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The Use of Speciality K-Flute as a Substitute for Common Grades of Single Wall and Double Wall

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The Use of Speciality K-Flute as a Substitute For Common Grades of Single Wall and Double Wall.

By Ron Pristash

A Thesis Submitted To Faculty of the Undergraguate College in Partial Fulfillment for a Baccalaureate Degree In Paper Science.

Advisor: Dr. Scheller
Sponsors: Arvco Container Corporation
& Union Camp Corporation.

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Abstract

This study exmines a new corrugated flute profile known as "K" flute. The purpose of the study was to show that K flute can maintain the same structual integrity and use significantly less paper. The main tests performed were tests for compression strength. Studiying the results of compression testing, allows the designer to engineer the corrugated container to meet the performance level required. The study consists of two parts. The first part of the study examines the effect of an increase in caliper has on Edgwise Compresssion Testing (ECT) . It was found that K flute tested 5% stronger than A flute, 22% stronger than C flute, 40% stronger than B flute. The next part of th study compaired K flute as a subistute for commonly used grades of singlewall and doublewall, the results of the comparison are as follows: 275lb C vs 200lb K, the K flute tested 18% less in compression strengh, used 61% less paper in the liner and 7.6% more in the medium. In the next comparison, 200lb BC vs 200lb K, the K flute tested 42% less in compression strength, used 18% less paper in the liner and 80% less paper in the medium. 200lb A vs 200lb K, the K flute tested 7% stronger in compression strength, it used 0% less paper in the liner and 2% less paper in the medium. 275lb BC vs 44ECT K, the K flute tested 23% less in compresson strength, K flute used 3.6% more paper in the liner and 80% less in the medium.

Historical Introduction

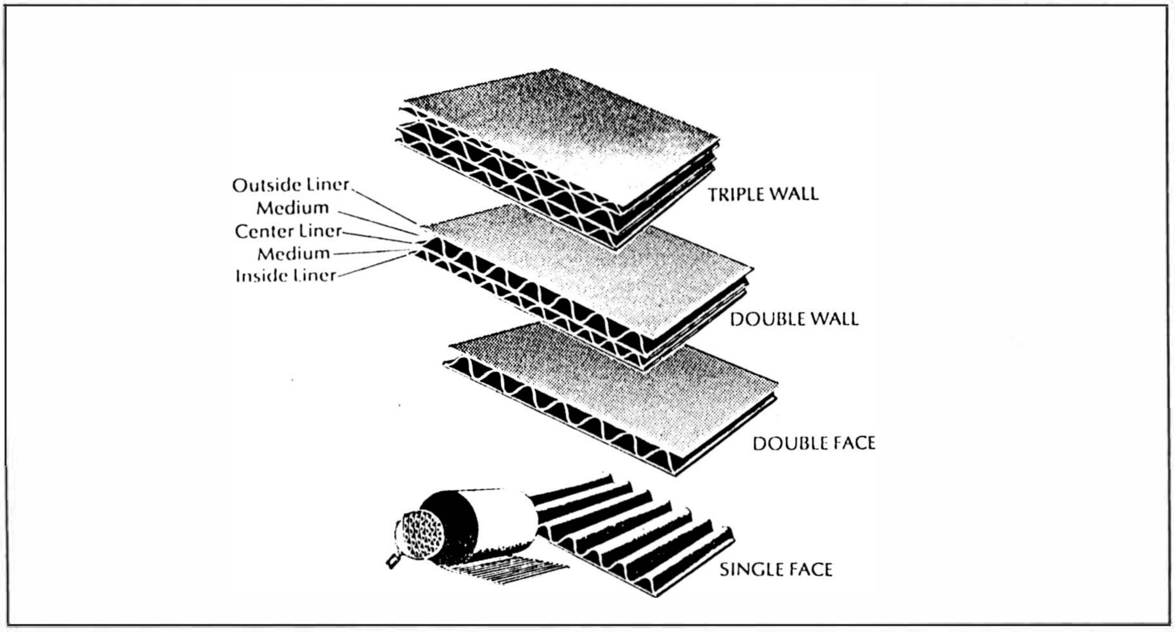
The first fluted material closely related to the present fluted member of corrugated board is believed to have appeared in England on July 7, 1856, when a patent was granted to Edward Charles Healy and Edward Ellis Allen. The corrugated material was made by wetting the paper and passing it between a heated pair of corrugated rollers. The new invention did not receive credit for the development of corrugated containers because very little progression seems to have been made with the invention.(1)

The first patent for corrugated material that is traceable to the present day, was patent no. 122,023 granted on December 19,1871, to an American, Albert L. Jones. In 1874 Oliver Long received a patent for adding facings to the corrugated. The Facings eliminated the undesirable stretch experienced by the unlined corrugated material. The fluted corrugated material was produced separately, and one surface by brushing the facing with paste and then applying the facing to the corrugated material. (1)

The first continuous corrugator was patented August 27, 1895 by Jefferson T. Ferres. Development of continuos corrugators came rapidly; on December 9,1897 , Willam G. Chapin applied for a patent on which is said to have been the first practical machine for producing double face board as a continuos operation. On Feburary 4, 1908 Samuel M. Langston patented a double face corrugator that applied certain new principals that are still in use today. The Langston corrugator utilized a single facer together with a double backer, yet each had independet control while operating in tandem style. (1)

Figure 1 (10) shows the structure of single wall board. It consists of a inside liner, out side liner and a corrugated medium. This type of board is used in 90% of all shipping applications. The strenght of the container is varied by changing, the liner, medium, or by varing the corrugation flute profile.

