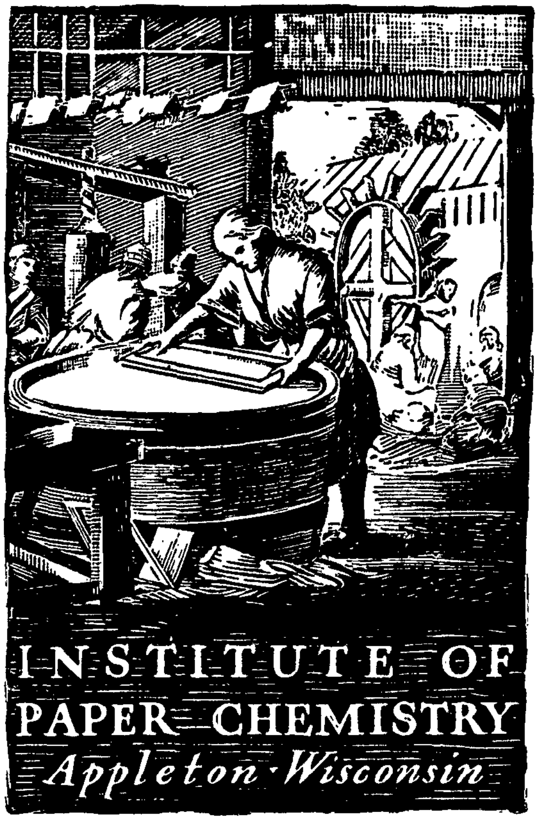

INVESTIGATION OF SINGLE-FLUTE TESTERS

Project 1108

Preliminary Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

October 15, 1952

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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INTRODUCTION

At the 1951 fall meeting of the Fourdrinier Kraft Board Institute, a committee was selected by the F.K.I. group to design, in conjunction with The Institute of Paper Chemistry, an investigation of the intercorrelation of single-flute testers so that, where necessary, these testers may all be brought into calibration. It was suggested that this investigation be completed before giving consideration to a continuous program on corrugating medium. This preliminary report presents a comparison of all test data received by the Institute as of September 15, although it should be mentioned that additional data are forthcoming from a few mills who were late in joining the study.

MATERIALS

The materials used in this study consisted of samples of commercial corrugating mediums submitted by the participating members. The various types of medium are presented in Table I.

SAMPLING AND TESTING PROCEDURE

The procedure was designed with the idea that it was desirable to eliminate, in so far as possible, all variables except the testers. For correlation of testers, it was desired to work with materials having as little variability as possible, and in this connection, it was felt that there is less variability within a given area of the board than between different sample areas of the same board. The following procedure was used:

TABLE I

IDENTIFICATION OF MATERIALS

Mill Code	Sample Number	Type of Corrugating Medium
D-1	179 - 182	kraft
D-1	183	semichemical
D-2	184- 187	kraft
D-2	188	semichemical
D-3	189 - 192	kraft
D-3	193	semichemical
F	130- 134	26-lb. kraft
H	125 - 129	Chemfibre
M	206 - 210	26/28-lb. kraft
N-1	145 - 149	semichemical (chestnut)
N-2	150- 154	semichemical (chestnut)
O-1	119 - 124	Chemfibre
O-2	119A - 124A	Chemfibre
P	155 - 159	semichemical
Q-1	135 - 139	semichemical
Q-2	140 - 144	semichemical
R	160 - 164	semichemical

A. Selection of Samples and Specimens

1. Each participating mill was to submit at least five different samples of their medium.

2. Each sample was to consist of a strip 13 inches wide and 72 inches in the machine direction. The sample was to be folded to form a folded pad 13 x 13 inches and marked with proper identification.

3. The samples were to be shipped to The Institute of Paper Chemistry.

4. When the samples were received at the Institute, each one was given a code number. The Institute cut the test specimens according to the accompanying diagram (Figure 1) from the 13 x 72-inch sheet composing each sample. The specimens corresponding to those marked "mill" were returned to the respective mill for testing on their single-fluter. The samples marked IPC in the diagram were tested at the Institute. The balance of each sample will be stored for future reference in case a recheck between testers is necessary.

B. Conditioning

The following procedure was suggested for use both at the mill and at the Institute.

