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TESTS OF SOLID FIBERBOARD BOXES MADE OF WET-STRENGTHENED RECLAIMED MATERIAL

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TESTS OF SOLID FIBERBOARD BOXES MADE OF
WET-STRENGTHENED RECLAIMED MATERIAL¹

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Abstract

A wet-strengthened container board made of reclaimed material has been developed at the Forest Products Laboratory. This report presents the results of tests of boxes made from this fiberboard and V2s grade fiberboard. One size of the regular slotted style box for 24 No. 2 cylindrical cans was tested.

The fiberboard boxes made of six-ply, 0.110-inch reclaimed material were shown to be superior in compression tests to those made of four-ply, 0.098-inch reclaimed material and of V2s board, under all moisture conditions. The six-ply board was also found to be better in the rough-handling tests in which the boxes were immersed in water for 24 hours prior to test. In this condition the V2s boxes were the poorest of the three groups. The V2s grade boxes were found to be superior to the reclaimed in rough-handling tests dry, and after 16 days' storage at 80° F., 97 percent relative humidity. All three groups gave about the same protection to the contents. Application of a sleeve to a box was shown to be somewhat advantageous to both the life of the box and protection afforded its contents, but did not add to the strength of the empty box in compression.

Purpose

The tests summarized in this report were made at the request of the Office of Production Research and Development of the War Production Board. The purpose of this work was to ascertain whether boxes made of wet-strengthened reclaimed material would compare favorably with boxes made of V2s-grade material. The reason for the study was the acute shortage of new kraft available for containers.

¹Based on studies of the U. S. Forest Products Laboratory at Madison, Wisconsin in cooperation with the Office of Production Research and Development of the War Production Board.

Description of Materials

All boxes tested were made by the manufacturer who produced the board. The furnish used for the manufacture of the board consisted of 20 percent all kraft waste papers and 80 percent old containers. Two types of the reclaimed fiberboard were made. One was made up of six plies of 0.016-inch material with a total thickness of 0.106- to 0.110-inch, hereafter referred to as 6-16. It was wet-strengthened with 3 percent urea formaldehyde. The wet-strengthening agent was added to the furnish at the beater. The liners of each ply were sized with 3 percent rosin and the filler with 8 percent emulsified asphalt solids. Asphalt (hot melt) adhesive was used between the liners and adjacent interior plies. A polyvinyl resin adhesive was used to bond the four filler plies together. The other type was made up of the same material but of four plies 0.024-inch thick, with a total thickness of 0.098 inch, hereafter referred to as 4-24. This board had no asphalt adhesive, both liners and filler plies being bonded together with the polyvinyl adhesive. When sleeves were used they were of approximately the same material and construction as the box on which they were used.

Boxes made of commercial V2s grade board also were obtained from the manufacturer of the experimental boxes. The V2s board contained at least 65 percent new kraft fibers. Bursting-strength tests showed these boxes to be of an exceptionally high grade of material while the sleeves for these boxes met V1s grade specifications.

The boxes, which were the regular slotted style, were received (collapsed) in good condition. Only one size was tested, that being the size to hold 24 No. 2 cylindrical cans. The inside dimensions of the boxes in order of length, width, and depth were 13-3/4 by 10-3/8 by 9-1/4 inches. Cans used for test loads were filled with sand and sawdust and sealed with a hand sealer. The gross weight of each can was approximately 2.25 pounds.

The boxes were assembled by fastening the bottom flaps with metal staples. (Details of assembly and other pertinent data are given in the appendix.) They were then weighed and loaded and the top flaps glued with water-resistant adhesive which was allowed to set for 24 hours under pressure. In gluing the top flaps of empty boxes the pressure was applied by means of two 1-inch thick wood panels, one inside and one outside, held together at the center by a 1/2-inch bolt. After the glue had set, the nut from the end of the bolt was removed, releasing the outside wood panel and leaving the other panel and bolt loose inside the box.

Loaded boxes given rough-handling tests were reinforced in one of the two following ways: (1) a fiberboard sleeve over the top, ends and bottom with the body joint of the sleeve at the top-end edge, opposite the body joint of the box and a 3/8- x 0.015-inch flat metal band girthwise around the center of the box (fig. 1); (2) no sleeve, but two 3/8- 0.015-inch flat metal bands, one lengthwise around the center and the other at right angles over it, around the top, sides, and bottom (fig. 2). The empty boxes used for compression tests were tested with and without sleeves. No metal bands were used on these boxes.

Test Procedure

Conditioning

Prior to all tests the closed boxes were conditioned in one of the following ways:

1. Stored in an atmosphere of 72° to 80° F. and 60 percent relative humidity. Boxes conditioned in this manner are referred to as dry.
2. Stored for 16 days in an atmosphere of 80° F. and 97 percent relative humidity. Boxes conditioned in this manner are referred to as moist.
3. Immersed in water for 24 hours. Boxes conditioned in this manner are referred to as wet.

Compression Tests

Compression tests were all made with empty boxes to determine their stacking properties or rigidity without the support of a load.

Dry, moist, and wet boxes, closed but unfilled, were tested in top-to-bottom and end-to-end compression in a universal testing machine. Pressure was applied by parallel surfaces of the machine with no adjustment made to insure even distribution of stress, to simulate conditions encountered in storage (stacking) and in rail shipment. An automatic continuous recording device gave a complete record of loads in pounds and corresponding compression in inches for the entire test. A record was made of all damage to the box as well as a description of the final failure.

Rough-Handling Tests

Small drum tests.--The small 7-foot revolving hexagonal box-testing machine was used for the drum tests of the fiberboard boxes (fig. 7). Baffles and guides on the six inner faces of this drum cause the box to slide, tumble, and fall as the drum revolves, simulating the condition of actual shipping and handling. A low conical projection represents the puncture hazard, having an effect like that of dropping one box cornerwise onto the face of another. Tumbling of the box from one face of the drum to the next is counted as one fall, and six falls occur with each revolution. The speed of operation is approximately two revolutions per minute. Boxes made of the three types of board, with and without sleeves were tested at dry, wet, and moist conditions. They were loaded with 24 No. 2 cans weighing a total of 54 to 55 pounds. The number of falls causing the first 1-inch score cut and first entire score to be cut were recorded. The tests were continued until the contents spilled or until the box failed completely and the contents were unusable.

Table 1.--Schedule of tests

Kind of box <u>1</u> /	Direction of test	Condition <u>2</u> /	Number of boxes tested	
			With sleeves	Without sleeves
COMPRESSION				
6-16	:Top to bottom	: Dry	: 5	: 5
	:	: Moist	: 5	: 5
	:	: Wet	: 5	: 5
	:End to end	: Dry	: 5	: 5
	:	: Moist	: 5	: 5
	:	: Wet	: 5	: 5
4-24	:Top to bottom	: Dry	: 5	: 5
	:	: Moist	: 5	: 5
	:	: Wet	: 5	: 5
	:End to end	: Dry	: 5	: 5
	:	: Moist	: 5	: 5
	:	: Wet	: 5	: 5
V2s	:Top to bottom	: Dry	: 4	: 4
	:	: Moist	: 4	: 4
	:	: Wet	: 4	: 4
	:End to end	: Dry	: 4	: 4
	:	: Moist	: 4	: 4
	:	: Wet	: 4	: 4

Total number of tests = 516

1/ 6-16 = Boxes made of six-ply reclaimed fiberboard.

4-24 = Boxes made of four-ply reclaimed fiberboard.

2/ Dry = Boxes stored at 72° to 80° F. and 60 percent relative humidity before testing.

Moist = Boxes stored 16 days at 80° F. and 97 percent relative humidity before testing.

Wet = Boxes immersed in water for 24 hours before testing.

(Continued on next page)

Small drum tests to evaluate the protection afforded the contents by the box were also conducted. The same testing conditions used in the drum tests to failure were followed in these tests except in the number of falls given each box. Here the boxes were given 100 falls in the small drum, after which the cans were inspected and the amount of damage they sustained was evaluated. Damage was scored according to the schedule used by the Committee on Standardization of Packages and Supplies of the American Meat Institute (table 7). The amount of damage was computed as a percent of the maximum possible damage, which is 62 points per can or 1,488 points per box of 24 cans.

