RP85

A STUDY OF SHEATHING PAPERS

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ABSTRACT

In order to obtain data which might be used in the formulation of standard specifications for sheathing paper a study was made of some of the important properties of 36 samples of building papers made by 14 different manufacturers. These samples consisted of asphalt-saturated, paraffin-saturated, laminated and asphalt-treated, and machine-finished papers. The papers were tested for weight, thickness, tensile breaking strength, bursting strength, tearing resistance, water resistance, and air permeability.

The papers differ considerably in weight and thickness and also in density. Only in the case of papers of like structure does there appear to be any definite relation between weight and thickness or between either of these and other properties. A fair degree of parallelism exists between the tensile breaking strength and the bursting strength. In each of these two properties there were found differences amounting to about fourfold between extremes. Some of the strongest papers are among the thinner ones, and some of the heavier papers are comparatively weak. The papers differ greatly in strength retention after wetting. The time required for water to penetrate through the sheet differs between wide limits, from less than a minute to several days. In the rate of flow of air through the papers there are relatively large differences, although most of the papers are fairly resistant to air, a few being air-tight within the ability of the testing method to detect permeability.

It is concluded from the test data and supplementary information about sheathing paper that the thickness of building papers is relatively unimportant; that strength is of significance chiefly in handling the paper during erection; that water resistance and impermeability to air are of prime importance in making a wall weatherproof; but that most commercial sheathing papers are capable of performing this function sufficiently well.

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I. INTRODUCTION

Sheathing paper, although it is a relatively insignificant cost item in building construction, has some very important functions to perform in helping to make a weatherproof wall. In addition to its use in wall construction, the material has other uses, chiefly of a protective nature, which are very important. The wise choice of a building paper suited to a given purpose would obviously be greatly facilitated by a knowledge of the more important properties possessed by such materials and by the correlation of these properties with service demands. Practically no information of a definite character is available with reference to the properties of the many kinds of sheathing papers on the market.

In order to obtain some definite data which might be used in the formulation of standard specifications for sheathing paper, the National Bureau of Standards has made a study of some of the more important physical and mechanical properties of as representative a lot of samples as could be obtained. This work was done at the request of the National Lumber Manufacturers' Association, which desired the information to use as a part of its service to members. This association contemplates conducting field experiments to correlate the laboratory data with service results, which is a necessary sequel to the investigation reported in this publication.

II. DESCRIPTION OF SAMPLES

1. MEANS OF PROCURING SAMPLES

A preliminary survey was made of the products being used as building papers, and laboratory tests were made on a number of representative samples. A preliminary report was then prepared and sent out with a form letter to 34 concerns scattered over the United States, inviting them to cooperate and to submit samples, together with such information as might be useful in formulating specifications. Compliance was made by 14 concerns, as a result of which 36 samples, consisting of 4 distinct groups and many types and weights, were included in the investigation.

2. GROUP A, ASPHALT-SATURATED PAPERS

A group of eight samples, designated as 1A, 2A, 3A, etc., was made up of papers which had been impregnated with asphalt to make them more resistant to permeation by air and water. The base papers ranged in composition from strong wrapping paper to rather weak paper containing a considerable amount of low-grade fiber, such as ground wood and fibers from waste materials of sundry sorts. The base paper of sample 1A was made of kraft pulp, such as is used in making strong wrapping papers; of 2A, 3A, and 5A to 8A, mixed fibers; of 4A, chemically prepared wood fiber similar to that used in medium-grade wrapping papers.

3. GROUP P, PARAFFIN-SATURATED PAPERS

A second, small group, designated as 1P, 2P, and 3P, consisted of three different weights of kraft paper impregnated with paraffin so as to make the sheathing paper weather resistant.

4. GROUP L, LAMINATED PAPERS OF HETEROGENEOUS STRUCTURE

A third group, designated as 1L, 2L, 3L, etc., consisted of laminated building papers made up of two or more layers of paper cemented together with one or more layers of asphalt, the asphalt layers constituting the weather-resisting medium and the paper imparting strength to the material. The base papers of most of these were kraft (strong wrapping paper stock), either plain or previously impregnated with oil or asphalt. The base paper of a few was made of reclaimed waste paper. The paper base of sample 1L consisted of one layer of plain kraft paper and one of kraft previously saturated with asphalt; of 2L, three layers of oiled kraft; of 7L, two layers of oiled kraft; of 3L, 6L, and 8L, two layers of plain kraft; of 4L, two layers of asphalt-saturated kraft; of 5L, 9L, 10L, and 11L, two layers of paper made from reclaimed waste paper. Sample 3L, in addition to the layers of paper and asphalt, had a layer of crossed fibers or threads embedded in the asphalt layer in order to impart additional strength to the material. Sample 8L also, in addition to the layers of paper and asphalt, had a layer of metal foil embedded in the asphalt layer in order to increase the weather-resisting properties.

