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DEVELOPMENT OF STANDARDS FOR FLEXIBLE CASELINING MATERIALS

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PREFACE

Paper and paper products played a vital part in World War II One of the most important uses of such products was the safe guarding against deterioration by moisture of supplies for ou armed forces scattered around the world. This is the chief func tion of papers used to line shipping cases. To serve satisfactoril they must be excellent moisture barriers, and, of course, remai intact under the stresses to which packaged materials are sub jected. Because of the many adverse conditions under which ou troops fought in this war, these requirements were particularl severe. For this reason, this investigation was undertaken to as sist in providing caseliners that would withstand the most ab normal conditions of transportation and storage.

E. U. CONDON, Director.

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ABSTRACT

An investigation was made for the development of improved specifications for materials used to line shipping cases so that the liners would give better service in overseas shipments of supplies, particularly those for our armed forces.

The sheetings were given various kinds of tests considered to have a bearing on their serviceability, such as strength, stretch, flexibility, resistance to puncture, scuffing, and permeation by water vapor and water. As a part of the work, an improved cabinet for making water-vapor permeability tests under accurately controlled atmospheric conditions simulating those of the tropics was developed. This was so designed that the test specimens are weighed inside the cabinet, thus obviating errors inherent in removing them for weighing.

Packages containing liners, made of the same materials as the sheetings tested, were subjected to simulated service conditions at a commercial testing laboratory. The packages were put through cycles of being tumbled in a drum, dropped on a concrete floor, and bounced on a vibrator, with wetting, under both tropical and arctic conditions. They were then examined for permeation of moisture and for the condition of the liners.

Correlation of the test data of the sheetings with their performance in the simulated service trials indicated that for the most satisfactory service, the caseliners should be composed of sheets of kraft paper cemented together with asphalt, and that the important properties are areal weight of paper and of asphalt, wet tensile strength, stretch, resistance to tearing and puncture, and permeation by water vapor and water. Recommended requirements for these properties are included.

I. INTRODUCTION

At the request of the Container Coordinating Committee, War Production Board, and with the assistance of funds from the Board's Office of Production Research and Development, the National Bureau of Standards participated in an investigation of flexible caselining materials. The investigation was made for the development of improved specifications for such materials so that they would perform more satisfactorily in shipments of supplies, particularly those for our armed forces.

The project comprised mainly (1) subjection of packed shipping cases containing the materials as caseliners to simulated service conditions at the Package Research Laboratory, Rockaway, N. J., (2) testing by the National Bureau of Standards of the materials from which the liners were made, (3) correlation of the results obtained at the two laboratories to determine the properties that the materials should have to function satisfactorily as caseliners, and (4) the formulation of recommended standards for the significant properties for use in purchase specifications.

The tests at the Package Research Laboratory were made as follows: Standard wooden and fiber shipping boxes of different sizes were lined with the caselining materials made into liners of one-piece construction for "satchel" closure. The large boxes were filled with cartonized hollow steel cylinders and wooden blocks and the small boxes with wrapped hollow steel cylinders alone. The closure of the liner was folded over and sealed with a moisture-resistant adhesive. The boxes were then put through cycles of being tumbled in a revolving drum, dropped on a concrete floor, and bounced on a vibrator, with intermittent spraying with water, under both tropical and arctic temperatures. The boxes were opened on completion of the cycles and the contents examined for number of wet pieces, after which the liners were removed and examined for holes, scuffs, or other damage. Detailed descriptions of these tests and accounts of the results obtained have been published. [1], [2], [3], [4]

The following is a report of the tests made at the National Bureau of Standards and of the correlation of them with the results of the simulated service tests. Recommended standards are included.

II. MATERIALS TESTED

1. CASELINING MATERIALS

The caselining materials tested consisted of 31 samples. There were 24 asphalt-laminated kraft papers, made variously with plain paper, paper infused with asphalt, paper containing waxy materials, paper treated with melamine resin to improve its strength and resistance to scuffing when wet, and paper treated for mold resistance. Some of the papers were reinforced with strands of fibers or cords imbedded in the laminating asphalt.

[1] H. A. Wolsdorf and E. G. Mullen, Modern Packaging 18, No. 9, 131 (May 1945).
[2] H. A. Wolsdorf, Paper Trade J. 121, No. 4, 46 (July 26, 1945).
[3] E. R. Stivers, Paper Trade J. 121, No. 4, 47 (July 26, 1945).
[4] H. A. Wolsdorf and E. G. Mullen, Modern Packaging 19, No. 4, 154 (Dec. 1945).

The remaining materials were made of other kinds of sheetings. Detailed descriptions of these follow. The letters at the left are the sample designations. The weights are on a basis of 3,000 square feet of material.

Asphalt-Laminated Kraft Papers

Duplex Uncreped

M—One 40-pound plain sheet, one 60-pound sheet infused with wax resin compound.

D—One 60-pound plain sheet, one 60-pound sheet infused with asphalt.

J—One 50-pound plain sheet, one 50-pound sheet infused with asphalt.

S—One 50-pound plain sheet, one 50-pound sheet infused with asphalt; embossed after lamination.

F—Reinforced, plain 30-pound sheets.

G—Reinforced, plain 30-pound sheets.

Duplex Creped

V—40-pound machine-creped sheets.

H—40-pound machine-creped sheets.

G—One 30-pound plain sheet, one 60-pound sheet infused with wax resin compound; creped after lamination.

K—One plain 60-pound machine-creped sheet, one 60-pound machine-creped sheet infused with asphalt.

T—One 60-pound machine-creped sheet, one 60-pound machine-creped sheet infused with asphalt.

B—Two 50-pound machine-creped sheets, one sheet treated for wet strength; wax applied to treated side.

C—Reinforced, one 45-pound machine-creped sheet, one 75-pound machine-creped sheet.

U—Reinforced, 35-pound machine-creped, wet-strength sheets.

E—Reinforced, 45-pound machine-creped wet-strength sheets.

Triplex Creped

E—One 30-pound machine-creped sheet on one side; other sheets plain, 30 pounds.

A—One 40-pound machine-creped outer sheet treated for mold resistance, two 30-pound plain sheets.

C—One 60-pound machine-creped outer sheet infused with asphalt; two 30-pound plain sheets.

B—All sheets 40 pounds, outer sheets creped and infused with asphalt before lamination, center sheet uncreped.

A—All sheets 30 pounds, creped diagonally while being combined.

H—All sheets 40 pounds, machine-creped and serrated.

O—40 pound machine-creped sheets, outer sheets treated for wet strength.

D—40 pound machine-creped sheets, outer sheets treated for wet strength, one outer sheet wax treated.

V—All sheets 40 pounds, creped and infused with asphalt before lamination.

Miscellaneous Materials

P—Duplex; uncreped, two 32-pound cellulose-wadding sheets infused with asphalt.

Q—Duplex; uncreped, two 32-pound cellulose-wadding sheets infused with asphalt; one side coated with asphalt.

R—Triplex; uncreped, three 32-pound cellulose-wadding sheets infused with asphalt.

X—Lead foil laminated to one 30-pound plain kraft sheet. Foil side coated with polyvinyl butyral, scrim cloth laminated to kraft side.

Z—Cloth, one side coated with vinyl resin.

FF—Duplex; one 40-pound machine-creped kraft sheet, one 22-pound cellophane sheet.

II—Triplex; two 40-pound machine-creped kraft outer sheets, one 22-pound cellophane inner sheet.

2. BASE PAPERS

It was thought that tests of base papers used in the manufacture of the kraft caselining papers might, through correlation of the results with the results of the tests of the caselining papers, yield information that would be of value to manufacturers in their choice of base papers.

Tests were made on 35 base papers used in the manufacture of 17 of the caselining papers. The base papers were 15 plain and 9 creped laminating papers, 6 plain and 2 creped asphalt infusing papers, and 3 asphalt-infused papers. The basis weights were representative of the range generally used for laminated caselining papers.

The following tests were applied to these papers, as far as the various kinds of tests are applicable to the different types of papers: Weight per unit area and the thickness (the ratio of which yields density), folding endurance, tearing resistance, bursting strength, tensile breaking strength, air resistance, smoothness, time of oil permeation, amount of oil absorbed, acidity, and kind and condition of fibers. Although the test values for the different base papers varied widely, there was no significant relation between the properties of the base papers and the properties of the caselining papers. For this reason the test data for the base papers are not reported herein.

