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STUDY OF PAPER BOARD QUALITY

AS RELATED TO

FIBER BOX PERFORMANCE

REPORT NUMBER 2

Special Studies 1. Effect of Distribution of Weight of Components on Performance of Combined Board and Boxes

PART I. LINER WEIGHT STUDY

INSTITUTE OF PAPER CHEMISTRY
Appleton, Wisconsin

REPORT TO
FOURDRINIER KRAFT BOARD INSTITUTE, INC.

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A STUDY OF PAPERBOARD QUALITY AS RELATED TO BOX PERFORMANCE

Special Studies 1. Effect of Distribution of Weight of Components on Performance of Combined Board and Boxes

Part I. Liner Weight Study

SUMMARY

The three main structural elements of a corrugated board—single-face liner, corrugating medium, and double-face liner—were investigated in the Weight-Distribution Study. The liner materials used in the study were Fourdrinier kraft and the corrugating materials were Fourdrinier kraft, chestnut, Chem Fibre, and straw. These materials were fabricated into A- and B-flute combined board. A total of 13 different combinations of liners and mediums was fabricated. The combined board of each of the run combinations was converted into two types of boxes. One type of box was a B-flute R.S.C. to carry 24 No. 2½ cans. The other was an A-flute R.S.C. with the following inside dimensions: 22¾ by 15 by 24⅝ inches. The corrugating and converting operations were carried out under carefully controlled but normal operating conditions.

Samples of the component materials, combined board, and boxes were taken from each run combination. All samples were preconditioned at not higher than 35% R.H. prior to being conditioned and tested in an atmosphere maintained at 50 ± 2% R.H. and a temperature of 73 ± 3.5° F.

The component materials were tested for basis weight, caliper, bursting strength, G.E. puncture, Elmendorf tear, Amthor tensile and stretch, and ring compression. The physical tests carried out on the combined board samples were basis weight, bursting strength, G.E. puncture, G.E. stiffness, pin adhesion, and H. and D. flat crush. The A-flute box samples were tested for top- and end-load compression. In addition to these two tests, the B-flute box samples were tested by the small revolving drum test and the twelve-inch corner drop test.

The Effect of Liner Weight

The effect of liner weight on box characteristics was observed by studying the results obtained on Run Combinations 23, 24, 25, 26, and 35. In these combinations combined boards were fabricated from 38-lb. DF, 42-lb. DF, 47-lb. WF, 47-lb. DF, and 90-lb. WF liners and kraft corrugating mediums.

1. In general, as liner weight was increased, both top- and end-load compressive strength increased. Although the B-flute boxes showed a more uniformly progressive increase in top-load compressive strength with increase in liner weight than did the A-flute boxes, both A- and B-flute boxes showed a uniform increase in end-load compressive strength with increase in liner weight.

2. The drum and drop test values for the B-flute boxes, in general, increased as the weight of the liners increased.

The results obtained on the combined board samples of these same run combinations showed the effect of liner weight on combined board characteristics.

1. The general trend was for the bursting strength of the combined board to increase as the weight of the component liners increased. This trend was more apparent for the B-flute samples than for the A-flute samples. Also, it was noted that the bursting strength values for the B-flute combined board samples were higher than the bursting strength values for the corresponding A-flute samples.

2. In general, the G.E. puncture values for the combined board samples increased as the weight of the component liners increased. There was a tendency for the G.E. puncture results on the A-flute combined board samples to be higher than those on the B-flute samples of the corresponding run combinations.

3. The results of the G.E. stiffness tests for the samples of A- and B-flute corrugated board showed that the stiffness values increased with increase in the weight of the liners. The G.E. stiffness results obtained for the A-flute samples were approximately the same in magnitude as those obtained for the corresponding B-flute samples. Although it might normally be expected that A-flute combined board, by nature of its greater thickness, would give higher G.E. stiffness values than B-flute board, this tendency was apparently offset by the greater number of flutes in the B-flute board.

4. The H. and D. flat crush values for the B-flute combined board samples were, in general, about 10 lb. per sq. in. higher than the corresponding values for the A-flute samples.

The Effect of Type of Corrugating Medium

The effect of the type of corrugating medium on box characteristics was observed by studying the results obtained on Run Combinations 26, 27, 28, and 29. These combinations represent boxes fabricated with 42-lb. Fourdrinier kraft liners and corrugating mediums of Fourdrinier kraft, Chem Fibre, chestnut, and straw.

1. The compression test results showed that higher top- and end-load compression averages were obtained for the A-flute boxes fabricated with Chem Fibre than for those fabricated with any of the other three cor-

rugating mediums. Also, higher top-load compression averages were obtained for the B-flute boxes fabricated with Chem Fibre than for B-flute boxes fabricated with other types of medium. However, the B-flute boxes fabricated with Fourdrinier kraft medium gave higher end-load compression values than those fabricated with other mediums.

2. The B-flute boxes fabricated with Fourdrinier kraft corrugating medium were far more resistant to the rough handling action of the drum and drop tests than were those fabricated with any of the other corrugating mediums. The boxes fabricated with the roll of chestnut corrugating medium gave the lowest drum and drop test results.

The results obtained on the combined board samples of the same run combinations showed the effect of the *type of corrugating medium on combined board characteristics.*

1. The results indicate that the type of corrugating medium had a marked influence on the G.E. puncture values of the A- and B-flute combined board samples. The A- and B-flute combined board samples fabricated with kraft corrugating medium gave higher G.E. puncture values than those fabricated with any of the other mediums.

2. The type of corrugating medium had very little influence on the bursting strength of the A- and B-flute combined board samples.

3. The A- and B-flute combined board samples fabricated with Chem Fibre gave the highest G.E. stiffness averages and the highest H. and D. flat crush averages of any of the samples studied.

The Effect of Position of Liners of Different Weight

The combined boards of Run Combinations 30, 31, 32, 33, 34, and 35 were "unbalanced board" in that the single-face and double-face liners were of different weights. By studying these run combinations it was possible to observe some of the effects of the position of liners of different weights on the characteristics of the boxes fabricated from them. However, it should be borne in mind that the limited number of samples (run combinations) included in this study materially limit the significance which can be attached to the results. The results should be interpreted as merely indicating possible trends which might be expected.

1. Higher top-load compression values tended to result when the heavier of the two liners was placed on the inside (S.F.) and the lighter liner was placed on the outside (D.F.) than when the liners were in the reverse position. This observation was particularly apparent for boxes in which the liner weight differential was the greatest.

2. Conversely, there appeared to be a tendency for the boxes fabricated with the heavier liner on the outside (D.F.) and the lighter liner on the inside (S.F.) to give higher end-load compression values than those with the liners in the reverse position.

3. The drum and drop test values, in general, were higher for boxes which had the heavier liner on the inside (S.F.) and the lighter liner on the outside (D.F.) than for boxes having the reverse arrangement of liners.

4. When the B-flute boxes fabricated from unbalanced boards were compared with the boxes fabricated from "balanced boards" (boards fabricated with single-face and double-face liners of the same weight) of corresponding total liner weight, it was observed that, in general, *they gave lower end-load compression results than the* boxes from balanced boards.

5. The boxes fabricated with balanced board gave lower drop test values than the corresponding boxes fabricated with unbalanced board.

The results obtained on the combined board samples of the same run combinations showed the effect of the position of liner on the G.E. puncture test results. In the G.E. puncture test, the double-face liner was always contacted first by the puncture head. The combined board fabricated with the heavier liner as the single-face liner and the lighter liner as the double-face liner gave higher G.E. puncture values than when the reverse arrangement of liners was used.

Statistical Studies

The statistical studies were conducted on a group of ten run combinations which encompassed boxes having liners varying greatly in basis weight, but all made with kraft corrugating medium. The studies indicated rather high correlation coefficients for basis weight and top-load compression and for basis weight and end-load compression. A series of predicted values based upon basis weight checked fairly closely with the values of top- and end-load compression obtained in the laboratory.

The studies also indicated that, if unbalanced board is to be used in boxes, some advantage is gained for top-load compression if the heavier liner is placed on the inside (S.F.). The reverse arrangement was indicated to secure higher results for end-load compression.

Simple correlation coefficients were calculated to establish the relationship between the weight of the combined board and certain combined board strength tests and the relationship between the weight of the combined board and the top- and end-load compression tests on the corresponding boxes.

INTRODUCTION

The broad objective of the long-range co-operative research and development program initiated at The *Institute* of Paper Chemistry by the Fourdrinier Kraft Board Institute, Inc. was the determination and accumulation of the basic information needed for improving the quality of paperboard boxes and their components.

During March, April, and May, 1945, the paperboard production of the co-operating mills was sampled in an impartial cross-sectional manner so that a baseline study of current paperboard production could be carried out. The baseline study was conducted to provide a reference point or index of the quality of the paperboard being produced. Two reports have been completed on the information obtained during the baseline studies. The first report (Baseline Studies 1. Part I) was concerned with the sampling program employed and with the evaluation of the liner and corrugating medium samples by existing paperboard testing methods. The second report (Baseline Studies 1. Part II) was concerned with three objectives: (*1*) The selection of the most representative roll or rolls of each mill's sampled productions. (*2*) The fabrication of these representative rolls into combined boards and the conversion of the resulting combined boards into boxes. (*3*) The laboratory evaluation of these boxes by conventional box-testing methods. The baseline studies provided a background of information which made more meaningful the results of the present study.

The present study is an investigation of the distribution of weight in corrugated board. The importance of such a study of corrugated board is apparent when it is realized that a corrugated board is a structure. In general, structures are made up of several structural elements, each of which may be fabricated from materials of different physical strength; thus, the distribution of the strength among the several elements is a problem of utmost importance since it governs, to a large degree, the ultimate performance of the entire structure.

When a corrugated board is considered as a structure, the main structural elements are the single-face liner, corrugating medium, and double-face liner. The proper distribution of strength among these three elements to obtain a corrugated board of the most desirable characteristics presents an important problem. The structural materials used in the fabrication of corrugated board are, in general, specified on the basis of weight per thousand square feet and, within limits, the higher the weight, the greater the strength of the board.

From a practical and economic viewpoint, the paperboard and box manufacturers should be interested in knowing the effect of the weight of the liners or corrugating mediums on the performance of boxes made therefrom. For example, what is the effect on box performance when the total weight of the liners is increased by four pounds per thousand square feet of corrugated board? Also, is the effect on box performance the same if the equivalent weight increase is applied to the corrugating medium?

The economic importance of knowledge of this type to the manufacturers of paperboard is apparent. It was logical, therefore, for the Fourdrinier Kraft Board Institute to include a study of these factors as a part of their long-range research and development studies being carried out at The Institute of Paper Chemistry.

This study had as its initial objective the development of information regarding the effect on box performance of (*1*) weight of liners, (*2*) the type of corrugating medium, and (*3*) different weights of single- and double-face liners. The study of the effect of the weight (or strength) of the corrugating medium on box performance was not included in the first section of the weight-distribution study.

MATERIALS

In order to carry forward the weight-distribution study along the lines indicated by its three objectives, it was necessary to select carefully the various weights of liners and the various types of corrugating mediums which would be fabricated into combined board and ultimately converted into boxes. The general material shortage prevalent at the time the study was initiated made it advisable to limit the study to the materials listed in Table I. The materials were fabricated according to the schedule given in Table II. It was felt that the characteristics of the liners of different weights would be made more comparable if they were produced on one Fourdrinier machine from pulp which was as uniform as possible. In particular, this would allow liners of different weights to be produced at a more nearly constant density; this was desirable because the comparisons of the combined boards and boxes produced from them would be based more nearly on weight alone, and would not be complicated by such variables as the bulkiness of the sheets and nonuniform weight to caliper ratios.

The kraft liners and the 26-lb. kraft corrugating medium were produced at the St. Joe Paper Company, Port St. Joe, Florida, on the same Fourdrinier machine. The pulp evaluation data for the pulp used in producing the kraft liners and medium are given in Appendix B.

The second phase of the study, in which the combined boards were to be fabricated using corrugating mediums of various types, required the selection of rolls of corrugating mediums of 26-lb. Chem Fibre, 26-lb. chestnut, and 30-lb. straw, in addition to the 26-lb. kraft corrugating medium which was produced at the St. Joe Paper Company. In selecting these rolls, an attempt was made to secure a roll of each corrugating medium which could be considered representative of its type.

TABLE I

MATERIALS USED FOR FABRICATION COMBINATIONS

Grade	Manufacturer	Number of Rolls
38-lb. DF liner	St. Joe Paper Company	2
42-lb. DF liner	St. Joe Paper Company	5
47-lb. DF liner	St. Joe Paper Company	2
47-lb. WF liner	St. Joe Paper Company	3
52-lb. WF liner	St. Joe Paper Company	1
90-lb. WF liner	St. Joe Paper Company	3
26-lb. kraft corrugating medium	St. Joe Paper Company	5
26-lb. Chem Fibre corrugating medium	International Paper Company, Georgetown, S. C.	1
26-lb. chestnut corrugating medium	The Mead Corporation, Nashville, Tenn.	1
30-lb. straw corrugating medium	The Weston Paper & Manuturing Co., Dayton, Ohio	1

TABLE II

FABRICATION SCHEDULE

Run Combination	Order of Running	Flute	Single-Face Liner*	Roll No.	Corrugating Medium	Roll No.	Double-Face Liner*	Roll No.
23	1	A	47-lb. WF	1	26-lb. kraft	1	47-lb. WF	2
23	2	B	47-lb. WF	1	26-lb. kraft	1	47-lb. WF	2
24	3	B	47-lb. DF	1	26-lb. kraft	1	47-lb. DF	2
24	4	A	47-lb. DF	1	26-lb. kraft	1	47-lb. DF	2
25	5	A	38-lb. DF	1	26-lb. kraft	2	38-lb. DF	2
25	6	B	38-lb. DF	1	26-lb. kraft	2	38-lb. DF	2
26	7	B	42-lb. DF	1	26-lb. kraft	2	42-lb. DF	2
26	8	A	42-lb. DF	1	26-lb. kraft	2	42-lb. DF	2
27	9	A	42-lb. DF	1	26-lb. Chem Fibre	1	42-lb. DF	2
27	10	B	42-lb. DF	1	26-lb. Chem Fibre	1	42-lb. DF	2
28	11	B	42-lb. DF	3	26-lb. chestnut	1	42-lb. DF	4
28	12	A	42-lb. DF	3	26-lb. chestnut	1	42-lb. DF	4
29	13	A	42-lb. DF	3	30-lb. straw	1	42-lb. DF	4
29	14	B	42-lb. DF	3	30-lb. straw	1	42-lb. DF	4
30	15	B	42-lb. DF	5	26-lb. kraft	3	52-lb. WF	1
30	16	A	42-lb DF	5	26-lb. kraft	3	52-lb. WF	1
31	17	A	52-lb. WF	1	26-lb. kraft	3	42-lb. DF	5
31	18	B	52-lb. WF	1	26-lb. kraft	3	42-lb. DF	5
32	19	B	38-lb. DF	1	26-lb. kraft	4	47-lb. WF	2
32	20	A	38-lb. DF	1	26-lb. kraft	4	47-lb. WF	2
33	21	A	47-lb. WF	1	26-lb. kraft	4	38-lb. DF	2
33	22	B	47-lb. WF	1	26-lb. kraft	4	38-lb. DF	2
34	23	B	90-lb. WF	1	26-lb. kraft	5	47-lb. WF	3
34	24	A	90-lb. WF	1	26-lb. kraft	5	47-lb. WF	3
35	25	A	47-lb. WF	3	26-lb. kraft	5	90-lb. WF	2
35	26	B	47-lb. WF	3	26-lb. kraft	5	90-lb. WF	2

*All liners were Fourdrinier kraft.

In the fabrication phase of the Weight-Distribution Study, starch was used as the adhesive. The starch was a commercial grade of Bondcor C starch obtained from Stein, Hall and Company, Inc. The raw starch was from the same lot as that used for the fabrication run of the Baseline Study, and the analytical results reported for the raw starch in Baseline Studies 1. Part II are applicable for this run of the Weight-Distribution Study.

FABRICATION

General Procedure

In order that the objectives of the Weight-Distribution Study might be attained, it was necessary to accomplish the corrugating operation and the box conversion operation under controlled but normal conditions of manufacture. It was also necessary to obtain the services of an impartial boxmaker in carrying out the fabrication according to the predetermined schedule of run combinations shown in Figure 1. The services of the Menasha Wooden Ware Corporation of Menasha, Wisconsin were obtained for this purpose. Each run combination was to be fabricated into both A- and B-flute combined board, and the entire fabrication was to be done in one day on one corrugator by the same operating crew.

In order to have a more complete picture of the effect of weight distribution of the components on the boxes fabricated from them, it seemed desirable to fabricate boxes of two sizes. The A-flute box was of such size as to be considered a compression-type box, whereas the B-flute box was a conventional 24 No. 2½ can size box.

The A-flute combined board was cut one-out on the corrugator to provide box blanks for R.S.C. boxes of the following inside dimensions: 22¾ by 15 by 24⅝ inches. The manufacturer's joint was taped. The blank for the above box was cut and flap scored on the corrugator. The blank size was 76⅜ by 40⅜. The flap scoring dimensions were 711/16 by 25 by 7 11/16 (see Figure 2). The B-flute combined board was cut two-out on the corrugator to provide box blanks for R.S.C. 24 No. 2½ can size boxes of the following inside dimensions: 16⅛ by 12 1/16 by 9 5/16 inches. The blank for the above box was cut 58⅜ by 21 13/16 inches and the flap scoring dimensions were 6⅛ by 9 9/16 by 6⅛ inches (see Figure 2). The manufacturer's joint of this box was stitched. In accord with the cutting schedule, approximately 250 sample boxes and 125 full width unscored combined board sample sheets were produced from each run combination for both the A- and the B-flute.

The corrugating equipment used in the fabrication run was a conventional 76-inch Langston duplex corrugator equipped with A- and B-flute rolls. The hot plate section of the corrugator consisted of 22 hot plates which gave an over-all drying length of about 33½ feet. Steam was supplied to the preheaters, rolls, and hot plates at a pressure of approximately 125 pounds per square inch. The cold or pull section of the corrugator was approximately 33½ feet in length. The corrugator was equipped with duplex slitting and scoring equipment and with a single cutoff.

Two batches of starch adhesive were prepared for this fabrication run. Representatives of the Menasha Wooden Ware Corporation and The Institute of Paper Chemistry collaborated in the preparation of the starch adhesive. The carrier portion of the first batch was prepared in a Francis mixer by suspending 75 pounds of Bondcor C starch in approximately 665 pounds of water. Sixteen and one-half pounds of sodium hydroxide dissolved in water were added and the carrier portion was heated to 165° F. and was held at this temperature for 15 minutes. The secondary mixer was charged with the following ingredients and was agitated until the suspension was thoroughly mixed:

Water	Approximately 1400	lb.
Bentonite	12	lb.
Borax	16½	lb.
Bondcor C starch	510	lb.
Formaldehyde	3	lb.
Sulphonated oil	3	lb.

The carrier portion was mixed thoroughly with the above charge in the secondary mixer until a homogeneous starch suspension resulted. The total volume was approximately 333 gallons. The second batch of starch adhesive was prepared by essentially the same procedure. It was estimated that approximately 440 gallons of starch adhesive or 770 pounds of raw starch were used during the fabrication run.

Actual Fabricating Procedure

The actual fabrication of the combined board was carried out in the following manner. A set of unidentified rolls of liner and corrugating material that were not to be used during the actual fabrication were run over the corrugator, and the various adjustments and corrugating roll settings were made. Also, at this time the starch adhesive was circulated in the pans, and the adjustments of the glue pickup and transfer rolls were checked. The clearances between the glue pickup rolls and the glue transfer rolls at three positions across the rolls for both the A- and B-flute combined board are given in Table III. With one exception, after the final adjustments were made, they were not changed materially throughout the entire fabrication of the selected rolls. The exception was the setting of the clearance between the glue transfer

TABLE III

CLEARANCES BETWEEN GLUE PICKUP AND TRANSFER ROLLS

Double Backer		Single Facer
A Flute		
Front	0.0090 in.	0.0090 in.
Center	0.0095 in.	0.0090 in.
Back	0.0100 in.	0.0090 in.
B Flute		
Front	0.0090 in.	0.0085 in.
Center	0.0095 in.	0.0085 in.
Back	0.0100 in.	0.0085 in.

Rolls of Corrugating Medium	Run Combination	Rolls of Liner
26-lb. Kraft (Roll 1)	23	47-lb. WF Kraft (Roll 1) 47-lb. WF Kraft (Roll 2)
	24	47-lb. DF Kraft (Roll 1) 47-lb. DF Kraft (Roll 2)
26-lb. Kraft (Roll 2)	25	38-lb. DF Kraft (Roll 1) 38-lb. DF Kraft (Roll 2)
	26	42-lb. DF Kraft (Roll 1) 42-lb. DF Kraft (Roll 2)
26-lb. Chem Fibre (Roll 1)	27	42-lb. DF Kraft (Roll 1) 42-lb. DF Kraft (Roll 2)
26-lb. Chestnut (Roll 1)	28	42-lb. DF Kraft (Roll 3) 42-lb. DF Kraft (Roll 4)
30-lb. Straw (Roll 1)	29	42-lb. DF Kraft (Roll 3) 42-lb. DF Kraft (Roll 4)
26-lb. Kraft (Roll 3)	30	42-lb. DF Kraft (Roll 5) 52-lb. WF Kraft (Roll 1)
	31	52-lb. WF Kraft (Roll 1) 42-lb. DF Kraft (Roll 5)
26-lb. Kraft (Roll 4)	32	38-lb. DF Kraft (Roll 1) 47-lb. WF Kraft (Roll 2)
	33	47-lb. WF Kraft (Roll 1) 38-lb. DF Kraft (Roll 2)
26-lb. Kraft (Roll 5)	34	90-lb. WF Kraft (Roll 1) 47-lb. WF Kraft (Roll 3)
	35	47-lb. WF Kraft (Roll 3) 90-lb. WF Kraft (Roll 2)

FIGURE 1. Fabrication Sequence.

roll and the top riding roll on the double backer. This clearance was set at a minimum of 0.1895 inch for the A-flute and a minimum of 0.0908 inch for the B-flute combined board. When the run combinations using 90-lb. liner were run (Run Combinations 34 and 35), this clearance was increased 0.003 inch for both the A- and B-flute boards.

The A-flute corrugating rolls had 36 corrugations per circumferential foot. The outside diameter of the large corrugating roll was 9.875 inches and that of the small corrugating roll was 9.032 inches. The B-flute corrugating rolls had 52 corrugations per circumferential foot. The outside diameter of the large corrugating roll was 9.875 inches and that of the small corrugating roll was 7.618 inches.