5. GROUP M, MACHINE-FINISHED PAPERS

A fourth group, designated as 1M, 2M, 3M, etc., consisted of machine-finished papers which had not been subsequently treated or processed to enhance those properties desirable in building papers. Samples 1M, 6M, 11M, and 12M were composed of chemically-prepared wood fibers and were of the general nature of heavy wrapping papers. Sample 13M was made of reclaimed waste papers. Sample 14M was made of various kinds of fibers apparently derived from waste materials of the textile and paper industries. All the other samples in this group were composed of mixed wood fibers. Sample 14M was not strictly a sheathing paper in the same sense as the others, but was a heavy felt intended for use in deadening sound.

Other characteristics of these four groups of sheathing papers are shown in Table 1. Practically all the sheathing papers examined are furnished in rolls 36 inches wide. A few types are furnished also in the additional widths of 20, 40, 48, and 60 inches.

TABLE 1.—*Physical and mechanical properties of sheathing papers*

Identification No.	Weight of 1,000 square feet	Thickness	Tensile breaking strength: Dry paper, Machine direction	Tensile breaking strength: Dry paper, Cross direction	Tensile breaking strength: Wet paper, Machine direction	Tensile breaking strength: Wet paper, Cross direction	Tensile breaking strength: Ratio of wet to dry, Machine direction	Tensile breaking strength: Ratio of wet to dry, Cross direction	Bursting strength	Tearing resistance: Machine direction	Tearing resistance: Cross direction	Transudation of water	Air permeability	Price index per unit of area
	Pounds	*Thousandths inch*	*Lbs./in.*	*Lbs./in.*	*Lbs./in.*	*Lbs./in.*			*Points*	*g*	*g*	*Minutes*	*Ft.³/ft.²/min.*	
Group A:														
1A	48	7.8	76.3	36.2	57.8	31.0	0.76	0.86	97	171	140	150	----------	----------
2A	101	23.4	57.2	32.0	59.6	34.0	1.04	1.06	76	319	253	2,500	----------	----------
3A	100	22.5	42.3	28.2	45.4	29.7	1.07	1.05	59	214	182	1,700	----------	180
4A	44	13.3	61.0	18.9	9.5	3.4	.16	.18	76	244	154	18	0.003	89
5A	148	28.5	32.4	18.8	34.9	21.4	1.08	1.14	38	250	186	∞	----------	----------
6A	163	35.5	30.1	15.0	27.6	10.0	.92	.67	51	726	573	900	.007	----------
7A	79	14.7	27.4	13.0	12.1	5.3	.44	.41	30	212	176	90	----------	----------
8A	66	14.1	31.2	11.5	12.5	5.6	.40	.49	31	181	147	60	.006	----------
Group P:														
1P	35	6.5	60.8	32.0	24.6	11.3	.40	.35	75	146	114	35	----------	137
2P	26	5.3	36.4	24.6	8.8	5.0	.24	.20	45	99	99	17	----------	94
3P	18	3.9	29.6	13.0	6.7	2.8	.23	.22	38	58	55	7	----------	80
Group L:														
1L	63	13.0	97.2	46.8	24.0	11.0	.25	.24	117	362	312	2,500	----------	155
2L	70	13.8	79.3	40.9	38.6	20.5	.49	.50	93	255	250	3,200	----------	124
3L	54	17.8	83.8	38.2	38.4	20.6	.46	.54	116	----------	----------	1,100	----------	294
4L	41	7.8	58.7	31.1	18.2	8.6	.31	.28	78	157	157	25	----------	97
5L	84	25.7	60.8	27.2	10.2	4.4	.17	.16	52	256	163	41	.002	77
6L	30	7.8	46.9	26.9	5.4	2.8	.11	.10	64	162	153	50	----------	70
7L	47	9.4	60.9	22.4	18.4	7.3	.30	.33	73	245	201	1,100	----------	81
8L	50	8.4	43.8	21.6	9.6	7.7	.22	.36	49	177	140	∞	----------	291
9L	66	20.4	46.9	21.2	9.7	4.2	.21	.20	45	186	124	14	.004	61
10L	54	16.6	39.4	15.5	8.7	3.7	.22	.24	42	153	103	16	.002	50
11L	44	13.7	34.8	13.8	6.6	2.9	.19	.21	36	102	77	13	.004	41