III. METHODS OF TESTING

1. STANDARD METHODS

The following tests were made according to the methods of the Technical Association of the Pulp and Paper Industry (TAPPI).[5] The Association's designations of the methods are included: Basis weight, T 410 m; tearing resistance, T 414 m; bursting strength, T 403 m; tensile breaking strength, dry T 404 m; tensile breaking strength, wet, T 456 m; stretch, T 457 m; water resistance, T 433 m; water-vapor permeability at 73° F and 50 percent relative humidity, T 448 m; water-vapor permeability at 100° F and 90-percent relative humidity, T 464 m; resistance to

[5] Copies may be obtained from the Association at 122 East 42d Street, New York 17, N. Y.

puncture, T 803 m; and acidity, pH, hot extraction, T 435 m. The wet tensile strength was determined on samples after they had been immersed in water for 24 hours. Tearing tests could not be made on reinforced papers because of the interference of the reinforcing material. As the apparatus for the puncture test is of comparatively recent development, it might be well to explain briefly that it measures the energy required to force a tetrahedral puncture head (simulating the corner of a box) completely through the test specimen. The rupturing force is provided by the release of a heavy pendulum from a horizontal position. As the pedulum swings down, the puncture head, carried at the end of a curved arm attached to the pendulum and concentric with its bearing, is driven through the specimen. The energy thus absorbed in puncturing the specimen is indicated by a pointer on a dial.[6]

2. SPECIAL METHODS AND APPARATUS

The following are descriptions of the testing methods and apparatus for which no standards were available.[7]

(a) STIFFNESS

The stiffness test was used as a means of determining the probable performance of the caselining materials in the folding operations incident to forming them into liners and to closing the liners. Excessive stiffness is undesirable. The method consists in finding the load required to force the material between two rollers. An apparatus devised for the purpose by M. L. Downs was modified to permit its use in a standard type of paper tensile strength testing instrument.

The device, illustrated in figure 1, consists of two stirrups. A single stirrup, the cross bar of which is a ½-inch metal tube, is fastened in the upper clamp of the tensile tester. An inverted double stirrup, which is fastened in the lower clamp of the tensile tester, has two ⅞-inch rollers, separated by a distance of ¾ inch. The tensile tester, with pendulum weights removed, is calibrated over the desired range by hanging small weights to the upper clamp (with the single stirrup clamped in place).

To make a test, the lower clamp of the tensile tester is run up until the tubular cross bar of the upper stirrup passes between the rollers of the lower stirrup and comes below them. A specimen, 4 inches square, is then slipped under the rollers of the double stirrup and over the tubular cross bar of the single stirrup. The lower clamp is then run down, as in making a tensile test, the specimen being bent and pulled between the rollers of the double stirrup. The force required to do this, which is determined from the scale reading and the calibration of the tensile tester, is used as a measure of the relative stiffness of the material tested.

(b) SCUFFING

The scuff test was used as a measure of the probable resistance of the materials to wear when rubbed against the walls and con-

[6] R. L. Beach, Paper Trade J. 108, No. 5, 30 (Feb. 2, 1939).

[7] The apparatus for creasing test specimens, for making the stiffness tests and the wet-rub tests, and the cabinet for water-vapor permeability at high temperature and humidity, were developed by F. T. Carson and V. Worthington of the Bureau staff.

tents of containers. The test was made with the Taber Abraser[8] and with the Wet-Rub Tester[9] developed at the Bureau.

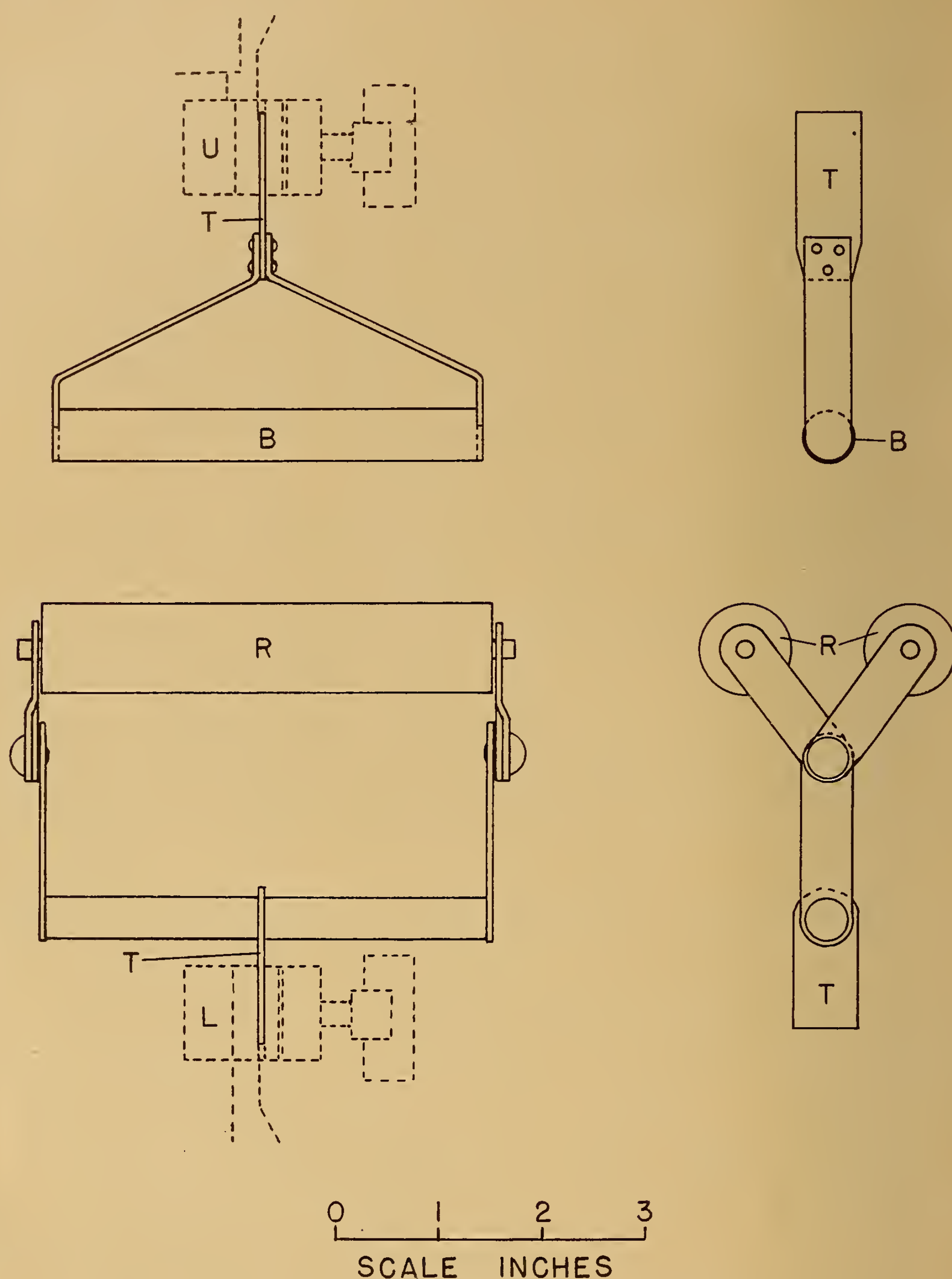

FIGURE 1.—*Device for testing stiffness of caselining materials.*

A stirrup having a single cross bar, B, is fastened by a tab, T, in the upper clamp U, of a tensile tester. An inverted stirrup, carrying two rollers, R, is fastened in the lower clamp, L.

The Taber Abraser, shown in figure 2, is in common use for testing many sheet materials other than paper for resistance to abrasion. The apparatus consists of a horizontal motor-driven turntable upon which the test specimen is attached, and two weighted parallel arms, each carrying a special abrasive-filled rubber wheel that rotates on the specimen under a given load. A load of 1,000 grams was used for these tests. The two wheels revolve in opposite directions and exert a combined abrasive, com-

[8] Paper Trade J. 119, No. 3, 24 (July 20, 1944).
[9] F. T. Carson and V. Worthington, Paper Trade J. 84, No. 2, 45 (Jan. 13, 1927).

