THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

DEVELOPMENT OF RIGID-WHEN-WET CORRUGATED BOARD

Project 1108-27

Preliminary Report Two

A Progress Report

to

Rigid-When-Wet Committee

Fourdrinier Kraft Board Institute, Inc.

September 16, 1964

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Sometime ago The Institute of Paper Chemistry initiated a study on behalf of the Fourdrinier Kraft Board Institute, Inc., for the purpose of studying ways of developing a rigid-when-wet corrugated board and box. The results of this study were distributed to the co-operator in the form of Progress Report One to the Fourdrinier Kraft Board Institute, Inc., entitled "Development of Rigid-When-Wet Corrugated Board", Project 1108-27, March 12, 1963.

The results obtained in the above investigation indicated that impregnation of the components with a small amount of thermosetting resin followed by a second stage application of thermoplastic material appeared to offer the best approach to date in the development of a reinforced corrugated box.

Late in February 1964, The Institute of Paper Chemistry was authorized to proceed with a pilot scale trial to develop more concrete data relative to the feasibility of the treatment, the material cost, and the performance to be expected. The Institute was advised that the pilot scale trial should be directed to providing basic design data for a chicken box. The maximum material cost goal established by the co-operator was $5.00 per thousand square feet of combined board upcharge for the treatment.

The pilot scale trial involved: (a) the manufacture of linerboard and corrugating medium on an experimental paper machine in which varying percentages of thermosetting resins were added at the size press, and (b) the subsequent

impregnation of the trial-produced components with the thermoplastic materials and their ultimate fabrication into corrugated combined board with a nonaqueous adhesive.

Manufacture of Liner and Medium Impregnated with Thermoset Resin.

The experimental liners and mediums were made on the experimental paper machine at the School of Paper Technology, Western Michigan University, Kalamazoo, Michigan. The machine in question is a scaled-down replica of a conventional fourdrinier machine equipped with a vertical size press with means for applying treatment to one or both sides of the sheet. The trim width is approximately 24 inches. As a result of the scaled-down wire length, number and size of driers, etc., the machine is limited to much slower speeds on given grades than its commercial counterpart. The stock preparation equipment is limited to one Valley beater and one plug refiner.

Linerboard.

Four different experimental linerboards were made - each at a different level of thermoset resin. Initially five had been planned; however, it was decided to abandon the highest impregnation level (15%) because of: (a) inability to hold to a given fiber substance weight, and (b) the sheet at the next lower level (10%) was extremely brittle. The four different liners were made from a furnish of unbleached kraft pulp obtained at wet lap pulp with a permanganate number of 26-30. The pulp was refined at 4% consistency in the Valley beater to a freeness of 585 cc. (C.S.). When the above freeness level was attained, the beater roll was raised and 1% dry rosin size added and then 3% dry alum. After thorough mixing, the stock was pumped to a beater chest where it was diluted to

2% consistency. From the beater chest the stock was pumped through the refiner to the machine chest.

The fiber substance of the linerboards was set at 42-lb./M ft.^{2}; however, it was not possible to hold this level even within a given linerboard sample because of deficiencies in the machine drive and the stock pumping system. The Institute had been advised that previously a similar grade of board had been made at 50 f.p.m. without difficulty; however, in the trials described herein, the machine speed had to be reduced to 30 f.p.m.

The thermoset resin used was Durez ~~19873~~ 17983 made by the Durez Division, Hooker Chemical Corporation. The resin was applied to each side of the sheet at the size press. As mentioned previously the initial plans called for five levels of thermoset resin impregnation: 0, 5, 7.5, 10, and 15%; however, due to unforeseen difficulties only four levels were used, namely, 0, 5, 7.5, and 10%. These levels of treatment were obtained by diluting the resin with water to give a concentration about twice the pickup desired in the board and adjusting the moisture level of the sheet at the size press. No difficulty was encountered with resin dilution except at the 5% level wherein it was necessary to use deionized water because of the extreme hardness of the tap water in the Kalamazoo area. The pickup at the size press on a given sheet is primarily a function of the dwell time or machine speed, the viscosity of the resin and the moisture content of the sheet entering the size press -- the pickup appeared to go through a maximum as the moisture content of the sheet entering the size press increased. As previously mentioned, due to unavoidable variations in basis weight, the amount of pickup varied far more than desired. The liner sample with no thermoset resin was run first and then in sequence the increasing resin contents.

It was planned initially that the actual resin pickup would be determined by quantitative chemical analysis of the treated samples. However, this analysis has been held in abeyance pending the outcome of the results on the fabrication and evaluation phases because of the complexity of the analytical method and the excessive variation in the weight of fiber substance even within a given sample.

Corrugating Medium.