TABLE 1.—*Physical and mechanical properties of sheathing papers*—Continued

Identification No.	Weight of 1,000 square feet	Thickness	Tensile breaking strength: Dry paper, Machine direction	Tensile breaking strength: Dry paper, Cross direction	Tensile breaking strength: Wet paper, Machine direction	Tensile breaking strength: Wet paper, Cross direction	Tensile breaking strength: Ratio of wet to dry, Machine direction	Tensile breaking strength: Ratio of wet to dry, Cross direction	Bursting strength	Tearing resistance: Machine direction	Tearing resistance: Cross direction	Transudation of water	Air permeability	Price index per unit of area
Group M:	*Pounds*	*Thousandths inch*	*Lbs./in.*	*Lbs./in.*	*Lbs./in.*	*Lbs./in.*			*Points*	*g*	*g*	*Minutes*	*Ft.³/ft.²/min.*	
1M	40	13.1	63.8	40.5	7.3	5.1	0.11	0.13	85	393	360	2	0.039	77
2M	111	24.4	65.2	39.9	19.1	3.7	.29	.09	82	637	613	30	.022	129
3M	85	41.4	49.0	31.8	5.8	3.6	.12	.11	53	430	342	1	.233	85
4M	83	19.9	64.5	29.8	22.3	8.9	.35	.30	71	496	443	16	.024	96
5M	94	28.1	61.8	29.2	8.1	3.4	.13	.12	46	313	196	7	.008	
6M	22	6.8	41.5	25.7	5.8	3.4	.14	.13	61	202	174	1	.111	68
7M	62	15.5	43.2	23.1	10.6	6.3	.25	.27	48	421	379	10	.061	72
8M	60	17.6	39.8	22.0	4.4	2.3	.11	.10	41	171	124	3	.008	
9M	40	8.6	37.5	20.2	7.8	4.4	.21	.22	43	222	217	6	.022	50
10M	51	12.1	37.6	18.2	9.5	9.5	.25	.52	41	257	233	7	.037	59
11M	26	9.3	36.4	16.4	2.6	1.2	.07	.07	39	129	101	1	.034	37
12M	32	14.2	48.0	15.6	5.1	1.8	.11	.12	49	188	167	1	.132	74
13M	40	13.5	28.0	11.9	3.6	1.6	.13	.13	27	111	80	3	.013	29
14M	188	85.5	22.4	14.7	3.0	1.7	.13	.12	47	528	478	4	.365	

NOTE.—Tensile breaking strength recorded in pounds per inch of width. Machine direction is direction of travel of paper on paper-making machine. It is, in general, the stronger direction. Cross direction is transverse to the machine direction and is, in general, the weaker direction. Points = Bursting pressure in pounds per square inch of a 1.13-in.² circular area of paper under hydraulic pressure. Air permeability measured under pressure equivalent to that of a 20-mile wind.

III. LABORATORY TESTS MADE AND METHODS EMPLOYED

1. PROPERTIES CONSIDERED IMPORTANT

In view of the function of sheathing paper as a relatively impermeable membrane whose integrity within the wall must be maintained during and after erection, the important properties of the material appear to be strength and impermeability to air and water. Other characteristics, such as aging properties and repellence or passivity toward ravaging insects, are of considerable interest but are difficult of evaluation.

Thermal conductivity was suggested as an important property of sheathing paper. In fact, some sheathing papers are made thick in order to increase their insulating value. It was the opinion of members of the staff of the heat transfer section of the Bureau of Standards, however, that it would not be worth while to measure thermal conductivities of sheathing papers. Such measurements would give information of little or no value in this connection. Irrespective of the thermal conductivity or of the thickness of the paper (within practical limits), the resistance to heat flow by conduction through the paper itself is negligibly small compared to the total thermal resistance of the complete wall. A thin layer of paper would not have a significant thermal resistance from surface to surface unless its conductivity were much less than that of any known solid substance. It is true that sheathing paper might be so installed in a wall as to divide air spaces, and thus increase the insulating value of the wall by a significant amount. For the reasons given above, however, this effect is practically independent of the thermal conductivities and thicknesses of commercial building papers.