FIGURE 2.—*Apparatus used for determining resistance to scuffing of caselining materials when dry.*

pressive, and twisting action over a circular path. The turntable was rotated until the surface of the material was just completely removed, with continuous brushing of the debris from the specimen. The amount of material removed was determined by the difference in the weight of the paper before and after abrasion, and was calculated to revolutions per centigram of material removed. Only a dry-abrasion test was made; satisfactory results could not be obtained on wet materials of this kind because of their various water-resistant components. Even the dry-abrasion test could not be applied satisfactorily to the cellulose wadding materials because of the large amount of asphalt present.

The wet-rub tester shown in figure 3, has a metal plate on which the test specimen, C, is clamped and rubbed by a chrome-plated rounded end of a cylinder, F, projecting from a horizontally reciprocating member that is weighted. For testing the caselining materials, a load of 5 pounds was used. The number of double rubs required to wear a hole through a specimen wetted with an excess of water is recorded. The abrading surface of this apparatus is not suitable for making dry tests.

(c) CREASING

The water-resistance and the water-vapor permeability tests were made on both uncreased and creased specimens. Tests on creased specimens are important because of the creasing of case-

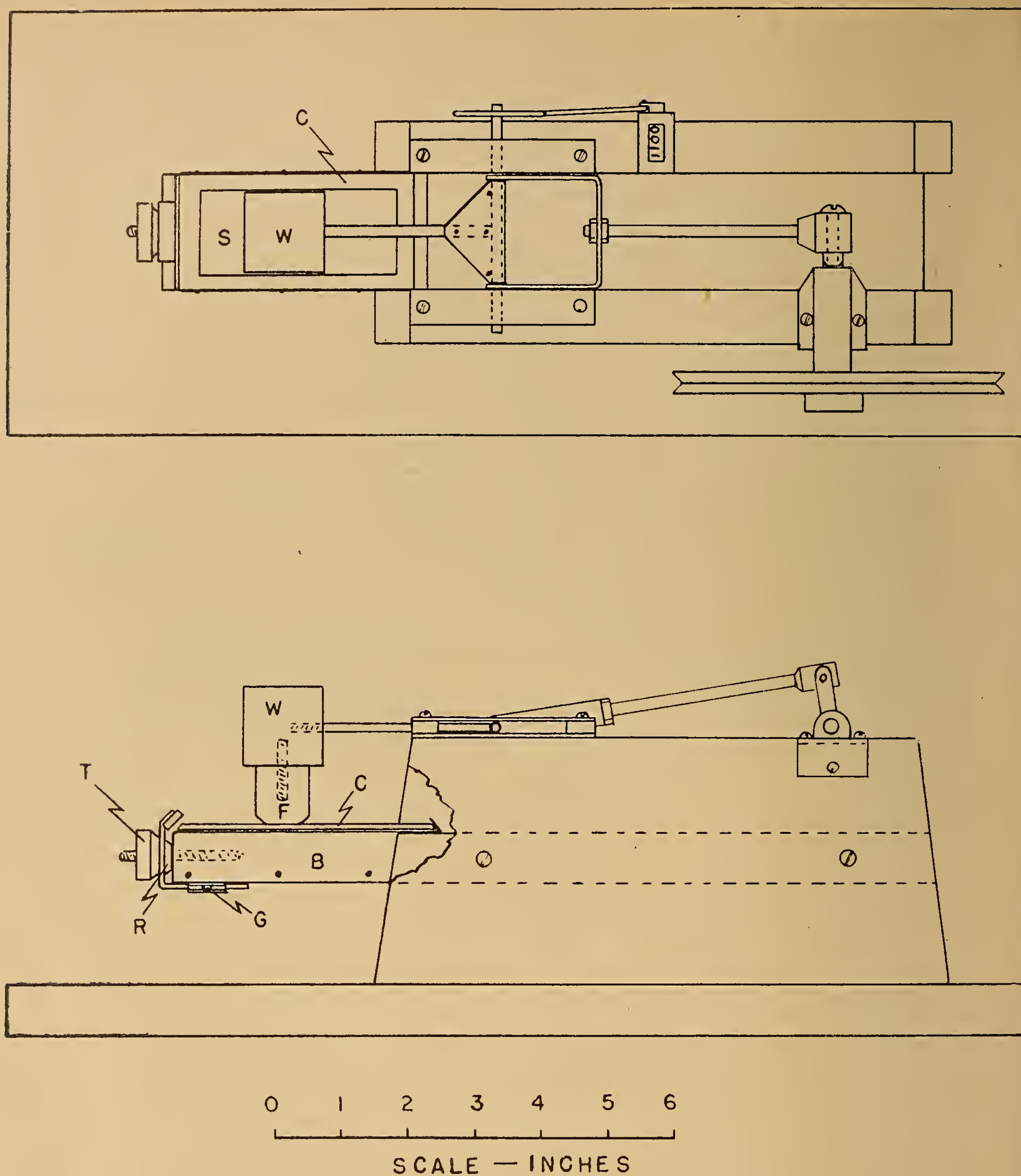

FIGURE 3.—*Apparatus used for determining resistance to scuffing of caselining materials when wet.*

lining materials in forming and closing the caseliners and because of the load on the creases after the container is filled. The materials were creased at low temperature because the caselining operations are often done with very cold material, and asphalt has a greater tendency to crack on creasing as the temperature is lowered.

The test specimens before they were creased were exposed for at least 2 hours to air having a temperature of approximately 40° F and a relative humidity of approximately 60 percent. The conditions were chosen by the Task Group as being convenient to use and suitable for the purpose. The test specimens were then transferred to an insulated container, from which they were taken one at a time for creasing. They were creased in a cabinet maintained at 40° ±2° F and having arm holes fitted with sleeves to permit manipulation of the creasing apparatus. The specimens were 4 inches square, and they were creased on two diagonals, under a pressure of 2.36 pounds per inch of crease.

The creasing apparatus is illustrated in figure 4. A lower plate, P, hinged at A, is lifted by a handle, H, until it contacts and lifts the upper plate, R. Attached to the upper plate is a weight, W, of such size that it and the upper plate together apply the required load per inch of crease. The upper plate is held in position by a guide until it is lifted. A stop, S, limits the movement. A square