After all the settings and adjustments of the cut-off knife, slitters, and creasing wheels were completed and the corrugator was producing satisfactory combined board at the desired machine speed of approximately 280-290 feet per minute, the machine was stopped and the unidentified rolls were replaced with the rolls which were selected for Run Combination 23. The fabrication of Run Combination 23 was begun and, when the corrugator was producing satisfactory A-flute combined board at a speed of approximately 280-290 feet per minute, the first samples were taken. After approximately 250 samples of box blanks were obtained, the machine was stopped and the slitter assembly was rotated to the horizontal position so that full-width unscored sheets of A-flute combined board could be obtained. One hundred and twenty-five of these sheets were saved after the corrugator was again operating satisfactorily at the desired speed This completed the sampling for the A-flute fabrication for Run Combination 23. The single-face liner and corrugating medium were changed from the A-flute to the B-flute corrugating rolls, and essentially the same procedure was followed as above, except that the 125 full-width sheet samples of B-flute combined board were produced first, followed by the 250 box blank samples of B-flute board. In this way, the number of creasing wheel changes was kept at a minimum.

On completion of both phases (A- and B-flute) of Run Combination 23, the corrugator was stopped and the three rolls selected for Run Combination 24 were placed on the corrugator. The fabrication of this run combination was carried out in a manner similar to that described for Run Combination 23, with the exception that the B-flute box blanks and sheets were produced before those of A-flute in order to eliminate an additional changeover from B-flute to A-flute and back to B-flute. In this manner, the fabrication of all the run combinations listed in Table I was carried out. The sequence of fabrication of the run combinations was as shown in Figure 1.

The box blank samples and the sheet samples of each run combination were stacked on separate skids and were completely identified to prevent confusion in later operations. Also, the box blanks of B-flute combined

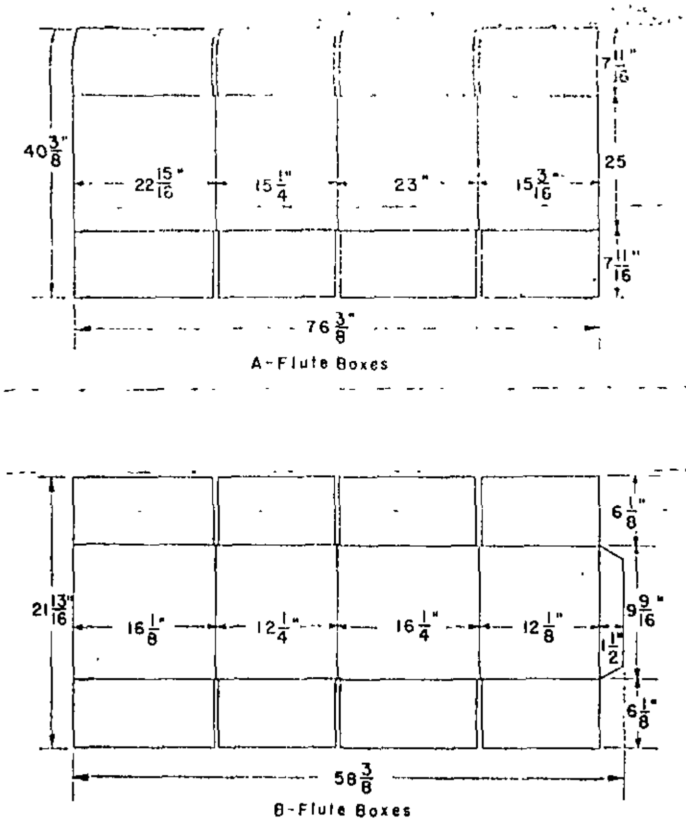

FIGURE 2. Scoring and Slotting Specifications.

board from the front of the machine were stacked separately from those from the back of the machine. This procedure was necessary in order that the samples to be tested at a later time could be made up of an equal number of specimens from the front and back of the machine.

Following the fabrication, the box blanks were allowed to season for at least 48 hours before they were run on the printer-slotters. The A-flute box blanks were scored, slotted, and printed on a 64 by 120 inch Langston printer-slotter. The scoring and slotting dimensions are shown in Figure 2.

The B-flute box blanks were scored, slotted, and printed on a 42 by 90-inch Langston printer-slotter. The scoring and slotting dimensions are shown in Figure 2.

The printing part of the operation was done merely to mark the boxes for identification purposes, and consisted of the boxmaker's certificate, run combination or lot number and, in the case of the B-flute boxes, the letter F or B. The letter F identified the blank as having been made on the front side of the corrugator. Similarly, the letter B denoted a back-side blank. The various run combinations were printed and slotted in the same sequence as that used in the fabrication.

After the printing and slotting operation, all the A-flute boxes were taped on one Progressive taping machine which was equipped with a 20-foot pressure belt section. Hand folding was used in the operation. The tape used was 2-inch regular cloth tape manufactured by The Rexford Tape Company. The B-flute boxes were stitched with 6 stitches each. The stitching wire was 0.020 inch in thickness and 0.104 inch in width. The reach dimension of the stitch was $\frac{7}{16}$ inch and the clinching legs were $\frac{3}{8}$ inch long. All the B-flute boxes were stitched on one Model 385 Bliss Wire Stitcher manufactured by the Boston Wire Stitcher Company and marketed by Dexter Folder Company.

The finished boxes and the sheet stock were forwarded to Appleton by motor freight. The samples were handled with care to prevent crushing and edge damage. Also, the bundles of boxes were loose tied to prevent string cuts.

Sampling and Fabrication Data Obtained

Rather extensive data were taken during the fabrication run to insure that the fabrication was done under carefully controlled but normal conditions of manufacture. The actual operation of the corrugator was carried out by the regular operating crew of Menasha Wooden Ware Corporation. The collecting and recording of pertinent operational information and the sampling of the components and combined board during the fabrication were done by representatives of The Institute of Paper Chemistry.

For each of the run combinations of the Weight-Distribution Study, nine samples of component materials were obtained. To illustrate the sampling procedure, reference may be made to Run Combination 23 (see Figure 1). Full roll width samples about 15 feet in length were removed from each of the component rolls of Run Combination 23 (47-lb. WF kraft, Roll 1; 26-lb. kraft, Roll 1; and 47-lb. WF kraft, Roll 2) before the rolls were threaded on the corrugator. After 250 A-flute box blank samples and 125 sheets of flat stock samples were produced, the single-face liner and the corrugating medium were changed from the A-flute to the B-flute corrugating rolls. At the time of the change, full roll width samples about 15 feet in length were removed from each of the three component rolls. These three samples were representative of the component materials being used at the end of the fabrication of the A-flute combined board of Run Combination 23; also, they were representative of the component materials being used at the beginning of the fabrication of the B-flute combined board of Run Combination 23. After 125 sheets of flat stock samples of B-flute combined board and 250 box blank samples of B-flute combined board were obtained, the machine was stopped and again full roll width samples were obtained from each of the three component rolls. Since the corrugating medium roll was to be used also in Run Combination 24, the corrugating medium sample represented the material used at the end of B-flute combined board of Run Combination 23 and at the beginning of the B-flute combined board of Run Combination 24. However, it was necessary to obtain full roll width samples of the two liner rolls of Run Combination 24 (47-lb. DF Roll 1, and 47-lb. DF Roll 2) to represent the liner materials being used at the beginning of the fabrication of the B-flute combined board of Run Combination 24. The B-flute combined board of Run Combination 24 was fabricated before the A-flute in order to avoid an additional change-over from one flute to the other. The preceding illustration indicates the procedure of sampling used throughout the entire fabrication run.

Each of the samples of the components was identified as to the roll number, run combination number, position sampled, and time sampled. As each of the full roll width component samples was removed from the machine, it was immediately cut to provide moisture specimens representative of the front, center, and back positions of the roll. The three specimens were marked to identify them completely and were weighted immediately to determine their "as-used" weight. They were then forwarded to The Institute of Paper Chemistry where they were oven dried to constant weight in an oven which was equipped with forced air circulation and was maintained at a temperature of 103-105° C. All weighings were made on a balance which was graduated to 0.01 gram. The results of the moisture determinations on the component materials are shown in Table IV. The remainder of each component sample which was not used for the moisture determination was forwarded to The Institute of Paper Chemistry to be used for test purposes.

TABLE IV

MOISTURE CONTENT OF COMPONENT MATERIALS AT TIME OF FABRICATION

Run Combination	Moisture (ovendry basis), % Single-Face Liner	Corrugating Medium	Double-Face Liner
23A	7.8	9.3	8.4
23B	7.4	8.0	7.5
24A	6.3	7.6	6.7
24B	8.6	7.4	8.0
25A	8.2	8.9	10.3
25B	8.3	8.0	10.5
26A	7.4	6.8	8.4
26B	7.6	7.5	8.2
27A	7.0	6.5	8.7
27B	6.5	6.0	9.0
28A	6.9	4.9	7.9
28B	7.2	5.5	8.0
29A	7.4	7.7	8.2
29B	7.3	8.6	8.0
30A	5.8	6.3	6.1
30B	6.4	7.2	6.9
31A	6.0	6.3	6.3
31B	5.9	7.2	6.4
32A	5.8	6.8	6.3
32B	7.4	7.3	6.8
33A	6.2	6.6	7.5
33B	6.0	6.1	6.8
34A	6.7	6.0	5.4
34B	7.2	6.9	6.5
35A	5.1	6.7	7.4
35B	5.0	8.3	7.3

In Table V a compilation is given of the pertinent fabrication data; this includes information concerning the machine speed, and the various temperature and pressure readings taken during the fabrication. Table V also gives information regarding the number of sample

TABLE V

CORRUGATOR OPERATING DATA

(Including Number of Sample Boxes and Flat Stock Sheets Produced)

Run Combi-nation	Sampling Period Time		Machine Speed, lineal feet/minute*	Single-Facer Temp. Data, °F.				Hot Plate Temp., °F.†	Steam Pressure, lb./sq. in.	Number of Samples Produced‡	
				Top Corrugated Roll		Bottom Corrugated Roll					
	Start	End		Front	Back	Front	Back			Boxes	Sheets
23A	8:35 a.m.	8:39 a.m.	285	305	310	310	315	288	130	250	
23A	8:41 a.m.	8:42 a.m.	285								125
23B	9:04 a.m.	9:06 a.m.	285	305	300	300	300	309	120	252	
23B	9:07 a.m.	9:10 a.m.	285								125
24B	9:19 a.m.	9:22 a.m.	280	320	320	310	300	301	130	254	
24B	9:23 a.m.	9:27 a.m.	280								142
24A	9:37 a.m.	9:42 a.m.	280	285	310	295	330	318	125	250	
24A	9:43 a.m.	9:45 a.m.	280								88
25A	9:57 a.m.	10:03 a.m.	280	300	310	300	320	304	125	265	
25A	10:04 a.m.	10:06 a.m.	280								90
25B	10:21 a.m.	10:23 a.m.	280	320	315	320	315	313	125	254	
25B	10:24 a.m.	10:25 a.m.	280								86
26B	10:37 a.m.	10:40 a.m.	280	300	310	320	325	322	127	252	
26B	10:41 a.m.	10:43 a.m.	280								111
26A	10:53 a.m.	11:00 a.m.	280	295	320	305	310	307	130	250	
26A	11:02 a.m.	11:04 a.m.	280								80
27A	11:12 a.m.	11:13 a.m.	280	295	310	320	325	321	130		75
27A	11:15 a.m.	11:21 a.m.	280							244	
27B	11:31 a.m.	11:34 a.m.	280	325	325	310	300	305	130	256	
27B	11:35 a.m.	11:39 a.m.	280								100
28B	11:49 a.m.	11:50 a.m.	280	325	330	310	305	321	130		74
28B	11:51 a.m.	11:55 a.m.	280							307	
28A	12:06 p.m.	12:11 p.m.	280	305	315	320	325	305	125	250	
28A	12:12 p.m.	12:14 p.m.	280								91
29A	12:23 p.m.	12:25 p.m.	280	300	320	310	320	318	127		100
29A	12:28 p.m.	12:33 p.m.	280							235	
29B	12:42 p.m.	12:45 p.m.	280	320	315	310	310	305	130	250	
29B	12:46 p.m.	12:48 p.m.	280								91

TABLE V—Continued

CORRUGATOR OPERATING DATA

(Including Number of Sample Boxes and Flat Stock Sheets Produced)

Run Combination	Sampling Period Time: Start	Sampling Period Time: End	Machine Speed, lineal feet/minute*	Single-Facer Temp. Data, °F.: Top Corrugated Roll Front	Top Corrugated Roll Back	Bottom Corrugated Roll Front	Bottom Corrugated Roll Back	Hot Plate Temp., °F.†	Steam Pressure, lb./sq. in.	Number of Samples Produced‡: Boxes	Sheets
30B	12:57 p.m.	1:01 p.m.	285	325	320	310	305	317	125		99
30B	1:03 p.m.	1:06 p.m.	285							278	
30A	1:17 p.m.	1:22 p.m.	285	305	315	320	315	308	125	250	
30A	1:24 p.m.	1:26 p.m.	285								77
31A	1:37 p.m.	1:39 p.m.	280	320	310	320	325	322	122		75
31A	1:42 p.m.	1:48 p.m.	280							248	
31B	1:55 p.m.	1:57 p.m.	280	320	320	310	310	312	125	250	
31B	1:58 p.m.	2:00 p.m.	280								84
32B	2:09 p.m.	2:10 p.m.	290	325	320	325	320	321	130		75
32B	2:12 p.m.	2:14 p.m.	290							294	
32A	2:21 p.m.	2:27 p.m.	290	305	320	315	315	305	130	250	
32A	2:28 p.m.	2:30 p.m.	290								72
33A	2:38 p.m.	2:39 p.m.	280	305	320	320	315	322	125		75
33A	2:41 p.m.	2:47 p.m.	280							259	
33B	2:54 p.m.	2:56 p.m.	280	310	315	310	305	314	132	242	
33B	2:56 p.m.	2:58 p.m.	280								76
34B	3:04 p.m.	3:06 p.m.	230	320	320	310	310	317	132		101
34B	3:09 p.m.	3:16 p.m.	230							244	
34A	3:22 p.m.	3:29 p.m.	230	310	320	310	320	317	130	250	
34A	3:30 p.m.	3:33 p.m.	230								97
35A	3:43 p.m.	3:45 p.m.	230	310	310	320	315	320	135		77
35A	3:47 p.m.	4:01 p.m.	230							272	
35B	4:37 p.m.	4:39 p.m.	230	315	325	310	310	302	125	254	
35B	4:40 p.m.	4:43 p.m.	230								103

*Values obtained from a tachometer manufactured by The Electric Tachometer Corp., Philadelphia, Pa.

†Average of 22 plates

‡Approximately 206,000 sq. ft. of board (samples plus scrap) were fabricated.

boxes and sample sheets produced. The data referred to above were obtained and recorded by various representatives of The Institute of Paper Chemistry who were assigned to specific tasks and positions about the machine. At the single-facer, one representative measured the temperature at both the front and the back of the top and bottom corrugating rolls twice during each run combination. Another representative recorded the temperature readings for each of the 22 hot plates for both the A- and B-flute combining periods of each run combination. Alnor pyrometers, which had been checked for accuracy, were used in measuring the temperatures. Temperature check diagrams were used to assist the observers in collecting and recording the data. The pressure of the steam being supplied to the hot-plate section was checked and recorded during both the A-flute and the B-flute combining periods of each run combination.

One Institute representative was assigned the responsibility of checking and recording the data that were pertinent to the application of the starch adhesive. The characteristics measured were: (*1*) the gel point of the starch suspension in the supply tank, (*2*) the pH of the suspension, (*3*) the temperature of the suspension in the supply tank and in the machine pan, (*4*) the viscosity of the suspension in the tank and in the pan, and (*5*) the specific gravity of the starch suspension in the supply tank. These data are given in Table VI; in general, they indicate that the starch suspension characteristics were rather uniform throughout the run.

TABLE VI

DATA ON THE CORRUGATING ADHESIVE DURING FABRICATION RUN

Time	pH	Gel Point in Tank, °F.	Temperature, °F. Storage Tank	Temperature, °F. Starch Pan	Viscosity, sec.* Storage Tank	Viscosity, sec.* Starch Pan	Specific Gravity in Storage Tank	Mixing Room Temp., °F.
8:40 a.m.	11.77	149	98	95	31.0		1.075	
9:20 a.m.				97		30.5		72
9:50 a.m.			98	97	30.6			74
10:25 a.m.		150						
10:35 a.m.			100	101	29.3	27.0		
10:55 a.m.				102				77
11:10 a.m.				102	30.0			
11:20 a.m.				104		26.0		
11:30 a.m.	11.65		95	98	29.5	26.0		77
12:00 p.m.		146		98	30.0	27.0	1.075	
1:00 p.m.			99	98	38.0	37.0		
1:15 p.m.			100		35.0			
1:30 p.m.			100		33.0	34.0		81
1:40 p.m.			101	103	32.0	31.0		
2:00 p.m.			102	103	30.0	29.5		
2:15 p.m.	11.30							
2:35 p.m.		153	104	106	29.0	27.0		
3:15 p.m.			104	106	27.0	27.0	1.075	
3:55 p.m.			107	108	29.0	26.5		
4:30 p.m.	11.25		106	104	30.0	26.0	1.075	
4:55 p.m.		153	106	104	30.0	27.0		81

*The Institute of Paper Chemistry viscometer (water—15 seconds at 72° F.)

The samples obtained during the fabrication of the various run combinations were forwarded to the Institute where the testing program was carried out. The testing program consisted of determining the physical characteristics of (*1*) the component materials from which the combined board was produced, (*2*) the combined board from which the boxes were produced, and (*3*) the finished boxes.

Components

A component sample may be defined as a sample of the liner or of the corrugating medium which is representative of the material being fabricated into combined board at any specific sampling period of any given run combination. In the Weight-Distribution Study, each component sample included specimens selected across the full width of the rolls. The component samples were preconditioned and conditioned before they were tested for the following physical characteristics: basis weight, caliper, bursting strength, G.E. puncture, Elmendorf tear, Amthor tensile and stretch, and ring compression. The bursting strength values for the corrugating mediums were obtained on both the "Jumbo" and the "Paper" (Model C) bursting strength testers. Ring compression tests were obtained on two sizes of specimens—2 x ½ in. and 6¼ x ½ in. The preconditioning, conditioning, testing procedures, and number of specimens were essentially the same as those given in Baseline Studies 1, Part II.

Combined Board Tests

Following the fabrication of the selected rolls into corrugated boards and their subsequent conversion into boxes, the "knockdown" boxes were transported by truck to The Institute of Paper Chemistry. As soon as the boxes were received, each specimen within each run combination or sample lot was stamped with a code number which identified that particular sample lot. Following the coding, the specimens in each sample lot were thoroughly shuffled. Ten "knockdown" boxes in the case of the B-flute boxes and five boxes in the case of the A-flute boxes were withdrawn for the combined board tests. For the B-flute boxes, an equal number of front and back specimens were selected. Within each sample lot of B-flute boxes, the combined board samples taken from the two positions were tested separately. However, the results shown in the body of the report are the average of the results thus obtained. The combined board tests were carried out on the panels and flaps of the boxes selected for testing from each sample lot. The number of specimens per sample and the combined board tests performed were the same as outlined in Baseline Studies 1, Part II.

The box samples which were used for the combined board tests were preconditioned for at least 24 hours at a relative humidity of not higher than 35% and at a temperature of 73 ± 3.5° F. Following the preconditioning, the samples were conditioned for at least 48 hours, and were tested in an atmosphere of 50 ± 2% relative humidity and a temperature of 73 ± 3.5° F.

Box Tests

The specimens in each sample lot were coded and thoroughly shuffled to obtain random selection of each test specimen. In the case of the B-flute boxes, in order to compensate for any possible difference between the boxes made on the front side of the corrugator and those made on the back side, equal numbers of the two types of boxes were tested and the results are given as the average of the two tests. Both the A- and the B-flute samples were tested for top- and end-load compression. In addition, the B-flute samples were tested in the small revolving drum and the 12-inch corner drop test.

The number of specimens per sample and the testing procedures used were the same as those outlined in Baseline Studies 1, Part II. Prior to testing, the boxes were preconditioned for at least 24 hours in an atmosphere of 35 ± 2% relative humidity and a temperature of 73 ± 3.5° F. They were then placed in an atmosphere of 50 ± 2% relative humidity and a temperature of 73 ± 3.5° F. for 48 hours. At the end of this period the bottom flaps of the boxes were flexed and then were sealed with silicate of soda. Those boxes which were to be used for the drum and drop tests were loaded with 24 No. 2½ cans (filled with water) and the closure was completed by flexing and sealing the top flaps. Those boxes which were to be used for the compression test were not loaded. They were sealed by using sealing boards to hold the flaps in place while the sodium silicate adhesive dried. After the sealing operations, the boxes were allowed to condition 48 hours in an atmosphere of 50 ± 2% relative humidity and a temperature of 73 ± 3.5° F. before they were tested.

DISCUSSION OF RESULTS

The Effect of Liner Weight

Single-face and double-face liners are structural elements of combined board and boxes. As such, the effect of their weight on the physical characteristics of the combined boards and boxes fabricated from them is of importance in a weight-distribution study. In this study of the effect of liner weight, "balanced" combined boards fabricated from 38-lb. DF, 42-lb. DF, 47-lb. WF, and 47-lb. DF Fourdrinier kraft liners were considered. In addition, one "unbalanced" combined board fabricated with 47-lb. WF and 90-lb. WF Fourdrinier kraft liners was tested. The term "unbalanced" is used to indicate a board having single- and double-face liners of different weights.

The Effect of Liner Weight on Box Characteristics

The results of the physical tests on the A- and B-flute boxes made from Run Combinations 23, 24, 25, 26, and 35 are given in Tables VII and VIII, and are graphically presented in Figures 3 to 6, inclusive. In Figure 3, the top- and end-load compression test values on A-flute boxes are graphed against the average weight of the liners used in their fabrication. The same type of graph for the B-flute boxes is given in Figure 4. In general, both graphs indicate an increase in top- and end-load compressive strengths as the liner weight is increased. The progressive increase in compressive strength of both A- and B-flute boxes with increase in liner weight was quite uniform for end-load compression. However, the B-flute box samples showed a more uniform increase in top-load compression with increase in liner weight than did the A-flute box samples. An examination of the results indicates that, under the conditions of the study and within the weight range involved, the greater the average weight of the liners used, the higher the compressive strength values of the corresponding boxes.

In addition to the compression tests, drum and drop tests were carried out on the boxes fabricated with the B-flute board. The results are given in Table VIII and are shown graphically in Figures 5 and 6. Both the drum and the drop test results indicate that the general trend was for the values to increase as the weight of the liners of the box increased. This trend was more apparent in the drop test than in the drum test.