30-inch cornerwise-drop tests.--Drop tests were made by dropping boxes cornerwise from a height of 30 inches. A drop table consisting of two leaves approximately 36 inches long and 18 inches wide hinged at the edges and supported at the center by a post was used in these tests. The box was placed in position in the center of the table with diagonally opposite corners in a vertical line. The box was dropped by suddenly removing the post support permitting the table to open in trapdoor fashion and the box to fall and strike the floor in the predetermined position (fig. 8). Drops were made on successive corners until the box failed. Definition of failure was the same as described in small drum test. The same number and kinds of boxes as were used for the small drum tests were tested.

Tests of boxes to evaluate protection they afforded contents were continued until they had absorbed approximately 1,000 foot pounds of work. (The work absorbed by the box is the product of its gross weight, in pounds, and the sum of the heights of drop in feet.) The same method used in evaluating damage to contents of the drum tests was used in these tests.

Table 1.--Schedule of tests (continued)

Kind of box	Condition:	Small drum		30-inch drop	
		With sleeves	Without sleeves	With sleeves	Without sleeves
ROUGH-HANDLING TESTS (TO EVALUATE DAMAGE TO CONTENTS <u>3/</u>)					
6-16	Dry	5	5	5	5
	Moist	5	5	5	5
	Wet	5	5	5	5
4-24	Dry	5	5	5	5
	Moist	5	5	5	5
	Wet	5	5	5	5
V2s	Dry	4	4	4	4
	Moist	4	4	4	4
	Wet	4	4	4	4
ROUGH-HANDLING TESTS (BOXES TESTED TO FAILURE <u>4/</u>)					
6-16	Dry	5	5	5	5
	Moist	5	5	5	5
	Wet	5	5	5	5
4-24	Dry	5	5	5	5
	Moist	5	5	5	5
	Wet	5	5	5	5
V2s	Dry	5	5	5	5
	Moist	5	5	5	5
	Wet	5	5	5	5

3/ Boxes tested in drum were given 100 falls. Boxes drop tested were given seven drops (approximately 1,000 foot pounds of work).

4/ Tested until contents spilled or box failed completely.

(Concluded)

Minor Tests

Bursting-strength and moisture absorption tests were made on 6-inch by 10-inch samples cut from boxes of each group. Samples for moisture absorption tests were weighed, soaked in water 24 hours, and reweighed. The moisture absorption was computed as a percent of the original weight. Samples were also checked for ply separation. Bursting-strength tests were made on dry and wet samples. Amount of moisture absorbed by the closed boxes at moist and wet conditions was also recorded.

Results of Tests

Compression Tests

Results of compression tests on empty boxes are given in tables 2 to 4 and illustrated in figures 3 to 6. Top-to-bottom maximum loads were somewhat lower than end-to-end loads. The reason for this may have been that in the top-to-bottom tests the pressure was applied perpendicular to the machine direction of the material whereas in the end-to-end tests it was applied parallel to the machine direction. The average maximum load of all tests was 861 pounds for the 6-16 boxes; 593 pounds for 4-24; and 668 pounds for V2s. There was a definite decrease in the maximum load from the dry condition to the wet condition, the 6-16 and V2s boxes losing the least. The average maximum loads were as follows in the order of dry, moist, and wet conditions: 6-16 boxes 1,102 pounds, 802 pounds, and 678 pounds; 4-24 boxes, 1,051 pounds, 474 pounds, and 253 pounds; V2s boxes, 850 pounds, 664 pounds, and 491 pounds. Based on the dry values, the percent of decrease in maximum loads of moist and wet boxes for the 6-16 group was 27 and 38 percent respectively; for 4-24 group, 55 and 76 percent; and for V2s, 22 and 43 percent. Table 4 shows the loads recorded at various degrees of compression (top-to-bottom or end-to-end) and moisture content of box at time of test. Typical failures of boxes were, crushing of score lines and corners followed by bulging of faces and buckling of vertical edges and faces. Boxes with sleeves showed no advantage in these tests. Table 5 shows the moisture gain of the boxes given moist or wet treatment for the compression tests.

Table 2.--Average maximum load of all fiberboard boxes in compression

Direction of compression	Average maximum load (all moisture conditions)		
	6-16 boxes	4-24 boxes	V2s boxes
	<u>Pounds</u>	<u>Pounds</u>	<u>Pounds</u>
Top-to-bottom	710	455	655
End-to-end	1,011	732	681

Table 3.--Average maximum load of fiberboard boxes tested dry, moist, or wet, 1/ in compression

Moisture condition and direction of compression	Average maximum load		
	6-16 boxes	4-24 boxes	V2s boxes
	<u>Pounds</u>	<u>Pounds</u>	<u>Pounds</u>
Dry			
Top-to-bottom	906	747	844
End-to-end	1,299	1,356	857
Moist			
Top-to-bottom	715	392	697
End-to-end	888	536	631
Wet			
Top-to-bottom	508	225	425
End-to-end	846	281	557

1/ Prior to test dry boxes were stored at 80° F. - 60 percent relative humidity, moist at 80° F. - 97 percent relative humidity, wet submersed in water 24 hours.

Table 4.--Average results 1/ of compression tests

Test condition and kind of box:	Reinforcement:		Moisture:		Load at :		Load at :		Maximum:		Compression at	
					content : 0.25-inch :		0.5-inch :		load :		load : maximum	
					of board:	compression:	compression:	compression:				
			Percent :	Pounds :	Pounds :	Pounds :	Pounds :	Pounds :	Pounds :	Pounds :	Inches :	Inches :
TOP-TO-BOTTOM COMPRESSION												
Dry 6-16	Sleeve		8.6	249	352	788	839	1.20				
	No sleeve		7.8	245	422	946	973	.91				
4-24	Sleeve		7.8	228	338	526	745	1.01				
	No sleeve		7.7	208	438	689	749	.82				
V2s	Sleeve		10.1	250	426	828	868	1.00				
	No sleeve		9.8	178	448	669	820	.74				
Moist 6-16	Sleeve		10.2	238	457	779	809	1.07				
	No sleeve		11.8	177	312	600	622	.88				
4-24	Sleeve		21.8	136	216	292	324	.93				
	No sleeve		17.7	141	289	409	461	.77				
V2s	Sleeve		11.4	201	334	650	680	.89				
	No sleeve		12.7	188	356	671	714	.85				
Wet 6-16	Sleeve		23.0	148	247	482	490	1.02				
	No sleeve		21.3	154	264	496	527	.92				
4-24	Sleeve		37.7	119	197	213	239	.86				
	No sleeve		33.0	101	191	181	212	.75				
V2s	Sleeve		24.6	113	191	412	432	1.11				
	No sleeve		24.1	82	152	401	418	.94				

(Continued)

1/ Each value is the average of five boxes tested in the 6-16 and 4-24 groups and of four boxes in the V2s group.

Table 4.---Average results 1/ of compression tests (continued)

Test condition : Reinforcement: Moisture: Load at : Load at : Load at : Maximum: Compression at and kind of box:		: content : 0.25-inch : 0.5-inch : 1.0-inch : load : maximum load		: of board: compression: compression: compression:							
		: Percent :		Pounds :		Pounds :		Pounds :		Pounds :	
				END-TO-END COMPRESSION							
Dry 6-16	Sleeve	:	8.6	:	225	:	433	:	793	:	895
	No sleeve	:	8.0	:	310	:	658	:	1,428	:	1,702
		:		:		:		:		:	
4-24	Sleeve	:	7.8	:	210	:	497	:	1,014	:	1,345
	No sleeve	:	7.8	:	385	:	700	:	1,294	:	1,368
V2s	Sleeve	:	10.1	:	228	:	417	:	805	:	824
	No sleeve	:	9.9	:	217	:	438	:	822	:	890
Moist 6-16	Sleeve	:	10.7	:	214	:	372	:	580	:	618
	No sleeve	:	11.2	:	286	:	453	:	1,035	:	1,158
		:		:		:		:		:	
4-24	Sleeve	:	20.1	:	160	:	315	:	476	:	569
	No sleeve	:	19.4	:	232	:	377	:	491	:	544
V2s	Sleeve	:	11.6	:	177	:	320	:	609	:	664
	No sleeve	:	12.8	:	182	:	351	:	493	:	597
Wet 6-16	Sleeve	:	23.8	:	184	:	330	:	672	:	757
	No sleeve	:	21.4	:	227	:	332	:	817	:	936
4-24	Sleeve	:	42.6	:	151	:	238	:	210	:	258
	No sleeve	:	34.4	:	146	:	208	:	275	:	305
V2s	Sleeve	:	27.3	:	108	:	166	:	450	:	548
	No sleeve	:	25.5	:	94	:	167	:	459	:	566

1/ Each value is the average of five boxes tested in the 6-16 and 4-24 groups and of four boxes in the V2s group.