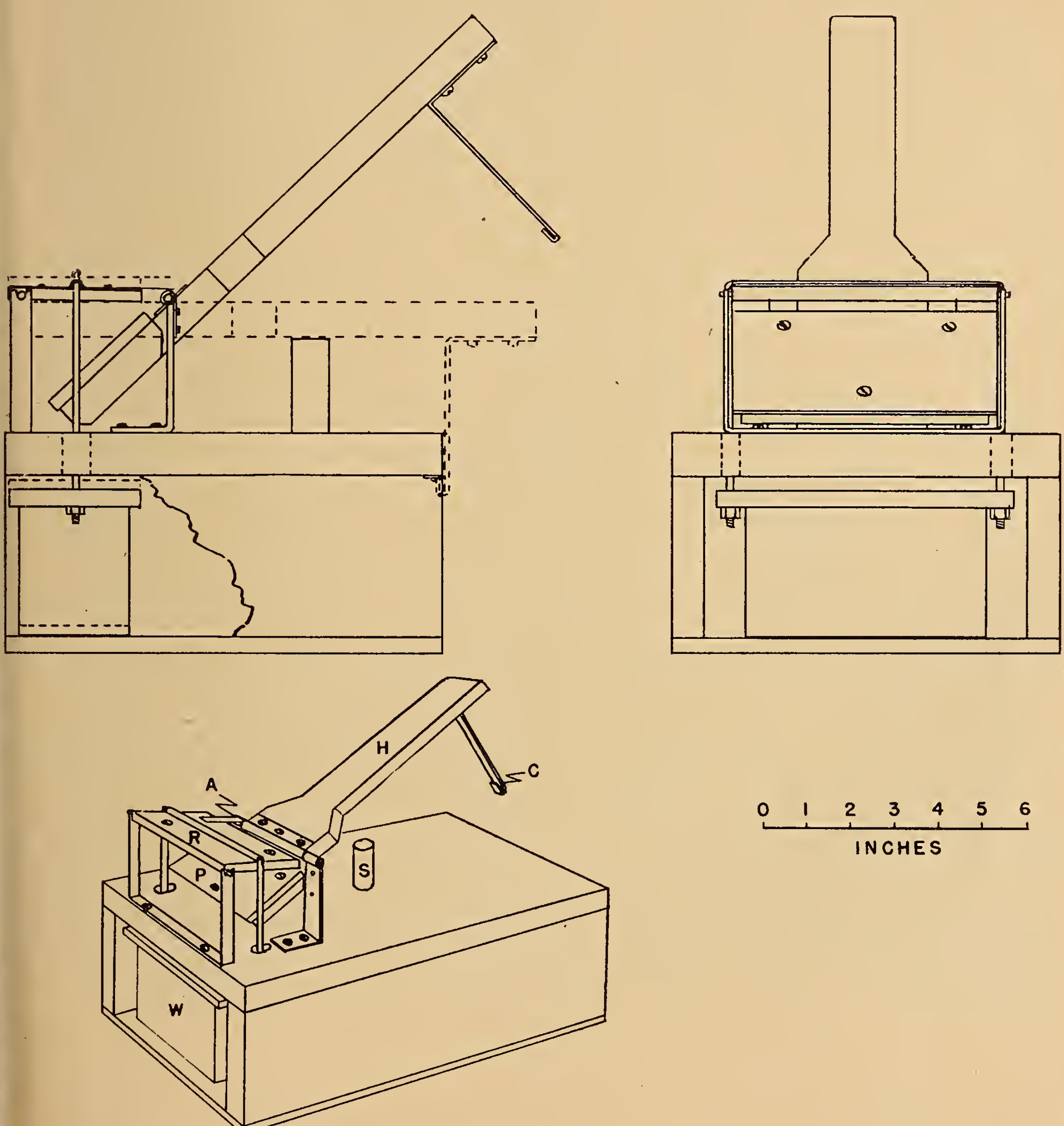

FIGURE 4.—*Apparatus for creasing caselining materials for tests for water and water-vapor permeability.*

of the paper to be creased is first wrapped along its diagonal around a ¾-inch round rod (wood preferably) with diagonally opposite tips held together, then the rounded section along the diagonal is centered between the plates, and creased by depressing the handle, H. It is held in position shown by dotted lines by the catch, C, for the required time.

(d) WATER-VAPOR PERMEABILITY

For making the water-vapor permeability tests, cells 3¾ inches in diameter and about ⅜ inch deep were used. A flanged rim, forming a shallow groove, provides a means of embedding the perimeter of the specimen in the wax used to seal the specimen to the dish, leaving a free area of 50 square centimeters through which water vapor passes from the exterior to the desiccant within. Each dish holds about 15 grams of 8-mesh anhydrous calcium chloride. The dishes were formed from disks of annealed sheet aluminum 0.020 inch thick by pressing them between steel dies.

The cells were first exposed and weighed at intervals in an air-conditioned room maintained at 50 ±2 percent relative humidity and 73° ±3.5° F until they reached a steady rate of gain. They were then transferred to a cabinet especially designed to maintain the air within it at 90 ±1 percent relative humidity and 100° ±0.5° F and to obviate the necessity of removing the cells for weighing them. The latter feature gives improved accuracy in the determinations and reduces considerably the time required for weighing.

The cabinet, illustrated in figure 5, consists of a metal box, 14 by 14 by 14 inches, within an insulated box, a 1-inch air space separating the two. Air is circulated in this interspace by a centrifugal fan in the bottom of the cabinet. A heater of about 80-watts capacity and a thermoregulator in the interspace keep the envelope of circulating air at the required temperature. The inner box is heated only by transfer of heat from the air in the interspace. In the bottom of the inner box are pans containing a saturated solution of monoammonium phosphate or of potassium nitrate. A small fan blowing air on the pans circulates the air in this enclosure and keeps it at a uniform humidity characteristic of the relative vapor pressure of the solution. A port is shown through which access is had to the pans, and another in the side gives access to the test cells. Each port is sealed by an insulated, rectangular plug held against a rubber gasket.

The test cells are hung by means of hooks to a notched disk in the top of the inner box. A rod, hanging from the left arm of the balance, passes through a hole in the floor of the balance and through an aperture in the top of the cabinet, and ends in a hook designed to engage the hooks supporting the test cells. The rod is divided between the balance and the top of the cabinet, the two parts being joined by a tab sliding in a sleeve. When the crank at the left side of the balance is rotated a mechanism lifts the weighing hook (together with the test cell just below it), locks the two parts of the weighing rod together, and leaves the test cell freely suspended from the balance arm ready to be weighed. The disk supporting the test cells is fastened by means of a shaft to a numbered disk on top of the cabinet, projecting from underneath the balance. The number on the numbered disk opposite the pointer is the number of the disk in the weighing position. Any number is selected by turning the disk. An interlocking device holds the disk so that it can not be turned while a test cell is

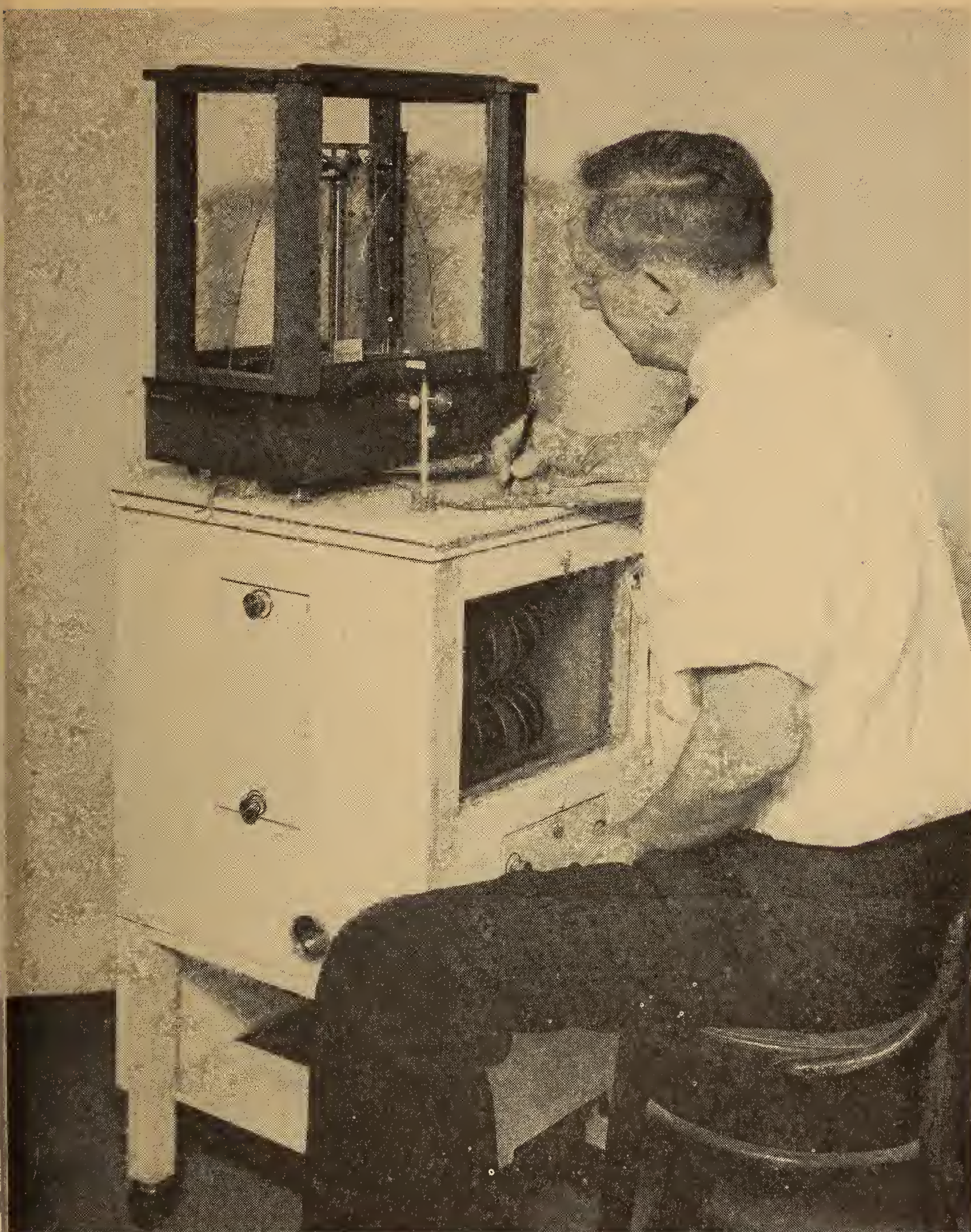

FIGURE 5.—*Cabinet for testing for permeability to water and water vapor under tropical conditions.*

being weighed. The cabinet has a capacity of 60 cells of the size used.[10]

It was found that 48-hour intervals of weighing over a period of about 2 weeks were satisfactory in arriving at a steady rate of transfer of moisture through the specimens.