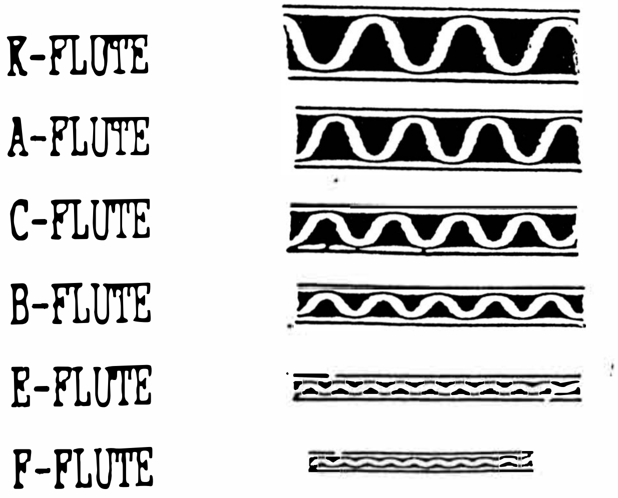
FIGURE 1 **The Structure of Single, Double And Triple Wall**



Double wall, also shown in figure 1, is utilized when higher compression strengths are needed, and to meet carrier regulations for size and weight. There is also a combination of 3 single wall layers known as triple wall. This type of board is used mostly in severe duty government applications.

The flute profiles are shown in figure 2. The flutes shown are actual size. It can be seen from figure 2 that the flutes do not follow a particular size pattern aplhebetacially.

FIGURE 2 Flute Height From Base To Peak



All flutes are named with a single alphebetical letter. The alphebitical lettering is assigned chronologically, "A" flute came first, then "B" and so on. New terminogly being added is Jumbo flute which is "K" flute and micro flute which is "F" flute. Figure 3, shows the make up of each flute profile. A flute profile consists of: a take up factor, number of flutes per inch, and the distance from base to peak of the flute. The take up factor is the ratio of the liner to the medium. For example, one lineal inch (machine direction) of liner requires 1.585 lineal inches of K fluted corrugated medium. The flutes per inch is the frequency of the fluting. The height is the height from base to peak for a particular flute. (9)

FIGURE 3 Flute Profiles

FLUTE	FLUTES PER LINEAR FOOT	*APPROXIMATE HEIGHT* (INCHES)	TAKE UP FACTOR
K-FLUTE	30	.220 (7/32)**	1.585
A-FLUTE	35.25	.188 (3/16)**	1.614
C-FLUTE	39	.145 (9/64)**	1.473
B-FLUTE	47	.106 (7/64)**	1.381
E-FLUTE	90	.055 (7/128)**	1.319
F-FLUTE	128	.030 (1/32)**	1.224

The flute profile with the highest caliper in theory should yeild the the greatest column strength. High flute profiles yeild containers with high top-to-bottom crush strengths. The high caliper also give the container the lowest flat crush making the box best suited for applications were a cushioning effect is required. (6)

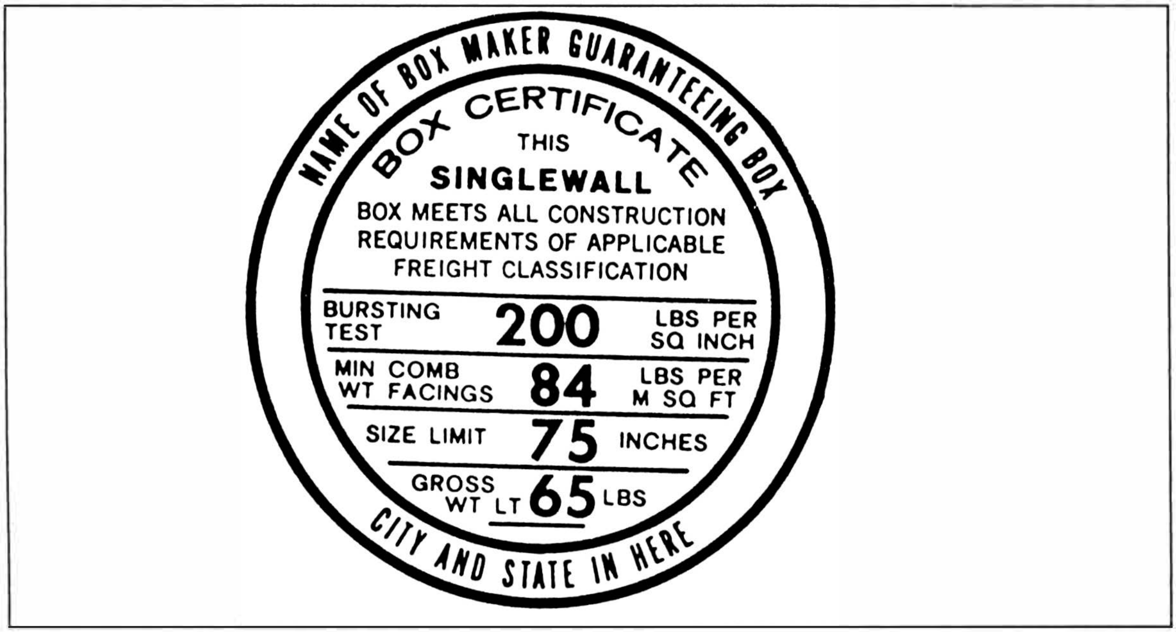
The fluting with the lowest caliper in theory will have the greatest resisitance to puncture. It will also have the highest flat crush. Low caliper flute profiles are best suited for applications wear less cushioning is needed and a high resistance to damage of the container in handling is desired. (6)