(Concluded)

Table 5.--Average weight and moisture gain of boxes 1/ tested in compression

Kind of box	Weight: when closed:	Conditioning	Weight after conditioning:	Gain in weight:	Percent of original weight
	Pounds:		Pounds	Pounds:	Percent
6-16 with sleeve	4.67	None	---	---	---
	4.72	Stored at 80° F. 97%	4.89	0.18	104
		: R.H. for 16 days			
	4.67	Submerged in water	5.41	.74	116
		: 24 hours			
6-16 without sleeve	3.13	None	---	---	---
	3.09	Stored at 80° F. 97%	3.25	.16	105
		: R.H. for 16 days			
	3.11	Submerged in water	3.58	.47	115
		: 24 hours			
4-24 with sleeve	4.08	None	---	---	---
	4.07	Stored at 80° F. 97%	4.65	.58	114
		: R. H. 16 days			
	4.05	Submerged in water	5.55	1.50	137
		: 24 hours			
4-24 without sleeve	2.69	None	---	---	---
	2.70	Stored at 80° F. 97%	2.97	.27	110
		: R.H. 16 days			
	2.70	Submerged in water	3.45	.75	128
		: 24 hours			
V2s	4.24	None	---	---	---
	4.15	Stored at 80° F. 97%	4.45	.30	107
		: R.H. 16 days			
	4.18	Submerged in water	5.24	.96	123
		: 24 hours			
V2s without sleeve	2.77	None	---	---	---
	2.78	Stored at 80° F. 97%	2.94	.16	106
		: R.H. 16 days			
	2.77	Submerged in water	3.44	.67	124
		: 24 hours			

1/ Each value is an average of 10 boxes tested in the 6-16 and 4-24 groups and of 8 boxes in the V2s group.

Rough-Handling Tests to Measure
Protection Afforded Contents

There was very little difference between the three groups as to protection afforded contents. The greatest difference was between the 4-24 and V2s grade boxes, without sleeves, tested in the small drum. This difference was 3 percent with the V2s boxes having the advantage. Average percent of possible damage to contents of all boxes tested, was as follows:

Table 6.--Percent of possible damage to box
contents occurring in rough-
handling tests

Reinforcement	4-24	6-16	V2s
SMALL DRUM			
With sleeve and one girth strap	12.7	12.7	13.2
Without sleeves; two straps at right angles	16.7	16.2	13.7
CORNERWISE DROP			
With sleeve and one girth strap	20.8	20.6	21.1
Without sleeves; two straps at right angles	22.0	22.9	22.1

Each value is the average of boxes tested at all conditions (dry, moist, and wet).

Typical condition of boxes and contents after the drum and cornerwise-drop tests is shown in figures 9 and 10. Contents in boxes subjected to the cornerwise-drop test until they had absorbed 1,000 foot-pounds of work were damaged more than those in boxes given 100 falls in the revolving drum. The difference was 7.4 percent. Boxes with sleeves also afforded a little more protection to contents than boxes without sleeves. This amounted to 3.0 percent in the drum tests and 1.5 percent in the drop tests. The schedule used in scoring damage to cans is shown in table 7. Average results for each kind of test and moisture condition are given in table 8.

Table 7.--Can damage scoring schedule

Type of damage	Degree of damage	Damage score points
Disturbed seams	Light	6
	Medium	8
	Heavy	10
Seam jams	Light	6
	Medium	8
	Heavy	10
Seam dents	Light	6
	Medium	8
	Heavy	10
Ends sprung	Light	6
	Heavy	10
Ends buckled	Light	6
	Heavy	8
Ends bulged	Heavy	10
Body dents	Light	1
	Medium	2
	Heavy	4

Rough-Handling Tests to Failure

Small drum tests.--Results of tests in the small drum showed the V2s grade boxes to be better than the 6-16 and 4-24 boxes when tested in the dry (fig. 11) and moist conditions. Both the 6-16 and 4-24 boxes were better than the V2s when tested after submersion in water for 24 hours (fig. 12). The addition of a sleeve proved to be more advantageous to the V2s than to the 6-16 and 4-24 boxes. This probably was due to the high grade of material in the sleeves used on the V2s grade boxes: bursting-strength tests showed this material to be of V1s grade.

The average number of falls to cause contents to spill from a box in each of the three groups was as follows: Boxes without sleeves, 4-24 group, 770 falls; 6-16 group, 958 falls; and V2s group, 1,003 falls. Boxes with sleeves, 909, 1,072, and 1,640 falls for the 4-24, 6-16, and

Table 8.--Average results 1/ of tests to measure protection afforded contents by boxes

Kind of test	Condition:	4-24				6-16				V2s			
		With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve
	2/	damage	damage	damage	damage	damage	damage	damage	damage	damage	damage	damage	damage
		Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent	Points:Percent
	3/												
Small drum:	Dry	192	12.9	262	17.6	185	12.4	235	15.8	180	12.1	209	14.1
100 falls:	Moist	188	12.6	217	14.6	193	13.0	231	15.5	186	12.5	191	12.8
	Wet	186	12.5	266	17.9	191	12.8	256	17.2	224	15.0	212	14.3
Seven	Dry	295	19.8	318	21.4	303	20.4	294	19.6	319	21.4	359	24.1
drops at	Moist	334	22.4	344	23.0	312	21.0	390	26.2	314	21.1	332	22.3
30-inch	Wet	301	20.2	318	21.4	303	20.4	344	23.0	308	20.8	298	20.6
height													
AVERAGE MOISTURE CONTENT OF BOXES, PERCENT													
	Dry	7.8	7.7	8.1	7.8	7.8	7.8	7.8	7.8	10.1	10.1	9.9	9.9
	Moist	20.9	18.5	10.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	12.7	12.7
	Wet	40.1	33.7	23.8	21.4	21.4	21.4	21.4	21.4	25.9	25.9	24.8	24.8

1/ Each value is the average of five boxes tested for the 4-24 and 6-16 groups and of four boxes for the V2s grade.

2/ Dry boxes tested after storage at 80° F. - 60 percent relative humidity. Moist boxes tested after 16 days' storage at 80° F. and 97 percent relative humidity. Wet boxes tested after 24 hours' submersion in water.

3/ Percent of damage based on total possible amount of damage of 1,488 points per box of 24 cans.

Table 9.--Average results 1/ of small drum tests

Kind of box	Condition	Moisture	Weight of	Number of falls to cause--		
	of box	content	box and contents	First score cut	One score cut entire length	Spilling of contents
		Percent	Pounds			
4-24	Dry	7.8	57.00	100	492	736
(Without sleeve)	Moist	17.0	57.24	214	1,118	1,286
	Wet	29.1	57.86	72	240	289
6-16	Dry	7.4	57.40	165	758	1,007
(Without sleeve)	Moist	10.6	57.60	567	1,323	1,491
	Wet	18.5	58.00	115	267	376
V2s	Dry	9.6	57.14	427	877	1,191
(Without sleeve)	Moist	11.1	57.25	651	1,297	1,615
	Wet	22.6	58.22	47	131	202
4-24	Dry	7.8	58.42	176	541	798
(With sleeve)	Moist	19.8	59.03	387	926	1,543
	Wet	35.0	59.55	111	259	387
6-16	Dry	7.6	58.95	302	771	1,139
(With sleeve)	Moist	9.7	59.18	439	1,031	1,529
	Wet	20.6	59.70	181	457	549
V2s	Dry	9.5	58.48	456	1,519	1,980
(With sleeve)	Moist	10.6	58.62	631	1,639	2,573
	Wet	23.3	59.45	65	202	366

1/ Each value is the average of five boxes tested.