(e) BLEEDING

The possibility of exudation at high temperature of asphaltic, waxy, or oily substances, used to impart water resistance and

[10] F. T. Carson and V. Worthington, Paper Ind. 27, 1799 (March, 1946).

other properties to caselining materials, is of importance with respect to damage from this source that might occur to the contents of shipping cases. Asphalt stains of course do the most serious damage. Trouble from this source could be avoided by using asphalt having a very high melting point, but such asphalt would be more likely to crack when cold than an asphalt with a lower melting point. For this reason, in choosing a temperature at which to test for bleeding, it is necessary to use as low a temperature as is consistent with the highest temperature to which shipments may normally be exposed in the tropics. It appears that this would occur in the holds of ships where maximum temperatures around 145° F have been recorded. Accordingly, 150° F was chosen as the testing temperature. The test specimens were sandwiched between sheets of white paper, heated at this temperature for 5 hours under a pressure of 72 pounds per square foot, then the sheets of white paper were examined for kind and degree of staining.

IV. TEST DATA

The test data for the physical properties of the materials, with the exception of moisture resistance, and for acidity are given in tables 1 and 3. The weight of asphalt is based on information received from the manufacturers as satisfactory test data could not be obtained. The test for acidity was made because it was thought that the heat of the laminating process might cause deterioration of the materials if the acidity were too high. However, with only a few exceptions the pH of the materials was 5.0 or more, which indicates acidity that would not be harmful.

The test data for the resistance of the materials to water and water vapor are given in tables 2 and 4.

Table 5 shows the results of the bleeding tests.

TABLE 1.—*Physical properties and acidity of asphalt-laminated kraft papers*

Sample designation	Special treatments[1]	Weight per 3,000 sq. ft.		Bursting strength	Puncture resistance		Tearing[3] resistance		Tensile strength		Tensile strength retained when wet		Stretch		Stiffness		Resistance to scuffing				Acidity, hot extraction
																	NSB wet rub		Taber dry rub		
		Total	Asphalt		MD[2]	CD[2]	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	Inside[4]	Outside[4]	
DUPLEX, UNCREPED																					
		lb	*lb*	*Points*	*Points*	*Points*	*g*	*g*	*lb/in.*	*lb/in.*	%	%	%	%	*g*	*g*	*Double rubs*	*Double rubs*	*rev/cg*	*rev/cg*	*pH*
M	W_1	174	75	110	28	28	380	470	88.8	47.2	12	13	2	5	930	570	540	470	10	12	5.7
D	I_1	212	90	112	35	36	470	480	85.8	56.6	13	14	2	6	1,200	840	1,000	810	10	42	7.0
J	I_1	165	65	100	25	26	380	440	75.6	50.7	9	9	3	5	910	630	780	790	11	40	5.8
S	I_1	193	90	108	23	23	330	340	72.5	40.2	18	20	3	6	810	450	850	680	8	59	6.6
F	R	214	135	103	43	49	----	----	71.4	41.8	24	23	2	4	850	550	380	370	11	14	6.6
G	R	175	95	72	29	30	----	----	67.0	34.2	31	27	2	5	560	320	230	200	26	14	5.2
DUPLEX, CREPED.																					
V	----	214	115	57	81	48	310	400	29.7	30.3	22	19	23	7	200—	450	220	260	15	19	6.2
HH	----	243	155	61	73	49	320	380	28.3	37.8	22	26	15	5	200—	730	460	680	6	33	4.1
GG	W_1	193	95	88	30	27	330	380	39.5	31.6	31	28	6	6	260	420	310	430	5	11	5.9
K	I_1	314	180	110	54	52	500	630	53.0	44.2	26	23	13	7	640	1,100	1,000	1,200	24	48	4.7
T	I_1	245	115	110	45	35	420	450	41.4	52.6	30	35	16	6	250	850	350	420	8	130	5.8
BB	WS_1, W_1	199	110	69	63	39	320	340	29.1	39.0	29	24	18	5	200—	680	610	580	9	21	4.4
C	R	320	180	110	67	73	----	----	36.6	46.6	36	36	14	5	420	1,000	750	920	14	13	6.0
U	R, WS_2	262	155	104	53	54	----	----	42.0	42.0	55	57	5	4	590	860	1,600	2,400	30	48	5.7
EE	R, WS_2	274	160	116	59	65	----	----	39.0	60.0	56	45	17	5	590	1,100	2,300	2,100	24	50	6.8
TRIPLEX, CREPED (ONE SHEET CREPED).																					
E	----	228	140	71	30	30	350	460	67.4	36.2	12	11	2	8	720	570	530	490	19	21	6.9
AA	MR_1	262	170	77	32	32	450	490	57.3	37.5	26	19	3	5	620	560	920	880	10	9	5.2
CC	I_1	307	175	88	44	46	470	610	69.6	43.6	27	29	3	8	790	900	1,200	850	17	100	5.7
TRIPLEX, CREPED (TWO SHEETS CREPED)																					
B	I_2	270	130	88	34	35	370	460	44.2	34.2	38	28	5	9	350	500	590	610	143	67	6.1
TRIPLEX, CREPED (THREE SHEETS CREPED)																					
A	----	567	430	80	237	127	600	830	34.2	26.0	51	47	26	25	430	560	2,700	3,000	67	42	7.8
H	----	363	180	95	45	42	480	470	32.0	47.8	25	27	22	7	520	890	1,200	1,100	24	22	7.6
O	WS_2	418	275	117	313	143	1,100	920	54.5	55.7	45	49	33	12	660	1,300	600	620	23	22	6.8
DD	WS_2, W_1	427	280	98	316	184	790	900	50.7	50.3	39	43	24	7	580	1,000	360	320	16	42	5.7
W	I_3	300	150	124	53	52	560	720	52.2	49.7	36	40	12	8	440	1,200	580	590	56	48	6.0

[1] W—waxed; I, infused with asphalt; R, reinforced with strands or cords of fibers; WS, treated with melamine resin for high wet strength; MR, treated for mold resistance. The numbers are the number of sheets treated.

[2] MD=Machine direction; CD=cross direction.

[3] Test for tearing resistance of reinforced (R) caseliners could not be made because of interference of the reinforcing materials.

[4] Inside and outside indicate the positions of the sides of the paper in the caseliner made from it.

Physical tests made at 50-percent relative humidity and 73° F.

TABLE 2.—*Resistance of asphalt-laminated caselining papers to water and water vapor*

