor-permeability (perm) values, the wet method showing higher perm values in almost every case than the dry method. Other investigators have also found that perm values obtained by the wet method are consistently higher than those obtained by the dry method.

Table 1 shows the water-vapor permeability of various classes of papers and felts in the order of their resistance to water-vapor transmission as based on the dry method of test. Corresponding values derived by the wet method are shown opposite values for the dry method for ease of comparison. Ratios of values for the wet method to those for the dry method are also shown.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Bell, E. R., Seidl, M. G., and Krueger, N. T. Water-Vapor Permeability of Building Papers and Other Sheet Materials. Heating, Piping, and Air Conditioning, ASHVE Journal, December 1950.

Figure 1 shows the spread between the average perm value based on dry test procedure and wet test procedure for all materials in each class or type represented.

Of course, the spread in perm values for individual test materials, as determined by the dry and wet tests, was considerably greater in many cases than the spread between average values. Several types of material yielded average values, as shown in figure 1, well below 1 perm by the dry test method, the limit commonly assumed to be satisfactory for vapor barriers in walls of houses. The individual values, however, indicate that individual materials in several of the classes represented would not meet the 1-perm requirement (fig. 2).

So far as is known, no other investigator has attempted to explain the difference in perm value due to test method used. Some possible contributing factors are suggested in this report that could be responsible for the differences in perm values. The suggestions, of course, are purely theoretical, being based on study of the test data.

Materials With Aluminum Foil Facings

The foil-faced barriers showed the highest resistance under the dry method of test. If the foil were perfect, having no pin holes or other defects, there should be virtually no detectable vapor transmission. The high resistance obtained indicated that the material was almost free from defects. The wet test method values, on the other hand, showed definite moisture movement. It is reasonable to assume that any pin holes present would be essentially the same in average size in the specimens used for the wet test as in those for the dry test. Two suggestions are offered to explain the possible reasons for the higher perm values for the wet test than the dry test on the foil-faced specimens: (1) Liquid "creep" through pin holes, and (2) corrosive action of liquids on the metal foil around pin holes, which had the effect of enlarging the holes. If corrosion was an important factor, it should have been noted when the study was being made, because of the increasing rate of moisture loss from the test pans. In cases where the change in weight between weighings was as small as that which occurred in these tests, it is possible that any increase in the rate of loss would not be noted.

Materials Without Foil Facing

Specimens without foil facing are tested by the dry method by sealing them in a dish containing a dessicant, anhydrous calcium chloride, and exposing the dish in a chamber held at a constant temperature of 90° F. and 50 percent relative humidity. In the wet method the specimens are sealed to a pan containing water and exposed in the same chamber. It is assumed that the relative humidity is 0 in the dish with the dessicant and 100 percent in the pan over the water. The differences in vapor pressure on opposite sides of the test specimens would then be equal by either method of test. Perhaps actual exposure conditions do not quite meet this ideal, but certainly they are approximately about as described.

If we assume that the difference in vapor pressure generates the only form of energy moving water vapor through the membrane, we could then expect that perm values would be essentially the same by either method of test. The perm values in table 1 show consistently higher values by the wet method than by the dry method and greater differences in some materials than in others. Apparently there are other forces or forms of energy in the wet tests that are not equally effective in the dry test, and the variation in ratio between wet and dry values for different materials indicates that such forces affect some materials more strongly than others.

The test materials are made up of paper or felt to which asphalt has been added as a coating, a saturant, or an adhesive between sheets of paper. Surfacing materials, such as aluminum foil and reflective coatings, were used on some materials. In themselves, the papers and felts are low in vapor resistance; the added saturant or coatings make the membrane resistive to vapor transmission.

Where the fibers of the membrane would not be completely embedded in the coating or saturant, differences in the equilibrium moisture content on opposite sides of the membrane could contribute to moisture transfer. In the dry test method, the equilibrium moisture content on the surface facing the dessicant could be assumed to be 0 percent and that on the opposite side 9 percent. In the wet test method, the equilibrium moisture content of the surface toward the water could be 30 percent and that of the opposite surface 9 percent. The big difference in equilibrium moisture content values thus created by the wet and dry methods might very well contribute to the higher rate of moisture transmission found in the wet test method.