V2s groups respectively. Boxes tested wet failed at a much smaller number of falls as compared to those tested dry in all groups; whereas the boxes tested in the moist condition failed at a considerably larger number of falls as compared to those tested dry. The percent of decrease in number of falls from dry to wet boxes was as follows: 4-24 boxes 57 percent, 6-16 boxes 57 percent, V2s boxes 82 percent; whereas the increase from the dry to the moist condition was 84 percent for 4-24 boxes, 41 percent for the 6-16, and 33 percent for the V2s.

Table 9 gives results of boxes tested to failure in the small drum. The predominating failure of all boxes tested in the drum was cuts at horizontal score lines. Contents usually spilled when cuts at two or more of the edges, perpendicular and adjacent to each other, extended the entire length. The 6-16 and 4-24 boxes received more punctures than the V2s boxes tested in the dry condition; however, the dry V2s boxes averaged about 2 percent greater moisture content than the other groups (table 9). Seventeen of the twenty boxes tested in the 4-24 and 6-16 groups had one or more faces pierced. Only 2 of the 10 V2s boxes tested dry were punctured. Three of the boxes tested in moist and wet conditions were punctured, but only after several hundred falls. No difficulty was experienced with either the glued or stapled flaps of the boxes pulling loose.

Cornerwise-drop test.--The results of the cornerwise-drop tests showed, as did the drum tests, that the V2s grade boxes were somewhat better than those of reclaimed fiberboard when tested in the dry condition (fig. 13) and the moist condition. The reclaimed fiberboard boxes showed to better advantage than the V2s boxes when tested after 24-hour submersion in water (fig. 14). The average number of drops to cause contents to spill is shown below. The results are for boxes tested with and without sleeves.

Table 10.--Average number of drops to
cause spilling of contents of
boxes with and without sleeves

Condition	4-24 boxes	6-16 boxes	V2s boxes
Dry	22	42	48
Moist	43	49	59
Wet	26	30	17

The average number of drops to cause spilling of contents in all tests was 30 drops for the 4-24 group, 40 drops for the 6-16 group, and 41 drops for the V2s group. Except for badly crushed corners, the failures in these boxes were practically the same as for those tested in the small drum. Detailed results are shown in table 11.

Minor tests.--Tables 12 and 13 show the results of bursting-strength and moisture absorption tests of fiberboard samples cut from the boxes and sleeves. The 4-24 boxes averaged 506 points dry and 453 wet; the sleeves averaged 527 points dry and 466 points wet; 6-16 boxes, 601 points dry and 557 points wet; sleeves 643 points dry and 579 points wet. The V2s boxes averaged 675 points dry and 568 points wet; the sleeves 897 points dry and 715 points wet. Results of the moisture-absorption tests are given in table 13. No ply separation was shown in any of the three types of board. All wet samples were submerged in water 24 hours.

Conclusions

In the compression tests the 6-16 boxes of reclaimed material were found to be superior to the other types tested under all conditions. The average maximum load for this type was 861 pounds as compared to 593 pounds for the 4-24, and 668 pounds for the V2s boxes.

In the rough-handling tests the two types of box made of reclaimed material were shown to be better than the V2s when tested wet. When rough-handled in the dry and moist conditions the V2s boxes showed somewhat better results than the boxes of reclaimed material. The three groups were approximately equal in protection given to contents.

Table 11.--Average results 1/ of 30-inch cornerwise-drop tests

Kind of box	Condition of box	Moisture content: of board	Weight of box and contents	Number of drops to cause--	First score	One score	Spilling
				cut	cut	entire	of contents
		Percent	Pounds				
WITHOUT SLEEVES							
4-24	Dry	7.8	57.06	2	14		20
	Moist	19.5	57.53	4	20		26
	Wet	29.1	58.00	4	11		14
6-16	Dry	7.6	57.38	6	22		45
	Moist	11.0	57.44	9	23		43
	Wet	20.4	58.60	5	15		28
V2s	Dry	8.8	57.35	8	28		40
	Moist	11.8	57.29	15	42		56
	Wet	23.6	57.91	4	11		15
WITH SLEEVES							
4-24	Dry	7.0	58.42	6	20		23
	Moist	18.6	58.78	16	40		60
	Wet	36.2	59.49	12	33		39
6-16	Dry	7.5	59.08	15	33		39
	Moist	10.2	59.27	25	46		55
	Wet	21.2	59.75	10	31		33
V2s	Dry	8.9	58.48	18	44		56
	Moist	11.2	59.16	21	61		63
	Wet	24.2	59.90	7	15		19

1/ Each value is the average of five boxes tested.

Table 12.--Results of bursting-strength tests 1/

Box	Condition <u>2/</u>	Number of tests	Bursting strength		
			High	Low	Average
			<u>Points</u>	<u>Points</u>	<u>Points</u>
4-24	: Dry	: 24	: 550	: 450	: 506
	: Wet	: 25	: 490	: 410	: 453
6-16	: Dry	: 24	: 680	: 540	: 601
	: Wet	: 25	: 670	: 490	: 557
V2s	: Dry	: 24	: 830	: 540	: 675
	: Wet	: 24	: 690	: 460	: 568
<u>Sleeve</u>					
4-24	: Dry	: 24	: 590	: 490	: 527
	: Wet	: 25	: 510	: 400	: 466
6-16	: Dry	: 16	: 700	: 600	: 643
	: Wet	: 25	: 650	: 500	: 579
V2s	: Dry	: 24	: 1,000	: 810	: 897
	: Wet	: 24	: 810	: 610	: 715

1/ Tests made on model A Jumbo Mullen Tester.

2/ Dry - specimens stored at 80° F. 60 percent relative humidity; wet - specimens submersed in water 24 hours.

Table 13.--Results of moisture gain test (fiberboard soaked
24 hours in water at 70° F.)

Type of container board	Moisture gain, percent of original <u>1</u> / weight				
	Individual test results				Average
	a	b	c	d	
	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>
4-24 (box)	28.7	27.4	26.8	28.4	27.8
4-24 (sleeve)	28.2	27.9	31.6	27.5	28.8
6-16 (box)	18.7	18.0	17.9	18.2	18.2
6-16 (sleeve)	18.7	18.2	17.5	17.6	18.0
V2s (box)	42.3	38.0	36.4	40.6	39.4
V2s (sleeve)	43.3	44.6	45.4	50.0	45.8

1/ Specimens conditioned at about 80° F. and 60 percent relative humidity prior to test.

The boxes of the three groups sustained the greatest compression loads when tested in a dry condition. They offered greatest resistance to rough handling when tested in a moist condition.

Typical failures in the compression tests were crushing of score lines and corners followed by bulging and buckling of vertical edges and faces. In the rough-handling tests typical failures were cuts at the horizontal score lines.

The results of these tests point to the possibility of manufacturing satisfactory container board with a much smaller percent of kraft and entirely without virgin kraft. The test results indicate that the 6-16 boxes of reclaimed material compared favorably with V2s boxes. Performance of this wet-strengthened board under wet conditions suggests that it would have certain advantages over the V2s board for overseas shipment. The test results suggest also that urea formaldehyde as a wet-strengthening agent added to commercial V-board furnish might improve the performance of V-board boxes when wet.

APPENDIX

Description of Boxes Tested

Kind of fiberboard -- 4-24 reclaimed material, 6-16 reclaimed material, V2s grade material.

Caliper -- 6-16, 0.110 inch; 4-24, 0.098 inch; V2s, 0.100 inch.

Type of boxes -- Regular slotted.

Machine direction -- horizontal.

Inside dimensions -- Length 13-3/4 inches; width 10-3/8 inches; depth 9-1/4 inches.

Scores - width -- Vertical - inside 1/4 inch, outside 5/8 inch.
Horizontal - inside 1/4 inch, outside 3/4 inch.

Body joint -- Overlap, 1-1/2 inches. Seven staples spaced 1-1/2 inches apart.