Sample designation	Special treatments[1]	Water resistance (73° F, 50-percent relative humidity)				Water-vapor permeability (g/m²)/24 hr							
		Side[2] 1		Side 2		73° F, 50-percent relative humidity				100° F, 90-percent relative humidity			
						Side 1		Side 2		Side 1		Side 2	
		Uncreased	Creased	Uncreased	Creased	Uncreased	Creased	Uncreased	Creased	Uncreased	Creased	Uncreased	Creased
DUPLEX, UNCREPED													
		hr	*hr*	*hr*	*hr*								
M	W_1	78	55	64 to 100+	80 to 100+	2.2	2.8	2.2	5.3	18.0	25.6	19.7	39.1
D	I_1	[3]100+	18	100+	7	1.3	10.9	1.5	3.3	9.9	60.1	10.2	18.1
J	I_1	90 to 100+	84	100+	76 to 100+	2.7	5.3	2.4	7.7	22.2	61.1	18.5	88.1
S	I_1	92 to 100+	21	97	57	1.8	2.5	1.7	2.8	17.3	20.2	16.7	19.3
F	R	25	19	29	15	1.9	3.8	1.6	3.0	15.2	31.3	13.1	23.8
G	R	51	13	52	9	1.9	5.7	2.0	6.8	18.6	39.2	20.2	45.8
DUPLEX, CREPED													
V	------	20	16	19	14	2.0	2.1	1.9	2.1	18.3	17.2	14.9	18.0
HH	------	33	39	27	42	1.6	1.7	1.6	1.7	13.1	13.3	12.8	13.6
GG	W_1	43	43	48	45	1.8	1.8	1.5	1.7	16.4	15.3	13.6	14.7
K	I_1	100+	62 to 100+	70 to 100+	38	1.1	1.2	1.1	1.1	9.9	10.3	10.7	8.9
T	I_1	60	44	49	47	2.0	3.8	1.7	3.8	30.0	45.8	23.0	48.1
BB	WS_1, W_1	36	25	33	21	2.8	3.0	2.4	2.6	34.0	29.8	23.9	23.9
C	R	20	28	29	23	1.2	1.3	1.1	1.1	13.4	14.7	12.8	12.8
U	R, WS_2	47	32	41	26	1.2	1.8	1.3	2.2	11.5	13.9	12.5	17.9
EE	R, WS_2	41	30	25	31	1.3	1.5	1.2	2.3	12.7	14.0	11.4	19.2
TRIPLEX, CREPED (ONE SHEET CREPED)													
E	------	100+	92 to 100+	100+	100+	1.3	1.7	1.2	1.8	9.5	13.6	8.4	14.5
AA	MR_1	88 to 100+	100+	100+	100+	0.9	0.9	0.8	1.0	7.2	7.3	6.7	7.5
CC	I_1	100+	66	100+	100+	7	1.6	.7	1.6	5.5	7.6	5.0	6.6
TRIPLEX, CREPED (TWO SHEETS CREPED)													
B	I_2	64	57	57	63	1.3	1.5	1.1	1.6	10.7	13.5	9.4	14.9
TRIPLEX, CREPED (THREE SHEETS CREPED)													
A	------	100+	100+	100+	100+	0.3	0.4	0.3	0.3	2.6	2.8	2.6	2.6
H	------	68	43 to 100+	69	91 to 100+	.8	.9	.7	1.5	6.8	6.6	6.4	9.9
O	WS_2	96 to 100+	60	32 to 100+	60	.7	1.7	1.1	0.9	7.0	23.6	13.4	9.2
DD	WS_2, W_1	88 to 100+	60	100+	98 to 100+	.6	0.8	0.7	.8	8.2	7.4	11.2	10.6
W	I_3	69	23	92	18	2.4	2.9	1.6	2.8	19.7	18.6	14.1	18.7

[1] W, waxed; I, infused with asphalt; R, reinforced with strands or cords of fiber; WS, treated with melamine resin for high wet strength; MR, treated for mold resistance. The numbers are the number of sheets treated.

[2] Side 1 and side 2 indicate the side exposed to water or water vapor. Side 1 is the outer side of the paper in the caseliner made from it. In papers having one side infused with asphalt or other materials, it is the side so treated.

[3] All tests for water resistance discontinued at the end of 100 hours.

TABLE 3.—*Physical properties and acidity of miscellaneous caselining materials*

Sample designation	Description of caseliner	Weight per 3,000 sq ft		Bursting strength	Puncture resistance		Tearing resistance		Tensile strength		Tensile strength retained when wet		Stretch		Stiffness		Resistance to scuffing				Acidity hot extraction
																	NBS wet rub		Taber dry rub		
		Total	Asphalt		MD[1]	CD[1]	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	Inside[3]	Outside[3]	
		lb	*lb*	*Points*	*Points*	*Points*	*g*	*g*	*lb/in.*	*lb/in.*	*%*	*%*	*%*	*%*	*g*	*g*	*Double rubs*	*Double rubs*	*rev/cg*	*rev/cg*	pH
P	Duplex. Cellulose wadding infused with asphalt.	425	350	97	41	41	630	930	31.3	11.1	76	65	11	13	700	410	3,800	3,100	------	------	7.5
Q	Duplex. Cellulose wadding infused with asphalt and coated on one side with asphalt.	587	510	91	------	------	760	940	26.7	11.0	105	71	26	14	660	340	3,600	3,300	------	------	7.3
R	Triplex. Cellulose wadding infused with asphalt.	605	510	135	------	------	920	------	43.5	11.8	116	87	17	15	1,000	500	4,700	4,000	------	------	7.5
X	Kraft paper with lead foil laminated to one side and scrim cloth laminated to the other side.	301	[2]	86	98	102	990	------	54.9	31.9	66	74	3	5	200—	200—	2,800	2,600	500	------	--------
Z	Cloth, one side coated with vinyl resin	255	None	125	271	336	690	890	71.3	46.2	107	122	8	24	------	------	13,000	9,000	321	115	--------
FF	Duplex. Kraft paper laminated with asphalt to cellophane sheet.	155	90	73	21	23	190	190	30.3	25.6	27	20	15	10	200—	210	550	430	6	156	5.0
II	Triplex. Kraft paper laminated with asphalt to both sides of a cellophane sheet.	222	110	80	32	32	350	400	44.1	41.9	25	18	15	7	330	650	690	700	10	7	6.1

[1] MD = Machine direction; CD = cross direction.
[2] All omissions are because satisfactory test data could not be obtained owing to the nature of the material.
[3] Inside and outside indicate the positions of the sides of the material in the caseliner made from it.
Physical tests made at 50-percent relative humidity and 73° F.

TABLE 4.—*Resistance of miscellaneous caselining materials to water and water vapor.*

Sample designation	Description of caseliner	Water resistance hr 73° F, 50-percent relative humidity				Water-vapor permeability, $(g/m^2)/24$ hr							
						73° F, 50-percent relative humidity				100° F, 90-percent relative humidity			
		Side[1] 1		Side 2		Side 1		Side 2		Side 1		Side 2	
		Uncreased	Creased	Uncreased	Creased	Uncreased	Creased	Uncreased	Creased	Uncreased	Creased	Uncreased	Creased
P	Duplex. Cellulose wadding infused with asphalt	[2]100+	84 to 100+	100+	73 to 100+	0.5	5.8	0.5	1.9	4.3	28.0	4.8	11.4
Q	Duplex. Cellulose wadding infused with asphalt and coated on one side with asphalt.	100+	100+	100+	100+	.3	0.4	.3	0.5	2.8	2.9	2.7	3.3
R	Triplex. Cellulose wadding infused with asphalt	100+	86 to 100+	100+	54 to 100+	1.1	.6	.5	.5	6.4	4.6	4.0	3.9
X	Kraft paper with lead foil laminated to one side and scrim cloth laminated to the other side.	100+	100+	100+	100+	0.0	.0	.0	.0	0.0	0.0	0.0	0.0
Z	Cloth, one side coated with vinyl resin	3	3	14	16	9.4	10.2	7.0	7.1	89.5	98.0	68.4	70.2
FF	Duplex. Kraft paper laminated with asphalt to cellophane sheet.	78	38	72 to 100+	72	2.1	2.4	1.9	1.7	21.5	24.5	16.0	14.4
II	Triplex. Kraft paper laminated with asphalt to both sides of a cellophane sheet.	20	25	31	27	2.0	2.2	1.7	2.2	19.3	21.8	15.1	21.6

[1] Side 1 and side 2 indicate the side exposed to water or water vapor. Side 1 is the outer side of the material in the caseliner made from it.

[2] All tests for water resistance were discontinued at the end of 100 hours.

TABLE 5.—*Bleeding tests of caselining materials*

Sample designation	Nature and degree of staining of white paper in contact with both sides of test specimens at 150° F and under pressure of 72 pounds per square foot for 5 hours
A	Slight asphalt staining, spots; brown wax stains
B	Moderate asphalt staining, streaks.
C	No staining.
D	One side considerable asphalt staining, spots; other side (infused) slight asphalt staining, spots.
E	Slight to moderate asphalt staining, spots.
F	No staining.
G	Do.
H	No asphalt staining, brown wax spots.
J	Do.
K	One side moderate asphalt staining, spots; other side (infused) slight asphalt staining, spots.
M	No asphalt staining, brown wax spots.
O	Moderate asphalt staining, streaks.
P	One side no staining; other side slight asphalt staining; test paper sticks partly to caselining material.
Q	Considerable asphalt staining; test paper sticks to caselining material.
R	Considerable asphalt staining; test paper sticks to caselining material.
S	Infused side, considerable asphalt staining; other side, slight asphalt staining.
T	Infused side, considerable asphalt staining; other side, no staining.
U	No staining.
V	Do.
W	Moderate asphalt staining, streaks.
AA	Very considerable asphalt staining. Test paper laminated firmly to caselining material.
BB	No asphalt staining, slight wax stains.
CC	Moderate asphalt staining, spots. Test paper sticks around edges of caselining material.
DD	Very considerable asphalt staining. Test paper laminated firmly to caselining paper.
EE	No staining.
FF	Slight asphalt staining, brown wax spots.
GG	No asphalt staining, brown wax spots.
HH	Do.
II	Slight asphalt staining on one side; other side brown wax spots.