1. Sample Conditioning

a. Precondition for 6 hours at 35% R.H. and 73°F.

b. Condition for 12 hours at 50% R.H. and 73°F. before fluting.

c. After fluting, condition for 6 hours at 50% R.H. and 73°F. before making the flat crush determination.

12 inches
Machine Direction

3"

1"

12 inches
Cross Machine

No. 1 - IPC	No. 11 - Mill	No. 21 - IPC	No. 31 - Mill
No. 2 - Mill	No. 12 - IPC	No. 22 - Mill	No. 32 - IPC
No. 3 - IPC	No. 13 - Mill	No. 23 - IPC	No. 33 - Mill
No. 4 - Mill	No. 14 - IPC	No. 24 - Mill	No. 34 - IPC
No. 5 - IPC	No. 15 - Mill	No. 25 - IPC	No. 35 - Mill
No. 6 - Mill	No. 16 - IPC	No. 26 - Mill	No. 36 - IPC
No. 7 - IPC	No. 17 - Mill	No. 27 - IPC	No. 37 - Mill
No. 8 - Mill	No. 18 - IPC	No. 28 - Mill	No. 38 - IPC
No. 9 - IPC	No. 19 - Mill	No. 29 - IPC	No. 39 - Mill
No. 10- Mill	No. 20 - IPC	No. 30 - Mill	No. 40 - IPC

Figure 1

Method of Cutting Test Specimens

Note: The Institute tests the odd numbers 1 to 10, 21 to 30 and the even numbers 11 to 20 and 31 to 40; the Mill is to test the others.

C. Testing

1. Single-fluter Conditions

a. Flute all specimens with wire side up--i.e., wire side will be concave.

b. Temperature of die--325 ± 5°F.

c. Pressure--650 ± 25 pounds total

d. Time in press--3 ± 0.5 seconds

2. Flat Crush Test

a. Tester conditions: A compression tester with a rate of loading equivalent to 300 ± 100 pounds per minute was suggested for use. The slotted die used to align the holder containing the fluted specimen should be secured to the bottom platen of the crush tester. Two-sided pressure sensitive tape manufactured by the Minnesota Mining and Manufacturing Company was suggested for this purpose. All test readings were to be discarded when examination indicated that the specimen slipped in the specimen holder during the flat crush test.

b. Calibration: The flat crush tester should be calibrated by means of deadweights so that the tester is correct to within 0.5% of the scale reading or 0.05 pound, whichever is the greater over the entire range used. Platen parallelism should be within 0.002 inch under no load.

D. Report

1. Each mill reported the individual test values for each sample to the Institute on data sheets which the Institute supplied with specimens. Individual readings were reported to the nearest 0.1 lb.

DISCUSSION OF RESULTS

As previously mentioned, the purpose of this study was to compare the performance of single-fluters in operation at the various mills with The Institute of Paper Chemistry's tester. For each sample of corrugating medium submitted by the mills, 20 single-flute flat crush test results which had been obtained at the mill were compared with 20 results obtained at the Institute. In order to compare the results, the "t" test was performed on each sample submitted in order to analyze the significance of the differences between the averages. The calculation methods and individual test results relevant to the "t" test are presented in the Appendix.

A summary of the comparison of the test results for mill and Institute data is presented in Table II. In this comparison, as well as in the following tables, the Institute's test values have been used as the reference line. It may be noted in Table II that the maximum variation between the average flat crush results of the Institute and those of a given mill is 12.3% and the minimum is 1.4%. Further, it may be noted that the average flat crush results for Mills H, N-2, O-2, and Q-1 are ~~higher~~ lower than those for the Institute, whereas the results for Mills O-1 and P are ~~lower~~ higher.

A comparison of the test results for individual sample lots submitted by each mill is presented in Table III.