The asphalt may add more resistance to vapor transmission when the materials are exposed to a low humidity than when they are exposed to a high humidity. In the group of papers and felts that are termed coated, infused, saturated, or laminated, it is the asphalt present that provides the resistance to vapor transmission. The paper or felt itself offers very little vapor resistance. Some coated papers have a thin wax finish on one side, and this finish could contribute somewhat to their vapor resistance.

The relationship of the weight of asphalt used in laminated papers to their vapor transmission as established by the dry and wet test methods, as well as to that of plain, reinforced creped, and treated material is shown in table 1. Each of the four classes of laminated papers shows about the same perm values by the dry test method, but values obtained by the wet test method make the plain laminated paper appear consistently more resistive to vapor transmission than the creped and treated types. Among the laminated papers, it might be expected that those having the heaviest asphalt lamina would have the highest resistance. This is generally the case, but nevertheless some of the specimens with lighter weight asphalt laminas have greater resistance than some of those with the heavier laminas. Perhaps this indicates that the quality of the asphalt varies, or perhaps it is indicative of variation in uniformity of application. If these questions could be answered for laminated papers, it might also lead to explanations for variations in other types of papers.

Dry Versus Wet Test

The dry test method is best suited for testing the permeance of materials that will not be subjected in service to high humidities or liquid moisture. An example would be a typical vapor barrier used in walls and ceilings in house construction as a protective measure against cold weather condensation.

The wet test method is best suited for testing the permeance of materials that may be exposed in service to high humidities or liquid moisture. An example would be a vapor barrier used under concrete floor slabs or as ground cover in crawl spaces of houses. Perhaps the wet test should also apply to sheathing, sheathing paper, and other materials used in the exterior portions of walls. Under certain exposure conditions, these elements of the wall may be exposed to saturated conditions and wet test values would be representative while dry test values could be very misleading.

Table 1.--Water-vapor permeability of various classes of papers tested by dry and wet method

Sample No.	Per square	Per roll 500 square feet	Per ream: Paper	Per ream: Asphalt	Per ream: Paper	Dry method: Number of specimens	Dry method: Perms[1]	Wet method: Number of specimens	Wet method: Perms[1]	Ratio wet to dry	Notes
	Lb.	Lb.	Lb.	Lb.	Lb.						
					FOIL-FACED PRODUCTS						
1613		18		20	30	2	0.000	2	0.027	∞	Aluminum face up
1705		43				2	.001	2	.163	163.0	Do.
1705		43				1	.002	2	.176	88.0	Aluminum face down
1613		18		20	20	2	.002	2	.228	114.0	Do.
1805		16			20	2	.003	2	1.072	390.0	Do.
1805		16			20	2	.005	2	4.370	874.0	Aluminum face up
2000		49				2	.012	2	.248	20.67	Aluminum face down
2000		49				2	.107	2	.331	3.09	Aluminum face up
1614		28	20	80	20	3	.230	3	.041	.178	Aluminum foil both sides
					ROLL ROOFING						
1802	65					3	.017	3	.122	7.17	
1202	45					3	.027	3	.366	13.52	
1208	65					3	.027	3	.376	13.93	
106	45					3	.030	3	.130	4.33	
1200	45					2	.030	3	.581	19.36	
104	45					2	.032	4	.143	4.47	
105	55					3	.035	3	.158	4.51	
100	65					3	.052	3	.239	4.60	
1203	60					3	.080	3	.293	3.66	
1803	55					3	.081	3	.180	2.22	
					KRAFT COATED WITH ASPHALT						
1005		50				2	.146	3	1.046	7.16	
1804		88				2	.156	3	.252	1.62	
400		43				5	.287	5	.566	1.97	
					INSULATION BACK-UP PAPER						
1000		48				2	.116	8	3.612	31.13	Asphalt side down
1004		18				3	.133	2	2.497	18.76	Asphalt side up
1616		18				2	.162	2	.446	2.75	Do.
1616		18				2	.232	2	.589	2.54	Asphalt side down
1004		18				4	.237	2	2.835	11.96	Do.
1000		48				2	.253	8	1.774	7.01	Asphalt side up
1806		21				2	.327	2	4.234	12.95	Glossy side up
1806		21				2	.377	2	.583	1.55	Glossy side down
1617		12				4	.443	2	1.801	4.07	Asphalt side up
1617		12				4	.583	2	.806	1.38	Asphalt side down
					LAMINATED--PLAIN						
1700		43	60	160	60	3	.227	3	.876	3.86	
1103		27	30	100	30	2	.280	1	.451	1.61	
1706		22	30	60	30	6	.323	3	.422	1.31	
1211		35	60	80	60	3	.330	3	.743	2.25	
609		16	30	30	30	8	.447	3	.768	1.72	
1709		30	60	60	60	6	.504	3	1.349	2.68	
1619		27	50	60	50	3	.526	2	.864	1.64	
605		21	30	60	30	5	.527	5	1.660	3.15	
1704		15	30	30	30	3	.703	6	1.585	2.25	
1603		17	30	40	30	3	.711	5	1.752	2.46	
602		11	20	20	20	2	.805	2	1.976	2.85	
1215		16	30	30	30	3	.846	3	2.917	3.45	
1600		15	30	30	30	3	1.081	3	2.014	1.86	