Flap closure -- Bottom - 20 metal staples; top - water-resistant glue.

Kind of adhesive -- Resin, polyvinyl chloride acetate type.

Time allowed to dry -- 24 hours.

Kind of contents -- 24 No. 2 cans.

Weight of contents -- Approximately 54.0 pounds.

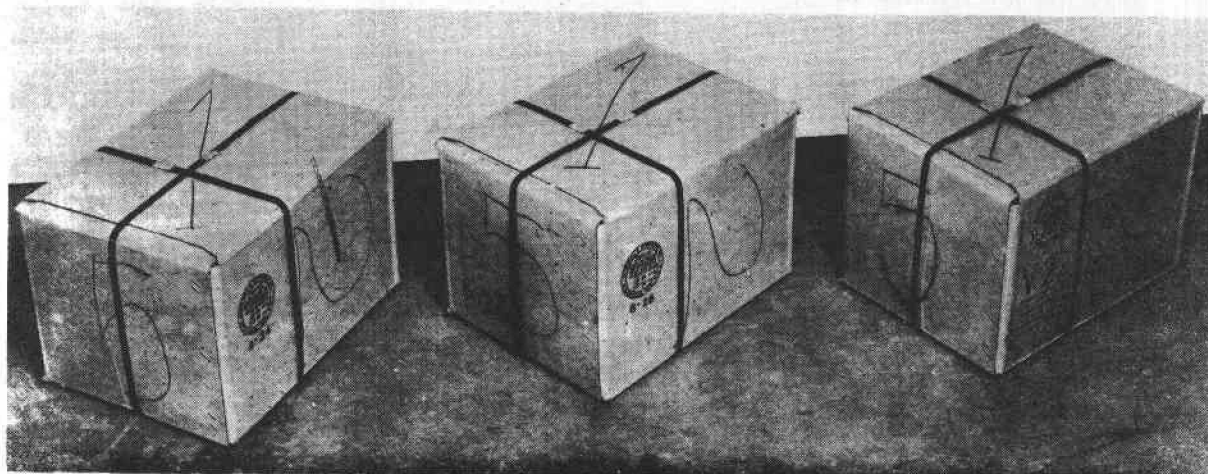
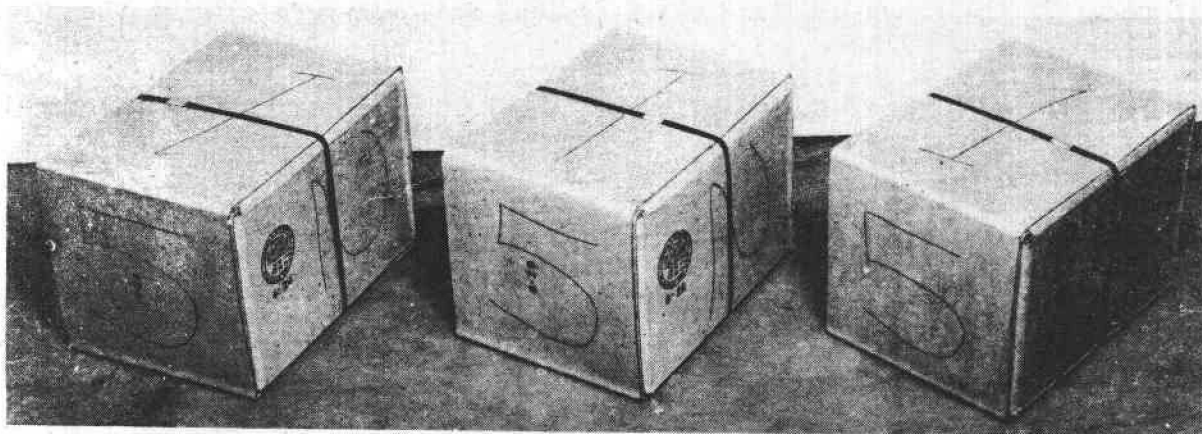


Figure 1 (Top).--Boxes from each group with sleeves as they appeared, ready for rough-handling test. At left is a 4-24 box; at center a 6-16, and at right a V2s grade box.

Figure 2 (Bottom).--Boxes from each group without sleeves as they appeared, ready for rough-handling test. At left is a 4-24 box; at center a 6-16; and at right a V2s grade box.

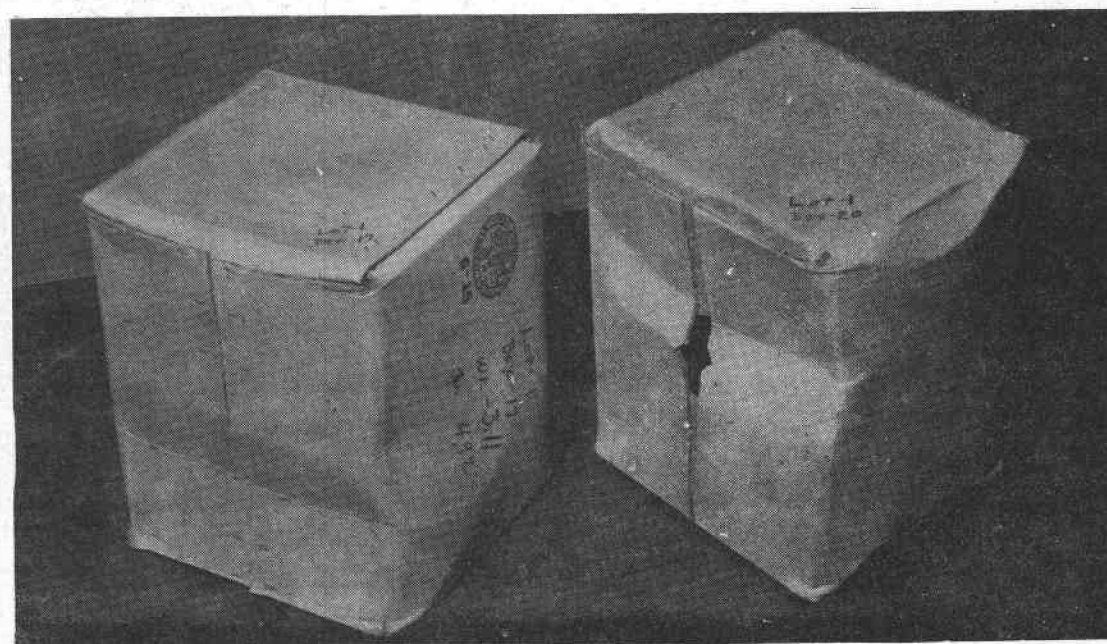
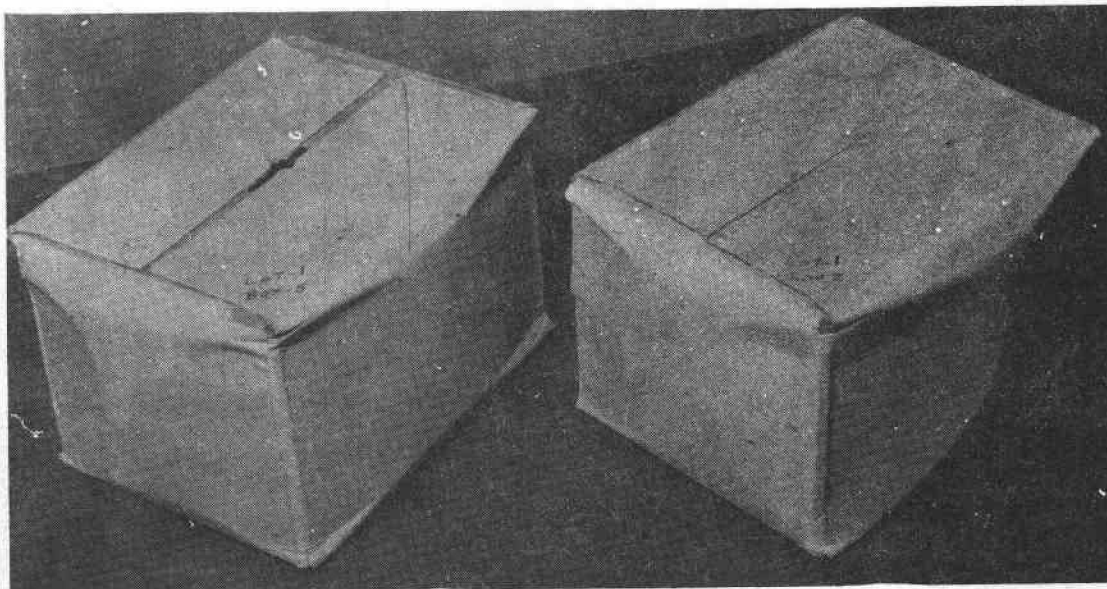


Figure 3 (Top).--Typical failures of 6-16 reclaimed fiberboard boxes, without sleeves, after top-to-bottom compression test. Both boxes were tested dry. Box at left, showing top flaps, withstood a maximum load of 990 pounds at a compression of 0.96 inch. Box at right, showing bottom flaps withstood a maximum load of 942 pounds at a compression of 0.88 inch. The same type of box tested wet showed similar failures.