The micro flute profiles ("f" flute) are becoming very popular with the fast food industry. This profile offers the printability of folding carton while using significantly less paper.(5)

A corrugated container serves 3 basic functions: 1) to protect the contents 2) safe storage until the contents are purchased 3) Provide advertising when printed. The most important is saftey. Since a container and its contents are not in sight durring shipping, a set regulations were needed to detertmine if damage to the contents are due to poor handling by the carrier, a defect from the manufacture, or a poorly designed container. (3)

Rule 41 is one of the 51 rules established in the railroads Uniform Freight Classification (UFC) and is the most rigorous of the material based rules. Rule 41 applies to corrugated or solid fiberboard boxes. It appears as the round certification stamp found on the outside of a box. The rule specifies; 1) The maximum weight of the box contents. 2) Maximum outside dimensions. 3) The minimum combined weight of the facings. 4) The minimum bursting test and 5) The minimum edge crush test. Figure 4, shows a round certification stamp that conforms to rule 41.

Figure 4 Rule 41 Certifacition Stamp



Item 222 is rules established by the National Motor Freight Classification. It is similar to Rule 41 in its requirements. These rules are very restrictive for the creative designer. It was mentioned in the last paragraph that changes in these rules are occurring. On January 21 of 1996, the National Classification Committee approved a new rule designated Rule 180. This rule alllows shippers to use any material or design for transport packaging used in the less than truckload common carrier shipping.

There are 4 main reasons for the interest in the use of new speciality flutes: 1) The use of quick-change single-facers has given the plants flexibility to run various flute profiles with a minimal delay in production. 2) The use of computer aided design programs and equipment, make design with various flute profiles simple. See figures 3, it is a CAD layout for a Regular Slotted Container. The allowances for each profile are calculated immediately. 4). Constantly changing rules and regulations that are giving designers more freedom in designing.(5)

Experimental Design

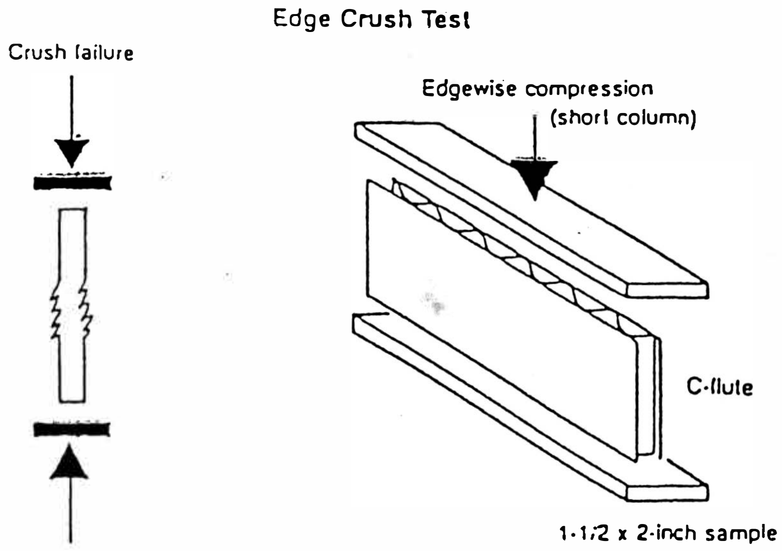
This study looks into the use of specialty K-flute as a possible replacement for various common grades of single and double wall. The overall objective for this experiment is to show that K-flute can develop similar structural performance and use significantly less paper.

The main tests will be compression strength performance testing. Examining compression strength tests gives the designer the ability to be able to engineer his container by controlling the amount of material and varying the flute height.

The first series of test involved using 200lbs K,A,C, and B flutes. The liner (42lb) and medium (26lb) for each of the samples was held constant. A 6x6 sample of each grade was soaked apart and each liner and medium weighted to ensure they are all the same weight. The only variable was the flute height. The following tests will be performed; edge-crush and top-to-bottom compression.

The Edge Crush Test (Figure 5) was performed following TAPPI test #T8 in a 22.2 C°/50% relative humidity environment. Ten samples for each profile will be crushed and an average value taken. Once the ECT tests are performed, the McKee formula was then used to evaluate the expected top-to-bottom compression strength. (4)&(1)