Table 1.--Water-vapor permeability of various classes of papers tested by dry and wet method (Cont.)

Sample No.	Per square	Per roll 500 square feet	Per ream: Paper	Per ream: Asphalt	Per ream: Paper	Water-vapor permeability: Dry method: Number of specimens	Dry method: Perms[1]	Wet method: Number of specimens	Wet method: Perms[1]	Ratio wet: to dry	Notes
	Lb.	Lb.	Lb.	Lb.	Lb.						
				LAMINATED--REINFORCED--UNTREATED							
1612	....	30	30	120	30	3	0.241	3	0.835	3.47	
1608	....	45	60	150	60	2	.274	3	1.257	4.59	Creped 1 face
1102	....	15	30	30	30	2	.305	1	2.194	7.20	
1501	....	34	30	120	30	3	.346	3	1.839	5.27	
1210	....	30	45	90	45	3	.362	3	2.423	6.70	Creped
1209	....	30	30	120	30	3	.389	3	1.119	2.88	
1105	....	24	30	85	30	2	.654	1	2.334	3.57	
1107	....	10	20	20	20	2	1.241	1	1.660	1.34	
				LAMINATED--CREPED--NOT REINFORCED							
1620	....	38	50	130	50	5	.205	3	.908	4.43	
1100	....	20	30	60	30	2	.345	1	.925	2.68	
1101	....	15	30	30	30	2	.583	1	1.547	2.65	
1104	....	15	30	30	30	2	.657	1	1.702	2.59	
1106	....	26	40	73	40	2	.840	1	2.391	2.85	
603	....	14	30	30	30	5	1.816	7	3.939	2.17	
610	....	21	20	80	20	8	2.145	5	3.845	1.79	
1213	....	23	40	55	40	6	3.159	6	6.184	1.96	
				LAMINATED--ONE OR MORE COVER SHEETS TREATED (SATURATED)							
1502	....	39	40	120	40	6	.258	6	1.067	4.14	Saturated 2 sides, reinforced
1611	....	27	30	100	30	3	.279	3	1.024	3.67	Saturated 2 sides, reinforced
1214	....	30	60	30	60	2	.935	4	5.741	6.14	Saturated side down
1214	....	30	60	30	60	2	1.037	4	6.369	6.14	Saturated side up
				ASPHALT FELT (SATURATED WITH ASPHALT)							
103	30	....	....	....	....	3	.498	2	3.465	6.96	
1801	30	....	....	....	....	6	.560	3	3.447	6.15	
1205	15	....	....	....	....	6	.774	3	2.815	3.65	Asbestos base
102	15	....	....	....	....	3	.971	3	5.564	5.74	
1800	15	....	....	....	....	3	1.207	3	5.661	4.67	
1206	15	....	....	....	....	3	2.007	3	8.158	4.06	
1207	30	....	....	....	....	3	3.022	3	6.394	2.11	
				TAR FELT (SATURATED WITH TAR)							
101	15	....	....	....	....	3	1.560	3	9.355	6.00	
1204	15	....	....	....	....	3	4.055	3	18.234	4.50	
1201	30	....	....	....	....	6	33.303	3	36.363	1.09	
				SINGLE SHEET KRAFT SATURATED WITH ASPHALT (DOUBLE INFUSED)							
1707	15	....	....	....	....	3	2.469	3	7.044	2.86	
1212	22	....	....	....	....	6	3.267	3	20.231	6.20	
1701	18	....	....	....	....	6	3.612	6	9.429	2.61	
607	11	....	....	....	....	5	6.197	5	9.755	1.58	
1703	11	....	....	....	....	6	7.447	3	11.916	1.60	
1702	23	....	....	....	....	5	7.987	6	12.235	1.55	
1710	23	....	....	....	....	3	11.656	3	16.515	1.42	
606	16	....	....	....	....	5	30.304	5	36.323	1.09	
608	9	....	....	....	....	3	99.323	5	67.807	.683	
1621	19	....	....	....	....	3	99.345	3	66.997	.674	