2. TESTING METHODS USED

The following properties were determined by laboratory tests: Weight, thickness, tensile breaking strength (of both dry paper and wet paper), bursting strength, tearing resistance, water resistance, and air permeability.

(*a*) Official Methods.—With the exception of the last two of these properties listed, for which no standard methods are available, the measurements were made according to the official paper-testing methods of the Technical Association of Pulp and Paper Industry.[1]

(*b*) Water Resistance.—Water resistance was measured by an adaptation of the dry indicator method.[2] A specimen about 2 inches square was sealed to a cover glass with a powdered indicator between

[1] Paper Testing Methods, 1928, Lockwood Trade Journal Co., New York, N. Y.

[2] Carson, Testing Paper for Permeability to Liquids, Tech. Assoc. Papers, 8, pp. 91–94, 1925; and Paper Trade J., March 5, 1925; Tech. Papers B. S., No. 326.

the specimen and the cover glass. The indicator was a mixture of a very soluble dye with a much larger amount of powdered sugar. The seal was made by turning the edges of the specimen over the edges of the cover glass and dipping these edges to a depth of a quarter of an inch in molten paraffin. No moisture could reach the indicator except by going through the paper. The specimens thus prepared were floated on water at a temperature of 20° to 25° C. The time required for water to penetrate through the paper and produce a decided coloration in the indicator powder was taken as a measure of the relative water resistance of the paper.

(*c*) Air Permeability.—Air permeability was measured with the apparatus pictured in Figure 1, which, in its original form, was developed by Weaver and Pickering, of the gas chemistry section of the Bureau of Standards. This apparatus consists of a permeability cell, a water manometer, a gas meter, and a rotary vacuum pump.

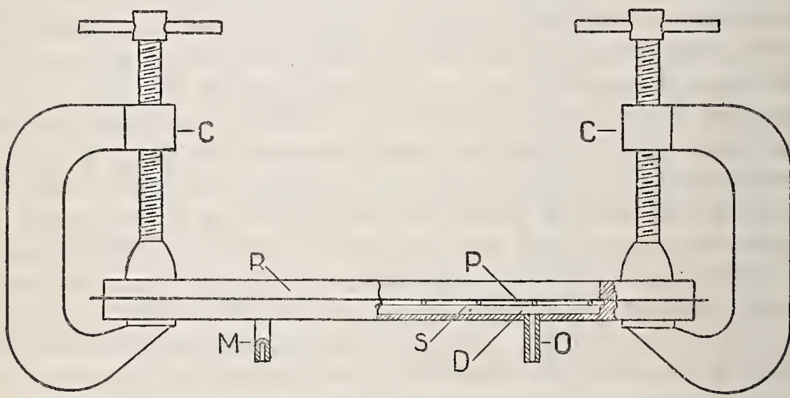

Figure 2.—*Permeability cell*

The permeability cell was designed to test a fairly large area of paper. This feature is particularly important in testing sheathing papers, since some of them lack uniformity, and hence a large area is necessary in order to obtain a test truly representative of the material. Furthermore, many of the sheathing papers tested were only slightly permeable to air, and a large area was desirable in order that a sufficient amount of air might be forced through these to give an adequate reading on the gas meter. The types of apparatus ordinarily used to test the porosity of paper present too small an area of paper to the air stream to be satisfactory for the testing of sheathing papers.

The details of the construction of the permeability cell are shown in Figure 2, which is drawn in partial section. This shallow cell consists of a steel plate having a circular depression, *D*, 7 inches in diameter and ¼ of an inch deep, covered by a very coarse wire screen, *S*, to support the paper. The paper *P*, the permeability of which is to be

FIGURE 1.—*Permeability apparatus*

measured, is clamped over the cell chamber by means of the ring *R*, which registers with the annular surface of the cell proper. An airtight joint is obtained by smearing the annular clamping surface with a heavy grease before laying the paper over it.