The corrugating medium was made from a furnish consistency of 85% waste semichemical corrugating medium and 15% of the unbleached kraft wet lap pulp obtained for the linerboard trials. The kraft pulp was fed to the beater first and then the waste semichemical medium. The mixed furnish was refined to a freeness of 385 cc. (C.S.). No size or alum was used in the medium furnish. The fiber substance was 26-lb./M ft.^{2} and the machine speed was held at 50 f.p.m. There was some fluctuation in basis weight; however, it was considerably less than in the case of the linerboard samples. The trim width was 24 inches. The sequence of running was to make the sample without resin first, then the 15% resin sample, and then the balance of the samples in the order of decreasing resin content.

The characteristics of the samples and the applied resin levels are given in Table I.

Combined Board Fabrication.

The linerboard and corrugating medium samples made at Western Michigan were in the form of 24-inch width rolls. These were forwarded to The Institute of Paper Chemistry where they were subsequently slit into 11-1/2-inch widths and rewound.

TABLE I

CHARACTERISTICS OF COMPONENT MATERIAL
(50% R.H.)

Roll No.	Resin Addition	Basis Weight, lb./M sq. ft.	Caliper, pt.	Mod. Ring Compression C.D. lb./in.	Concora Flat Crush p.s.i.	Bursting Strength, p.s.i.
			Liner			
4667	0	43.4	13.0	15.0	--	68
4673	5	43.2	12.7	14.4	--	76
4669	7-1/2	44.4	13.0	18.5	--	87
4671	10	44.8	12.8	23.4	--	93
			Medium			
4675	0	26.6	9.5	13.9	32.4	--
4683	5	27.9	9.3	17.0	49.0	--
4681	7-1/2	28.8	10.3	19.0	59.0	--
4679	10	28.1	9.5	17.8	58.0	--
4677	15	29.1	10.3	19.7	66.0	--

The four experimental samples of liner are being combined with their "corresponding" resin content medium on the Institute's corrugator using a non-aqueous adhesive. In addition the liner sample with the 10% applied resin is being combined with the medium with the 15% applied resin.

Three series of combined board are involved. These are:

1. Fabrication of experimental liners and medium without further treatment (no secondary treatment) with a nonaqueous adhesive.
2. Fabrication of experimental liners and medium (the latter impregnated with a thermoplastic resin) with a nonaqueous adhesive.
3. Fabrication of experimental liners and medium after impregnation with a thermosetting resin and using a nonaqueous adhesive.

At the present time the fabrication described in items 1 and 2, above, have been completed and work is progressing on item 3. The fabrication described in item 3 is, of course, the one which it is anticipated will give the best performance. Because of the limited amount of material available for experimentation, the performance of the various corrugated board samples in terms of box compression and rough handling are as an interim measure being estimated by means of combined board performance. It is planned, however, to make test boxes as soon as the most appropriate combining procedure has been worked out. As an interim measure, the single-faced samples have been double-faced manually and are evaluated for weight, caliper, torsion tear, and edgewise compression strength after conditioning at 50% R.H., 90% R.H., and after soaking in water for 24 hours. An estimate of box compression is calculated from a consideration of the edgewise compression, caliper and box dimension.

DISCUSSION OF RESULTS

The results obtained to date are tabulated in Tables II, III, and IV.

TABLE II

COMBINED BOARD RESULTS

Trial No.	Medium Treatment, %		Liner Treatment, %		C.D. Edgewise Compression, lb./in.			Caliper			Torsion Tear, in.-oz.					
					50% R.H.	90% R.H.	24-hr.-water	50% R.H.	90% R.H.	24-hr.-water	50% R.H.		90% R.H.		24-hr.-water	
	Durez	Piccopale-70	Durez	Piccopale-70							In	Cross	In	Cross	In	Cross
B-1	0	0	0	0	41.7	--	--	222.8	--	--	308	239	--	--	--	--
B-2	5	0	7.5	0	50.8	22.5	3.8	218.1	224.8	238.4	299	204	378	273	108	58
B-3	7.5	0	5	0	43.2	18.1	3.5	218.9	222.5	234.1	278	212	360	257	199	68
B-4	10	0	10	0	57.3	21.6	5.6	223.2	225.0	238.9	359	222	492	302	452	100
B-5	15	0	10	0	63.9	20.4	5.8	222.1	226.8	242.7	271	235	435	299	372	92
C-2	5	22.6	7.5	0	62.3	40.6	19.2	219.1	221.5	238.8	267	233	381	292	236	114
C-3	7.5	14.9	5	0	48.7	36.7	23.8	225.1	227.2	256.9	275	225	366	271	188	156
C-4	10	18.9	10	0	63.0	39.0	19.1	220.8	226.3	247.2	274	209	413	315	197	135
C-5	15	22.3	10	0	67.9	38.4	23.4	220.4	225.0	248.1	220	226	371	324	202	158
D-2	5	22.6	7.5	7.1	65.4 71.6*	45.2	46.2* 30.0	25.0* 220.8		225.4	214	164	366	243	243	230
D-3	7.5	14.9	5	12.1	56.6	46.2	26.8	226.5		232.5	336	217	349	339	339	207
D-4	10	18.9	10	11.4	68.3	49.5	35.0	225.0		230.1	163	149	190	368	368	175
D-5	15	22.3	10	11.4	72.5	59.1	42.6	230.4		233.1	171	184	255	263	263	231