Mill H

The maximum variation for flat crush on the five different samples submitted by Mill H is -12.0%. All flat crush averages for mill

TABLE II

SUMMARY OF TEST RESULT COMPARISONS
(Average Mill and Institute Results)

Mill Code	No. of Samples Submitted	Flat Crush (average), lb. Mill	Flat Crush (average), lb. I.P.C.	Average Difference, lb.*	Average Difference, %	Maximum Difference, lb. **	No. of Samples Significant	No. of Samples not Significant
D-1	5		14.3					
D-2	5		14.3					
D-3	5		14.5					
F	5		9.3					
H	5	16.3	17.3	-1.0	-5.8	-2.2	3	2
M	5							
N-1	5		15.6					
N-2	5	13.6	15.5	-1.9	-12.3	-2.3	5	0
O-1	6	14.4	14.1	+0.3	+2.1	+0.6	0	6
O-2	6	13.8	14.0	-0.2	-1.4	-1.2	1	5
P	5	15.1	13.5	+1.6	+11.9	+3.0	3	2
Q-1	5	13.0	13.7	-0.7	-5.1	-1.1	3	2
Q-2	5		13.6					
R	5							

* Average difference is the difference between the Institute average and the mill average.

**Maximum difference encountered in comparing the Institute average and the mill average for any sample submitted by that particular mill.

TABLE III

SUMMARY OF INDIVIDUAL SAMPLE LOTS

Mill Code	Sample Number	Basis Weight, lb.	Caliper, points	Flat Crush, lb. I.P.C.	Flat Crush, lb. Mill	Difference Amount	Difference %	Is Difference Significant?	95% Confidence Limits	$\pm t_{0.05} \cdot \frac{s}{\sqrt{n-1}}$
D-1	179	29.2	9.2	12.2					12.9-11.5	0.68
D-1	180	25.8	8.8	14.2					15.0-13.4	0.82
D-1	181	26.9	7.3	13.6					14.5-12.7	0.90
D-1	182	28.3	8.2	18.8					19.5-18.1	0.74
D-1	183	27.2	8.7	12.8					13.3-12.3	0.45+
D-2	184	30.0	9.3	13.3					13.8-12.8	0.54
D-2	185	27.2	8.3	14.6					15.3-13.9	0.65+
D-2	186	27.4	7.2	15.2					15.8-14.6	0.57
D-2	187	28.5	8.2	18.4					19.0-17.8	0.61
D-2	188	27.4	8.9	10.2					10.8- 9.6	0.64
D-3	189	30.0	9.4	10.9					11.6-10.2	0.65+
D-3	190	27.4	8.4	15.0					15.5-14.5	0.50
D-3	191	28.3	7.4	16.5					17.0-16.0	0.48
D-3	192	28.1	8.1	17.6					18.3-16.9	0.69
D-3	193	26.8	9.1	12.4					12.9-11.9	0.53
F	130	29.4	10.0	9.3					9.8- 8.8	0.45+
F	131	28.4	8.9	9.3					9.9- 8.7	0.65-
F	132	28.4	9.4	9.6					10.2- 9.0	0.55+
F	133	29.1	9.2	9.7					10.2- 9.2	0.53
F	134	28.6	8.8	8.4					9.0- 7.8	0.61
H	125	27.0	10.0	17.4	16.2	-1.2	-6.9	Yes	17.9-16.9	0.48
H	126	27.0	10.2	16.7	16.6	-0.1	-0.6	No	17.5-15.9	0.78
H	127	27.0	10.1	17.4	16.7	-0.7	-4.0	No	18.0-16.8	0.57
H	128	27.1	10.3	16.7	15.8	-0.9	-5.4	Yes	17.3-16.1	0.57
H	129	27.6	10.4	18.4	16.2	-2.2	-12.0	Yes	18.9-17.9	0.48

TABLE III (Continued)