V. CORRELATION OF TEST DATA FOR CASELINING MATERIALS WITH PERFORMANCE OF CASELINERS MADE FROM THEM

Determination of the significance of test data is necessary in arriving at a quality standard for any material. In the present instance, judgment of performance was based on results of the tests of the packed shipping cases at the Package Research Laboratory.[11] There the different materials were given ratings based on how well they survived the simulated service tests. The rating was made by a system of scoring with respect to the occurrence of holes and tears. A score of 6 was the maximum, indicating fewest failures; a score of 0 indicated the poorest performance. Caseliners A, C, K, W, and Z were given a score of 6; liners V and CC, a score of 5; and liners H, O, T, U, DD, and EE, a score of 4. These three scores were characterized as indicating satisfactory performance. The remaining caseliners, which received scores of 2, 1, and 0, were classed as unsatisfactory.[12]

A slightly different method of rating the caseliners is shown in table 6. This rating is based on the same data used in the above classification, with the addition of columns 7 and 8 of the

[11] See footnotes 1, 2, 3, and 4.
[12] See footnote 4.

table, but was arrived at by a different method of handling the data. In table 6 the liners are arranged in the eight numbered columns according to excellence of performance in the simulated service tests made at the Package Research Laboratory. The composite-rating value of each liner, shown in the last column, is the sum of the 8 position numbers of the liner in the 8 numbered columns. The first 13 liners in table 6 are the same 13 liners that were classified independently as satisfactory by the score method referred to above, but the order within both the "satisfactory" group and the "unsatisfactory" group is somewhat different. In the subsequent discussion the "satisfactory" group, which includes the same liners by either method of classification, will be called group I; the "unsatisfactory" liners will be called group II.

Table 6.—*Relative rating of caseliners according to simulated service tests*

Position No.	Average number of holes and tears				Weighted average number of holes				Liners with no holes or tears				Contents dry				Composite rating	
	1		2		3		4		5		6		7		8			
	Tropic		Arctic		Tropic		Arctic		Tropic		Arctic		Tropic		Arctic			
										%		%		%		%		
1	O	0.0	C	0.0	O	0.0	C	0.0	O	100	C	100	O	100	A	100	Z	25
2	Z	.1	W	.1	T	.1	Z	.2	T	93	W	93	R	100	C	100	W	28
3	T	.1	Z	.2	Z	.3	W	.3	Z	87	Z	90	P	93	K	100	O	48
4	W	.3	V	.3	W	.9	A	.8	W	80	A	80	Z	92	W	100	K	51
5	EE	.3	A	.4	EE	1.5	K	1.6	EE	80	K	73	W	87	Z	96	C	60
6	R	.3	H	.4	R	2.1	V	1.9	K	67	V	73	DD	87	BB	93	A	62
7	U	.8	K	.4	DD	2.5	DD	2.5	R	67	CC	73	EE	87	DD	93	DD	70
8	K	.9	EE	.5	K	2.9	GG	2.6	U	53	H	67	A	80	HH	93	EE	70
9	CC	1.0	U	.5	C	3.6	HH	2.9	DD	53	U	67	K	73	II	93	H	85
10	DD	1.0	O	.5	H	4.8	H	3.1	C	50	EE	67	Q	73	D	87	T	89
11	H	1.2	CC	.5	U	5.1	EE	3.5	CC	40	O	60	U	73	O	87	U	91
12	Q	1.6	DD	.7	A	5.7	O	3.8	H	33	DD	60	CC	53	T	87	CC	91
13	A	1.7	GG	.7	CC	7	T	4.1	Q	27	HH	60	H	50	X	87	V	103
14	B	1.8	HH	.8	Q	8	CC	4.1	B	27	D	47	HH	47	CC	87	R	117
15	C	2.2	T	.9—	B	10—	U	4.7	A	20	M	47	II	47	H	80	HH	128
16	S	2.7	B	.9	P	10	D	7—	P	20	GG	47	AA	40	M	80	GG	132
17	P	2.9	M	1.1	GG	10	BB	7	V	13	BB	40	V	33	V	80	B	135
18	V	4.2	BB	1.1	V	11	B	7+	AA	13	B	33	X	33	GG	80	P	152
19	AA	5.2	D	1.3	HH	11	M	9	GG	13	J	33	GG	33	EE	73	Q	154
20	BB	5.3	J	1.4	AA	13	J	10	D	7	T	33	B	30	B	67	BB	154
21	HH	6.1	AA	1.7—	S	23	AA	13	E	7	E	27	C	30	U	67	D	155
22	GG	7.2	R	1.7	BB	24	E	13+	S	7	AA	20	T	27	E	60	AA	165
23	E	12.4	E	1.9	X	26	II	15	F	0	Q	7	J	20	J	60	M	173
24	D	13.1	P	2.7	D	28	R	17	G	0	R	7	FF	20	FF	60	J	182
25	II	13.6	Q	3.6	E	34	X	21	J	0	P	0	M	13	P	53	II	187
26	J	21.1	II	4.1	J	34	P	24	M	0	S	0	BB	13	R	47	X	189
27	X	25.0	S	4.2	M	38	S	27	X	0	X	0	S	7	S	47	S	193
28	M	28.2	FF	19.5	F	49	Q	35	BB	0	FF	0	D	0	AA	47	E	195
29	FF	32.5	X	19.7	II	60	FF	53	FF	0	II	0	E	0	Q	33	FF	221
30	F	35.4	F	------	FF	127	F	------	HH	0	F	------	F	0	F	------	F	231
31	G	341.	G	------	G	358	G	------	II	0	G	------	G	0	G	------	G	241

In table 7 the caseliners are listed in the order of performance according to the composite rating of table 6, and the corresponding physical properties, determined by tests made at the National Bureau of Standards, are tabulated. The data given are averages of the values in the machine direction and in the cross direction, or averages of values for the two sides of the liners (according to the nature of the tests), obtained from tables 1 to 4. There is one exception; the Taber abrasion value given for each liner is the minimum value obtained on the two sides of the liner.

TABLE 7.—*Average values of physical properties*[1] *of caseliners, arranged in order of composite rating* (*table 6*)

Sample Designation	Bursting strength	Puncture resistance	Tearing resistance	Tensile strength	Wet-tensile strength	Stretch	Stiffness	Resistance to scuffing		Water resistance creased at 40° F	Water-vapor permeability at 100° F, 90 percent relative humidity creased
								NBS wet	Taber dry (min)		
GROUP I											
	Points	*Beach units*	*g*	*lb/in.*	*lb/in.*	*%*	*g*	*Hundred oscillations*	*rev/cg*	*hr*	*(g/m²)/24 hr*
Z	125	304	790	59	66	16	200—	110	115	10	84
W	124	53	640	51	19	10	820	6	48	21	19
O	117	228	1,010	55	26	23	980	6	22	60	16
K	110	53	565	49	12	10	870	11	24	50	10
C	110	70	--------	42	15	10	710	8	13	26	13
A	80	182	715	30	15	26	495	29	42	100+	3
DD	98	250	845	51	21	16	790	3	16	80+	9
EE	116	62	--------	50	24	11	845	22	24	31	17
H	95	44	475	40	10	15	705	12	22	85+	8
T	110	40	435	47	15	11	550	4	8	46	47
U	104	54	--------	42	24	5	725	20	30	29	16
CC	88	45	540	57	16	6	845	10	17	80+	7
V	57	65	355	30	6	15	325—	2	15	15	18
GROUP II											
R	135	--------	--------	28	30	16	750	44	--------	85+	4
HH	61	61	350	33	8	10	465—	11	6	41	14
GG	88	29	355	36	11	6	340	4	5	44	15
B	88	35	415	39	13	7	425	6	67	60	14
P	97	41	780	21	15	12	555	35	--------	90+	20
Q	91	--------	850	19	18	20	500	35	--------	100+	3
BB	69	51	330	34	9	12	440	6	9	23	27
D	112	36	475	71	10	4	1,020	9	10	13	39
AA	77	32	470	47	11	4	590	9	9	100+	7
M	110	28	425	68	8	4	750	5	10	80+	32
J	100	26	410	63	6	4	770	8	11	90+	75
II	80	32	375	43	9	11	490	7	7	26	22
X	86	100	--------	43	30	4	200—	27	--------	100+	0
S	108	23	335	56	10	5	630	8	8	39	20
E	71	30	405	52	6	5	645	5	19	100+	14
FF	73	22	190	28	7	13	200	5	6	55	15
F	103	46	--------	57	13	3	700	4	11	17	28
G	72	30	--------	51	15	4	440	2	14	11	43

[1] All tests made at 73° F, and 50-percent relative humidity, except water-vapor permeability. Values, except Taber are averages of both directions, or of both sides.