[1] Perms = grains transmitted per hour, per square foot, at a pressure differential equivalent to 1 inch of mercury.

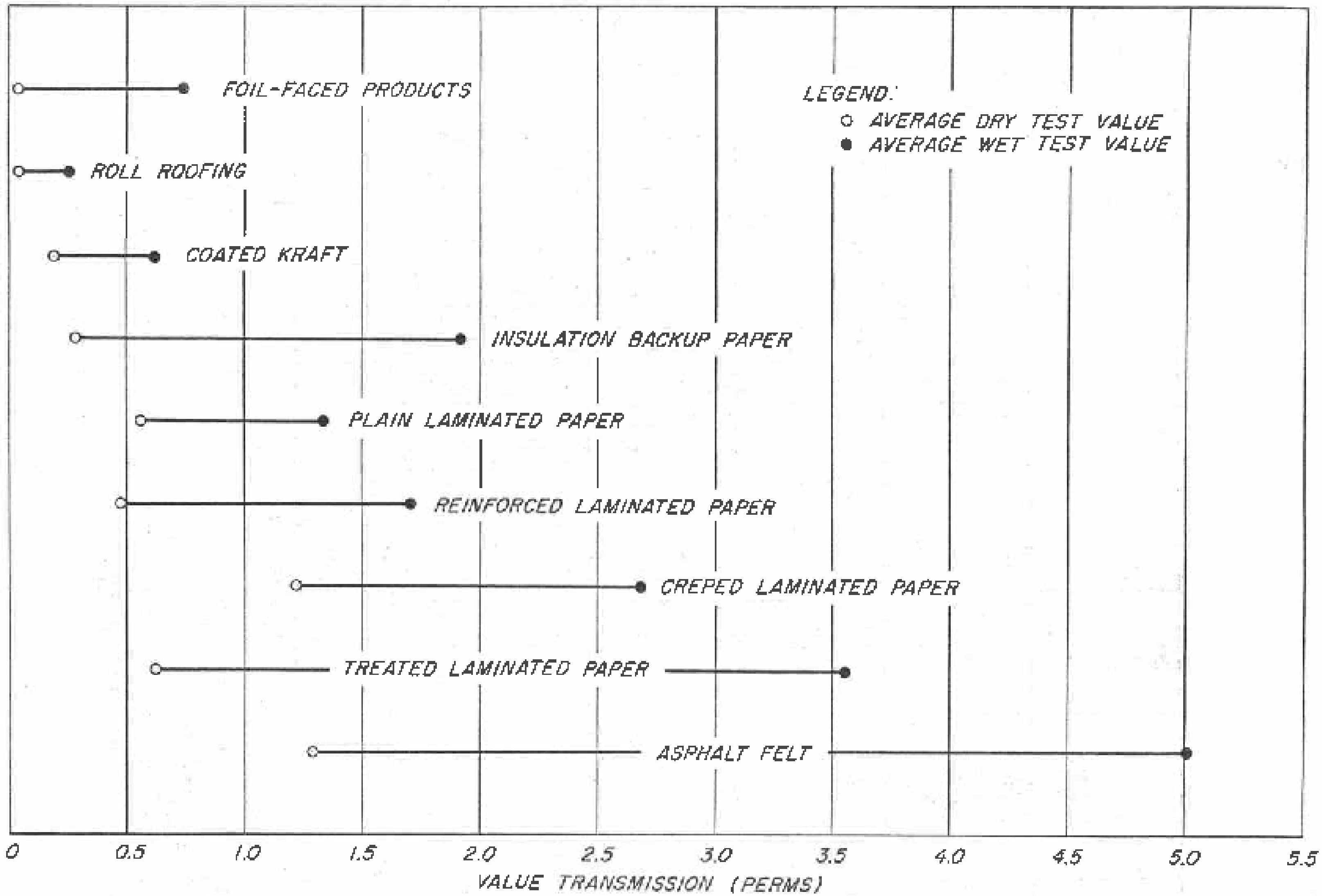

Figure 1. --Spread in average perm values of various classes of sheet materials showing varieties in permeance between dry test and wet test procedure.