SUMMARY OF INDIVIDUAL SAMPLE LOTS

Mill Code	Sample Number	Basis Weight, lb.	Caliper, points	Flat Crush, lb. I.P.C.	Flat Crush, lb. Mill	Difference Amount	Difference %	Is Difference Significant?	95% Confidence Limits	$\pm t_{0.05} \cdot \frac{s}{\sqrt{n-1}}$
M	206									
M	207									
M	208									
M	209									
M	210									
N-1	145	29.5	9.8	15.9					16.5-15.3	0.56
N-1	146	27.4	10.0	14.2					14.7-13.7	0.47
N-1	147	29.6	9.9	16.1					16.6-15.6	0.49
N-1	148	29.6	9.8	16.1					16.7-15.5	0.59
N-1	149	29.2	9.9	15.7					16.2-15.2	0.50
N-2	150	28.1	10.1	15.0	13.1	-1.9	-12.7	Yes	15.4-14.6	0.40
N-2	151	29.5	9.9	16.1	15.3	-0.8	-5.0	Yes	16.6-15.6	0.53
N-2	152	27.8	10.0	15.5	13.4	-2.1	-13.5	Yes	16.2-14.8	0.65+
N-2	153	27.8	10.0	15.5	13.2	-2.3	-14.8	Yes	15.9-15.1	0.41
N-2	154	28.8	10.0	15.2	13.1	-2.1	-13.8	Yes	15.6-14.8	0.41
O-1	119	25.1	10.1	14.5	15.1	+0.6	+4.1	No	15.1-13.9	0.57
O-1	120	25.3	10.1	14.3	14.2	-0.1	-0.7	No	14.8-13.8	0.46
O-1	121	25.3	10.2	14.5	14.6	+0.1	+0.7	No	15.2-13.8	0.68
O-1	122	25.4	10.2	14.1	14.7	+0.6	+4.3	No	14.7-13.5	0.57
O-1	123	25.3	10.2	14.0	14.3	+0.3	+2.1	No	14.7-13.3	0.71
O-1	124	25.1	10.1	13.2	13.6	+0.4	+3.0	No	13.9-12.5	0.66
O-2	119-A			13.8	13.8	0.0	0.0	No	14.5-13.1	0.72
O-2	120-A			14.8	13.6	-1.2	-8.1	Yes	15.4-14.2	0.62
O-2	121-A			14.4	14.7	+0.3	+2.1	No	15.1-13.7	0.67
O-2	122-A			14.1	14.3	+0.2	+1.4	No	14.7-13.5	0.64
O-2	123-A			13.8	13.1	-0.7	-5.1	No	14.4-13.2	0.62
O-2	124-A			13.4	13.0	-0.4	-3.0	No	13.9-12.9	0.52

TABLE III (Continued)

SUMMARY OF INDIVIDUAL SAMPLE LOTS

Mill Code	Sample Number	Basis Weight, lb.	Caliper, points	Flat Crush, lb. I.P.C.	Flat Crush, lb. Mill	Difference Amount	Difference %	Is Difference Significant	95% Confidence Limits	$\pm t_{0.05} \cdot \frac{s}{\sqrt{n-1}}$
P	155	27.5	10.7	14.6	17.4	+2.8	+19.2	Yes	15.1-14.1	0.53
P	156	27.6	10.4	14.3	14.3	0.0	0.0	No	14.9-13.7	0.64
P	157	27.0	10.8	12.2	12.7	+0.5	+ 4.1	No	12.8-11.6	0.60
P	158	27.8	10.6	12.8	14.6	+1.8	+14.1	Yes	13.3-12.3	0.48
P	159	28.0	10.4	13.6	16.6	+3.0	+22.1	Yes	14.4-12.8	0.81
Q-1	135	26.0	9.2	13.9	12.8	-1.1	- 7.9	Yes	14.6-13.2	0.67
Q-1	136	26.1	9.5	13.6	13.2	-0.4	- 2.9	No	14.2-13.0	0.60
Q-1	137	25.4	9.7	13.0	12.4	-0.6	- 4.6	No	13.4-12.6	0.45-
Q-1	138	27.4	9.4	13.7	13.0	-0.7	- 5.1	Yes	14.1-13.3	0.35+
Q-1	139	27.6	9.9	14.5	13.7	-0.8	- 5.5	Yes	14.9-14.1	0.44
Q-2	140	27.2	9.7	13.1					13.7-12.5	0.57
Q-2	141	27.9	10.1	13.4					13.9-12.9	0.49
Q-2	142	27.6	10.1	13.1					13.6-12.6	0.50
Q-2	143	28.8	10.0	14.4					14.9-13.9	0.49
Q-2	144	27.2	9.7	13.8					14.2-13.4	0.36
R	160									
R	161									
R	162									
R	163									
R	164									

test results are lower than the Institute averages on corresponding samples. Three of the five samples yielded significant differences between mill and Institute averages.

Mill N-2

The maximum variation for flat crush on the five samples submitted by Mill N-2 is -14.8%. All five samples yielded mill flat crush averages which were significantly lower than the Institute averages.