As the performance rating, by either method, is based largely on the development of holes and tears during the simulated service tests, the correlation of the simulated service tests with the physical properties of the liner material must logically be a correlation with the results of those tests of physical properties that apply stresses intended to produce some form of failure by rupture or wear. That there is some such correlation is indicated by the fact that it is possible to choose a combination of tests and limits of test values that will separate completely group I from group II. For example, a puncture resistance (Beach) of not less than 40 units; a tensile strength of not less than 30 pounds per inch; a stretch of not less than 5 percent; and a tearing resistance of not less than 355 grams will do this. All liners in group I will be retained under this combination of physical-property requirements. All but seven liners in group II will be eliminated by the first requirement; three of these seven will be eliminated by the second requirement; two of the remaining four, by the third requirement; and the remaining two, by the fourth requirement.

Of course, such a procedure is an elastic and arbitrary one, in that some other combination could be found that would divide the liners at a different level. It is apparent, however, that a reasonable specification of physical properties might be drawn up that would retain unequivocally most of the satisfactory liners, while eliminating equally unequivocally most of the unsatisfactory liners. The few liners that are a little difficult to place definitely in one group or the other, by their physical properties, are naturally those near the division line of table 7, between groups I and II. For example, liner R performed very well in the simulated service tests, while under tropical conditions, but performed poorly under arctic conditions. To make such a distinction by physical properties alone would require that certain tests to failure be made on the liner materials at a low temperature, under which condition the asphalt becomes brittle, but no such tests were made at the National Bureau of Standards. It is observed, however, that all the liners of this construction (P, Q, and R) are weak in tension under normal conditions, which provides a means of eliminating them by a tensile requirement. Then there are some liners above and below the division line that did not differ much in performance in the simulated service tests, when ranked according to table 6. Liners V, HH, and GG are similar in structure, and are comparable to one another in most physical properties. The propriety of regarding one of these as satisfactory and the other two as unsatisfactory may reasonably be questioned.

The physical properties tabulated in table 7 are useful in varying degrees in separating the two groups. All liners of group I (first 13 in table 7) have a puncture resistance (Beach) of 40 units or more; only five (tests of R and Q not having been made) in group II exceed this value. Of the liners in group I on which tests of tearing resistance could be made, all but one tested 435 grams or more; only four of those in group II exceeded this figure. Although tearing resistance is useful as far as it goes, satisfactory tests can not be made on many liners containing cloth, strands, or long fibrous material. For this reason, it is not very desirable to use tearing resistance in a specification if it can be avoided.

A bursting strength (Mullen) of 80 points or more was found for all liners in group I, with one exception; but two-thirds of the liners in group II also have bursting strength values above this figure. Bursting strength, therefore, is not very useful in separating the two groups. Likewise, the range of tensile-strength values is so much alike in the two groups that this property might be dismissed as of little value, except for one consideration. As previously stated, the liners P, Q, and R, made of cellulose wadding infused with asphalt, were classed as unsatisfactory because of their very poor performance under arctic conditions. The only physical test made at normal temperature that will eliminate these liners is tensile strength, and this fact appears to be the only logical reason for including the tensile test in the effort to separate group I and group II by their physical properties alone. The tensile strength of the liners when wet is, on the other hand, more useful. All but three of the satisfactory group have a wet tensile strength of 15 pounds per inch or more; only three of the unsatisfactory group exceed this figure. Stretch is also useful. Only two of the liners in group I have a stretch of less than 10 percent; about two-thirds of the liners in group II have a stretch of less than 10 percent.

Stiffness apparently has no bearing on the separation of the two groups. This might be expected, because a test of stiffness does not involve rupture or wear.

It was expected that the "wet-rub" test would be related to the separation of the two groups, inasmuch as the scuffing of the wet liners, and the wearing of holes through them, are the very essence of some of the simulated service tests. It is apparent, however, from the data in table 7 that the corresponding test on the liner materials has little relation to the separation of the two groups. The Taber abrasion test on the dry surface does, on the contrary, appear to help in the classification, provided that the minimum value for the two sides is used. All but two of the satisfactory liners have a minimum Taber value of 15 or more revolutions per centigram of material worn away; only two of the unsatisfactory liners have a minimum Taber value exceeding this figure.

Resistance to the transfer of moisture through the liners, although it probably had no direct bearing on the simulated service tests, is of primary importance in its own right, since the chief function of a caseliner is to serve as a moisture barrier. A liner may withstand all necessary rough treatment without injury, and still be inherently unable to protect the contents of a shipping case against damage by moisture. The values for water resistance and for water-vapor permeability are given in table 7. Very few liners in either group (but some in both) have a water-resistance value less than 20 hours. The water-vapor permeability is the only test listed for which the degree of excellence is inversely related to the numerical value given. In group I, all but two liners have a water-vapor permeability of 19 grams per square meter per 24 hours or less at 100° F and 90-percent relative humidity; in group II the liners were equally divided on each side of this figure.

The following combination of physical tests and limiting values seems to provide a reasonable basis for selecting satisfactory caseliners.

Puncture resistance (Beach), average of both directions, not less than 40 units.

Tensile strength, average of both directions, not less than 30 pounds per inch width.

Wet tensile strength, average of both directions, not less than 10 pounds per inch width.

Stretch, average of both directions, not less than 8 percent.

Water resistance, on creases made at 40° F, average of both sides, not less than 20 hours.

Water-vapor permeability at 100° F and 90-percent relative humidity, on creases made at 40° F, not more than 20 grams per square meter per 24 hours.

If it is desired to add some additional safeguard, it may be useful to add an abrasion value by the Taber instrument of not less than 10 or 12 revolutions per centigram on either side.

Based wholly on tests of physical properties, such a combination as that given above eliminates with little uncertainty the caseliners in group II, while retaining all but five in group I. Of these five, three (Z, T, and V) fail because they are not good enough as moisture barriers; the other two (U and CC), because of low stretch.

VI. RECOMMENDED STANDARDS

In a meeting attended by the Task Group and representatives of the War Department, the Navy Department, and the National Bureau of Standards, it was agreed that:

1. It is possible to correlate National Bureau of Standards physical tests on caseliner materials with performance results on caseliners made from them tested at Package Research Laboratory.

2. Based on such correlation, and without taking into account load, box construction, box size, and handling, a satisfactory caseliner material can be defined as follows:

The caselining material should be asphalt-laminated kraft paper having the following properties:

Total asphalt per 500 sheets, 24 by 36 inches, not less than 150 pounds.

Total kraft paper per 500 sheets, 24 by 36 inches, not less than 90 pounds.

Stretch, average of both directions, not less than 10 percent.

Tearing resistance, average of both directions, not less than 400 grams.

Tensile strength, average of both directions, not less than 40 pounds per inch width.

NOTE.—Variations below the minimum tensile-strength requirement are permissible, provided they are compensated by an increase over the tearing-strength requirement in the ratio of 10 units of tearing strength to 1 unit of tensile strength.

Puncture resistance (Beach), average of both directions, not less than 40 units.

Water resistance, on creases made at 40° F, average of both sides, not less than 16 hours.

Water-vapor permeability at 100°F and 90-percent relative humidity, on creases made at 40° F, average of both sides, not more than 20 grams per square meter per 24 hours.

In the foregoing specification, the tensile-strength requirement is coupled with the tearing-resistance requirement in a manner that seems rather awkward and strained, in order not to eliminate obviously good liners that have a tensile strength of less than 40 pounds per inch. It has already been pointed out that tensile strength, with one possible exception, seems to have very little relation to the classification of liners by the simulated service tests. As the specification confines acceptable caseliners to those composed of kraft paper, laminated with asphalt, it becomes unnecessary to include a tensile-strength requirement solely to eliminate those miscellaneous liners (P, Q, and R) found unsatisfactory under arctic conditions. It is recommended, therefore, that the tensile-strength requirement, and perhaps also the requirement for tearing resistance, be omitted, and that a wet-tensile-strength requirement of not less than 10 pounds per inch, be substituted for them.

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