Figure 5 The Edge Crush Test



The McKee formula is:

$$P = 5.87 \times (Pm \times \sqrt{h} \times \sqrt{z})$$

P= top-to-bottom compression strength of box

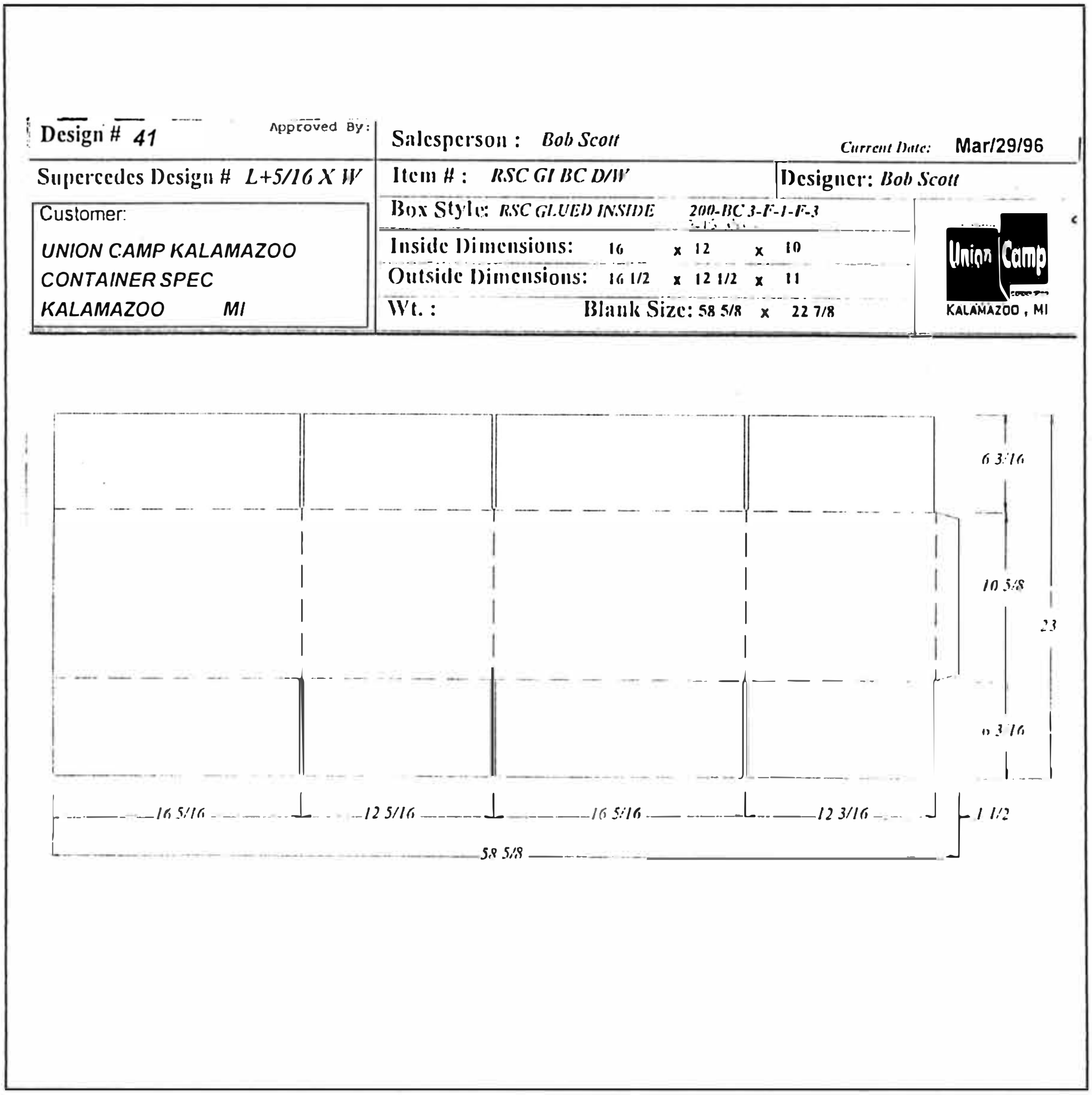
Pm = ECT Value

h= Caliper of board

z= perimeter of the box.

The next testing to be performed will be the full box compression tests. Ten boxes were constructed for each flute profile and allowed to condition for 24 hours at 22.2 C°/50% relative humidity. The size of the RSC's is 16 x 12 x 10. A regular slotted container has all flaps the same depth. The two outer flaps, normally the lengthwise flaps, are one-half the containers width (See Figure 6). The lengthwise flaps meet at the center when the box is folded. The RSC is the most commonly used box design in the corrugated industry.

Figure 6 Layout For A Regular Slotted Container



Design # 41 Approved By:	**Salesperson :** *Bob Scott*	*Current Date:* Mar/29/96
Supercedes Design # *L+5/16 X W*	**Item # :** *RSC GI BC D/W*	**Designer:** *Bob Scott*
Customer: *UNION CAMP KALAMAZOO* *CONTAINER SPEC* *KALAMAZOO MI*	**Box Style:** *RSC GLUED INSIDE* 200-BC 3-F-1-F-3 **Inside Dimensions:** 16 x 12 x 10 **Outside Dimensions:** 16 1/2 x 12 1/2 x 11 **Wt. :** **Blank Size:** 58 5/8 x 22 7/8	Union Camp KALAMAZOO, MI

The results from the above testing was analyzed, and compared to the predicted values. A strength analysis was then performed. The next series of test willl look into the use of K-flute for replacing common grades of single, and double wall. All of the testing done in the previous trials will be performed on the new group; edge crush and top-to-bottom compression. All of the tests were performed following TAPPI standards. 10 RSC's for each grad were constructed and allowed to condition for 24 hours before testing. For these tests, the strength, was the constant. After testing a cost analysis of each comparison was calculated.