The Effect of Liner Weight on Combined Board Characteristics

The results of the combined board tests on test specimens taken from boxes made from Run Combinations 23, 24, 25, 26, and 35 are given in Tables IX and X for A- and B-flute, respectively. Graphs of the results of the combined board tests vs. the average weight of the single- and double-face liners are given in Figures 7 and 8.

It may be observed that there was a general tendency for the bursting strength to increase as the weight of liners increased. This trend is more evident in the results obtained on the B-flute samples than in those obtained on the A-flute samples. A comparison of the combined board test results obtained on the A- and B-flute samples

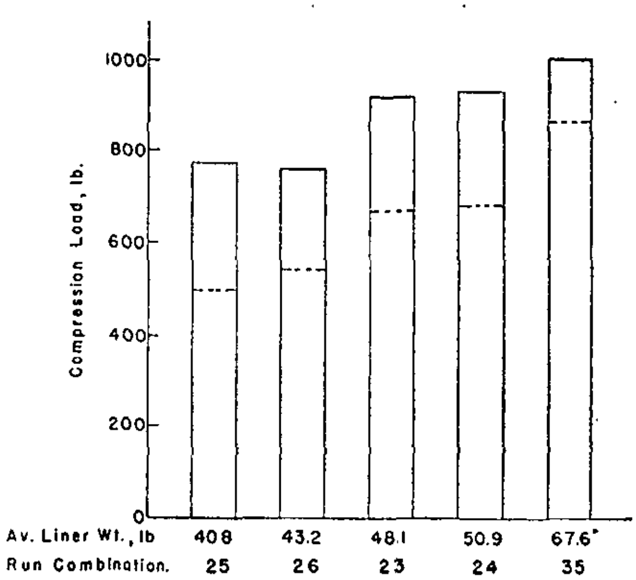

Figure 3. Compression Tests on A-Flute Boxes Made with Different Weight Liners.

——————Top Load (0–0.75 inch)
..................End Load (0–0.50 inch)

* This value is the average of S.F. liner 48.0 and D.F. liner 87.2 lbs.

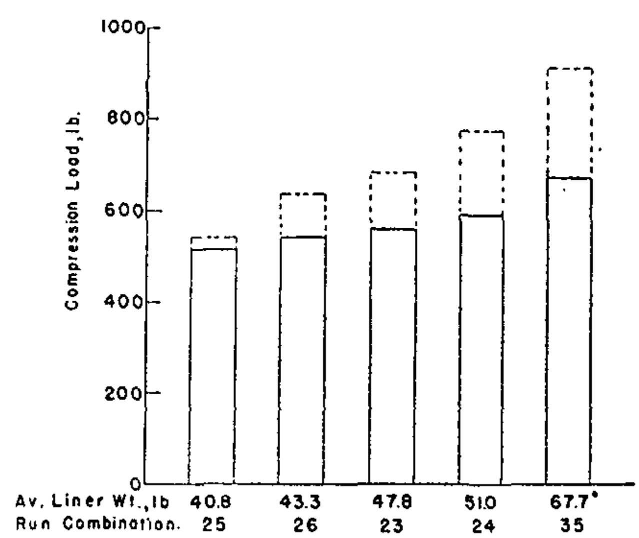

Figure 4. Compression Tests on B-Flute Boxes Made with Different Weight Liners.

——————Top Load (0–0.75 inch)
..................End Load (0–0.50 inch)

* This value is the average of S.F. liner 48.3 and D.F. liner 87.1 lbs.

TABLE VII

PHYSICAL CHARACTERISTICS OF A-FLUTE BOXES MADE WITH DIFFERENT WEIGHT LINERS

Run Combination	Materials* Single-Face Liner	Materials* Double-Face Liner	Average Basis Weight of Liners, lb.	Weight of 1000 Boxes, lb.	Top-Load Compression, lb. Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	0.-0.75 in.	Top-Load Max. Load, lb.	Top-Load Deflection at Max. Load, in.	End-Load Compression, lb. Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	End-Load Max. Load, lb.	End-Load Deflection at Max. Load, in.
25	38-lb. DF	38-lb. DF	40.8	2656	312	775	777	777	0.44	456	504	504	0.29
26	42-lb. DF	42-lb. DF	43.2	2776	299	760	765	765	0.49	423	546	546	0.35
23	47-lb. WF	47-lb. WF	48.1	2950	279	898	931	931	0.52	546	676	676	0.36
24	47-lb. DF	47-lb. DF	50.9	3062	281	935	938	938	0.47	519	687	687	0.35
35	47-lb. WF	90-lb. WF	67.6	3788	302	972	1009	1024	0.57	731	868	868	0 31

*26-lb. kraft corrugating medium used in each combination

TABLE VIII

PHYSICAL CHARACTERISTICS OF B-FLUTE BOXES MADE WITH DIFFERENT WEIGHT LINERS

Run Combination	Materials* Single-Face Liner	Materials* Double-Face Liner	Average Basis Weight of Liners, lb.	Weight of 1000 Boxes, lb.	Drum Test No. of Falls to 1st Can Cut	1st 6 in. Tear	Box Failure	Drop Test No. of Drops to 1st Can Cut	1st 6 in. Tear	Box Failure	Top-Load Compression, lb. Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	0.-0.75 in.	Top-Load Max. Load, lb.	Top-Load Deflection at Max. Load, in.	End-Load Compression, lb. Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	End-Load Max. Load, lb.	End-Load Deflection at Max. Load, in.
25	38-lb. DF	38-lb. DF	40.8	1034	13	50	64	4.3	11.4	13.1	436	516	516	516	0.33	541	541	541	0.21
26	42-lb. DF	42-lb. DF	43.3	1084	18	62	70	3.8	11.4	13.3	437	544	544	544	0.37	626	637	637	0.23
23	47-lb. WF	47-lb. WF	47.8	1150	12	56	65	3.7	10.6	11.7	386	561	561	561	0.40	548	683	683	0.31
24	47-lb. DF	47-lb. DF	51.0	1200	9	55	71	5.6	12.8	14.8	423	592	592	592	0.36	688	777	777	0.29
35	47-lb. WF	90-lb. WF	67.7	1506	28	88	97	9 2	15.8	17.2	502	673	677	677	0.43	763	915	915	0 33

*26-lb. kraft corrugating medium used in each combination

TABLE IX

PHYSICAL CHARACTERISTICS OF A-FLUTE COMBINED BOARDS MADE WITH DIFFERENT WEIGHT LINERS

Run Combination	Materials* Single-Face Liner	Double-Face Liner	Average Basis Weight of Liners, lb.	Basis Weight of Combined Board, lb.	Caliper, points	Bursting Strength, points	G. E. Puncture, units	G. E. Stiffness, units	Pin Adhesion, lb.	H. & D. Flat Crush, lb./sq. in.
25	38-lb. DF	38-lb. DF	40.8	124	173.5	245	248	96	46	27.0
26	42-lb. DF	42-lb. DF	43.2	130	177.8	236	267	102	47	27.0
23	47-lb. WF	47-lb. WF	48.1	138	165.9	242	251	108	52	23.7
24	47-lb. DF	47-lb. DF	50.9	142	180.5	262	264	116	49	24.7
35	47-lb. WF	90-lb. WF	67.6	180	186.6	324	346	129	57	25.1

*26-lb. kraft corrugating medium used in each combination

TABLE X

PHYSICAL CHARACTERISTICS OF B-FLUTE COMBINED BOARD MADE WITH DIFFERENT WEIGHT LINERS

Run Combination	Materials* Single-Face Liner	Double-Face Liner	Average Basis Weight of Liners, lb.	Basis Weight of Combined Board, lb.	Caliper, points	Bursting Strength, points	G. E. Puncture, units	G. E. Stiffness, units	Pin Adhesion, lb.	H. & D. Flat Crush, lb./sq. in.
25	38-lb. DF	38-lb. DF	40.8	121	108.3	250	250	99	72	38.0
26	42-lb. DF	42-lb. DF	43.3	126	108.8	256	262	100	81	37.8
23	47-lb. WF	47-lb. WF	47.8	135	110.0	259	243	108	82	38.7
24	47-lb. DF	47-lb. DF	51.0	139	115.0	263	274	116	79	36.8
35	47-lb. WF	90-lb. WF	67.7	175	124.0	336	316	135	88	38.4

*26-lb. kraft corrugating medium used in each combination

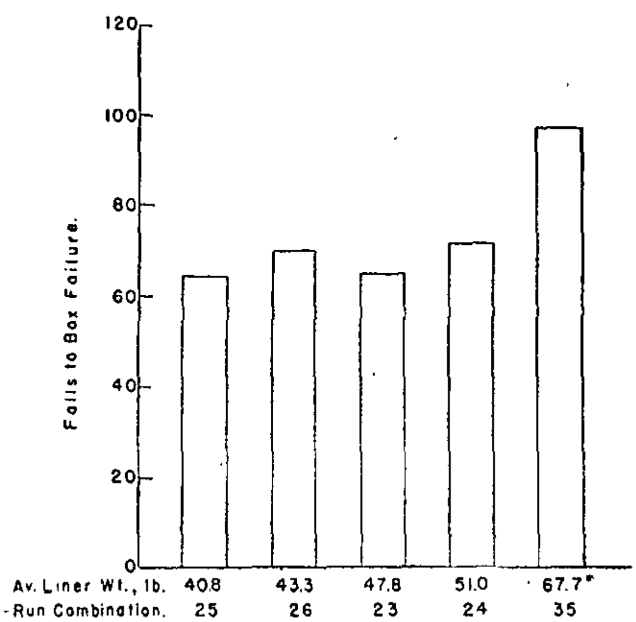

FIGURE 5. Drum Tests on B-Flute Boxes Made with Different Weight Liners.

* This value is the average of S.F. liner 48.3 and D.F. liner 87.1 lbs.

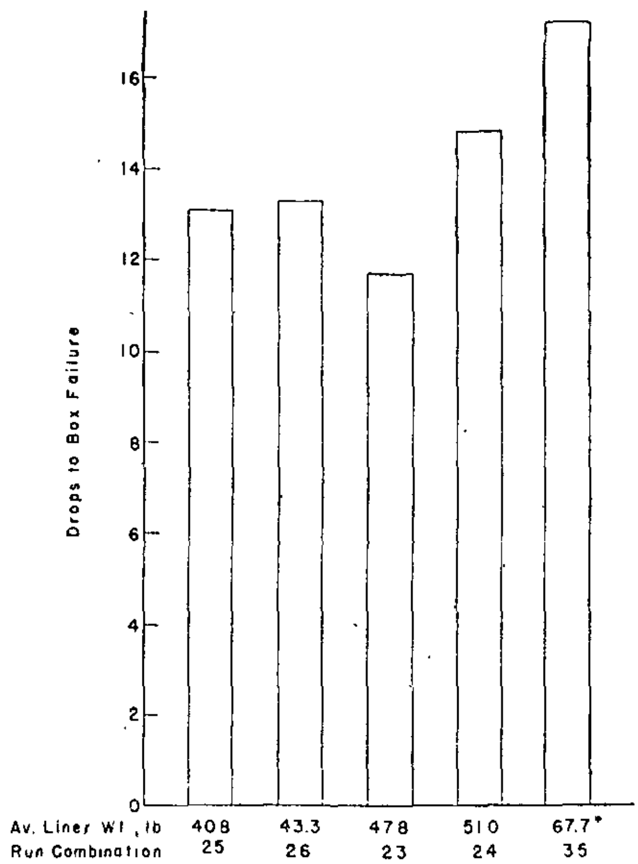

FIGURE 6. Twelve-Inch Corner Drop Tests on B-Flute Boxes Made with Different Weight Liners.

* This value is the average of S.F. liner 48.3 and D.F. liner 87.1 lbs.

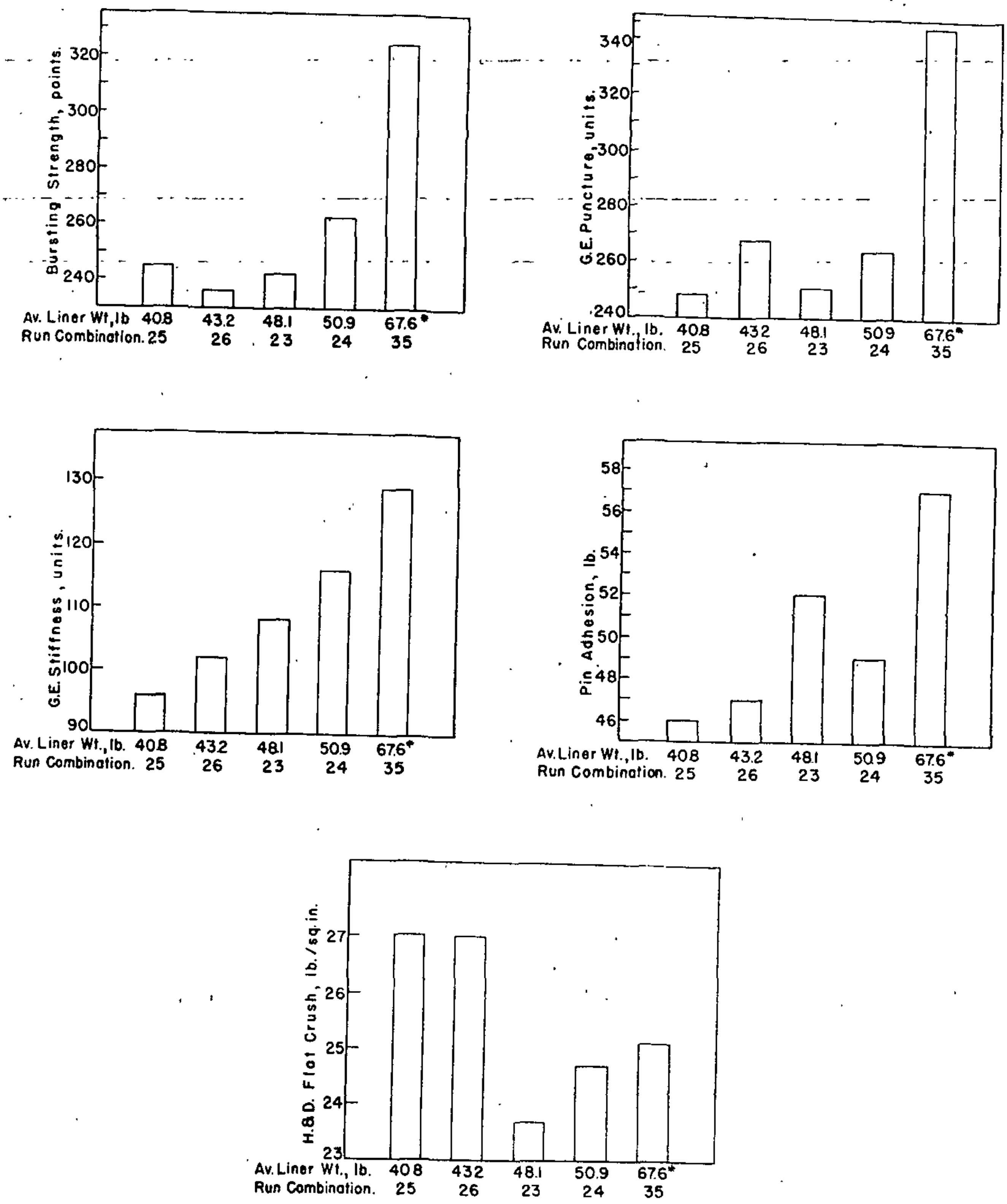

FIGURE 7. Physical Characteristics of A-Flute Combined Board Made with Different Weight Liners.

* This value is the average of S.F. liner 48.0 and D.F. liner 87.2 lbs.

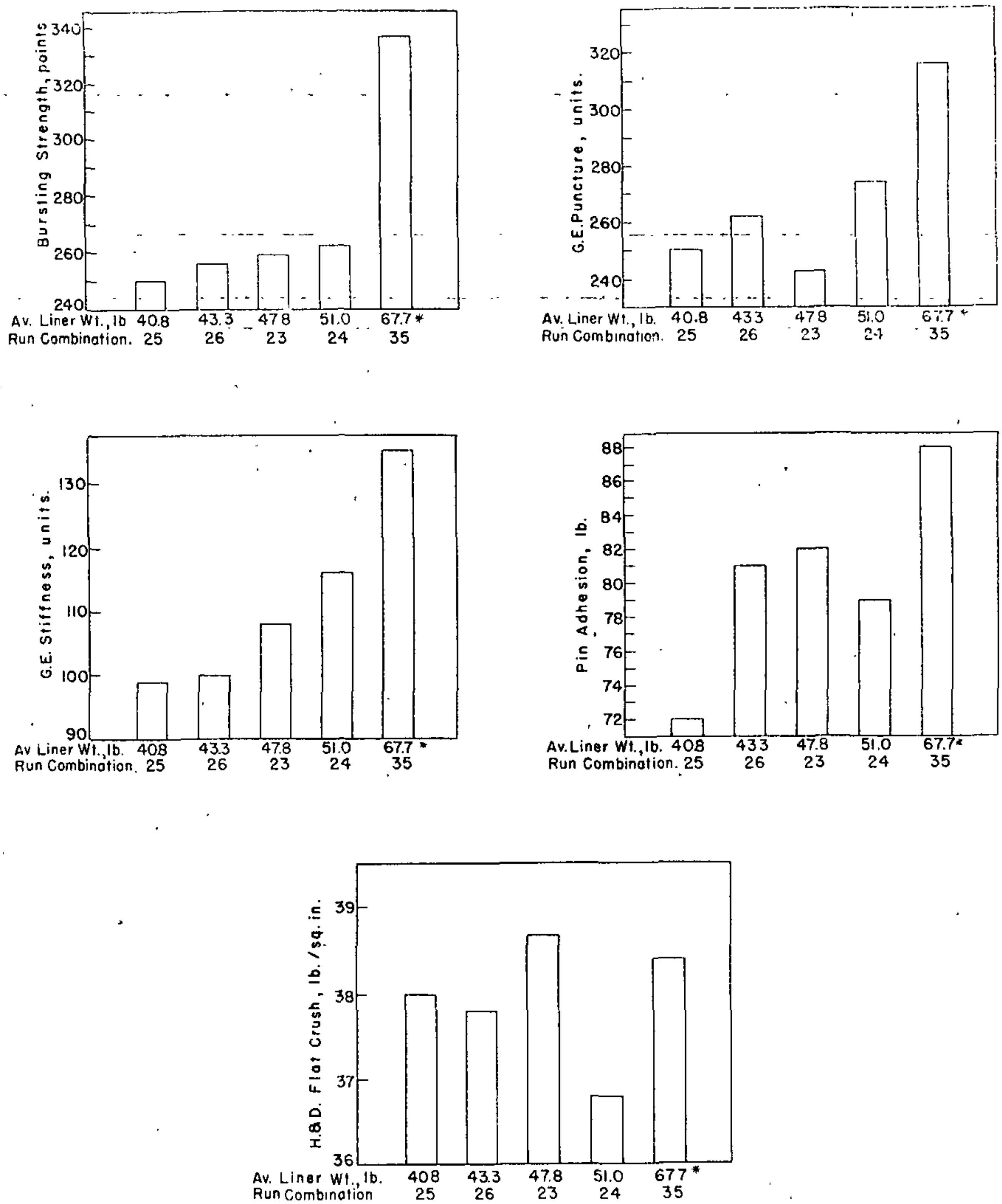

FIGURE 8. Physical Characteristics of B-Flute Combined Board Made with Different Weight Liners.

* This value is the average of S.F. liner 48.3 and D.F. liner 87.1 lbs.

TABLE XI

COMPARISON OF COMBINED BOARD TESTS ON A- AND B-FLUTE BOARDS

Run Combination	Materials* Single-Face Liner	Materials* Double-Face Liner	Basis Weight, lb. A	Basis Weight, lb. B	Caliper, points A	Caliper, points B	Bursting Strength, points A	Bursting Strength, points B	G. E. Puncture, units A	G. E. Puncture, units B	G. E. Stiffness, units A	G. E. Stiffness, units B	Pin Adhesion, lb. A	Pin Adhesion, lb. B	H. and D. Flat Crush, lb./sq. in. A	H. and D. Flat Crush, lb./sq. in. B
25	38-lb. DF	38-lb. DF	124	121	173.5	108.3	245	250	248	250	96	99	46	72	27.0	38.0
26	42-lb. DF	42-lb. DF	130	126	177.8	108.8	236	256	267	262	102	100	47	81	27.0	37.8
23	47-lb. WF	47-lb. WF	138	135	165.9	110.0	242	259	251	243	108	108	52	82	23.7	38.7
24	47-lb. DF	47-lb. DF	142	139	180.5	115.0	262	263	264	274	116	116	49	79	24.7	36.8
35	47-lb. WF	90-lb. WF	180	175	186.6	124.0	324	336	345	316	129	135	57	88	25.1	38.4

*26-lb. kraft corrugating medium used in each combination

is given in Table XI. It may be noted that the bursting strength values for the B-flute samples were higher than those obtained on the corresponding A-flute samples.

The results of the G.E. puncture test indicate that the greater the weight of the liners the greater the G.E. puncture values. Also, there appears to be a tendency for the G.E. puncture values on the A-flute samples to be higher than those obtained on the corresponding B-flute samples.

The results of the G.E. stiffness test on samples of A- and B-flute corrugated board given in Tables IX, X, and XI show that the stiffness values increase with increase in the weight of the liners. Also, the G.E. stiffness results obtained on the A-flute samples appear to be approximately the same as those obtained on the corresponding B-flute samples. It might be expected, from a consideration of the combined board as a structure, that the A-flute samples might exhibit higher G.E. stiffness values than the B-flute samples because of the thickness. However, the effect of the greater thickness of the A-flute board may be offset by the greater number of flutes per inch of the B-flute board. The effect of the number of flutes per inch on the magnitude of the H. and D. flat crush values also may be observed when the test values for the A- and B-flute board samples are compared. The average H. and D. flat crush values for the B-flute samples were, in general, about 10 lb. per sq. in. higher than the corresponding values for the A-flute samples.

The H. and D. flat crush data given in Tables IX, X, and XI and in Figures 7 and 8 show that both the A- and B-flute crush results were quite uniform. This indicates, as might be expected, that the properties measured by the flat crush test are not dependent on the strength characteristics of the liners. Rather, they appear to be primarily dependent on the characteristics of the corrugating medium.

The bursting strength, G.E. puncture, and G.E. stiffness appear to follow the same trend—namely, to increase with increase in the weight of the liners. The box test values likewise showed this same general trend. This would indicate that the above mentioned combined board tests would show a high correlation with box tests. However, correlation based on only five run combinations would not have much significance.