As shown in Figure 1, the vacuum pump is connected to the gas meter, which in turn is connected to the permeability cell at the outlet, *O*. (See fig. 2.) The water manometer is connected at the outlet *M* of the permeability cell. In making the air-permeability tests, conditioned air having a temperature of 70° F. and a relative humidity of 65 per cent was drawn through the paper and the gas meter by means of the vacuum pump. A constant pressure difference corresponding to that which would be produced on the two sides of a wall in a 20-mile wind was maintained. This pressure difference corresponds to a difference in head in the water manometer of 6¼ mm. The volume of air which was drawn through the paper under these conditions in 10 minutes was measured by means of the gas meter. Six determinations were made on each sample, and the average value was used in calculating the volume of air in cubic feet which would pass through each square foot of freely exposed sheathing paper in one minute under a pressure difference corresponding to that produced by a 20-mile wind. Determinations were also made at double and triple this pressure difference.

IV. EXPERIMENTAL RESULTS

The results of the laboratory tests are given in Table 1. The samples are tabulated in four groups, as previously indicated. In each group the samples are arranged in the order of the tensile breaking strength in the cross direction, since this is probably the most important of the strength properties measured.

1. WEIGHT AND THICKNESS

The weight of 1,000 square feet of the material is recorded in pounds and the thickness in thousandths of an inch. It is seen that the papers differ considerably in weight and thickness. The two properties are not strictly proportional. In fact, there are some rather striking differences in apparent densities. These apparent differences are in some cases not very real, however, for some of the papers have corrugated or uneven surfaces, as a result of which the measured thickness would be that of the high spots and not an average thickness. Weight and thickness do not appear to be correlated with any other measured property except in papers which are alike but for differences in thickness and weight, such as the second group of three papers in which there is a regular gradation of nearly all properties corresponding with the thickness.

2. STRENGTH

The tensile breaking strength, especially the strength in the cross direction or weaker direction, is probably the most important indication of the ability of the material to stand the required handling during erection without injury. The tensile breaking strength in the two principal directions, and the bursting strength as well, show a certain parallelism within each group, although there are a few rather outstanding exceptions. The so-called tearing resistance, although of some interest, probably does not give as good an indication of the tendency of the paper to tear as does the tensile breaking strength. In this tearing test the paper is torn from the apex of a previously made slit in the paper, a state of things which apparently has very little relation to the tendency of a tear to start at the edge. The sort of stress which ordinarily starts a tear at the edge is somewhat like an eccentrically applied tensile stress. Hence, it is probable that the tensile breaking strength is the most important of the strength measurements made. The tensile breaking strength of the papers after they had been immersed in water for 30 minutes was also determined. Such data were thought to be of some value in predicting the behavior of paper that becomes wet in the rain or is applied in damp weather. The test is admittedly very severe and is probably unfair to some of the papers, especially those of the laminated type containing a water resistant inner layer which would prevent the papers from becoming wet through when only one side is exposed. However, the test brought out some rather striking results. Most of the impregnated papers of the first group, the asphalt-saturated papers, retained a relatively large portion of their strength after this severe wetting treatment. A few of them, indeed, were stronger after wetting than before. The last group, the machine-finished papers, became rather weak after the wetting treatment, as might have been expected. That the test is not fair to the laminated papers is emphasized by the relatively high strength retention of samples 2L and 3L, which have a third inner layer of paper or of textile fibers protected on both sides by a layer of asphalt.

3. WATER RESISTANCE

The resistance to the transudation of water, which is recorded as the number of minutes required for an appreciable amount of water to penetrate from one side of the sheet to the other, roughly parallels the strength retention of the wet paper, which is itself a form of water-resistance test. However, the two are not strictly comparable. The transudation test more nearly simulates the likelihood of water seeping through the building paper to cause damage. The papers differ greatly in this respect even in the same group. Only the papers which contain asphalt as the water-resisting medium show any unusual degree of water resistance. In the case of two of the papers, 5A and 8L, no transudation of water could be detected by the method employed, which is the most sensitive method known to the writers. However, there were papers in all four groups which had comparatively little water resistance.

4. AIR PERMEABILITY

The susceptibility of sheathing paper to infiltration of air is recorded in Table 1 in cubic feet of air per square foot of paper per minute forced through sheathing paper under a pressure difference corresponding to that on the two sides of a wall exposed in a 20-mile wind. Most of the papers of the first three groups (all of the second) allowed no infiltration of air under conditions simulating wind pressures ordinarily encountered. The infiltration which was shown by a few of the samples in these three groups was very small, probably negligible for all practical purposes. A few of the machine-finished papers had good resistance to permeation of air, but most of them were only moderately resistant. It was only in this last group that relatively large differences in air permeability were observed.