The board comparisons will be as follows:

1) 200lb a vs 200 K
2) 275 lb c vs 200lb K
3) 275lb BC vs 44 ECT K
4) 200lb BC vs 200lb K

Results

Grade	Flute Profile	ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
275	BC	65.4	1623	1525	98
275	BC	66.3	1567	1525	42
275	BC	66.6	1605	1525	80
275	BC	66.1	1527	1525	2
275	BC	65.2	1553	1525	28
275	BC	66.3	1489	1525	-36
275	BC	65.9	1643	1525	118
275	BC	66.2	1584	1525	59
275	BC	66.4	1591	1525	66
275	BC	66.6	1673	1525	148
	Average	**66.1**	**1584**		
	Standard Deviation	**0.5**	**23**		

Grade	Flute Profile	ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
200	BC	59.7	1346	1410	-64
200	BC	61.3	1423	1410	13
200	BC	60.8	1394	1410	-16
200	BC	61.4	1375	1410	-35
200	BC	61.6	1408	1410	-2
200	BC	61.3	1321	1410	-89
200	BC	62.3	1378	1410	-32
200	BC	60.6	1432	1410	22
200	BC	62.6	1573	1410	163
200	BC	61.8	1412	1410	2
	Average	**61.3**	**1386**		**-4**
	Standard Deviation	**0.8**	**36**		

Grade	Flute Profile	ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
275	C	58.6	1172	1108	64
275	C	60.2	1385	1108	277
275	C	59.4	1131	1108	23
275	C	60.5	1146	1108	38
275	C	61.1	1038	1108	-70
275	C	59.1	1138	1108	30
275	C	59.3	1186	1108	78
275	C	59.6	1153	1108	45
275	C	59.9	1128	1108	20
275	C	60.3	1163	1108	55
	Average	**59.8**	**1152**		**29**
	Standard Deviation	**0.7**	**20**		

Grade	Flute Profile	ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
44ECT	K	55.6	1234	1410	-176
44ECT	K	56.7	1109	1410	-301
44ECT	K	54.7	1279	1410	-131
44ECT	K	55.8	1323	1410	-87
44ECT	K	57.1	1276	1410	-134
44ECT	K	56.3	1278	1410	-132
44ECT	K	56	1367	1410	-43
44ECT	K	57.5	1334	1410	-76
44ECT	K	56.9	1356	1410	-54
44ECT	K	57.0	1297	1410	-113
	Average	**56.4**	**1287**		**-125**
	Standard Deviation	**0.8**	**71**		

Flute Profile	Average ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
A	45.3	917	903	14
A	45.3	887	903	-16
A	45.3	907	903	4
A	45.3	925	903	22
A	45.3	975	903	72
A	45.3	917	903	14
A	45.3	923	903	20
A	45.3	893	903	-10
A	45.3	931	903	28
A	45.3	926	903	23
Average		**914**		**11**
Standard Deviation		**15**		**15**

Flute Profile	Average ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
B	43.7	696	676	20
B	43.7	701	676	25
B	43.7	692	676	16
B	43.7	687	676	11
B	43.7	679	676	3
B	43.7	685	676	9
B	43.7	704	676	28
B	43.7	691	676	15
B	43.7	733	676	57
B	43.7	694	676	18
Average		**696**		**20**
Standard Deviation		**15**		**15**

Flute Profile	Average ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
C	43.7	809	776	33
C	43.7	789	776	13
C	43.7	791	776	15
C	43.7	817	776	41
C	43.7	794	776	18
C	43.7	802	776	26
C	43.7	798	776	22
C	43.7	791	776	15
C	43.7	634	776	-142
C	43.7	787	776	11
Average		**798**		**22**
Standard Deviation		**10**		**10**

Flute Profile	Average ECT (lb/in)	Experimental Top-to-Bottom Compression (lb)	Predicted Top-to-Bottom Compression (lb)	Difference
K	44.1	986	945	41
K	44.1	978	945	33
K	44.1	1010	945	65
K	44.1	917	945	-28
K	44.1	939	945	-6
K	44.1	981	945	36
K	44.1	897	945	-48
K	44.1	952	945	7
K	44.1	993	945	48
K	44.1	1084	945	139
Average		**974**		**29**
Standard Deviation		**53**		**53**

Discussion of Results

For the first part of the experiment, the effect of an increase in caliper was examined in relation to the edge test(ECT). It can be seen from the graph in figure 7, that caliper had very little if any effect on ECT. The main contributor to ECT is the liner weight. The average ECT values were then used in the McKee formula to determine perdicted values. It can be seen in figure 8, that caliper has a significant role in box compression strength. The K-flute tested 5% stronger than the A flute, 22% stronger than cl flute and 40% stronger than B flute. It can also be noted how accurate the McKee formula is at predicting box compression strength.