Physical Characteristics of Components

The physical characteristics of the standard kraft corrugating medium and the different weight liners used in the fabrications of the A-flute combined boards are given in Table XII. Similar characteristics for the components used to fabricate the B-flute combined boards are given in Table XIII. It may be observed in Tables XII and XIII that the 26-lb. kraft standard *corrugating medium had rather uniform physical characteristics*. This is reflected in the uniformity of the flat crush results obtained on the combined board

TABLE XII

PHYSICAL CHARACTERISTICS OF COMPONENTS FABRICATED INTO A-FLUTE COMBINED BOARD*

Run Combination	Grade and Finish	Component Position	Roll No.	Basis Weight, lb.	Caliper, points	Bursting Strength, points "Jumbo"	Bursting Strength, points "Paper"	G. E. Puncture, units	Ring Compression, lb. 2x½ in. In	Ring Compression, lb. 2x½ in. Across	Ring Compression, lb. 6¼ x ½ in. In	Ring Compression, lb. 6¼ x ½ in. Across	Elemendorf Tear, g./sheet In	Elemendorf Tear, g./sheet Across	Amthor Tensile, lb./in. In	Amthor Tensile, lb./in. Across	Amthor Stretch, % In	Amthor Stretch, % Across
25	38-lb. DF	S.F.	1	40.6	14.0	99		34	30.3	26.5	89.4	78.0	381	394	72.8	50.2	2.0	3.5
	38-lb. DF	D.F.	2	40.9	14.1	100		36	31.8	27.7	86.3	77.9	383	386	72.6	51.8	2.3	4.0
		Liner Av.		40.8	14.1	99		35	31.0	27.1	87.8	78.0	382	390	72.7	51.0	2.1	3.7
	26-lb.	Corr.	2	27.5	9.0	76	83	21	19.3	15.7	46.6	39.2	244	255	57.2	34.3	2.2	4.4
26	42-lb. DF	S.F.	1	42.8	14.9	101		38	30.5	26.2	101.3	82.4	402	394	77.5	52.9	2.1	3.5
	42-lb. DF	D.F.	2	43.7	14.4	106		40	33.9	28.3	92.7	79.6	424	428	75.2	52.5	2.6	4.0
		Liner Av.		43.2	14.6	103		39	32.2	27.2	97.0	81.0	413	411	76.3	52.7	2.4	3.7
	26-lb.	Corr.	2	27.6	9.3	74	81	22	22.3	18.1	51.7	43.6	240	253	58.9	36.2	2.2	4.4
23	47-lb. WF	S.F.	1	47.9	16.1	103		39	32.7	26.4	114.5	98.5	422	428	78.8	55.7	2.0	2.9
	47-lb. WF	D.F.	2	48.3	16.2	105		39	33.2	30.5	111.3	103.6	467	458	81.5	55.7	1.9	2.8
		Liner Av.		48.1	16 1	104		39	33.0	28.4	112.9	101.0	445	443	80.1	55.7	1.9	2.9
	26-lb.	Corr.	1	27.1	9.4	72	78	20	18.7	15.0	49.1	41.0	240	243	59.4	34.8	2.0	4.2
24	47-lb. DF	S.F.	1	50.8	16.8	110		47	32.7	29.1	104.8	95.7	466	483	87.9	57.9	1.9	3.1
	47-lb. DF	D.F.	2	51.0	16.6	112		48	36.7	32.3	99.6	94.9	474	497	87.2	56.8	1.9	2.9
		Liner Av.		50.9	16.7	111		47	34.7	30.7	102.2	95.3	470	490	87.6	57.3	1 9	3.0
	26-lb.	Corr.	1	26.4	9.2	70	79	20	20.7	17.4	47.2	41.4	237	249	57.8	34.1	2.0	4.3
35	47-lb. WF	S.F.	3	48.0	15.8	103		42	35.5	32.7	104.7	87.2	417	452	77.1	54.8	1.8	3.1
	90-lb. WF	D.F.	2	87.2	26.9	143		94	55.7	48.0	162.9	141.4	820	838	113.3	73.2	1.6	2.6
		Liner Av.		67.6	21.3	123		68	45.6	40.3	133.8	114.3	619	645	95.2	64.0	1.6	2.9
	26-lb.	Corr.	5	26.4	8.9	70	75	20	20.9	17.7	40.4	33.0	217	233	54.5	36.0	1.9	4.4

*Both liners and corrugating medium were kraft

TABLE XIII

PHYSICAL CHARACTERISTICS OF COMPONENTS FABRICATED INTO B-FLUTE COMBINED BOARD*

Run Combination	Grade and Finish	Component Position	Roll No.	Basis Weight, lb.	Caliper, points	Bursting Strength, points "Jumbo"	Bursting Strength, points "Paper"	G. E. Puncture, units	Ring Compression, lb. 2 x ½ in. In	Ring Compression, lb. 2 x ½ in. Across	Ring Compression, lb. 6¼ x ½ in. In	Ring Compression, lb. 6¼ x ½ in. Across	Elmendorf Tear, g./sheet In	Elmendorf Tear, g./sheet Across	Amthor Tensile, lb./in. In	Amthor Tensile, lb./in. Across	Amthor Stretch, % In	Amthor Stretch, % Across
25	38-lb. DF	S.F.	1	40.7	14.2	101		35	29.8	27.3	98.8	82.9	382	404	73.4	51.9	2.2	3.7
	38-lb. DF	D.F.	2	41.0	14.3	101		37	29.3	26.1	94.4	80.4	403	404	71.2	53.2	2.5	3.9
		Liner Av.		40.8	14.2	101		36	29.5	26.7	96.6	81.7	393	404	72.3	52.6	2.3	3.8
	26-lb.	Corr.	2	27.3	9.4	76	84	20	18.8	15.0	49.0	41.1	238	253	56.8	34.1	2.4	4.6
26	42-lb. DF	S.F.	1	42.9	15.1	98		38	32.1	27.7	98.0	91.6	411	402	77.7	53.2	1.9	3.3
	42-lb. DF	D.F.	2	43.7	14.4	106		40	33.6	27.9	96.5	81.5	426	430	76.0	52.1	2.4	3.6
		Liner Av.		43.3	14.7	102		39	32.8	27.8	97.2	86.6	419	416	76.8	52.7	2.2	3.5
	26-lb.	Corr.	2	27.3	9.4	76	84	21	19.2	16.5	48.8	41.0	233	251	56.0	34.5	2.4	4.5
23	47-lb. WF	S.F.	1	47.9	16.1	102		38	31.2	28.0	108.5	96.3	430	435	78.3	55.8	2.0	2.8
	47-lb. WF	D.F.	2	47.6	16.0	104		39	32.8	29.5	111.2	99.5	467	458	79.8	55.3	1.8	2.8
		Liner Av.		47.8	16.0	103		39	32.0	28.7	109.8	97.9	448	446	79.0	55.6	1.9	2.8
	26-lb.	Corr.	1	27.2	9.3	75	81	20	19.9	15.3	48.2	40.5	235	241	58.0	34.0	2.2	4.2
24	47-lb. DF	S.F.	1	51.0	16.8	113		48	34.8	29.8	100.7	90.6	480	504	87.4	57.2	2.0	3.1
	47-lb. DF	D.F.	2	51.1	16.6	111		48	35.8	31.2	109.5	94.5	460	494	86.9	55.7	1.8	2.9
		Liner Av.		51.0	16.7	112		48	35.3	30.5	105.1	92.5	470	499	87.1	56.5	1.9	3.0
	26-lb.	Corr.	1	26.6	9.3	73	80	20	20.4	16.6	49.2	41.9	232	243	58.6	33.8	2.1	4.1
35	47-lb. WF	S.F.	3	48.3	15.8	105		42	36.2	32.6	107.5	93.2	429	451	81.2	56.0	2.0	3.2
	90-lb. WF	D.F.	2	87.1	26.5	145		95	57.0	49.8	162.3	142.7	777	842	116.2	73.5	1.7	2.6
		Liner Av.		67.7	21.2	125		68	46.6	41.2	134.8	117.9	603	647	98.7	64.8	1.8	2.9
	26-lb.	Corr.	5	27.4	8.9	73	78	22	21.5	17.3	43.6	34.9	230	250	55.3	35.1	2.0	4.4

*Both liners and corrugating medium were kraft

Boxes and combined board flat stock of both A- and B-flute were produced from 42-lb. DF Fourdrinier kraft liners and four different types of corrugating mediums—i.e., kraft, chestnut, Chem Fibre, and straw.

Effect of Type of Corrugating Medium on Box Characteristics

The effect of the type of corrugating medium on box characteristics may be studied by examining the test data for Run Combinations 26, 27, 28, and 29. These data are given in Tables XIV and XV, and in Figures 9-12, inclusive.

The compression test-data show that the A-flute boxes made with different types of corrugating mediums gave a wide range of compression resistance. For example, the average top-load compression value for the boxes fabricated with Chem Fibre medium was approximately 100 pounds greater than that for the boxes fabricated with kraft medium. A similar difference was shown between the corresponding averages obtained for end-load compression. The range of the averages exhibited by the B-flute boxes was much lower. This was particularly noticeable for the top-load compression averages. Figures 9 and 10 show that the relationship of the top-load compression to end-load compression for the A-flute boxes of each of the run combinations is more nearly constant than the corresponding relationship for the B-flute boxes.

The compression test data indicate that the boxes made with Chem Fibre corrugating medium had, in general, higher compression values than those made with other types of corrugating mediums. The exception to this was the end-load compression test for the B-flute boxes, in which the 26-lb. kraft corrugating medium and the 26-lb. chestnut medium gave considerably higher values than the boxes made with the Chem Fibre corrugating medium.

In addition to the compression test, drum and drop tests were carried out on the B-flute can boxes of Run Combinations 26, 27, 28, and 29. The drum and drop test data are presented in Table XV and are illustrated graphically in Figures 11 and 12, respectively. In general, the drum and drop tests appear to arrange the boxes of the four run combinations in about the same order. The arrangement of corrugating mediums in order of decreasing drum test values was kraft, straw, Chem Fibre, and chestnut. In order of decreasing drop test the arrangement was kraft, Chem Fibre, straw, and chestnut. The results indicate that the boxes made with 26-lb. kraft corrugating were far more resistant to the rough handling action of the drum or drop test than were those made with other types of corrugating medium. The boxes made with the kraft corrugating medium gave drum values which were approximately 63% higher than those for the next lower sample (straw medium).

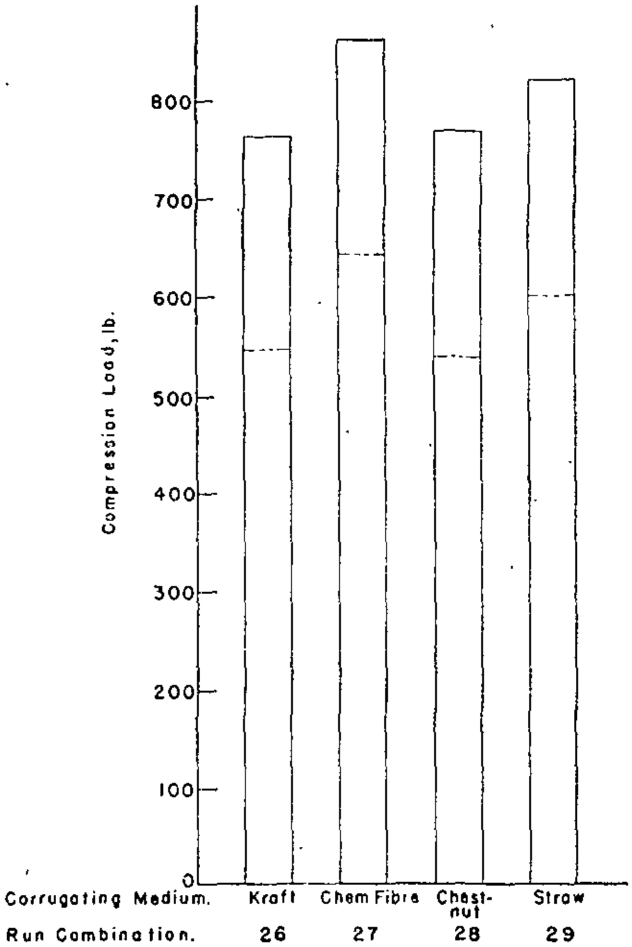

Figure 9. Compression Tests on A-Flute Boxes Made with Different Corrugating Mediums.

————Top Load (0–0.75 inch)
..............End Load (0–0.50 inch)

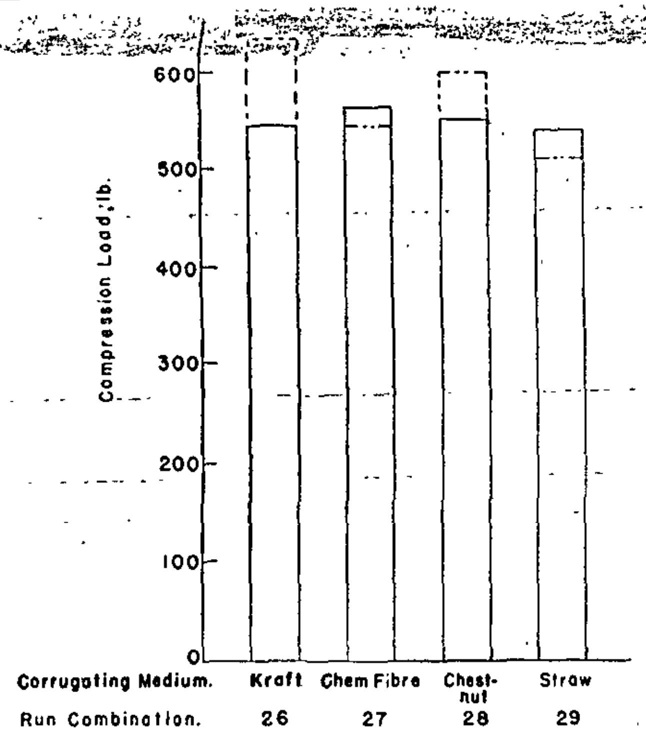

Figure 10. Compression Tests on B-Flute Boxes Made with Different Corrugating Mediums.

————Top Load (0–0.75 inch)
..............End Load (0–0.50 inch)

TABLE XIV

PHYSICAL CHARACTERISTICS OF A-FLUTE BOXES MADE WITH *DIFFERENT CORRUGATING MEDIUMS*

Run Combination	Corrugating Medium*	Average Basis Weight of Liner, lb.	Weight of 1000 Boxes, lb.	Top-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	0.-0.75 in.	Max. Load, lb.	Deflection at Max. Load, in.	End-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	Max. Load, lb.	Deflect. at Max. Load, in.
26	26-lb. kraft	43.3	2776	299	760	765	765	0.49	423	546	546	0.35
27	26-lb. Chem Fibre	43.4	2782	280	860	864	864	0.49	565	643	643	0.30
28	26-lb. chestnut	43.2	2806	292	770	770	770	0.44	442	538	538	0.32
29	30-lb. straw	43.6	3000	256	815	823	823	0.48	505	600	600	0.32

*The corrugating medium was combined with 42-lb. DF kraft liners.

TABLE XV

PHYSICAL CHARACTERISTICS OF B-FLUTE BOXES MADE WITH DIFFERENT CORRUGATING MEDIUMS

Run Combination	Corrugating Medium*	Average Basis Weight of Liners, lb.	Wt. of 1000 Boxes, lb.	Drum Test, No. of Falls to: 1st Can Cut	1st 6 in. Tear	Box Failure	Drop Test, No. of Drops to: 1st Can Cut	1st 6 in. Tear	Box Failure	Top-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	0.-0.75 in.	Max. Load, lb.	Deflection at Max. Load, in.	End-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	Max. Load, lb.	Deflection at Max. Load, in.
26	26-lb. kraft	43.3	1084	18	62	70	3.8	11.4	13.3	437	544	544	544	0.37	626	637	637	0.23
27	26-lb. Chem Fibre	43.4	1072	11	35	42	2.6	7.7	8.5	459	563	564	564	0.42	541	545	545	0.23
28	26-lb. chestnut	43.5	1084	10	28	34	2.7	6.3	6.8	407	551	552	552	0.38	580	598	598	0.25
29	30-lb. straw	43.8	1156	10	40	43	2.4	6.3	7.3	403	542	542	542	0.36	488	510	510	0.25

*The corrugating medium was combined with 42-lb. DF kraft liners.

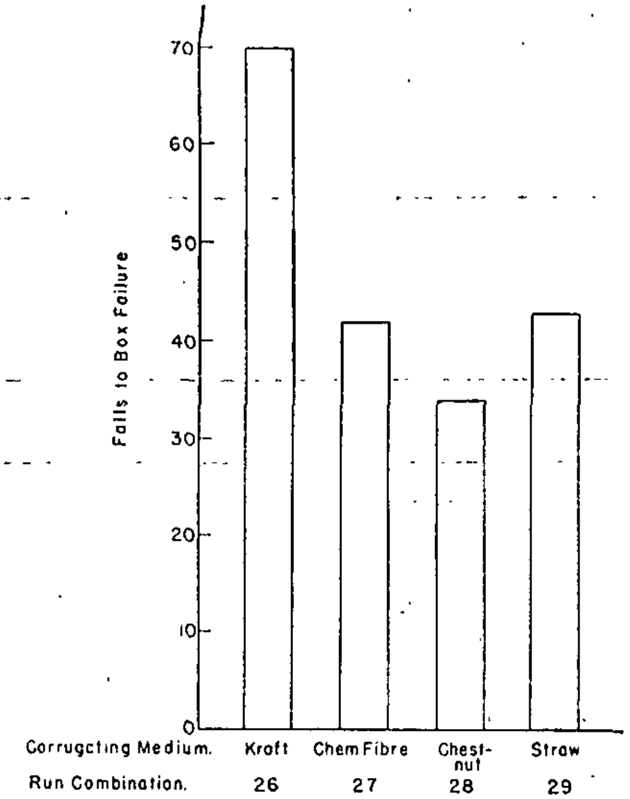

FIGURE 11. Drum Tests on B-Flute Boxes Made with Different Corrugating Mediums.

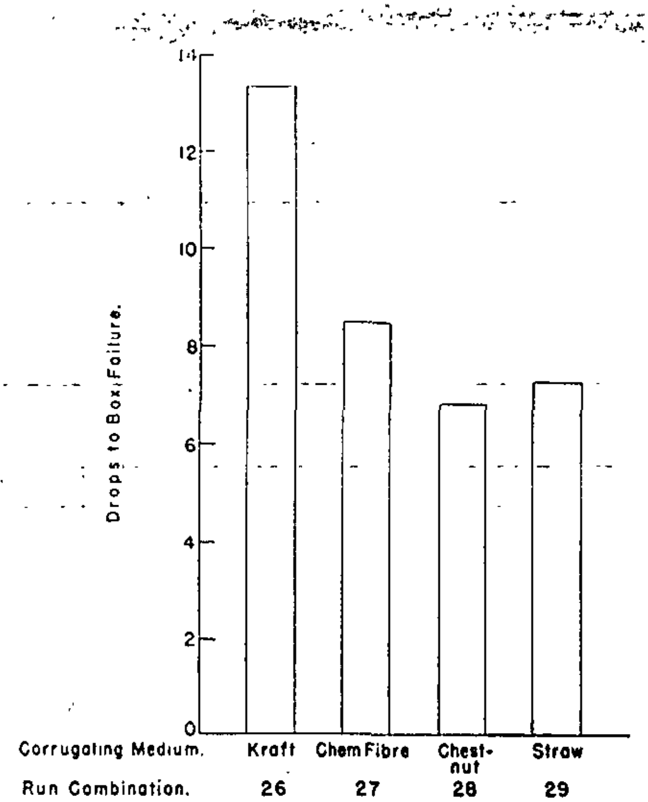

FIGURE 12. Twelve-Inch Corner Drop Tests on B-Flute Boxes Made with Different Corrugating Mediums.

Similarly, for the drop test, the corresponding difference was 56%. In both the drum and the drop test, the boxes made with the chestnut corrugating medium gave the lowest test results.

Effect of Type of Corrugating Medium on Combined Board Characteristics

The test results obtained on the combined board fabricated with the same liners and with different types of corrugating medium gave an opportunity to study the effect of a change of corrugating medium on the results obtained with the conventional combined board tests. These results are given in Tables XVI, XVII, and XVIII and are presented graphically in Figures 13 and 14. The bursting strength values for the A-flute combined board samples ranged from 236 to 247 points and for the B-flute samples from 251 to 256 points. These values indicate that the type of corrugating medium had very little influence on the bursting strength of the combined boards fabricated from them. It may be noted that the A-flute samples gave slightly lower bursting strength values than the corresponding B-flute samples.

The A- and B-flute combined board samples fabricated with kraft corrugating medium gave higher G.E. puncture values than those samples fabricated with Chem Fibre, chestnut, or straw corrugating mediums. For both the A- and B-flute samples, the arrangement of the corrugating medium samples in order of decreasing combined board G.E. puncture values was kraft, Chem Fibre, straw, and chestnut. The G.E. puncture values were approximately the same for the samples fabricated with the chestnut and straw mediums. It is apparent that the characteristics of the corrugating mediums have marked influences on the G.E. puncture results when the ranges of the puncture results are considered. For example, the range for the A-flute samples was from 210 to 267 units and for the B-flute samples from 192 to 262 units. The G.E. puncture values were slightly higher for the A-flute samples than for the B-flute samples.

The A- and B-flute combined board samples fabricated with Chem Fibre gave the highest G.E. stiffness values. These values were considerably higher than those obtained with samples fabricated with kraft, chestnut, or straw mediums. The G.E. stiffness values for the corresponding samples of A-flute and B-flute were of the same order of magnitude. In a previous paragraph it was mentioned that an A-flute board might be expected to have a greater stiffness; however, the idea was mentioned that a B-flute board had a greater number of flutes per inch that the A-flute board and that this might result in corresponding samples of A- and B-flute having nearly equal stiffness values. It may be noted that, although the samples fabricated with kraft medium gave the highest G.E. puncture averages, they gave G.E. stiffness averages considerably lower than those with Chem Fibre. This indicates that the G.E. puncture test and the G.E. stiffness test appear to measure different physical characteristics of the board.

The results of the flat crush test show that the sample fabricated with Chem Fibre medium had the highest flat crush values and the sample fabricated with straw

TABLE XVI

PHYSICAL CHARACTERISTICS OF A-FLUTE COMBINED BOARD MADE WITH DIFFERENT CORRUGATING MEDIUMS

Run Combination	Corrugating Medium*	Basis Weight, lb.	Caliper, points	Bursting Strength, points	G. E. Puncture, units	G. E. Stiffness, units	Pin Adhesion, lb.	H. & D. Flat Crush, lb./sq. in.
26	26-lb. kraft	130	177.8	236	267	102	47	27.0
27	26-lb. Chem Fibre	132	188.3	240	238	128	49	28.2
28	26-lb. chestnut	132	178.5	244	210	100	50	22.7
29	30-lb. straw	142	184.9	247	213	107	48	21.0

*The corrugating medium was combined with 42-lb. DF kraft liners.