Figure 4 (Bottom).--Typical failures of 6-16 reclaimed fiberboard boxes, without sleeves, after end-to-end compression test. These boxes were tested immediately after 24 hours submersion in water. Failures of all fiberboard boxes are practically the same, whether tested dry, moist, or after submersion in water. Box at left, showing stapled flaps, withstood a maximum load of 955 pounds at a compression of 1.14 inches. Box at right, showing glued flaps, withstood a load of 910 pounds at a compression of 1.18 inches.

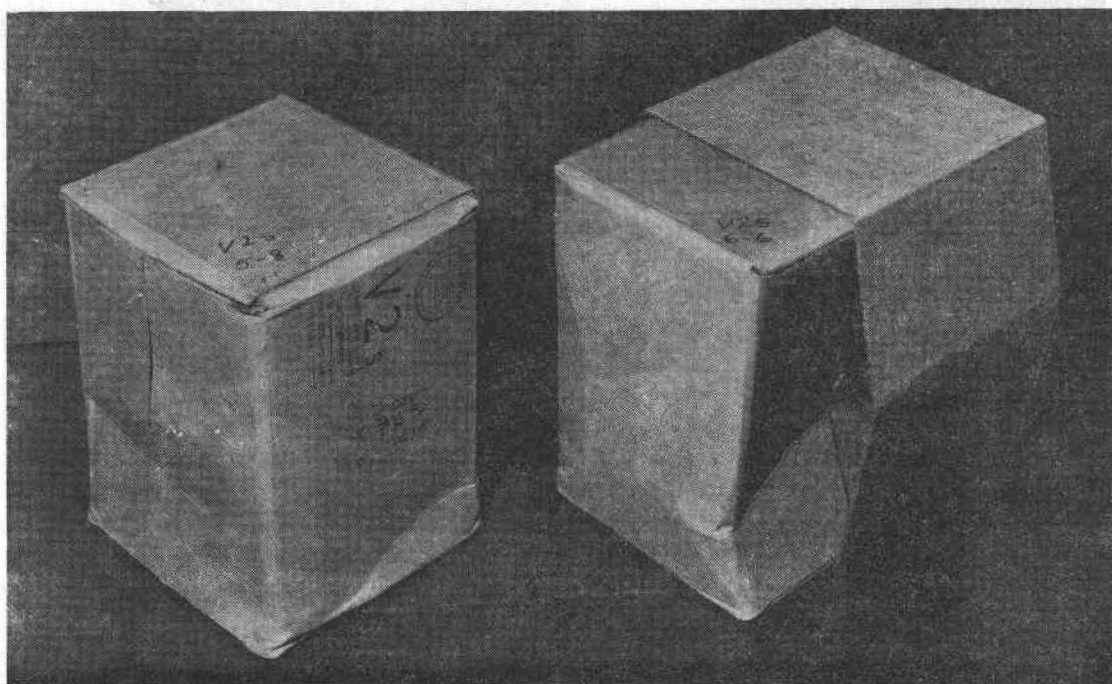
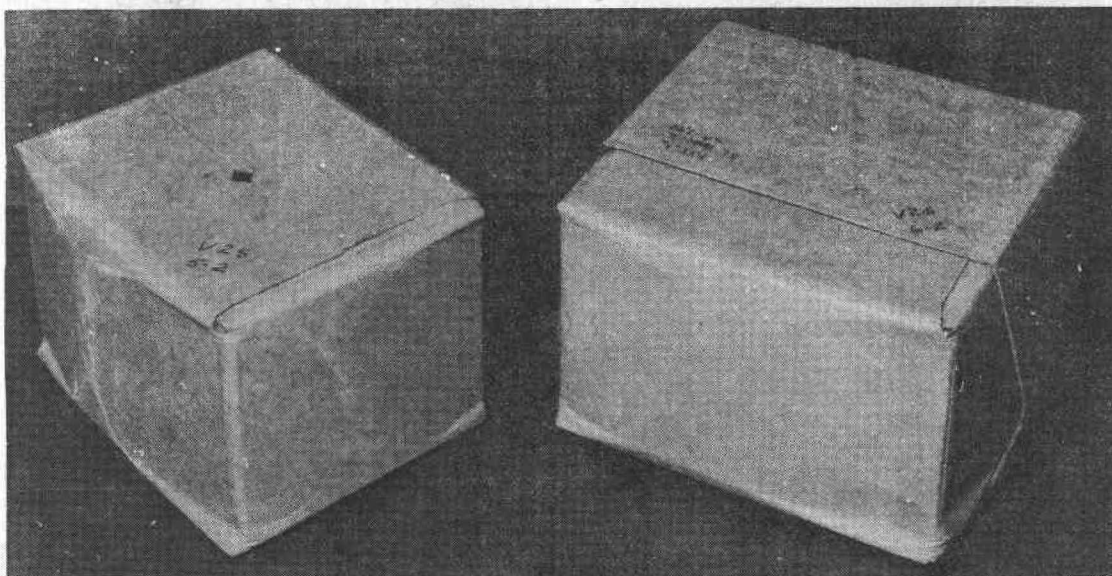


Figure 5 (Top).--Typical failures of V2s grade fiberboard boxes, with and without sleeve, after top-to-bottom compression test. Both boxes were tested dry. Box at left, without sleeve, withstood a maximum load of 858 pounds at a compression of 0.74 inch. The box on the right, with sleeve, withstood a maximum load of 896 pounds at a compression of 1.11 inches.

Figure 6 (Bottom).--Typical failures of V2s grade fiberboard boxes, with and without sleeve, after end-to-end compression test. Both boxes were tested dry, and withstood a maximum load at a compression of 1.08 inches. The addition of sleeves to the boxes did not appear to increase the compressive strength.