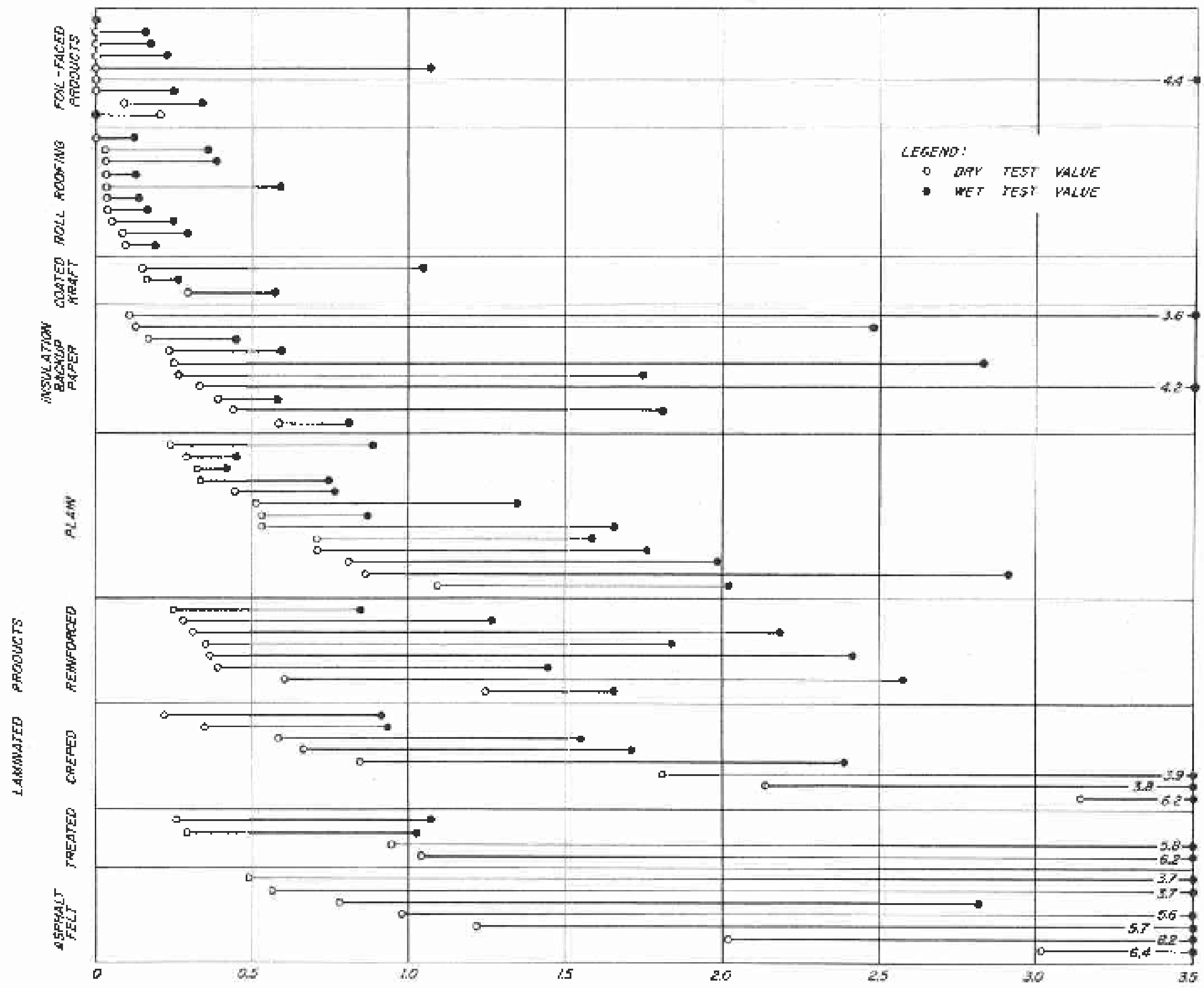

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Figure 2. --Spread in perm values of individual samples within classes of various sheet materials based on both dry and wet test procedure.