TABLE XVII

PHYSICAL CHARACTERISTICS OF B-FLUTE COMBINED BOARD MADE WITH DIFFERENT CORRUGATING MEDIUMS

Run Combination	Corrugating Medium*	Basis Weight, lb.	Caliper, points	Bursting Strength, points	G.E. Puncture, units	G. E. Stiffness, units	Pin Adhesion, lb.	H. & D. Flat Crush, lb./sq. in.
26	26-lb. kraft	126	108.8	256	262	100	81	37.8
27	26-lb. Chem Fibre	125	118.0	251	215	120	68	45.0
28	26-lb. chestnut	126	117.4	253	192	106	83	37.3
29	30-lb. straw	133	118.4	252	193	108	75	34.3

*The corrugating medium was combined with 42-lb. DF kraft liners.

TABLE XVIII

COMPARISON OF COMBINED BOARD TESTS ON A- AND B-FLUTE BOARDS

Run Combination	Corrugating Medium*	Basis Weight, lb.		Caliper, points		Bursting Strength, points		G. E. Puncture, units		G. E. Stiffness, units		Pin Adhesion, lb.		H. and D. Flat Crush, lb./sq. in.	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B
26	26-lb. kraft	130	126	177.8	108.8	236	256	267	262	102	100	47	81	27.0	37.8
27	26-lb. Chem Fibre	132	125	188 3	118.0	240	251	238	215	128	120	49	68	28.2	45.0
28	26-lb chestnut	132	126	178.5	117.4	244	253	210	192	100	106	50	83	22.7	37.3
29	30-lb. straw	142	133	184.9	118.4	247	252	213	193	107	108	48	75	21.0	34.3

*The corrugating medium was combined with 42-lb. DF kraft liners.

the lowest flat crush values. As previously mentioned, the flat crush values appear to be dependent on the quality of the corrugating medium. As might be expected, the H. and D. flat crush values for the B-flute combined board were higher than the corresponding values for the A-flute combined board.

Physical Characteristics of Components

The physical characteristics of the components used in Run Combinations 26, 27, 28, and 29 (boxes and combined boards fabricated with different types of corrugating mediums) are given in Tables XIX and XX. Examination of the test results for the corrugating mediums indicated that, for a majority of the strength tests, the arrangements of the samples in order of decreasing test values were practically the same. The most frequent arrangement was kraft, Chem Fibre, chestnut, and straw. Occasionally, the chestnut and the straw exhibited reversed positions in the order but, in such instances, the values were practically the same. The above observations were essentially the same for the components used in the A-flute board as for those used in the B-flute board. This, of course, was to be expected since the components for the two types of board were sampled from different sections of the same rolls.

The Effect of Position of Liners of Different Weights

Effect of Liner Position on Box Characteristics

The fabrication schedule was carried out in such a manner that a number of Run Combinations (30, 31, 32, 33, 34, and 35) furnished material which, on testing, gave information regarding the behavior of boxes made with different weights of single- and double-face liners.

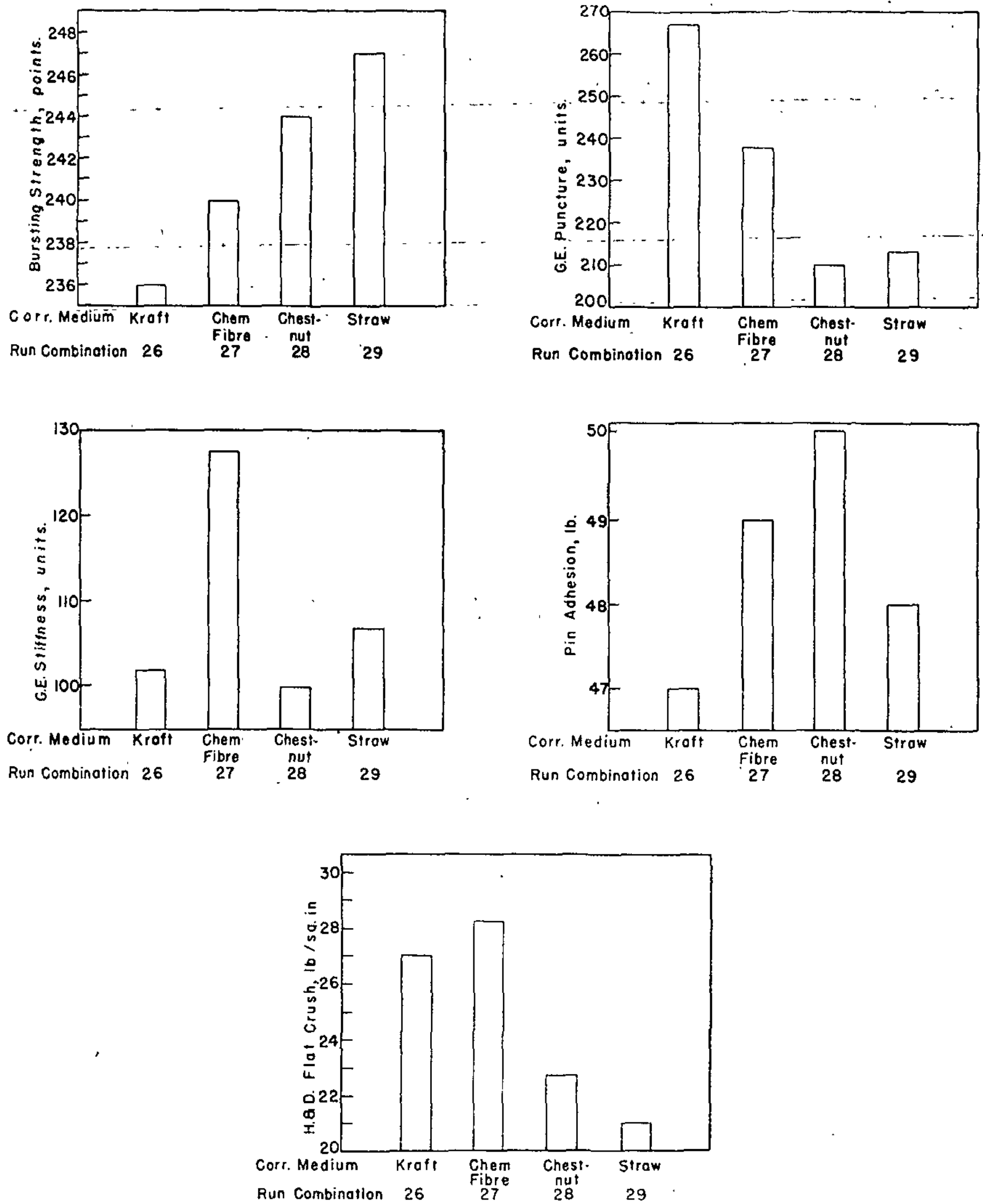

FIGURE 13. Physical Characteristics of A-Flute Combined Board Made with Different Corrugating Mediums.

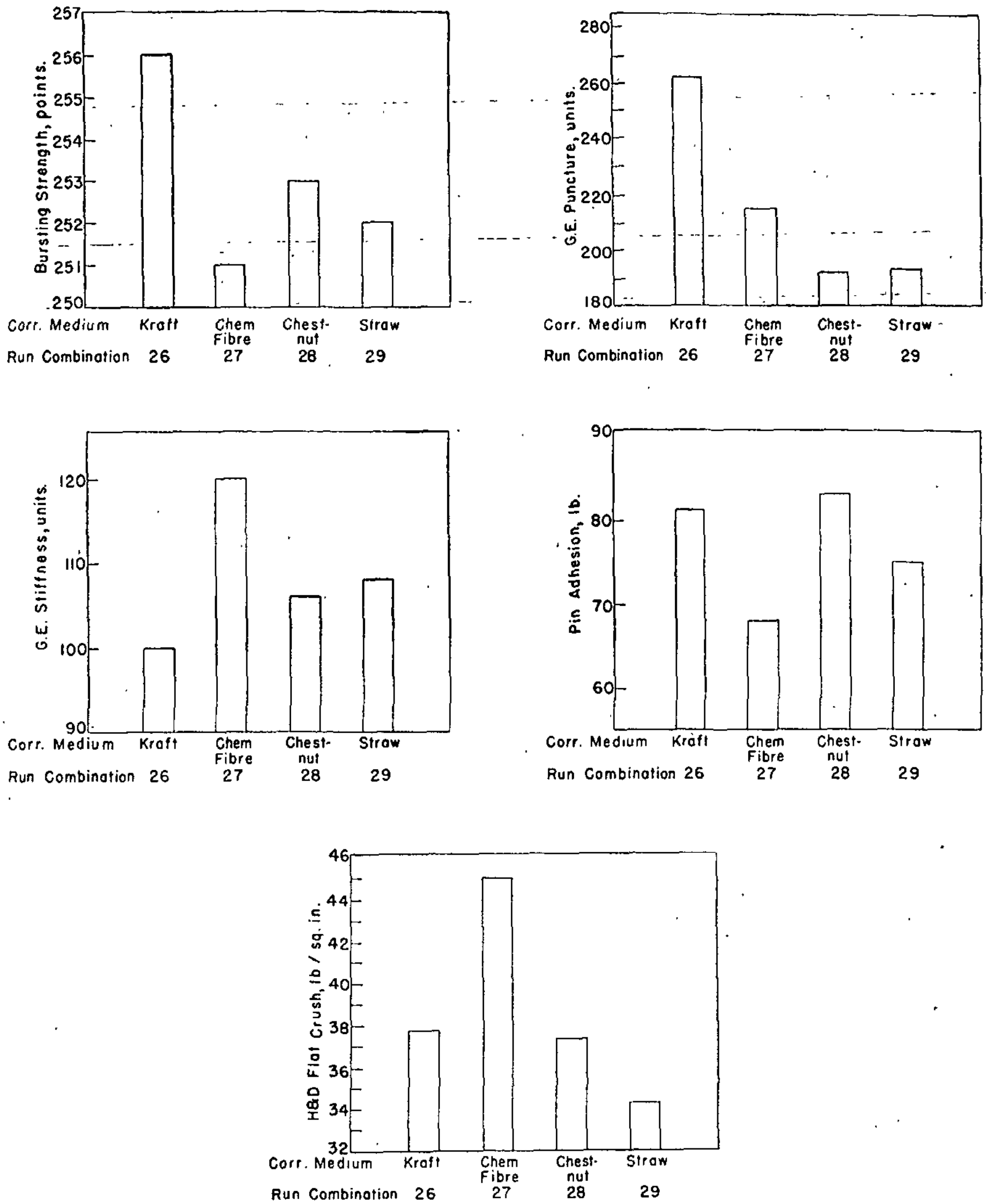

FIGURE 14. Physical Characteristics of B-Flute Combined Board Made with Different Corrugating Mediums.

TABLE XIX

PHYSICAL CHARACTERISTICS OF COMPONENTS FABRICATED INTO A-FLUTE COMBINED BOARD

Run Combination	Grade and Finish	Component Position	Roll No.	Basis Weight, lb.	Caliper, points	Bursting Strength, points "Jumbo"	Bursting Strength, points "Paper"	G. E. Puncture, units	Ring Compression, lb. 2 x ½ in. In	Ring Compression, lb. 2 x ½ in. Across	Ring Compression, lb. 6¼ x ½ in. In	Ring Compression, lb. 6¼ x ½ in. Across	Elmendorf Tear, g./sheet In	Elmendorf Tear, g./sheet Across	Amthor Tensile, lb./in. In	Amthor Tensile, lb./in. Across	Amthor Stretch, % In	Amthor Stretch, % Across
26	42-lb. DF	S.F.	1	42.8	14.9	101		38	30.5	26.2	101.3	82.4	402	394	77.5	52.9	2.1	3.5
	42-lb. DF	D.F.	2	43.7	14.4	106		40	33.9	28.3	92.7	79.6	424	428	75.2	52.5	2.6	4.0
		Liner Av.		43.2	14.6	103		39	32.2	27.2	97.0	81.0	413	411	76.3	52.7	2.4	3.7
	26-lb.	Corr. (kraft)	2	27.6	9.3	74	81	22	22.3	18.1	51.7	43.6	240	253	58.9	36.2	2.2	4.4
27	42-lb. DF	S.F.	1	43.1	14.7	103		38	31.0	27.3	98.9	80.0	388	384	75.2	52.7	2.2	3.6
	42-lb. DF	D.F.	2	43.6	14.6	104		40	33.1	28.8	90.7	80.1	409	403	74.3	52.9	2.4	3.9
		Liner Av.		43.4	14.6	103		39	32.1	28.0	94.8	80.0	399	394	74.8	52.8	2.3	3.7
	26-lb.	Corr. (Chem Fibre)	1	26.1	10.1	40	43	8	20.2	17.4	37.1	30.6	104	109	38.7	27.2	1.5	2.3
28	42-lb. DF	S.F.	3	43.1	15.0	99		39	32.5	27.1	93.1	83.0	382	370	73.8	55.4	2.0	3.5
	42-lb. DF	D.F.	4	43.4	14.8	99		39	33.9	27.5	82.9	74.5	404	400	75.2	52.2	2.1	3.5
		Liner Av.		43.2	14.9	99		39	33.2	27.3	88.0	78.7	393	385	74.5	53.8	2.1	3.5
	26-lb.	Corr. (chestnut)	1	25.3	9.3	20	23	6	17.2	10.3	29.0	20.4	69	88	28.8	9.7	1.3	1.4
29	42-lb. DF	S.F.	3	43.4	15.0	99		39	32.6	27.2	89.9	82.8	391	380	76.3	54.5	2.1	3.6
	42-lb. DF	D.F.	4	43.7	14.7	101		39	32.8	27.8	87.7	73.5	411	410	74.9	48.8	2.2	3.5
		Liner Av.		43.6	14.9	100		39	32.7	27.5	88.8	78.2	401	395	75.6	51.6	2.2	3.6
	30-lb.	Corr. (straw)	1	31.4	10.0	20	23	7	17.5	10.2	33.4	23.2	67	94	26.3	9.8	0.9	1.1

TABLE XX

PHYSICAL CHARACTERISTICS OF COMPONENTS FABRICATED INTO B-FLUTE COMBINED BOARD

Run Combination	Grade and Finish	Component Position	Roll No.	Basis Weight, lb.	Caliper, points	Bursting Strength, points "Jumbo"	Bursting Strength, points "Paper"	G. E. Puncture, Units	Ring Compression, lb. 2 x ½ in. In	Ring Compression, lb. 2 x ½ in. Across	Ring Compression, lb. 6¼ x ½ in. In	Ring Compression, lb. 6¼ x ½ in. Across	Elmendorf Tear, g./sheet In	Elmendorf Tear, g./sheet Across	Amthor Tensile, lb./in. In	Amthor Tensile, lb./in. Across	Amthor Stretch, % In	Amthor Stretch, % Across
26	42-lb. DF	S.F.	1	42.9	15.1	98		38	32.1	27.7	98.0	91.6	411	402	77.7	53.2	1 9	3 3
	42-lb. DF	D.F.	2	43.7	14.4	106		40	33.6	27.9	96.5	81.5	426	430	76.0	52.1	2 4	3 6
		Liner Av.		43.3	14.7	102		39	32.8	27.8	97.2	86.6	419	416	76.8	52.7	2 2	3 5
	26-lb.	Corr. (kraft)	2	27.3	9.4	76	84	21	19.2	16.5	48.8	41.0	233	251	56.0	34.5	2 4	4.5
27	42-lb. DF	S.F.	1	43.0	14.7	100		39	31.3	28.0	95.9	88.3	381	387	74.1	52.2	2 0	3.4
	42-lb. DF	D.F.	2	43.7	14.8	103		40	32.2	27.6	90.7	76.0	404	396	74.0	53.4	2.0	3.5
		Liner Av.		43.4	14.8	101		39	31.8	27.8	93 3	82.2	393	391	74.1	52.8	2.0	3 5
	26-lb.	Corr. (Chem Fibre)	1	26.1	10.2	40	43	8	20.6	17.3	40.6	35.3	106	110	39.5	27.5	1.5	2.3
28	42-lb. DF	S.F.	3	43.3	14.9	101		39	31.5	25.8	88.7	81.6	388	385	73.3	53.9	2.0	3.6
	42-lb. DF	D.F.	4	43.7	14.7	102		39	33.3	28.3	83.6	75.9	392	393	74.5	52.6	2.1	3.7
		Liner Av.		43.5	14.8	102		39	32.4	27.1	86.1	78.7	390	389	73.9	53.2	2.1	3.6
	26-lb.	Corr. (chestnut)	1	25.6	9.1	20	23	6	15.8	10.4	27.8	21.3	69	87	29.0	10.0	1.3	1.5
29	42-lb. DF	S.F.	3	43.7	14.9	103		40	31.5	27.0	84.6	82.1	393	397	77.0	52.7	2.3	3.5
	42-lb. DF	D.F.	4	43.9	14.9	102		40	33.0	29.0	88 9	76.6	398	406	73.7	48.3	2.2	3 6
		Liner Av.		43.8	14 9	102		40	32.2	28.0	86.7	79.3	396	402	75 4	50.5	2.3	3.5
	30-lb.	Corr. (straw)	1	31.8	9.9	21	23	7	17.8	10.7	29.4	22.8	68	94	25 9	9.8	0 9	1 6

boxes of these run combinations are given in Tables XXI and XXII, respectively, and are graphically presented in Figures 15 to 20, inclusive. In addition to the data on the boxes from unbalanced board, data obtained on boxes made from balanced board (Run Combinations 23 and 26) were included for comparative purposes. For example, the test results obtained for Run Combination 23 (47-lb. WF kraft liner, 26-lb. kraft medium, 47-lb. WF kraft liner)—a balanced board—have been included for comparison with the results obtained for Run Combination 30 (42-lb. DF kraft liner, 26-lb. kraft medium, 52-lb. WF kraft liner) and Run Combination 31 (52-lb. WF kraft liner, 26-lb. kraft medium, 42-lb. DF kraft liner)—both unbalanced boards with respect to liner weights (see Figures 15 and 16).

A study of the compression data for the run combinations mentioned above did not show any clearly defined relationship between compressive strength and the position of the heavier and presumably stronger liner. However, for samples having the same total liner weight, the following observations were made. There appeared to be a tendency for the boxes with the heaver liner on the inside and the lighter liner on the outside to give higher top-load compression values than those with the liners in the reverse positions. This was particularly apparent for boxes of Run Combinations 34 and 35, in which the liner weight differential was the greatest. Conversely, there appeared to be a tendency for the boxes fabricated with the heavier liner on the outside and the lighter liner on the inside to give higher end-load compression values than those with the liners in the reverse positions. The B-flute boxes fabricated from the balanced combined board gave higher end-load compression than the corresponding boxes fabricated from unbalanced combined board. The significance to be attached to the above observations is limited by the possibility that the variation between samples frequently appeared to be less than the variation between specimens of the same sample.

The drum and drop test results on the B-flute boxes are shown graphically in Figures 17 and 18. The following observations were made for boxes having the same total liner weight. The drum and drop test values, in general, were higher for the boxes which had the heavier liner on the inside and the lighter liner on the outside than for the boxes having the reverse arrangement of liners. This observation seems plausible when it is recalled that the B-flute boxes were loaded with filled cans during the testing, and that the cans exerted outward forces upon the scorelines of the boxes. The additional strength of the heavier inside liner seemed to be beneficial in resisting these forces. The drop test averages for Run Combinations 34 and 35 were apparently exceptions to the above observations since they were essentially the same, even though the heavier liners with balanced combined board gave lower drop test values than the corresponding boxes fabricated with unbalanced combined board.

Effect of Liner Position on Combined Board Characteristics

The effect of liner position on combined board characteristics may be studied by means of the data of Tables XXIII, XXIV, and XXV. These data are shown graphically in Figures 19 and 20. Examination of the test data for the balanced and unbalanced boards having the same total liner weight indicated the following points. There was a slight tendency for the bursting strength values of the A-flute boards to be higher for those boards having the lighter liner on the single face and the heavier liner on the double face than for those having the liners in the reverse position. Also, the former gave higher bursting strength values than the balanced boards. There was a slight tendency for bursting strength values of the B-flute board to be higher for those boards having the lighter liner on the single face and the heavier liner on the double face than for those boards having the liners in the reverse position; however, the balanced boards gave values equal to or slightly higher than the former boards. Usually, the bursting strength values of the B-flute samples were higher than those of the corresponding A-flute samples.

With certain exceptions in Run Combinations 34 and 35, the combined boards having the lighter liner on the single face and the heavier liner on the double face appeared to give lower G.E. puncture averages than the boards having the reversed arrangement of liners. It should be mentioned in this regard that the G.E. puncture tests were made with the puncture head contacting the double-face liner first. The G.E. puncture values for the balanced B-flute board were higher than those for the corresponding unbalanced board; however, this was not always true for the A-flute board.

For both A- and B-flute combined boards, the G.E. stiffness values were higher for the boards produced with the heavier liner on the single face and the lighter liner on the double face than for those produced with the liners in the reverse position. The G.E. stiffness values of the balanced boards were lower than those of the unbalanced boards. The G.E. stiffness values obtained on the A-flute samples were approximately the same as the values obtained on the corresponding B-flute samples.

Physical Characteristics of Components

The physical characteristics of the liners and corrugating mediums used in Run Combinations 23, 26, 30, 31, 32, 33, 34, and 35 are given in Tables XXVI and XXVII.

TABLE XXI

PHYSICAL CHARACTERISTICS OF A-FLUTE BOXES MADE WITH SINGLE- AND DOUBLE-FACE LINERS OF DIFFERENT WEIGHTS

Run Combination	Materials* Single-Face Liner	Materials* Double-Face Liner	Average Basis Weight of Liners, lb.	Weight of 1000 Boxes, lb.	Top-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	0.-0.75 in.	Top-Load Max. Load, lb.	Top-Load Deflection at Max. Load, in.	End-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	End-Load Max. Load, lb.	End-Load Deflection at Max. Load, in.
23	47-lb. WF	47-lb. WF	48.1	2950	279	898	931	931	0.52	546	676	676	0.36
30	42-lb. DF	52-lb. WF	47.6	2894	308	820	834	834	0.48	514	652	652	0.35
31	52-lb. WF	42-lb. DF	47.6	2900	283	748	840	817	0.60	498	643	643	0.35
26	42-lb. DF	42-lb. DF	43.2	2776	299	760	765	765	0.49	423	546	546	0.35
32	38-lb. DF	42-lb. DF	43.7	2782	274	810	857	857	0.57	430	546	546	0.37
33	47-lb. WF	38-lb. DF	44.0	2818	300	815	848	848	0.49	491	601	601	0.33
34	90-lb. WF	47-lb. WF	68.0	3794	312	1083	1117	1117	0.54	631	852	852	0.35
35	47-lb. WF	90-lb. WF	67.6	3788	302	972	1009	1024	0.57	731	868	868	0.31

*26-lb. kraft corrugating medium was used in each combination.