Some of the papers showed considerable lack of uniformity in that the deviations of individual results from the average for each sample were in some cases large. The mean deviations ranged from 5 to 80 per cent for the different samples. A part of such deviations, perhaps 5 per cent or so, resulted from the inability to prevent slight fluctuations in the small pressure difference maintained. When the individual results for the three pressures at which determinations were made were plotted, pressure against air permeation, curves were obtained, some of which were convex upward, some convex downward, others practically straight lines. The curvatures were such as to lead to the conclusion that the experimental errors presumably responsible for the differences in curvature amounted to some 5 per cent. The mean deviations in excess of this amount were, therefore, presumed to be due to lack of uniformity in the structure of the paper. Taking into account the probable magnitude of the experimental error, it appeared that within the small pressure range at which experiments were made the air permeation was substantially proportional to the pressure.

V. RELATION OF LABORATORY TESTS TO SERVICE DEMANDS

1. USES MADE OF SHEATHING PAPER

Besides the chief application of sheathing papers as weatherproofing media in the walls and floors of buildings there are many other uses of such materials which are of considerable importance. Among the other uses suggested by manufacturers and dealers are: Protective covering for materials on the job; protective covering for fresh cement and concrete work, especially sidewalks, to prevent too rapid loss of moisture; any use where a moisture proof or waterproof covering or medium is required; lining of shipping cases; insulating material; lining in refrigerator-wall construction; weatherproofing medium in the walls of street cars and similar passenger cars; temporary shelters, especially for livestock on farms. Builders use large amounts of sheathing paper as protection for finished floors during the finishing stages of dwelling construction and during the exhibit period of such buildings.

2. COST OF SHEATHING PAPER

Although the cost of sheathing paper is a relatively small item in the cost of a building, the price paid for such materials may be of interest in connection with certain uses of the paper as well as of academic interest. In Table 1 are given price index values per unit area of all the sheathing papers for which such information was available. The price indexes are based on the average price as 100. There is apparently no very definite relation between the price of building paper and the properties of the material which determine its value as sheathing paper.

3. SOME PROBABLE RELATIONS BETWEEN PROPERTIES AND SERVICE DEMANDS

The relation of measurable properties of sheathing paper to the service demands and conditions is a matter for future determination requiring extensive field experiments, but at this time a few observations may not be amiss by way of suggesting some of the probable relations and possibilities which may be encountered. The relative importance of these measurable properties is, of course, dependent upon the specific use which is to be made of the paper. For some applications strength may be of paramount importance, for others water resistance may overshadow all other properties, while for still others the air permeability may be the chief consideration.

(*a*) Thickness.—In view of the fact previously mentioned that the insulating effect of sheathing paper in a wall is practically independent of the thickness of the paper, there does not appear to be any particular advantage in using a thick sheathing paper if the other desirable properties of the material are satisfactory. For use under flooring, where the paper serves also in the capacity of deadening felt, thickness is doubtless an advantage.

(*b*) Strength.—The strength of sheathing paper, both dry and wet, is of importance in handling the paper and in getting it in place whole in any kind of weather. The strength of such materials, particularly when wet, is of considerable importance when the paper is used as a protective covering out of doors, for a flurry of wind and rain would rip to pieces a paper of inferior strength, particularly if the strength is largely destroyed by wetting.

(*c*) Water Resistance.—The water resistance of sheathing paper is of considerable importance, in that serious damage to plastering may be prevented in severe storms by a waterproof sheathing paper properly put in place. In some of the other suggested uses this property is obviously of great importance. It is also possible that paper which will remain moist in damp weather may promote mold or similar cause of deterioration. It is an interesting fact in connection with water resistance that waterproof sheathing paper put in floors laid over concrete in order to prevent moisture from coming through and warping the flooring has sometimes been observed to do more harm than good. In warm, humid weather the cool concrete causes condensation of water between the finished flooring and the sheathing paper. Since the paper is waterproof, the water remains in puddles on the paper until it is absorbed by the flooring and produces very serious warping. An interesting possibility in such a case lies in the use of paper of the type represented by the second group of Table 1. A paper well saturated with paraffin can be made air proof, but it is not very water resistant. This is a fairly well established characteristic of paraffin-saturated paper. In spite of the presence of the paraffin, when water comes in contact with the surface of such paper, capillary phenomena come into play, the paper swells, and the water finds its way through. Such a paper might effectually prevent moisture in the vapor phase from reaching the flooring from underneath and yet might alleviate the trouble somewhat by allowing water condensed on the paper to seep through to the concrete where it can do no harm.