Figure 7

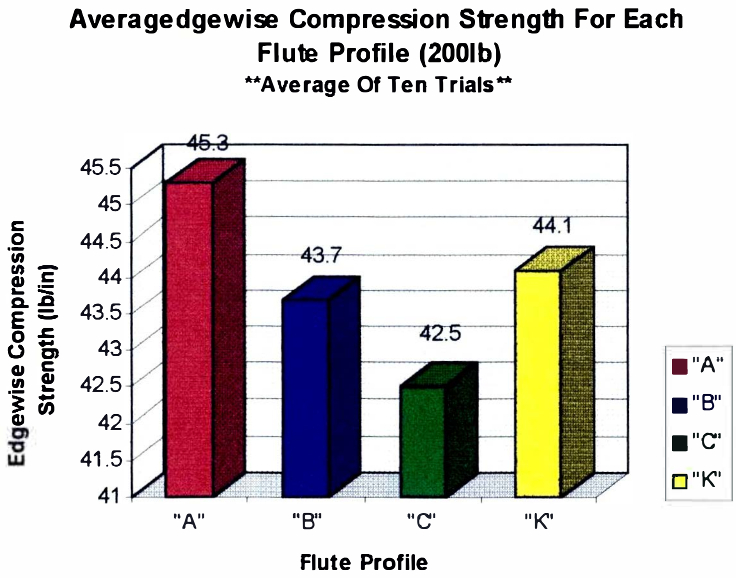
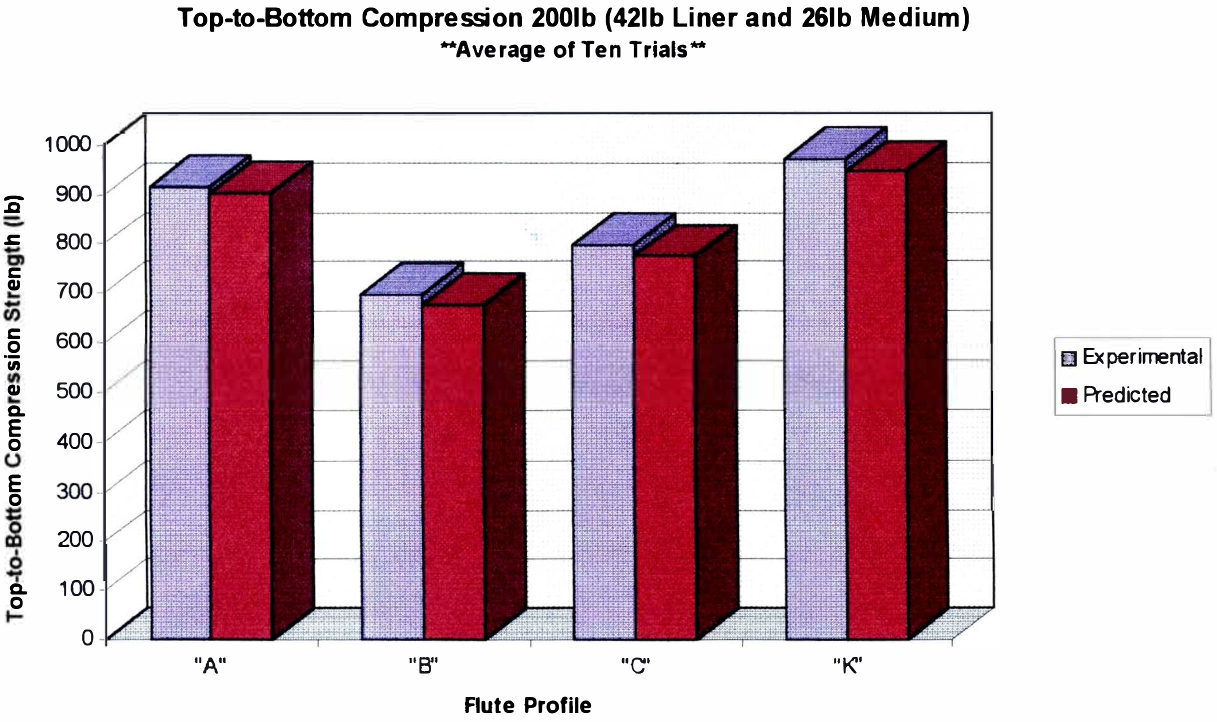