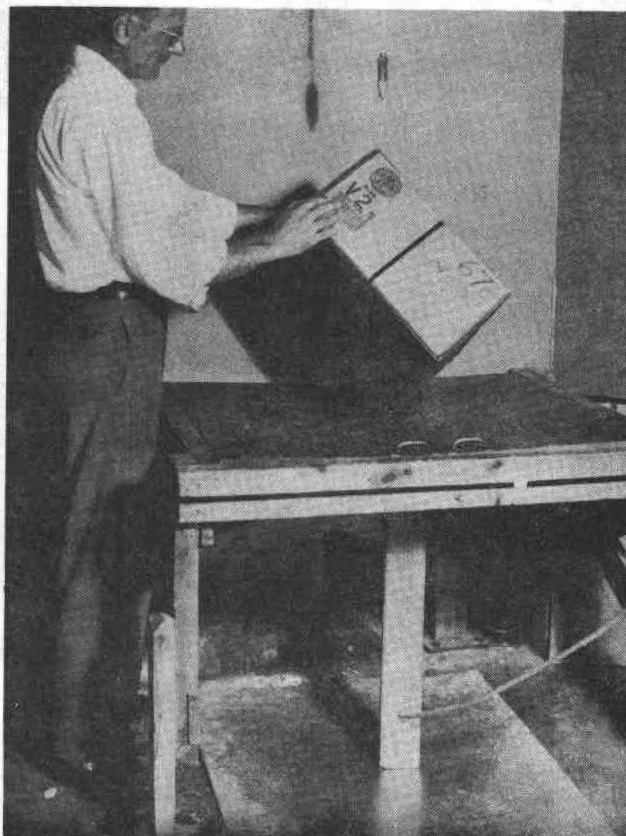
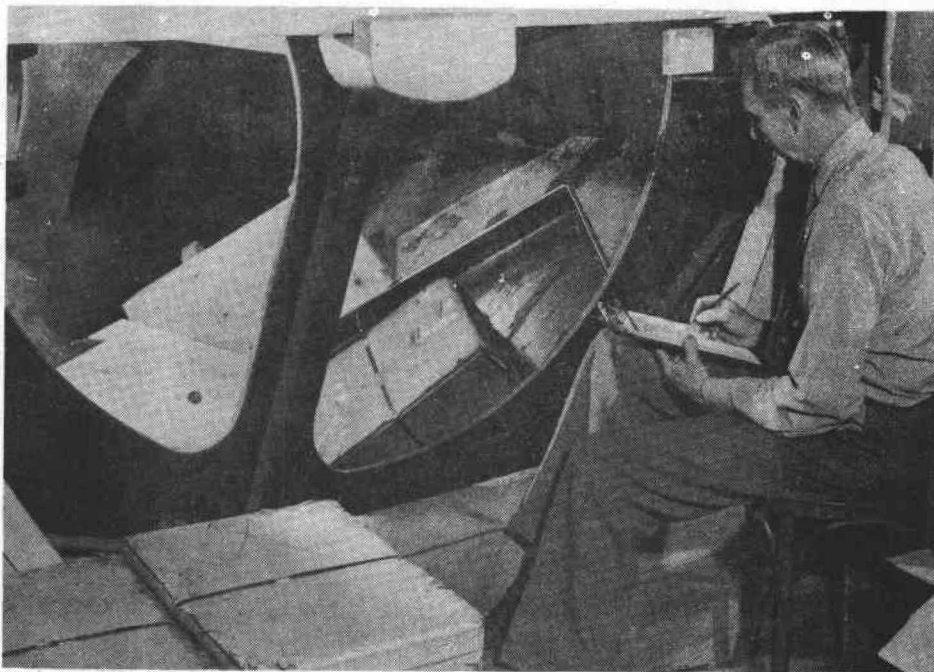


Figure 7 (Top).--Small 7-foot revolving hexagonal drum showing baffles and guides on one face of the drum and container being tested. (Boxes discussed in this report not shown.)

Figure 8 (Bottom).--Thirty-inch drop-cornerwise test. The container is placed cornerwise on the drop table and the post support for the two table leaves is jerked out. The container falls through to the metal plate on the selected corner. The plumb bob assists the operator in placing the diagonally opposite corners in a vertical line.

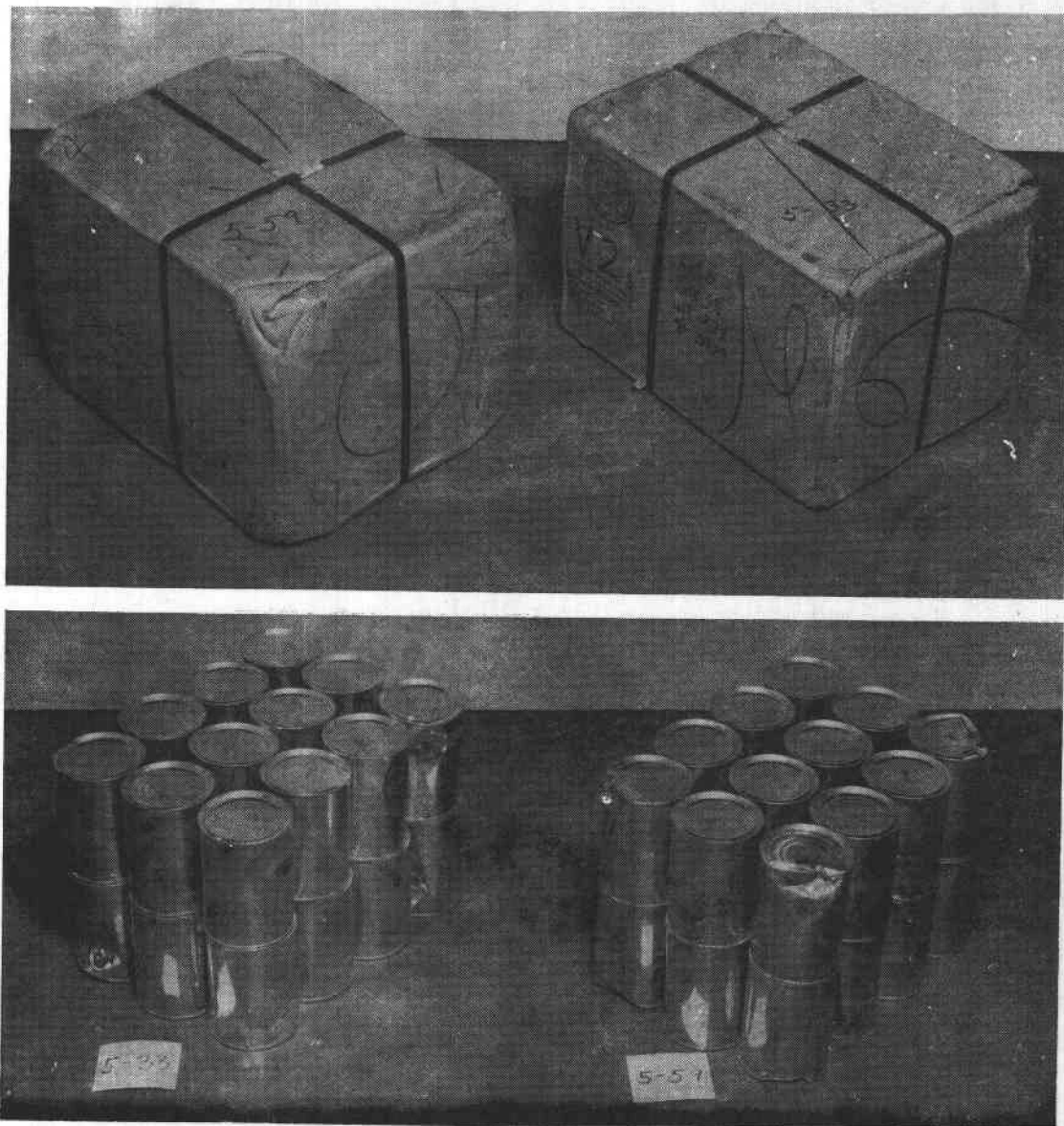


Figure 9 (Top).--These boxes, without sleeves, were tested to measure protection to contents. Box at left received 7 drops from a height of 30 inches, (equivalent to 1,000 foot-pounds of work) and the box at right received 100 falls in the revolving box testing drum. Neither box had any failures. The addition of sleeves provided somewhat better protection.

Figure 10 (Bottom).--Condition of contents after tests to measure protection afforded by boxes, without sleeves. The cans on the left were taken from a box which had been given 100 falls in the drum, while the cans on the right are from a box which had been given 7 cornerwise drops from a height of 30 inches. The damage to cans in the boxes that were drop tested was somewhat greater than to those in the containers tested in the drum. Cans in boxes tested with sleeves received slightly less damage.