Mill O-1

The maximum variation for flat crush on the six samples submitted by Mill O-1 is +4.3%. No significant differences between mill and Institute sample averages were observed.

Mill O-2

The maximum variation for flat crush on the six samples submitted by Mill O-2 is -8.1% which was obtained on sample 120-A. For the six samples submitted, only the difference between mill and Institute averages for Sample 120-A was significant.

Mill P

The maximum variation for flat crush on the five samples submitted by Mill P is +22.1%. The mill averages for samples 155, 157, 158, and 159 are higher than those for the Institute; the averages for sample 156 were the same for both mill and Institute test results. Three of the five samples yielded significant differences between mill and Institute averages.

Mill Q-1

The maximum variation for flat crush on the five samples submitted by Mill Q-1 is -7.9%. All flat crush averages for mill test results are lower than the Institute averages on corresponding samples. Three of the five samples yielded significant differences between mill and Institute averages.

The 95% confidence limits presented in Table III determine the interval within which 19 out of 20 times the true population mean, as determined from the Institute data, will lie. The method for calculating these limits is presented in the Appendix.

This study was designed to eliminate as much as possible the variation in material for each sample submitted. In the instances where the "t" test showed a significant difference between mill and Institute results, an analysis of variance was performed to separate the variability as a result of machines and the variability as a result of material. The results of these analyses showed that the variability resulting from material was not a factor contributing to the significant difference between the mill and Institute results. However, there are several other variables which could influence the single-flute flat crush test results. Among these are (1) variables in the operation of the single-fluter, (2) variables in the pretest treatment of the specimens, and (3) variables in the compression tester. If the procedures previously outlined regarding conditioning of specimens, single-fluter conditions, and flat crush testing were not rigidly followed, significant differences between mill and Institute test results could be expected. As pointed out in Compression Report 29 (April 1, 1952), previous experience has shown that there is a tendency for flat crush values to decrease as the press load is increased. The magnitude of the change with pressure depends on the type of medium which is being tested. If a higher forming temperature is used, the flat crush results will be higher. The time during which the specimen is subjected to heat and pressure does not appear to influence flat crush in a significant manner. Tension on the specimen during the fluting operation appears to decrease the flat crush markedly. Materials formed at higher relative humidities tend to give higher flat crush values than those formed at low humidities.

A graphic comparison of mill and Institute flat crush averages for individual samples is presented in Figures 2 through 7 for the six mills whose data are complete.

SUMMARY

This report presents the results of a study designed to investigate the intercorrelation of single-flute testers so that, where necessary, these testers may all be brought into calibration. Only one tester yielded single-flute flat crush results which compared favorably with Institute results on all samples submitted. Likewise, only one tester yielded flat crush results which differed significantly from Institute results on all samples submitted. The average percentage difference between mill and Institute results varied from +1.4 to +12.3.