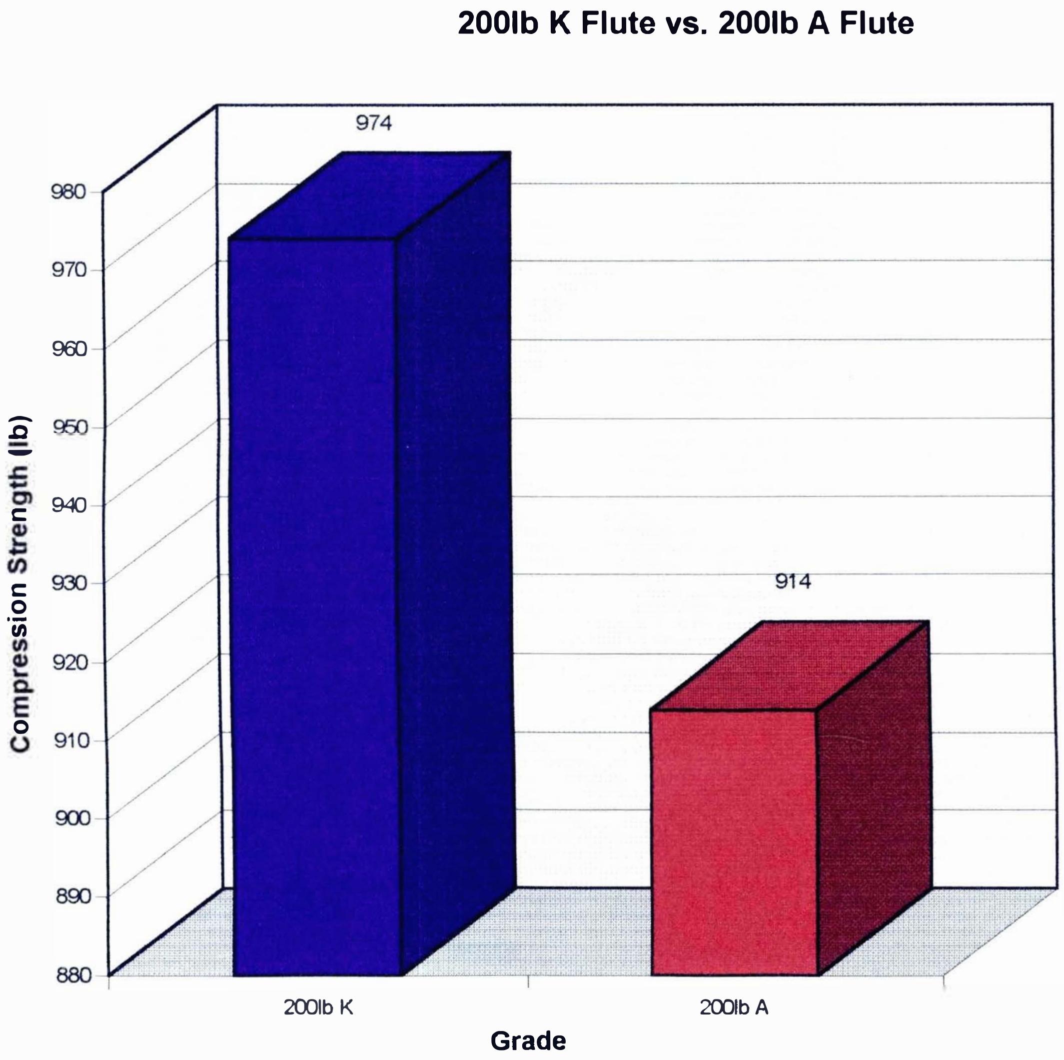
Figure 8



The next part of the study examined using K-flute as a substitute for various commonly used grades of single wall and double wall. The first test was ECT. 10 samples were cut and crushed and the values averaged. The predicted values for top-to -bottom compression were calculated. The regular slotted containers were then compressed and the values were averaged. The goal was to fall within 10% of the competitor in compression strength.

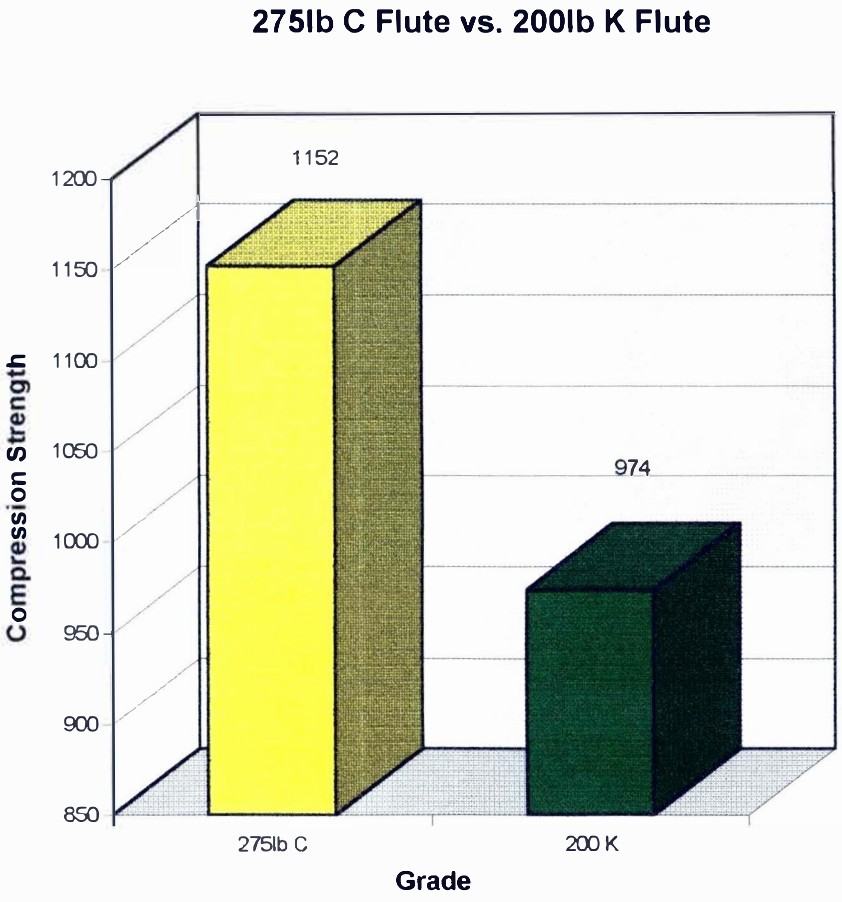
The first comparison invloved 200lb A vs 200lb K. It can be seen in figure 9, that the K-flute (974 ±531lbs) tested 5% stronger than the A-flute (914 ±15lbs). The cost analysis showed that K-flute used the same amount of liner but used 2% less paper in the medium.