TABLE XXII

PHYSICAL CHARACTERISTICS OF B-FLUTE BOXES MADE WITH SINGLE- AND DOUBLE-FACE LINERS OF DIFFERENT WEIGHTS

Run Combination	Materials* Single-Face Liner	Materials* Double-Face Liner	Average Basis Weight of Liners, lb.	Weight of 1000 Boxes, lb.	Drum Test, No. of Falls to 1st Can Cut	1st 6 in. Tear	Box Failure	Drop Test, No. of Drops to 1st Can Cut	1st 6 in. Tear	Box Failure	Top-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	0.-0.75 in.	Top-Load Max. Load, lb.	Top-Load Deflection at Max. Load, in.	End-Load Compression, lb.: Max. Load Sustained in Deflection Range 0.-0.25 in.	0.-0.50 in.	End-Load Max. Load, lb.	End-Load Deflection at Max. Load, in.
23	47-lb. WF	47-lb. WF	47.8	1150	12	56	65	3.7	10.6	11.7	386	561	561	561	0.40	548	683	683	0.31
30	42-lb. DF	52-lb. WF	47.8	1128	17	52	62	3.8	10.0	11.1	412	567	567	567	0.33	633	633	633	0.21
31	52-lb. WF	42-lb. DF	47.8	1144	20	59	69	4.4	12.6	14.5	380	576	582	582	0.48	553	572	572	0.24
26	42-lb. DF	42-lb. DF	43.3	1084	18	62	70	3.8	11.4	13.3	437	544	544	544	0.37	626	637	637	0.23
32	38-lb. DF	47-lb. WF	44.0	1097	23	56	67	3.5	9.7	10.9	421	503	503	503	0.36	485	495	495	0.23
33	47-lb. WF	38-lb. DF	43.8	1094	14	50	63	3.5	11.8	13.3	392	549	562	562	0.45	543	570	570	0.24
34	90-lb. WF	47-lb. WF	68.2	1503	29	103	117	8.4	16.1	17.2	417	702	738	742	0.56	699	848	848	0.31
35	47-lb. WF	90-lb. WF	67.7	1506	28	88	97	9.2	15.8	17.2	502	673	677	677	0.43	763	915	915	0.33

*26-lb. kraft corrugating medium was used in each combination.

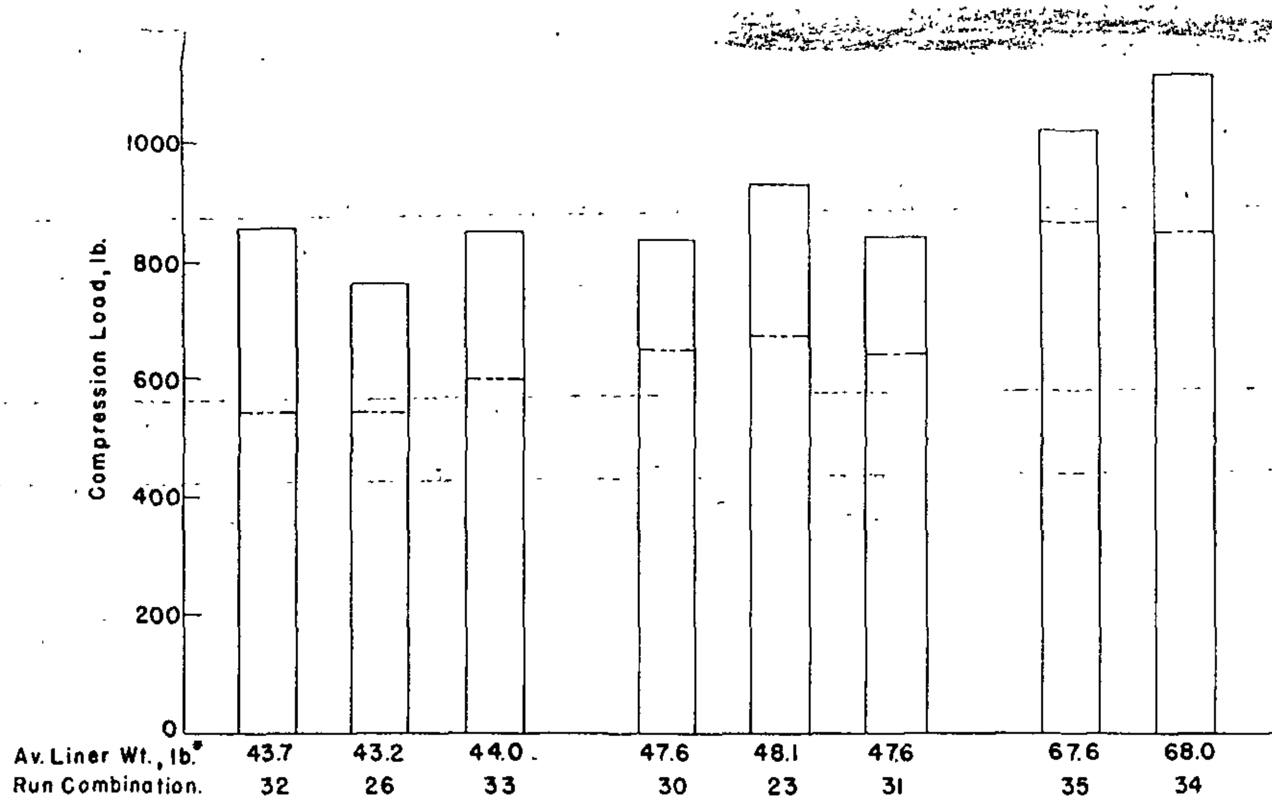

FIGURE 15. Compression Tests on A-Flute Boxes Made with Single- and Double-Face Liners of Different Weights.

——————Top Load (0–0.75 inch)
...................End Load (0–0.50 inch)

* Run Combination	32	26	33	30	23	31	35	34
S.F. Liner Wt., lb.	39.4	42.8	47.8	43.3	47.9	51.9	48.0	87.9
D.F. Liner Wt., lb.	48.0	43.7	40.2	51.8	48.3	43.4	87.2	48.0

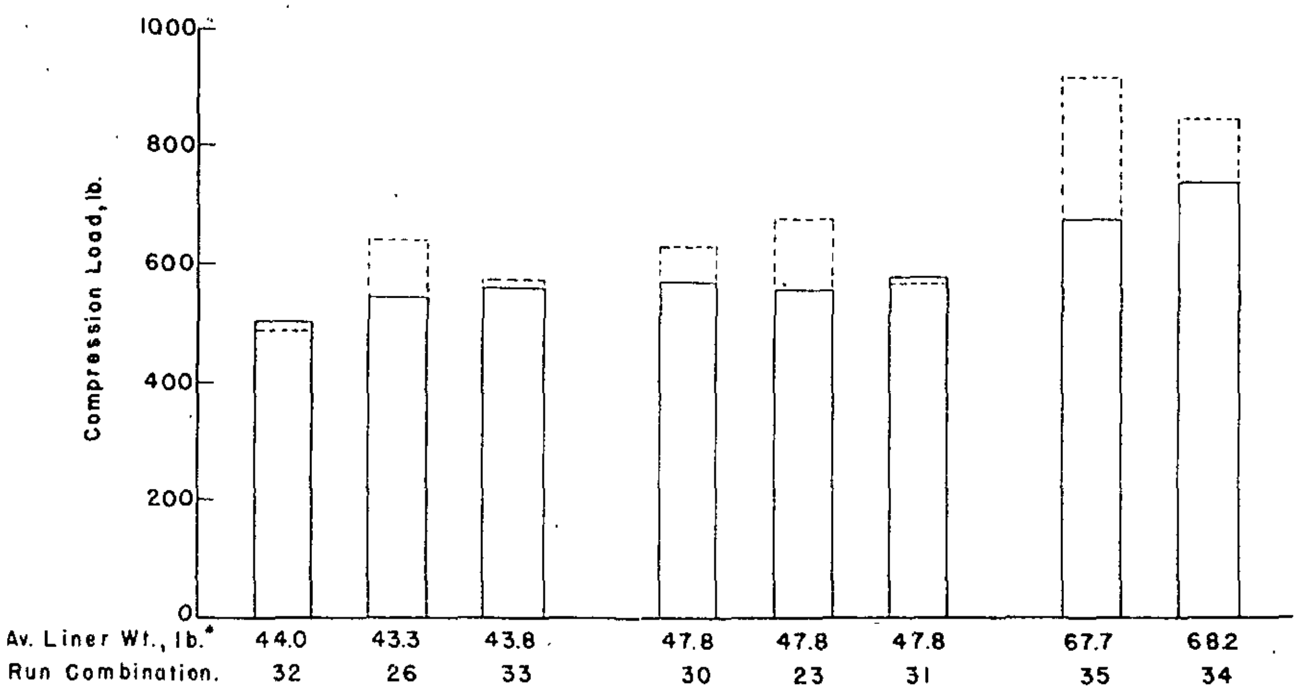

FIGURE 16. Compression Tests on B-Flute Boxes Made with Single- and Double-Face Liners of Different Weights.

———Top Load (0–0.75 inch)
End Load (0–0.50 inch)

* Run Combination	32	26	33	30	23	31	35	34
S.F. Liner Wt., lb.	40.1	42.9	48.0	43.3	47.9	52.1	48.3	88.5
D.F. Liner Wt., lb.	47.9	43.7	39.5	52.2	47.6	43.4	87.1	47.9

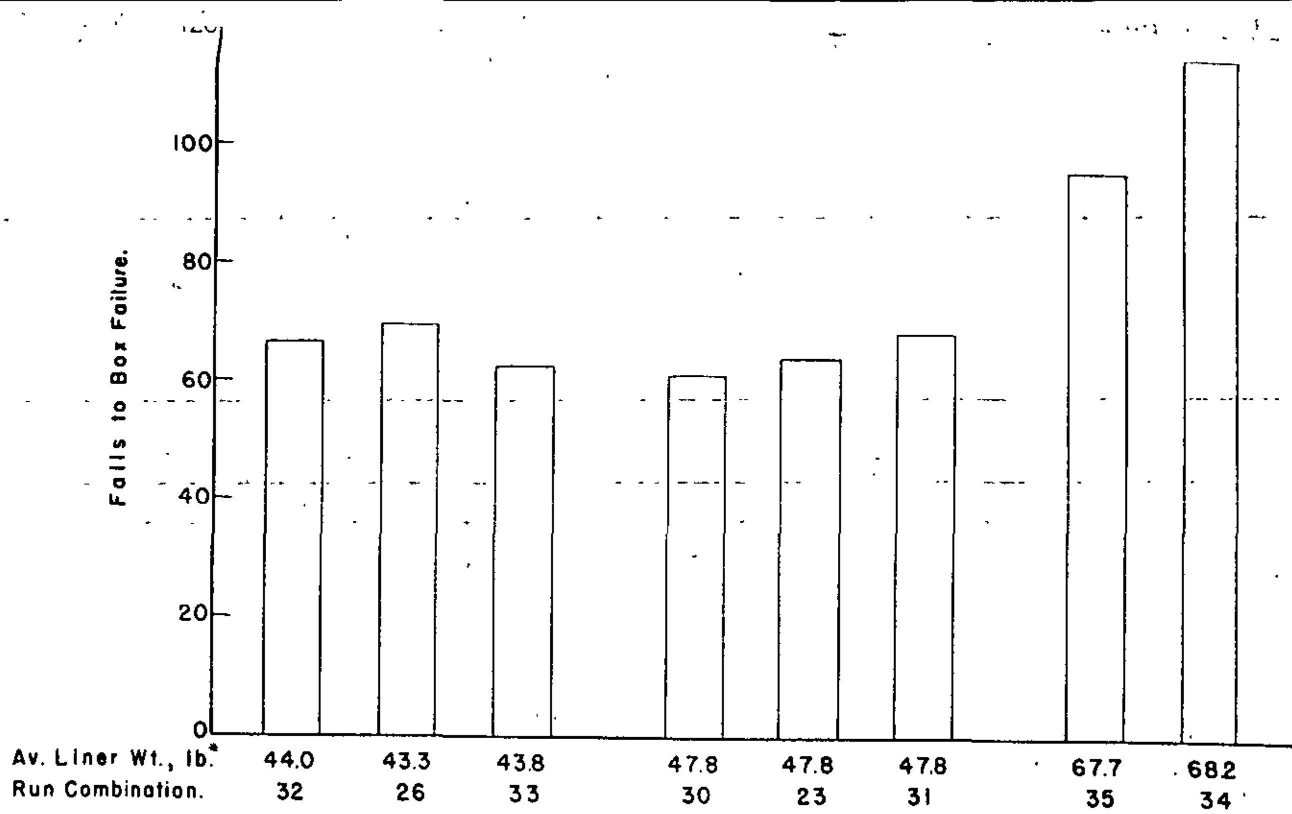

FIGURE 17. Drum Tests on B-Flute Boxes Made with Single- and Double-Face Liners of Different Weights.

* Run Combination	32	26	33	30	23	31	35	34
S.F. Liner Wt., lb.	40.1	42.9	48.0	43.3	47.9	52.1	48.3	88.5
D.F. Liner Wt., lb.	47.9	43.7	39.5	52.2	47.6	43.4	87.1	47.9

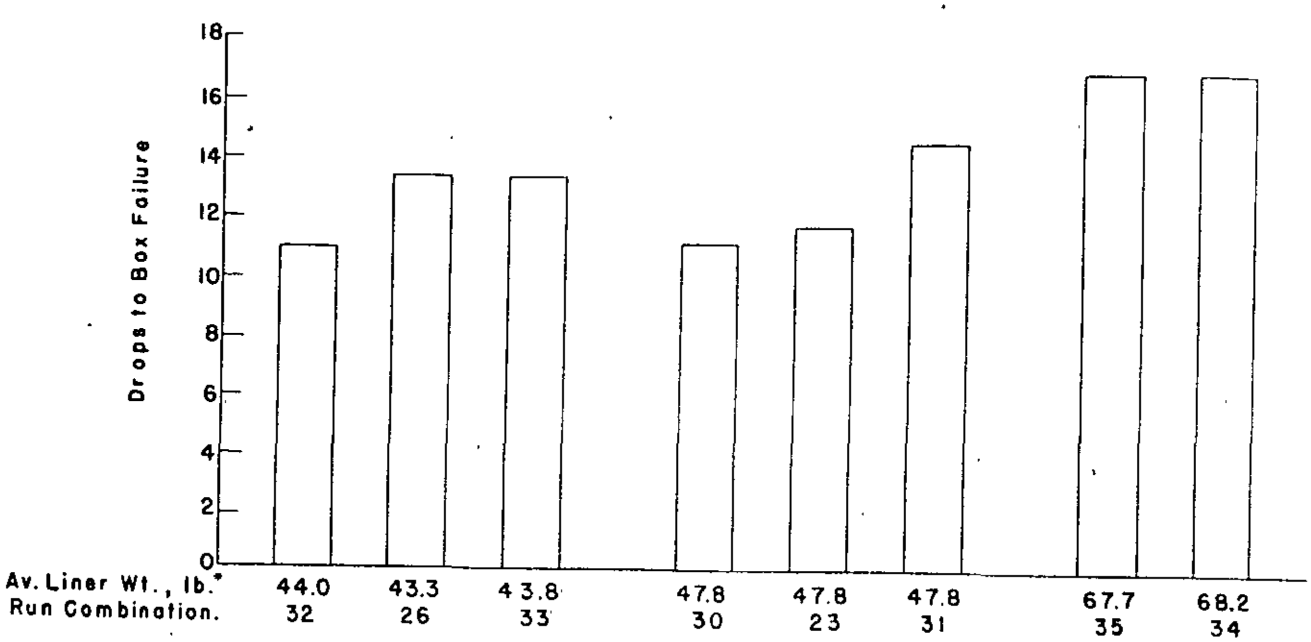

FIGURE 18. Twelve-Inch Corner Drop Tests on B-Flute Boxes Made with Single- and Double-Face Liners of Different Weights.

* Run Combination	32	26	33	30	23	31	35	34
S.F. Liner Wt., lb.	40.1	42.9	48.0	43.3	47.9	52.1	48.3	88.5
D.F. Liner Wt., lb.	47.9	43.7	39.5	52.2	47.6	43.4	87.1	47.9

TABLE XXIII

PHYSICAL CHARACTERISTICS OF A-FLUTE COMBINED BOARD MADE WITH SINGLE- AND DOUBLE-FACE LINERS OF DIFFERENT WEIGHTS

Run Combination	Materials*		Average Basis Weight of Liners, lb.	Basis Weight, lb.	Caliper, points	Bursting Strength, points	G. E. Puncture, units	G. E. Stiffness, units	Pin Adhesion, lb.	H. & D. Flat Crush, lb./sq. in.
	Single-Face Liner	Double-Face Liner								
23	47-lb. WF	47-lb. WF	48.1	138	165.9	242	251	108	52	23.7
30	42-lb. DF	52-lb. WF	47.6	137	177.8	259	258	107	41	23.6
31	52-lb. WF	42-lb. DF	47.6	136	174.4	258	263	109	40	21.7
26	42-lb. DF	52-lb. WF	43.2	130	177.8	236	267	102	47	27.0
32	38-lb. DF	47-lb. WF	43.7	130	175.5	239	252	108	49	24.3
33	47-lb. WF	38-lb. DF	44.0	130	176.4	228	265	113	47	25.4
34	90-lb. WF	47-lb. WF	68.0	178	181.0	322	349	139	60	25.6
35	47-lb. WF	90-lb. WF	67.6	180	186.6	324	346	129	57	25.1

*26-lb. kraft corrugating medium was used in each combination.

TABLE XXIV

PHYSICAL CHARACTERISTICS OF B-FLUTE COMBINED BOARD MADE WITH SINGLE- AND DOUBLE-FACE LINERS OF DIFFERENT WEIGHTS

Run Combination	Materials*		Average Basis Weight of Liners, lb.	Basis Weight, lb.	Caliper, points	Bursting Strength, points	G. E. Puncture, units	G. E. Stiffness, units	Pin Adhesion, lb.	H. & D. Flat Crush, lb./sq. in.
	Single-Face Liner	Double-Face Liner								
23	47-lb. WF	47-lb. WF	47.8	135	110.0	259	243	108	82	38.7
30	42-lb. DF	52-lb. WF	47.8	129	106.0	259	224	101	72	32.9
31	52-lb. WF	52-lb. DF	47.8	133	115.3	248	237	114	82	36.7
26	42-lb. DF	42-lb. DF	43.3	126	108.8	256	262	100	81	37.8
32	38-lb. DF	47-lb. WF	44.0	127	112.6	244	222	101	87	40.0
33	47-lb. WF	38-lb. DF	43.8	127	113.3	244	229	110	86	40.9
34	90-lb. WF	47-lb. WF	68.2	174	120.2	326	305	139	87	36.1
35	47-lb. WF	90-lb. WF	67.7	175	124.0	336	316	135	88	38.4

*26-lb. kraft corrugating medium was used in each of these combinations.

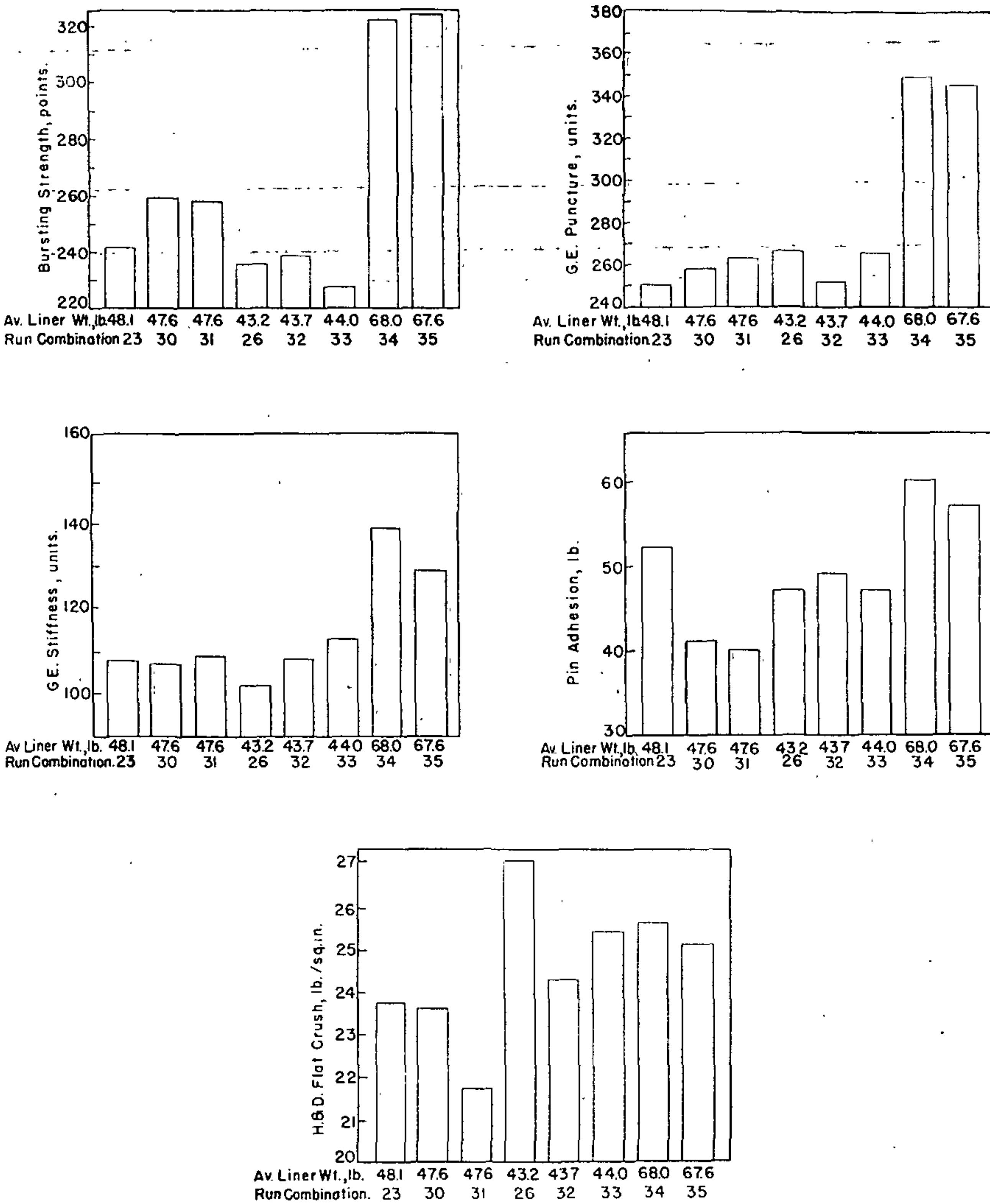

FIGURE 19. Physical Characteristics of A-Flute Combined Board Made with Single- and Double-Face Liners of Different Weights. The basis weights for the S.F. and D.F. liners are given in the footnotes of Figure 15.