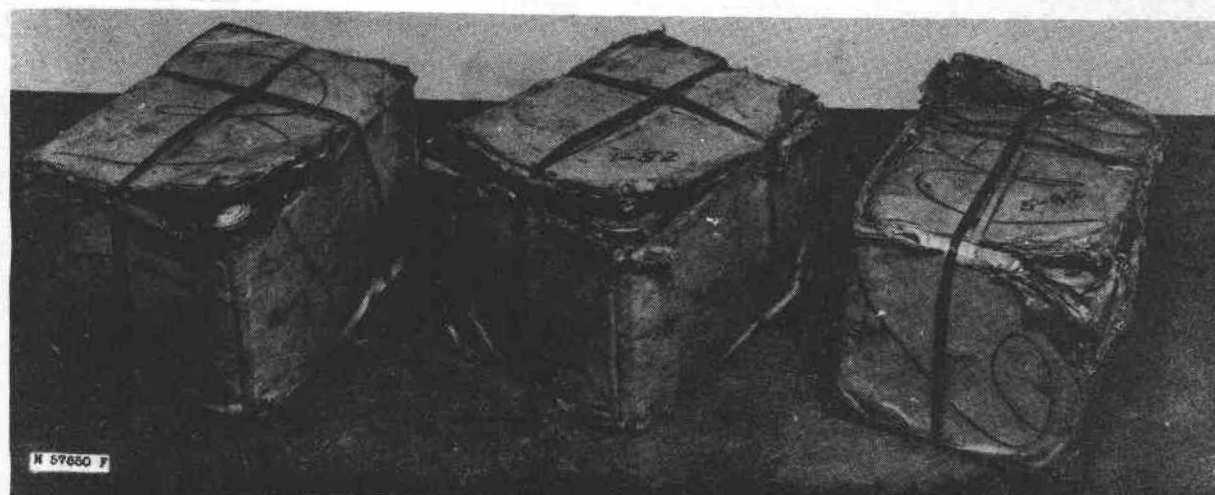
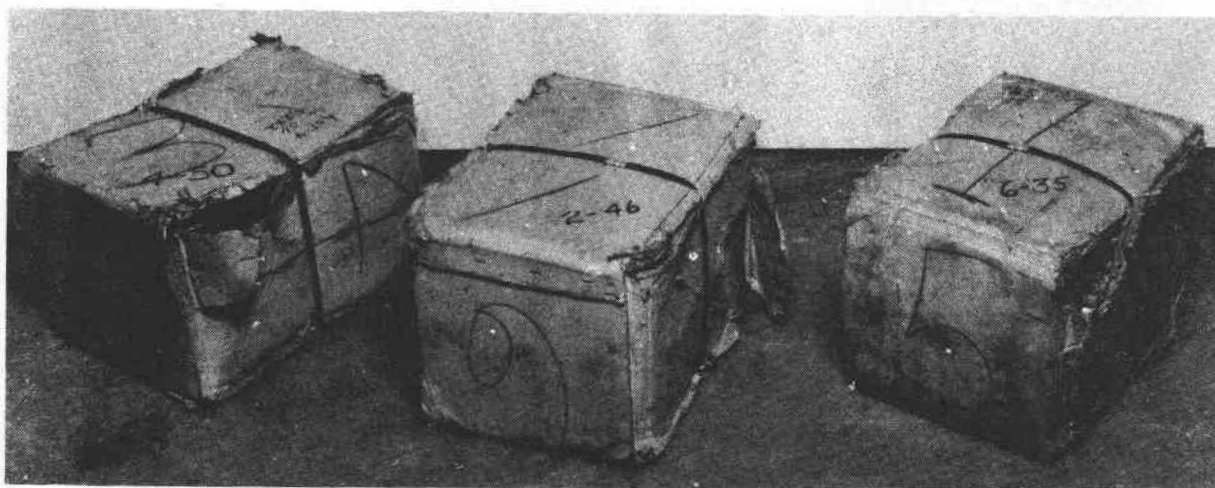


Figure 11 (Top).--Typical condition of reclaimed and V2s grade fiberboard boxes, with sleeves, after drum test to failure. The 4-24 box on the left required 759 falls to spill contents; the 6-16 box in the center required 1,059 falls; and the V2s grade box on the right, 1,851 falls. These containers were tested dry.

Figure 12 (Bottom).--Typical condition of reclaimed and V2s grade fiberboard boxes, without sleeves, after drum test to failure following 24-hour submersion in water. The 4-24 box on the left required 306 falls to spill contents; the 6-16 box in the center required 322 falls; while the V2s grade box on the right took 187 falls.

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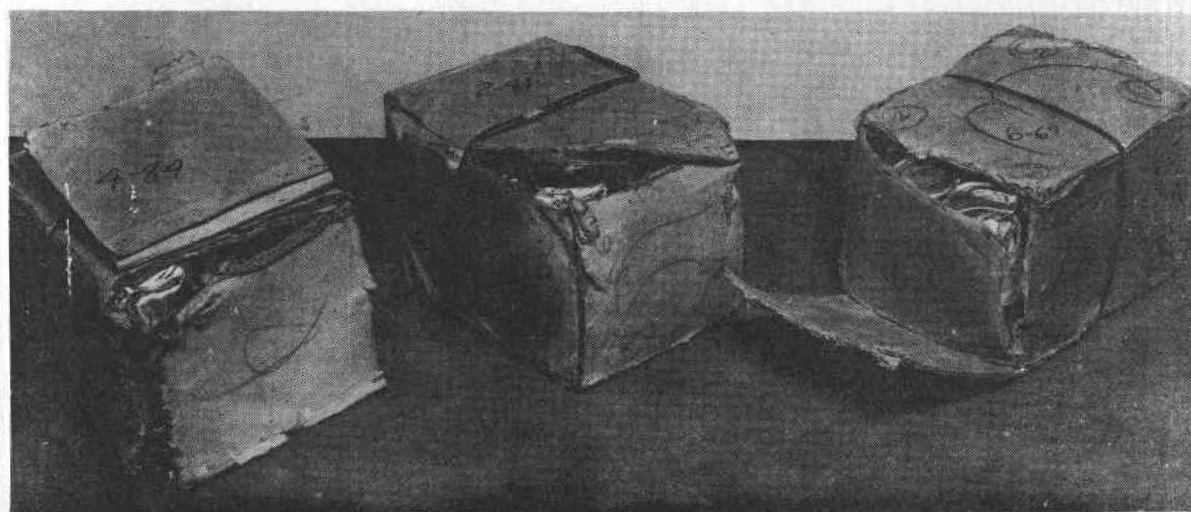
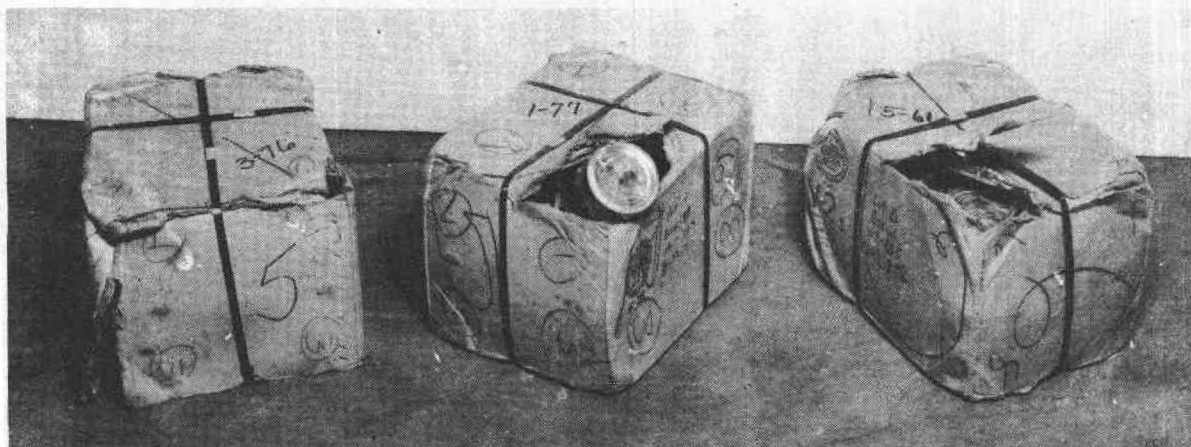


Figure 13 (Top).--Typical condition of reclaimed and V2s grade fiberboard boxes, without sleeves, after 30-inch cornerwise-drop test to failure. The 4-24 box on the left required 23 drops to spill contents; the 6-16 box in the center required 45 drops; and the V2s grade box on the right, 39 drops. These boxes were tested dry.

Figure 14 (Bottom).--Failures of reclaimed and V2s grade fiberboard boxes, with sleeves, after being subjected to the 30-inch cornerwise drop test. The 4-24 box at left received 34 drops; 6-16 box in center received 35 drops; and V2s box at right received 18 drops. Contents spilled from all of these boxes which had been submerged in water for 24 hours prior to test. Boxes tested in the drum, under the same conditions, show similar failures.