Figure 9



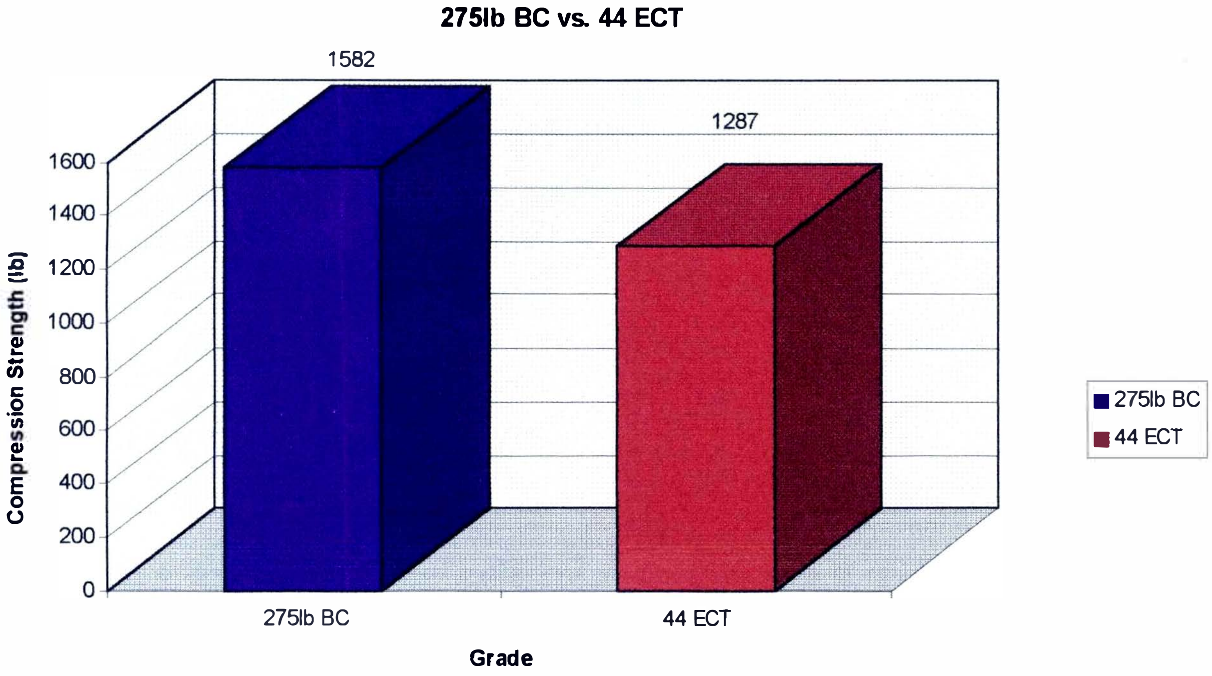
The next compression was 275lb C vs. 200lb K. In figure 10, it is shown that the K-flute came up short. The 200lb K-flute (974 ±53lb) tested 18% less in compression strength than the 275lb C flute (1152 ±20lbs). The cost analysis, if K-flute would have been successful is 61% less paper in the liner with only 7.6 more paper in the medium.

Figure 10



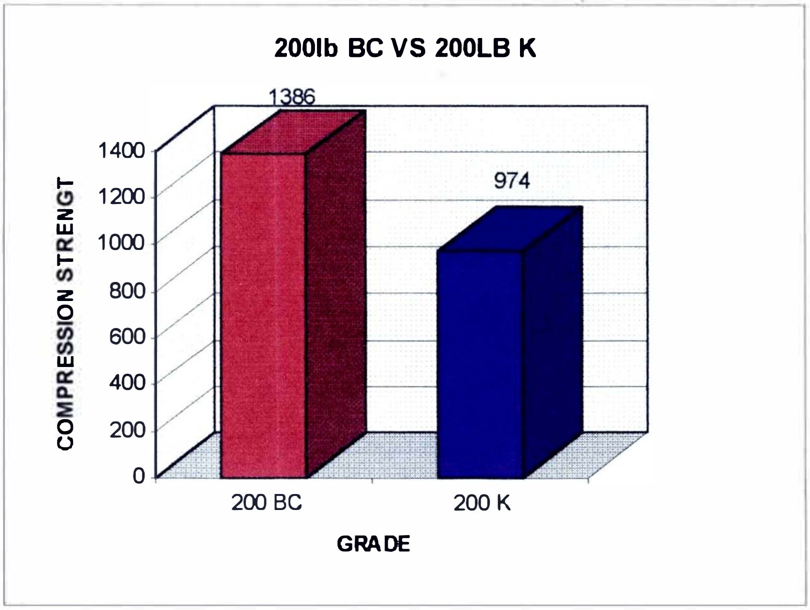
The next comparison involved 275lb BC vs. 44ECT K. In figure 11 it can be seen that the 275lb BC (1582 lbs) tested 23% stronger than the 44 ECT K (1287). The cost analysis shows that the K-flute if successful would have used 3.6% more paper in the liner, and used 80% less paper in the medium.

Figure 11



The final comparison involved 200lb K vs 200 lb BC. It figure 12 it shows that the 200lb K-flute (974 53 lbs) tested 42% less in compression strength than 200lb BC (1386 35 lbs). The cost analysis had the K-flute been successful, it would have used 18% less paper in the liner and 80% less paper in the medium.

Figure 12



Conclusion

Although, only in one of the comparisons did the K-flute exceed its competitors in compression strength (200lb K vs 200lb A), the study was still a success and will be valuable for future studies. Future studies could investigate the use of various medium weights in the k-flute profile to increase the compression strength closer to 10% goal. Also Since the K Flute samples were made from one run, the quality of the board may not be at peak performance levels.

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Appendix

Sample Calculation *200K*

TOP-TO-BOTTOM Compression = $5.87 \times (\text{ECT VALVE} \times \sqrt{\text{Caliper}} \times \sqrt{\text{Per}}$

$= 5.87 \times (44.1 \times \sqrt{0.230} \times \sqrt{56})$

$= 945$ lb