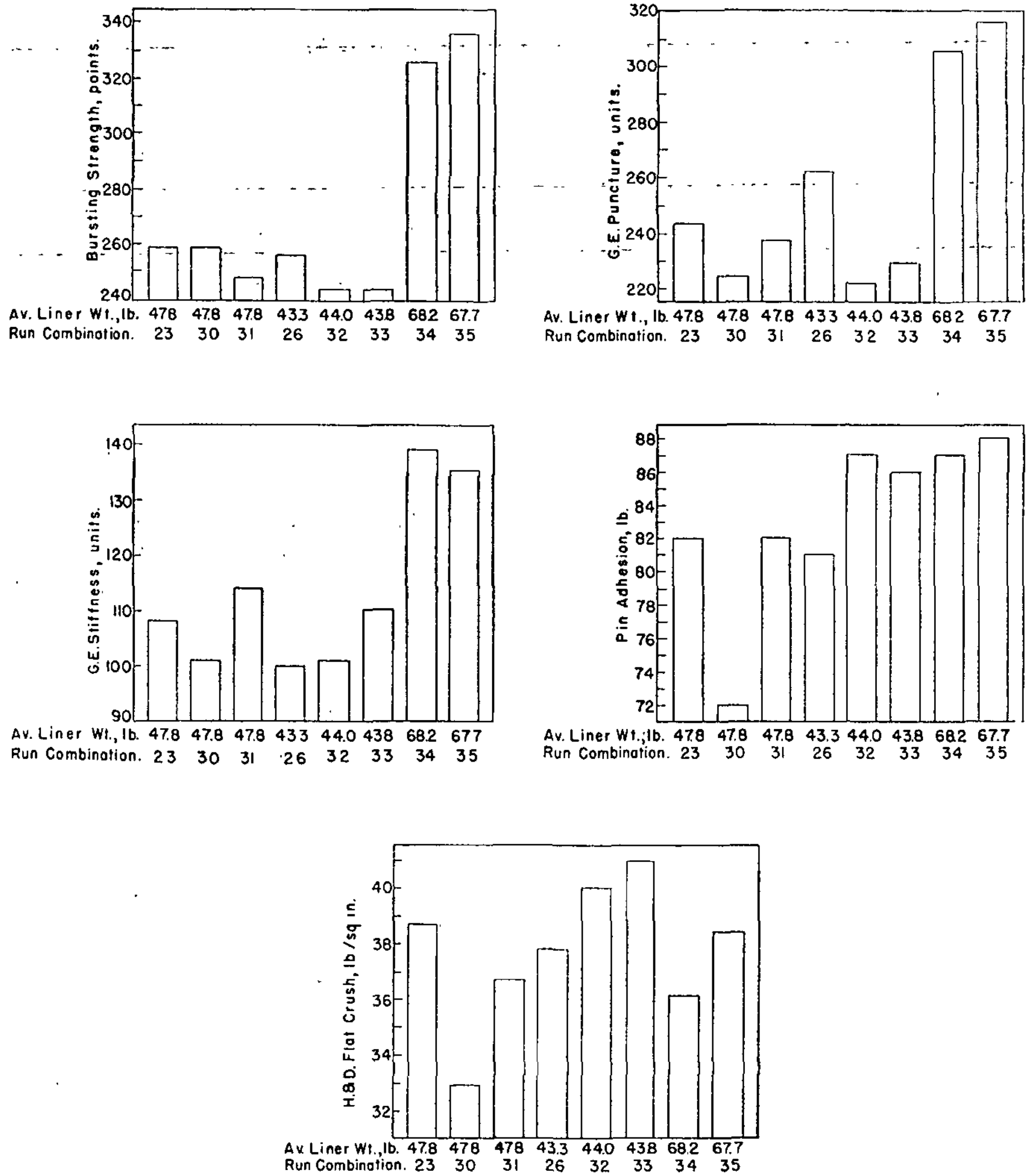

FIGURE 20. Physical Characteristics of B-Flute Combined Board Made with Single- and Double-Face Liners of Different Weights. The basis weights for the S.F. and D.F. liners are given in the footnotes of Figure 16.

TABLE XXV

COMPARISON OF COMBINED BOARD TESTS ON A- AND B-FLUTE BOARDS

Run Combination	Materials* Single-Face Liner	Materials* Double-Face Liner	Basis Weight, lb. A	Basis Weight, lb. B	Caliper, points A	Caliper, points B	Bursting Strength, points A	Bursting Strength, points B	G. E. Puncture, units A	G. E. Puncture, units B	G. E. Stiffness, units A	G. E. Stiffness, units B	Pin Adhesion, lb. A	Pin Adhesion, lb. B	H. and D. Flat Crush, lb./sq. in. A	H. and D. Flat Crush, lb./sq. in. B
23	47-lb. WF	47-lb. WF	138	135	165.9	110.0	242	259	251	243	108	108	52	82	23.7	38.7
30	42-lb. DF	52-lb. WF	137	129	177.8	106.0	259	259	258	224	107	101	41	72	23.6	32.9
31	52-lb. WF	42-lb. DF	136	133	174.4	115.3	258	248	263	237	109	114	40	82	21.7	36.7
26	42-lb. DF	42-lb. DF	130	126	177.8	108.8	236	256	267	262	102	100	47	81	27.0	37.8
32	38-lb. DF	47-lb. WF	130	127	175.5	112.6	239	244	252	222	108	101	49	87	24.3	40.0
33	47-lb. WF	38-lb. DF	130	127	176.4	113.3	228	244	265	229	113	110	47	86	25.4	40.9
34	90-lb. WF	47-lb. WF	178	174	184.0	120.2	322	326	349	305	139	139	60	87	25.6	36.1
35	47-lb. WF	90-lb. WF	180	175	186.6	124.0	324	336	346	316	129	135	57	88	25.1	38.4

*26-lb. kraft corrugating medium was used in each combination

TABLE XXVI

PHYSICAL CHARACTERISTICS OF COMPONENTS FABRICATED INTO A-FLUTE COMBINED BOARD*

Run Combination	Grade and Finish	Component Position	Roll No.	Basis Weight, lb.	Caliper, points	Bursting Strength, points "Jumbo"	Bursting Strength, points "Paper"	G. E. Puncture, units	Ring Compression, lb. 2 x ½ in. In	Ring Compression, lb. 2 x ½ in. Across	Ring Compression, lb. 6¼ x ½ in. In	Ring Compression, lb. 6¼ x ½ in. Across	Elmendorf Tear, g./sheet In	Elmendorf Tear, g./sheet Across	Amthor Tensile, lb./in. In	Amthor Tensile, lb./in. Across	Amthor Stretch, % In	Amthor Stretch, % Across
23	47-lb. WF	S.F.	1	47.9	16.1	103		39	32.7	26.4	114.5	98.5	422	428	78.8	55.7	2.0	2.[illegible]
	47-lb. WF	D.F.	2	48.3	16.2	105		39	33.2	30.5	111.3	103.6	467	458	81.5	55.7	1.9	2.[illegible]
		Liner Av.		48.1	16.1	104		39	33.0	28.4	112.9	101.0	445	443	80.1	55.7	1.9	2.[illegible]
	26-lb.	Corr.	1	27.1	9.4	72	78	20	18.7	15.0	49.1	41.0	240	243	59.4	34.8	2.0	4[illegible]
30	42-lb. DF	S.F.	5	43.3	14.9	99		38	33.7	28.8	88.2	73.7	392	397	73.4	51.9	2.1	4.[illegible]
	52-lb. WF	D.F.	1	51.8	15.9	113		46	37.4	32.6	107.0	92.4	456	482	88.0	57.4	2.2	3.[illegible]
		Liner Av.		47.6	15.4	106		42	35.5	30.7	97.6	83.0	424	439	80.7	54.7	2.1	3[illegible]
	26-lb.	Corr.	3	26.0	9.2	67	76	20	23.3	18.0	43.4	36.5	220	240	56.5	34.5	1.7	3.[illegible]
31	52-lb. WF	S.F.	1	51.9	16.2	111		49	37.5	32.9	111.2	96.8	455	480	89.1	57.4	2.2	3.[illegible]
	42-lb. DF	D.F.	5	43.4	14.9	100		39	34.6	29.8	92.6	82.4	402	393	73.1	51.9	2.1	4.[illegible]
		Liner Av.		47.6	15.6	106		44	36.1	31.3	101.9	89.6	429	436	81.1	54.7	2.1	3.[illegible]
	26-lb.	Corr.	3	26.0	9.2	68	76	20	22.7	18.2	43.3	34.2	214	236	57.3	33.6	1.8	4[illegible]
26	42-lb. DF	S.F.	1	42.8	14.9	101		38	30.5	26.2	101.3	82.4	402	394	77.5	52.9	2.1	3.[illegible]
	42-lb. DF	D.F.	2	43.7	14.4	106		40	33.9	28.3	92.7	79.6	424	428	75.2	52.5	2.6	4.[illegible]
		Liner Av.		43.2	14.6	103		39	32.2	27.2	97.0	81.0	413	411	76.3	52.7	2.4	3.[illegible]
	26-lb.	Corr.	2	27.6	9.3	74	81	22	22.3	18.1	51.7	43.6	240	253	58.9	36.2	2.2	4.[illegible]
32	38-lb. DF	S.F.	1	39.4	14.4	97		37	32.3	27.9	90.8	72.9	371	364	74.5	51.2	2.0	3.[illegible]
	47-lb. WF	D.F.	2	48.0	16.2	102		41	35.6	32.7	96.2	86.1	442	471	80.3	55.3	1.8	2.[illegible]
		Liner Av.		43.7	15.3	99		39	33.9	30.2	93.5	79.5	407	418	77.4	53.2	1.9	3.[illegible]
	26-lb.	Corr.	4	26.5	9.3	72	80	20	22.4	17.6	41.0	35.7	233	243	58.2	34.3	2.1	4[illegible]
33	47-lb. WF	S.F.	1	47.8	16.0	102		42	35.3	33.0	105.2	92.5	459	468	79.8	56.6	2.0	3[illegible]
	38-lb. DF	D.F.	2	40.2	14.2	100		37	31.5	28.1	83.8	78.7	382	404	70.9	51.0	1.9	3.[illegible]
		Liner Av.		44.0	15.1	101		39	33.4	30.5	94.5	85.6	420	436	75.4	53.8	1.9	3.[illegible]
	26-lb.	Corr.	4	26.3	9.3	69	78	19	21.5	17.5	40.0	32.0	228	247	56.7	34.1	2.0	4.[illegible]
34	90-lb. WF	S.F.	1	87.9	25.9	147		97	54.9	44.6	123.0	101.8	797	866	115.3	73.8	1.6	2.[illegible]
	47-lb. WF	D.F.	3	48.0	16.0	103		41	34.6	31.9	104.1	85.2	420	432	75.0	54.0	1.7	2[illegible]
		Liner Av.		68.0	20.9	125		69	44.8	38.2	113.6	93.4	608	649	95.1	63.9	1.6	2.[illegible]
	26-lb.	Corr.	5	26.0	9.0	68	76	19	21.6	17.9	41.4	34.9	211	233	53.1	35.8	2.2	4.[illegible]
35	47-lb. WF	S.F.	3	48.0	15.8	103		42	35.5	32.7	104.7	87.2	417	452	77.1	54.8	1.8	3.[illegible]
	90-lb. WF	D.F.	2	87.2	26.9	143		94	55.7	48.0	162.9	141.4	820	838	113.3	73.2	1.6	2[illegible]
		Liner Av.		67.6	21.3	123		68	45.6	40.3	133.8	114.3	619	645	95.2	64.0	1.6	2[illegible]
	26-lb.	Corr.	5	26.4	8.9	70	75	20	20.9	17.7	40.4	33.0	217	233	54.5	36.0	1.9	4[illegible]

*Kraft liners and corrugating medium were used.

TABLE XXVII

PHYSICAL CHARACTERISTICS OF COMPONENTS FABRICATED INTO B-FLUTE COMBINED BOARD*

Run Combination	Grade and Finish	Component Position	Roll No.	Basis Weight, lb.	Caliper, points	Bursting Strength, points "Jumbo"	Bursting Strength, points "Paper"	G. E. Puncture, units	Ring Compression, lb. 2 x ½ in. In	Ring Compression, lb. 2 x ½ in. Across	Ring Compression, lb. 6¼ x ½ in. In	Ring Compression, lb. 6¼ x ½ in. Across	Elmendorf Tear, g./sheet In	Elmendorf Tear, g./sheet Across	Amthor Tensile, lb./in. In	Amthor Tensile, lb./in. Across	Amthor Stretch, % In	Amthor Stretch, % Across
23	47-lb. WF	S.F.	1	47.9	16.1	102		38	31.2	28.0	108.5	96.3	430	435	78.3	55.8	2.0	2.8
	47-lb. WF	D.F.	2	47.6	16.0	104		39	32.8	29.5	111.2	99.5	407	458	79.8	55.3	1.8	2.8
		Liner Av.		47.8	16.0	103		39	32.0	28.7	109.8	97.9	448	446	79.0	55.6	1.9	2.8
	26-lb.	Corr.	1	27.2	9.3	75	81	20	19.9	15.3	48.2	40.5	235	241	58.0	34.0	2.2	4.2
30	42-lb. DF	S.F.	5	43.3	14.8	99		39	34.0	27.4	93.1	70.0	390	394	76.0	52.3	2.2	4.
	52-lb. WF	D.F.	1	52.2	15.2	113		45	36.2	32.6	105.5	94.5	460	458	87.5	57.2	2.2	3.4
		Liner Av.		47.8	15.0	106		42	35.1	30.0	99.3	82.2	425	426	81.7	54.8	2.2	3.9
	26-lb.	Corr.	3	26.2	9.3	68	75	20	21.7	16.1	42.6	37.4	230	246	57.0	34.5	1.9	3.9
31	52-lb. WF	S.F.	1	52.1	16.2	111		50	37.9	33.9	103.9	90.4	460	450	88.3	57.3	2.1	3.3
	42-lb. DF	D.F.	5	43.4	15.0	99		40	34.5	30.0	94.6	83.3	412	393	73.3	51.1	2.1	4.1
		Liner Av.		47.8	15.6	105		45	36.2	31.9	99.3	86.8	436	422	80.8	54.2	2.1	3.7
	26-lb.	Corr.	3	26.6	9.3	70	77	21	21.6	17.9	45.8	32.6	222	239	58.3	33.0	2.0	4.2
26	42-lb. DF	S.F.	1	42.9	15.1	98		38	32.1	27.7	98.0	91.6	411	402	77.7	53.2	1.9	3.3
	42-lb. DF	D.F.	2	43.7	14.4	106		40	33.6	27.9	96.5	81.5	426	430	76.0	52.1	2.4	3.6
		Liner Av.		43.3	14.7	102		39	32.8	27.8	97.2	86.6	419	416	76.8	52.7	2.2	3.5
	26-lb.	Corr.	2	27.3	9.4	76	84	21	19.2	16.5	48.8	41.0	233	251	56.0	34.5	2.4	4.5
32	38-lb. DF	S.F.	1	40.1	14.5	99		38	32.7	29.0	89.4	74.5	369	386	72.4	51.0	2.0	3.5
	47-lb. WF	D.F.	2	47.9	16.1	99		41	34.9	32.8	102.6	88.2	446	447	80.2	56.5	1.8	3.0
		Liner Av.		44.0	15.3	99		39	33.8	30.9	96.0	81.3	407	417	76.3	53.8	1.9	3.2
	26-lb.	Corr.	4	26.6	9.3	71	79	21	22.7	17.3	44.2	38.2	233	243	57.4	33.8	2.3	4.0
33	47-lb. WF	S.F.	1	48.0	16.0	103		42	35.4	32.6	101.8	92.9	463	453	78.0	58.0	2.0	3.2
	38-lb. DF	D.F.	2	39.5	14.1	98		35	34.7	30.2	92.4	83.4	366	378	69.6	51.6	1.9	3.6
		Liner Av.		43.8	15.1	100		39	35.1	31.4	97.1	88.1	415	415	73.8	54.8	2.0	3.4
	26-lb.	Corr.	4	26.6	9.4	71	79	20	22.0	17.4	46.1	31.7	232	247	55.5	34.4	2.1	4.4
34	90-lb. WF	S.F.	1	88.5	26.7	141		99	54.5	44.8	123.0	105.8	782	884	112.8	75.9	1.6	2.6
	47-lb. WF	D.F.	3	47.9	16.0	101		41	34.8	32.0	100.8	85.2	430	428	73.4	56.2	1.8	2.9
		Liner Av.		68.2	21.3	121		70	44.7	38.4	111.9	95.5	606	656	93.1	66.1	1.7	2.8
	26-lb.	Corr.	5	26.1	9.2	68	76	19	21.7	17.8	43.2	34.9	221	238	52.9	36.0	2.0	4.5
35	47-lb. WF	S.F.	3	48.3	15.8	105		42	36.2	32.6	107.5	93.2	429	451	81.2	56.0	2.0	3.2
	90-lb. WF	D.F.	2	87.1	26.5	145		95	57.0	49.8	162.3	142.7	777	842	116.2	73.5	1.7	2.6
		Liner Av.		67.7	21.2	125		68	46.6	41.2	134.8	117.9	603	647	98.7	64.8	1.8	2.9
	26-lb.	Corr.	5	27.4	8.9	73	78	22	21.5	17.3	43.6	34.9	230	250	55.3	35.1	2.0	4.4

*Kraft liners and corrugating were used.

APPENDIX A

STATISTICAL ANALYSIS

In order to obtain a more comprehensive insight into the relationships between weight and combined board or box tests, the data obtained on the ten run combinations listed in Table XXVIII were subjected to statistical analysis. The theory and methods employed in this type of analysis are given in Baseline Studies 1. Part II.

The first phase of the analysis was concerned with the determination of the relationships between the basis weight of the combined board and combined board tests, and also the box compression test. The degree to which two characteristics are related may be expressed in terms of the correlation coefficient. The correlation coefficients of the basis weight and combined board and box tests are presented in Table XXIX. The magnitude of the correlation coefficients indicates that, for the run combinations considered, all the combined board tests except flat crush and pin adhesion correlate highly with the weight of the combined board. Inasmuch as all the run combinations under consideration were fabricated using the same corrugating medium (which was selected on the basis of its uniformity), the change in the basis weight of the combined board was the result of the selection of the liners. Thus, the lack of correlation of basis weight and flat crush indicates that the flat crush may be dependent on the characteristics of the corrugated medium and that the liners have little influence.

The correlation coefficients for the basis weight and box compression tests indicate that, for the samples included in this study, the top- and end-load compression tests correlated highly with the weight of the combined board.

In interpreting the above correlations it should be borne in mind that the ten samples included in this analysis covered a rather wide range of basis weights and, thus, would be conducive to better correlation than would normally be expected if a greater number of samples had been included in the same range. However, a greater number of samples would improve the precision of the prediction. The results do indicate the trend to be expected when considering combined board and boxes fabricated from the same corrugating medium and liners of different basis weight made from the same pulp.

In addition to the determination of the simple correlation coefficients presented in Table XXIX an analysis was also made of the relationship between the basis weight of the liners and box compression tests. The purpose of this analysis was to determine if the box compression values could be predicted on the basis of the basis weight of the liner alone, inasmuch as the liners were made from relatively the same pulp and on the same paper machine but in different basis weight ranges. In this type of analysis, it is necessary to determine the appropriate weight factors which should be assigned to the basis weight value for both the single-

TABLE XXVIII

NOMINAL AND ACTUAL BASIS WEIGHTS OF THE COMPONENT LINERS AND COMBINED BOARD USED IN THE STATISTICAL STUDIES

A-FLUTE BOARDS

Run Combination	Single Face Nominal, lb.	Single Face Actual, lb.	Double Face Nominal, lb.	Double Face Actual, lb.	Combined Board Actual, lb.
23	47 WF	47.9	47 WF	48.3	138
24	47 DF	50.8	47 DF	51.0	142
25	38 DF	40.6	38 DF	40.9	124
26	42 DF	42.8	42 DF	43.7	130
30	42 DF	43.3	52 WF	51.8	136
31	52 WF	51.9	42 DF	43.4	136
32	38 DF	39.4	47 WF	48.0	130
33	47 WF	47.8	38 DF	40.2	130
34	90 WF	87.9	47 WF	48.0	178
35	47 WF	48.0	90 WF	87.2	180

B-FLUTE BOARDS

Run Combination	Single Face Nominal, lb.	Single Face Actual, lb.	Double Face Nominal, lb.	Double Face Actual, lb.	Combined Board Actual, lb.
23	47 WF	47.9	47 WF	47.6	135
24	47 DF	51.0	47 DF	51.1	139
25	38 DF	40.7	38 DF	41.0	121
26	42 DF	42.9	42 DF	43.7	126
30	42 DF	43.3	52 WF	52.2	129
31	52 WF	52.1	42 DF	43.4	133
32	38 DF	40.1	47 WF	47.9	127
33	47 WF	48.0	38 DF	39.5	127
34	90 WF	88.5	47 WF	47.9	174
35	47 WF	48.3	90 WF	87.1	175

TABLE XXIX

CORRELATION COEFFICIENTS OF BASIS WEIGHT AND OTHER COMBINED BOARD AND BOX TESTS

	Basis Weight of Combined Board, lb. A-Flute	Basis Weight of Combined Board, lb. B-Flute
Bursting strength, points	+0.97	+0.97
G.E. puncture, units	+0.97	+0.88
G.E. stiffness, units	+0.93	+0.96
Pin adhesion, lb.	+0.79	+0.56
H. and D. flat crush, lb./sq. in.	+0.01	−0.14
Top-load compression, lb.	+0.90	+0.95
End-load compression, lb.	+0.96	+0.90

TABLE XXX

WEIGHT FACTORS FOR BASIS WEIGHT OF LINERS IN PREDICTING COMPRESSIVE STRENGTHS

	Top-load Compression A-Flute	Top-load Compression B-Flute	End-load Compression† A-Flute	End-load Compression† B-Flute
1. Correlation coefficient	+0.94	+0.98	+0.97	+0.91
2. Single face	6.274839	4.321602	5.982222	5.572091
3. Double face	3.884537	2.643570	6.252978	7.275795
4. Numerical constant	382.409	234.368	43.938	22.020

*Maximum load sustained in deflection range 0-0.75 inch

†Maximum load sustained in deflection range 0-0.50 inch

face and double-face liners. The weight factors are determined by a statistical technique known as multiple regression. The weight factors determined for the basis weight of the liners used in the ten run combinations under consideration are given in Table XXX. The weight factors presented in Table XXX have been used in predicting the box compression values based on weight of the liners. It may be observed that, when top-load compression is being considered, the single-face liner has a much higher weight factor than the double-face liner. This would indicate that, if one liner of a box is to be heavier than the other, the heavy liner should be placed on the single face to obtain the greater advantage in increasing top-load compression. The above placement of liners should be reversed when end-load compression is being considered. A comparison of the predicted and observed compression values is given in Table XXXI and Figures 21 to 24.