(*d*) Air Permeability.—Although the primary function of sheathing paper is to prevent infiltration of cold air as a result of wind pressure, it does not follow that the differences ordinarily found in the air permeability of sheathing papers have very much significance. Only some 15 to 30 per cent of all the heat losses from buildings are ordinarily ascribed to infiltration of air from all sources. The infiltration of air through the joints of overlapping pieces of sheathing paper, around window casings and door frames, and especially through doors and windows frequently opened and closed during the day, is very considerable, so that the differences in air leakage through different kinds of building paper are probably not very significant, except, possibly, in the case of a few of the more permeable papers of the fourth group. Much of the surface of the sheathing paper is covered by boards, usually on both sides. The paper serves chiefly to prevent the wind from entering through the cracks between boards. The use of any kind of sheathing paper is so far superior to no paper at all that the differences between papers, in respect to air permeability, are, perhaps, largely negligible for all practical purposes. Some idea of the magnitude of the infiltration of air through the sheathing paper itself may be had by assuming a room of moderate size, the walls of which are made of the most permeable sheathing paper of the first three groups of Table 1, exposed on two sides to a 20-mile wind. Under these conditions about half a day would be required to change the air in the room once. In view of the fact that much of the surface of the sheathing paper is covered by boards and that infiltration is not a large factor in heat loss in good construction, it is apparent that a sheathing paper would have to be unusually permeable to air in order for its relative permeability to be of much consequence.

(*e*) Character of Surface.—The character of the surface of the paper is of importance for certain uses. This may be true if the sheathing paper is to be wholly or partially exposed. One of the sheathing papers tested was intended primarily for such purposes and was finished with a pleasing colored surface. Attention to character of surface is important in paper used as a temporary protection to finished floors. Paper coated with a material which would stick to the floor and mar its appearance is obviously unsuitable for the purpose.

(*f*) Permanence.—The question of permanence is important, but very little is known in this regard. Papers containing ground wood are known to increase in degree of sizing, or water resistance, with age and to decrease in strength and elastic properties. The asphalt in some asphalt-saturated papers is known to undergo a slow process of polymerization resulting finally in a friable or powdered material which would probably retain little of its original ability to impart air and water resisting properties to the paper; but it is not known how many years would be required for such influences to become serious. Possibly most papers of this type would be substantially as permanent as the wooden walls with which the papers are usually used. Doubtless the paraffin-saturated papers would be the most permanent type, since paraffin is relatively inert chemically.

The above comments are offered as suggestions as to the possible behavior of building papers under certain conditions. Field tests are contemplated by the National Lumber Manufacturers' Association to obtain information which can not be had in the laboratory.

VI. SUMMARY

As a result of a study of a considerable number of sheathing papers, representing the various types which are being used in the building trade, and the measurement of such properties as weight, thickness, tensile breaking strength, bursting strength, tearing resistance, water resistance, and air permeability, the following observations appear to be justified:

1. Sheathing papers differ considerably in weight, thickness, and density. These properties are, in general, not definitely related to other important characteristics of building papers.

2. A range of about fourfold is found between extremes in both the tensile breaking strength and the bursting strength of such papers. The tensile breaking strength in the cross direction of the paper is probably the best criterion of mechanical serviceability. The papers differ greatly in their retention of strength after wetting, most of the papers losing more than half their strength as a result of immersion in water for 30 minutes.

3. The time required for water to penetrate through the papers differs within wide limits—from less than a minute to several days. Only sheathing papers containing asphalt as the waterproofing medium have any unusual degree of water resistance.

4. Sheathing papers, except some of the machine-finished variety, are relatively impermeable to air under conditions simulating wind pressures ordinarily encountered.

5. The price range of sheathing papers is about tenfold between the cheapest and the most expensive. There is no very definite relation between the price of such papers and their value as building papers.

6. There is no advantage in using a relatively thick sheathing paper if the strength and impermeability to air and water are satisfactory, except, perhaps, where sound deadening is a factor.

7. Strength sufficient to insure getting the material in place whole, water resistance sufficient to insure against the damage to plastering and inside finish which sometimes occurs in severe storms, and impermeability to air are apparently the requisite elements in a good sheathing paper.

8. Most sheathing papers, with the possible exception of some of the more permeable of the machine-finished type, appear to be sufficiently air-tight for all practical purposes.

WASHINGTON, January 18, 1929.