*D-2 except 42# wet strength liner

TABLE III

ESTIMATED BOX COMPRESSION

Trial No.	Medium Treatment, %		Liner Treatment, %		Estimated Box Compression, lb.*					
					50% R.H.	Diff., % **	90% R.H.	Diff., % **	24-hr.-water	Diff., % **
	Durez	Piccopale-70	Durez	Piccopale-70						
B-1	0	0	0	0	913	--	--	--	--	--
B-2	5	0	7.5	0	1100	+ 20.5	495	- 45.8	86	- 90.6
B-3	7.5	0	5	0	937	+ 2.7	396	- 56.6	79	- 91.4
B-4	10	0	10	0	1256	+ 37.5	475	- 47.9	127	- 86.1
B-5	15	0	10	0	1397	+ 53.0	451	- 50.6	131	- 85.6
C-2	5	22.6	7.5	0	1352	+ 48.1	886	- 2.9	453	- 52.3
C-3	7.5	14.9	5	0	1072	+ 17.4	811	- 11.1	559	- 38.8
C-4	10	18.9	10	0	1373	+ 50.4	862	- 5.6	441	- 51.7
C-5	15	22.3	10	0	1478	+ 61.9	844	- 7.6	542	- 40.6
D-2	5	22.6	7.5	7.1	1425	+ 56.1	996	+ 9.1	664	- 27.3
D-3	7.5	14.9	5	12.1	1250	+ 36.9	947	+ 3.7	600	- 34.3
D-4	10	18.9	10	11.4	1503	+ 64.6	1089	+ 19.3	775	- 15.1
D-5	15	22.3	10	11.4	1614	+ 76.8	1324	+ 45.0	954	+ 4.5

* Based on RSC size, 20x14x10, and abridged box formula, $P = 5.875\ P_m\ h^{0.508}\ Z^{0.492}$

** Based on B-1 as reference.

Table IV

QUALITY AND ESTIMATED COST

Trial No.	Medium Treatment, %		Liner Treatment, %		Estimated Box Compression, lb.			Torsion Tear, in.-oz.						Material Cost/M ft.^{2} Combined Board, $ *			
					50% R.H.	90% R.H.	24-hr-water	50% R.H.		90% R.H.		24-hr.-water					
	Durez	Piccopale-70	Durez	Piccopale-70				In	Cross	In	Cross	In	Cross	Durez	Piccopale-70	Adhesive	Total
B-1	0	0	0	0	913			308	239	--	--	--	--				
B-2	5	0	7.5	0	1100	495	86	299	204	378	273	108	58	1.20	0	1.20	2.40
B-3	7.5	0	5	0	937	396	79	278	212	360	257	199	68	1.18	0	1.20	2.38
B-4	10	0	10	0	1256	475	127	359	222	492	302	452	100	2.39	0	1.20	3.59
B-5	15	0	10	0	1397	451	131	271	235	435	299	372	92	2.79	0	1.20	3.99
C-2	5	22.6	7.5	0	1352	886	435	267	233	381	292	236	114	1.20	1.06	1.20	3.46
C-3	7.5	14.9	5	0	1072	811	559	275	225	366	271	188	156	1.18	0.70	1.20	2.98
C-4	10	18.9	10	0	1373	862	441	274	209	413	315	197	135	2.39	0.89	1.20	4.48
C-5	15	22.3	10	0	1478	844	542	220	226	371	324	202	158	2.79	1.04	1.20	5.03
D-2	5	22.6	7.5	7.1	1425		664	214	164			243	230	1.20	1.78	1.20	4.18
D-3	7.5	14.9	5	12.1	1250		600	336	217			339	207	1.18	1.92	1.20	4.30
D-4	10	18.9	10	11.4	1503		775	163	149			368	175	2.39	2.04	1.20	5.63
D-5	15	22.3	10	11.4	1614		954	171	184			263	231	2.79	2.20	1.20	6.19

* Based on 42-26-42 material combination and no allowance for differential between regular and nonaqueous adhesive costs.