TABLE XXXI

THE PREDICTION OF COMPRESSIVE STRENGTH FROM BASIS WEIGHT OF LINERS

Run Combination	Top-load Compression* A-Flute Predicted	Top-load Compression* A-Flute Observed	Top-load Compression* B-Flute Predicted	Top-load Compression* B-Flute Observed	End-load Compression† A-Flute Predicted	End-load Compression† A-Flute Observed	End-load Compression† B-Flute Predicted	End-load Compression† B-Flute Observed
23	872	931	568	561	633	676	637	683
24	898	938	590	592	667	687	678	777
25	785	777	519	516	543	504	547	541
26	817	765	535	544	573	546	579	637
30	862	834	559	567	627	652	642	633
31	883	840	574	582	626	643	628	572
32	818	857	534	503	580	546	593	495
33	840	848	546	562	581	601	577	570
34	1119	1117	743	738	870	852	864	848
35	1021	1009	673	677	876	868	925	915

*Maximum load sustained in the deflection range 0–0.75 inch
†Maximum load sustained in the deflection range 0–0.50 inch

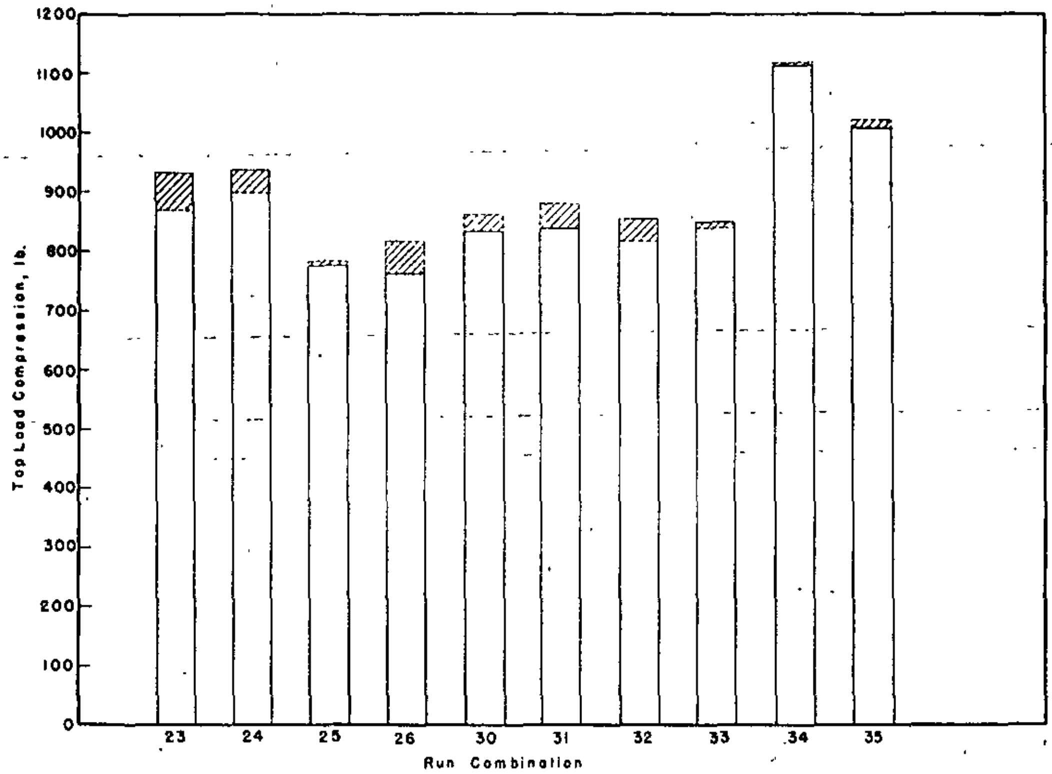

FIGURE 21. Comparison of Observed and Predicted Top-Load Compression Tests on A-Flute Boxes (0-0.75 inch)—Based on the Basis Weight of the Liners.

———— Observed .... Predicted

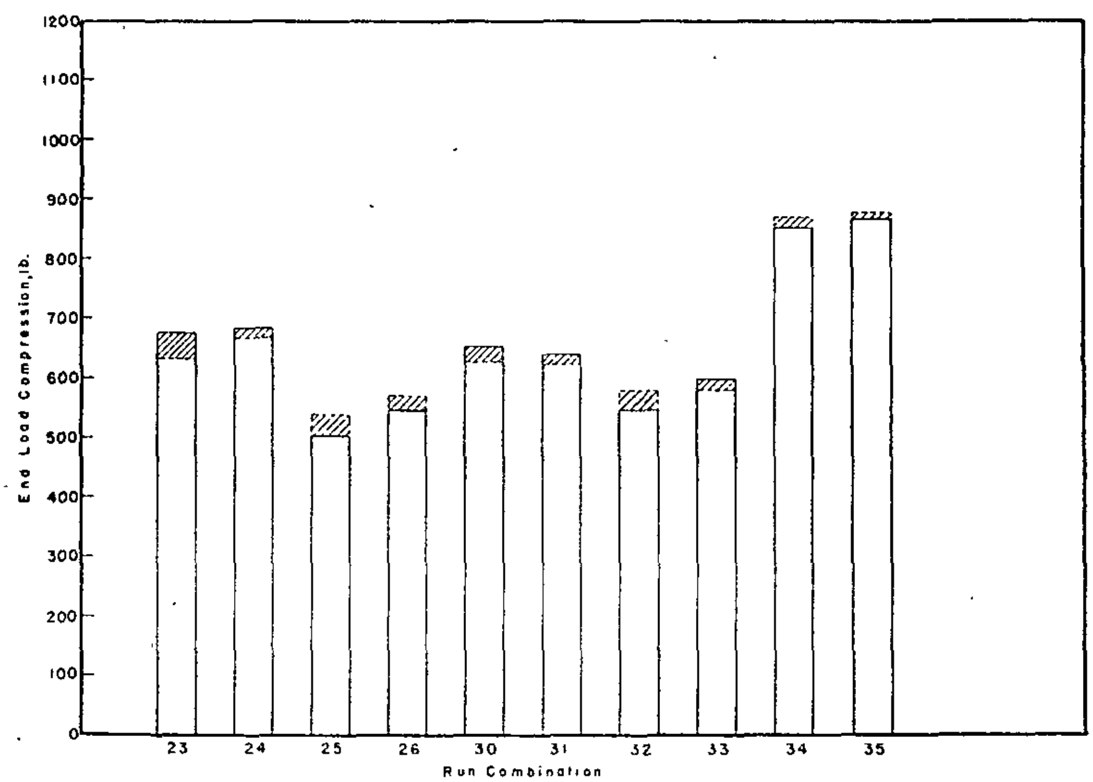

FIGURE 22. Comparison of Observed and Predicted End-Load Compression Tests on A-Flute Boxes (0-0.50 inch)—Based on the Basis Weight of the Liners.

———— Observed .... Predicted

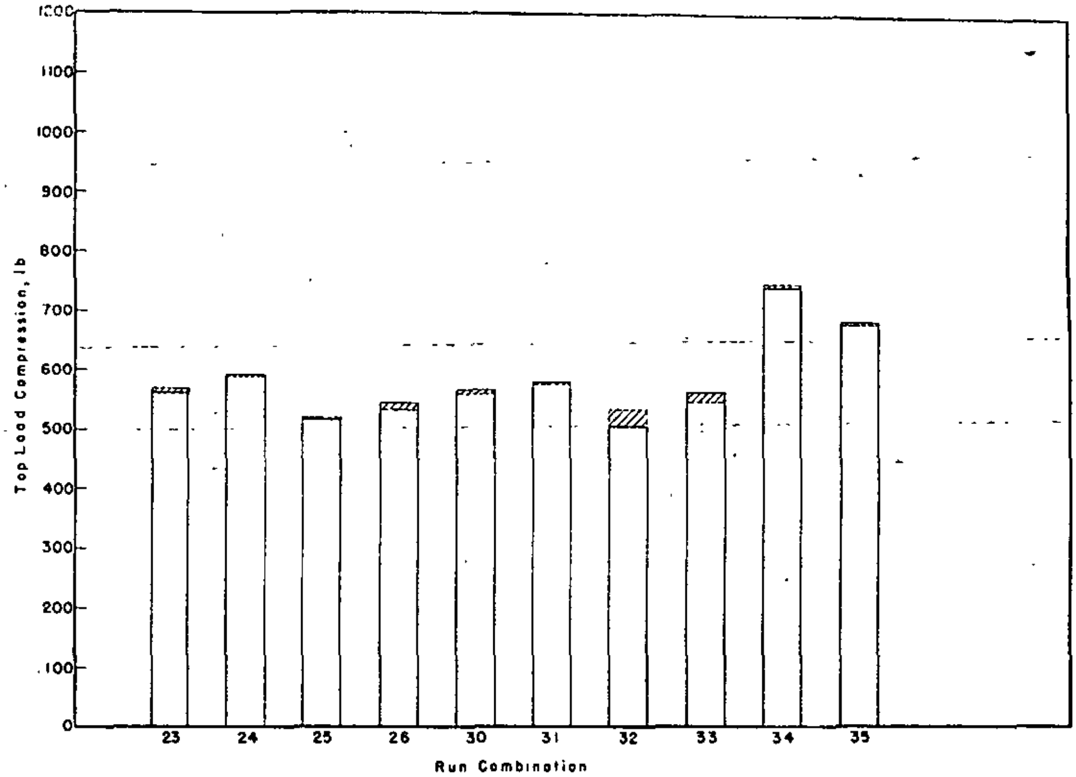

FIGURE 23. Comparison of Observed and Predicted Top-Load Compression Tests on B-Flute Boxes (0-0.75 inch)—Based on the Basis Weight of the Liners.

——— Observed .... Predicted

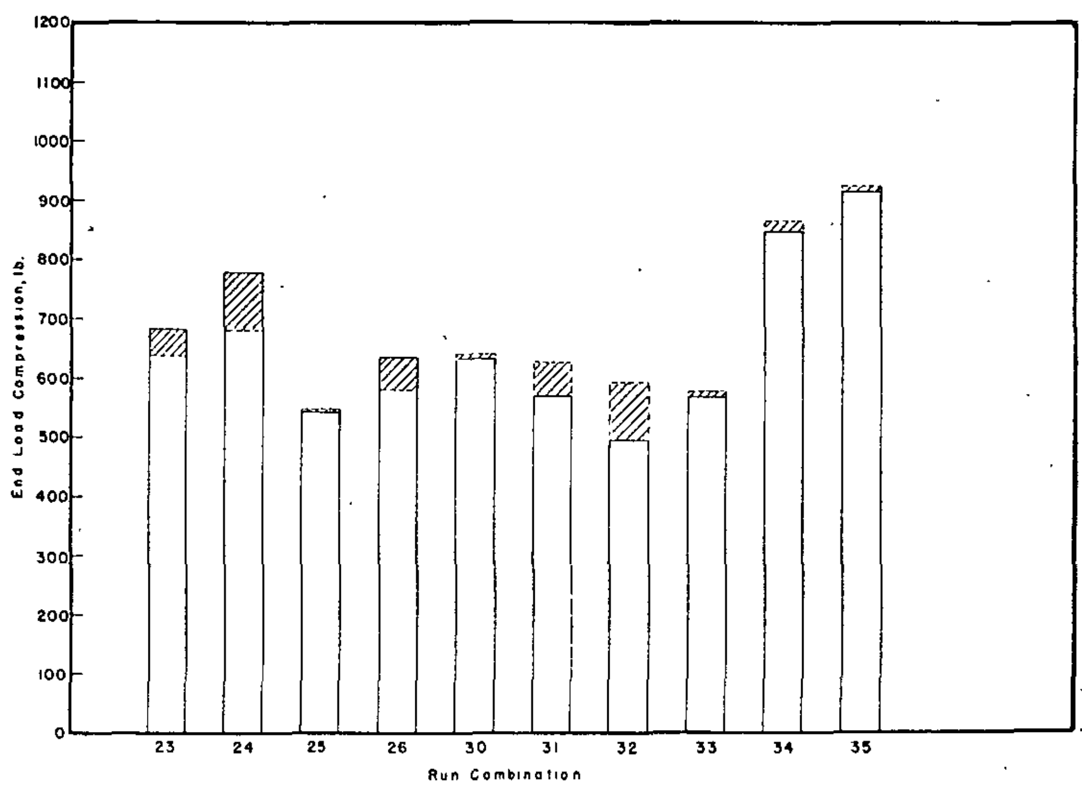

FIGURE 24. Comparison of Observed and Predicted End-Load Compression Tests on B-Flute Boxes (0-0.50 inch)—Based on the Basis Weight of the Liners.

——— Observed .... Predicted

PULP CHARACTERISTICS

The kraft liners and the 26-lb. kraft corrugating medium used in the Weight-Distribution Study were produced at St. Joe Paper Company, Port St. Joe, Florida, on one Fourdrinier machine from approximately the same pulp. Table XXXII gives a few of the chemical characteristics of the pulps and Table XXXIII gives the beating characteristics.

The pulps were beaten in a laboratory beater according to Institute Method 410 and were formed into hand sheets which were evaluated for the various strength tests indicated in Table XXXIII. The beating curves for the pulps are given in Figures 25 to 29.

TABLE XXXII

CHARACTERISTICS OF THE KRAFT PULPS USED FOR THE LINERS OF THE WEIGHT DISTRIBUTION STUDY

Pulp	Chlorine Number,* %	Lignin,† %	Permanganate Number‡
38-lb. DF	10.1	8.2	30.6
42-lb. DF	8.4	6.9	28.1
47-lb. DF and WF	7.9	6.9	27.8
52-lb. WF	9.6	8.2	30.0
90-lb. WF	8.1	6.7	28.0

*Institute Method 408
†Institute Method 428
‡Institute Method 410
Note: These data are reported on the ovendry basis.

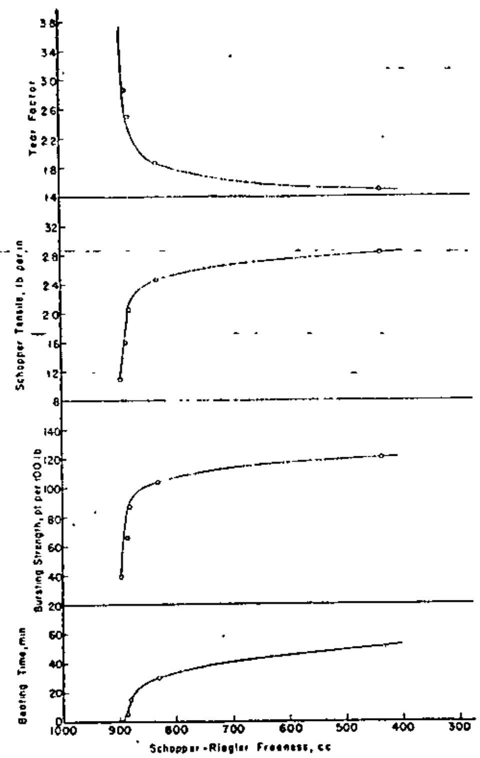

FIGURE 25. Beating Characteristics of Kraft Pulp Used for the 38-lb. DF Liner.

TABLE XXXIII

BEATING CHARACTERISTICS OF THE KRAFT PULPS USED FOR THE LINERS OF THE WEIGHT DISTRIBUTION STUDY

Beating Time, min.	Schopper-Riegler Freeness, cc. at 20° C.	Basis Weight (25 x 40—500), lb.	Bursting Strength, points per 100 lb.	Elmendorf Tear Factor	Schopper Tensile, lb./in.	Schopper Stretch, %
			Pulp for 38-lb. DF Liner			
0	895	45.9	39	3.73	10.8	2.0
5	885	46.1	66	2.86	16.0	2.1
15	880	47.8	87	2.49	20.5	3.0
30	830	47.1	104	1.85	24.6	3.4
50	435	45.6	120	1.49	28.1	4.1
			Pulp for 42-lb. DF Liner			
0	890	47.0	46	3.21	10.9	2.0
5	885	47.4	70	2.97	16.7	2.4
15	865	47.0	90	2.30	20.2	2.9
30	775	48.0	106	1.81	26.7	3.5
50	395	47.2	125	1.55	30.4	3.9
			Pulp for 47-lb. DF and WF Liners			
0	890	45.2	48	3.63	12.1	2.4
5	875	46.3	72	2.83	17.5	2.9
15	865	45.6	96	2.13	22.2	3.1
30	760	46.5	119	1.78	25.9	3.5
50	360	45.4	128	1.50	28.7	3.8
			Pulp for 52-lb. WF Liner			
0	865	45.9	44	3.16	8.6	1.8
5	875	46.8	68	2.59	17.5	2.4
15	865	46.5	88	2.19	21.1	2.7
30	820	45.4	107	1.85	25.0	3.0
50	390	45.8	119	1.46	27.3	3.6
			Pulp for 90-lb. WF Liner			
0	890	45.1	46	3.61	11.7	2.1
5	885	45.8	71	2.71	17.3	2.6
15	875	50.7	95	2.23	23.7	2.8
30	765	45.7	110	1.75	26.2	3.1
50	360	45.8	122	1.46	29.7	3.4

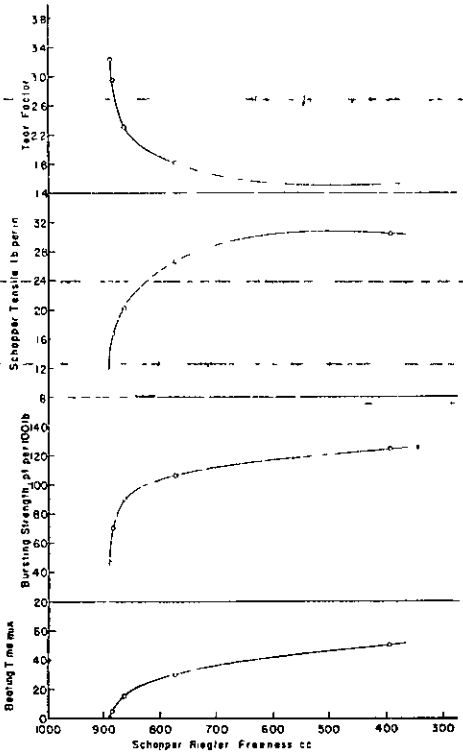

FIGURE 26 Beating Characteristics of Kraft Pulp Used for the 42-lb DF Liner

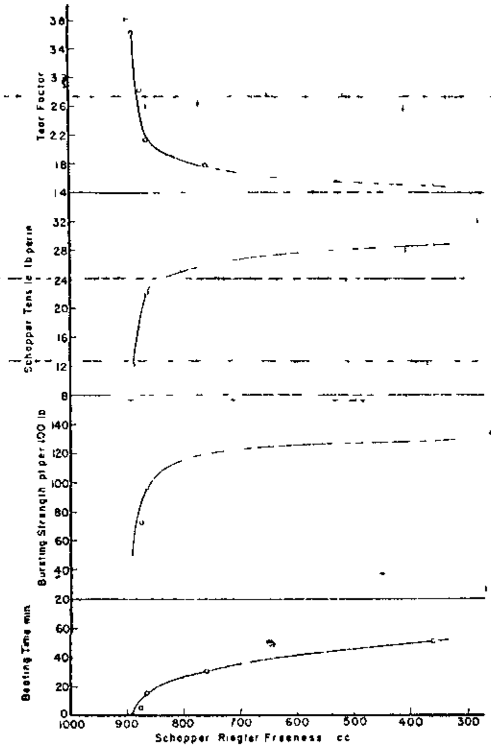

FIGURE 27 Beating Characteristics of Kraft Pulp Used for the 47-lb DF and WF Liner

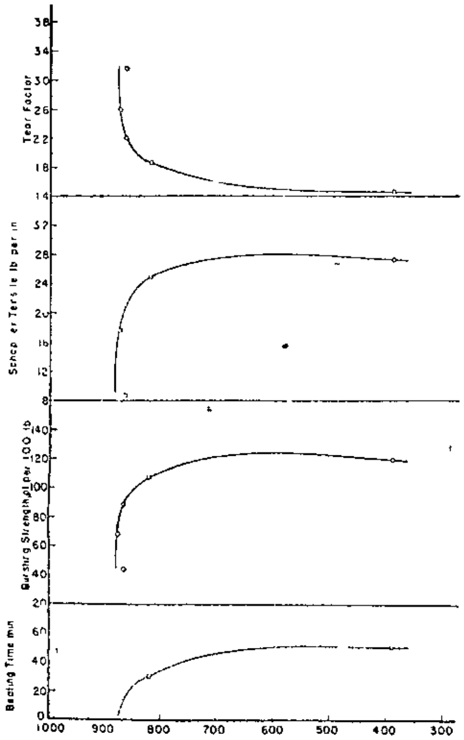

FIGURE 28 Beating Characteristics of Kraft Pulp Used for the 52-lb WF Liner

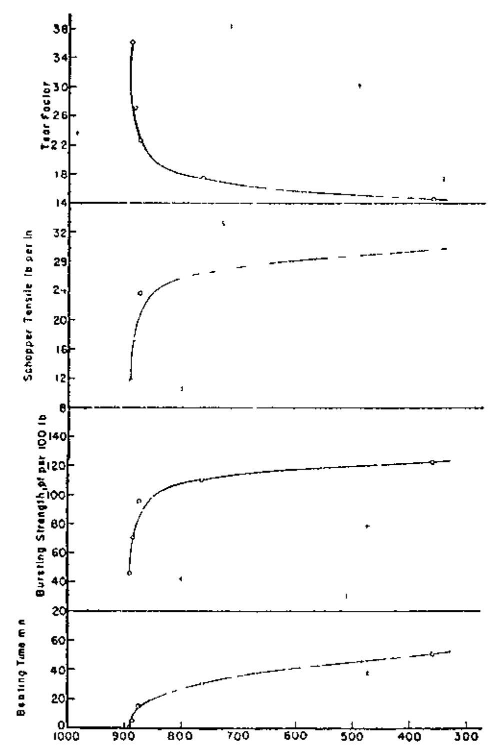

FIGURE 29 Beating Characteristics of Kraft Pulp Used for the 90-lb WF Liner