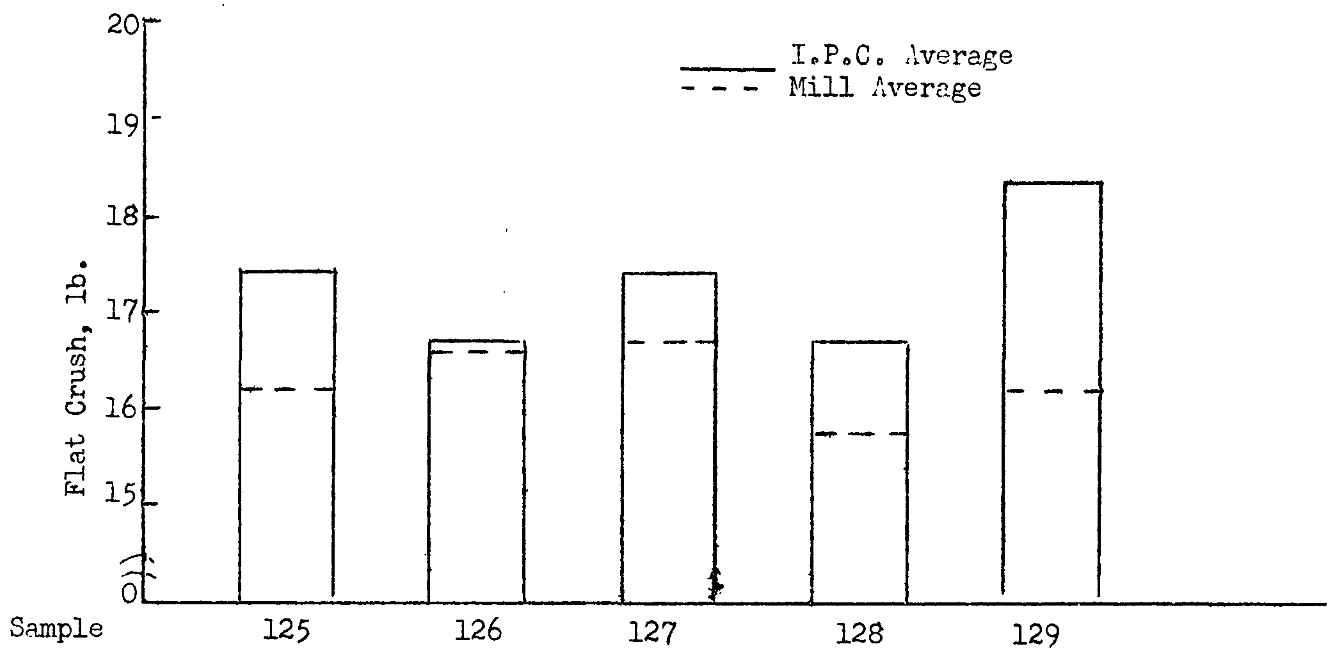

Figure 2

Mill H

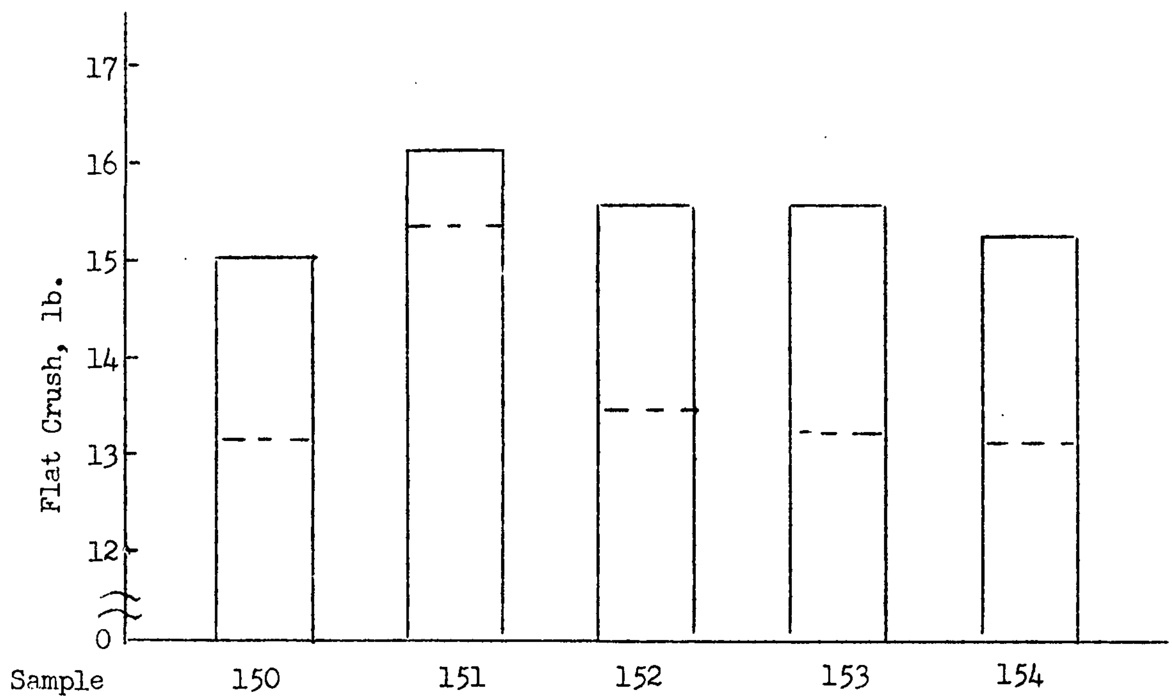

Figure 3

Mill N-2

COMPARISON OF SINGLE-FLUTE FLAT CRUSH RESULTS

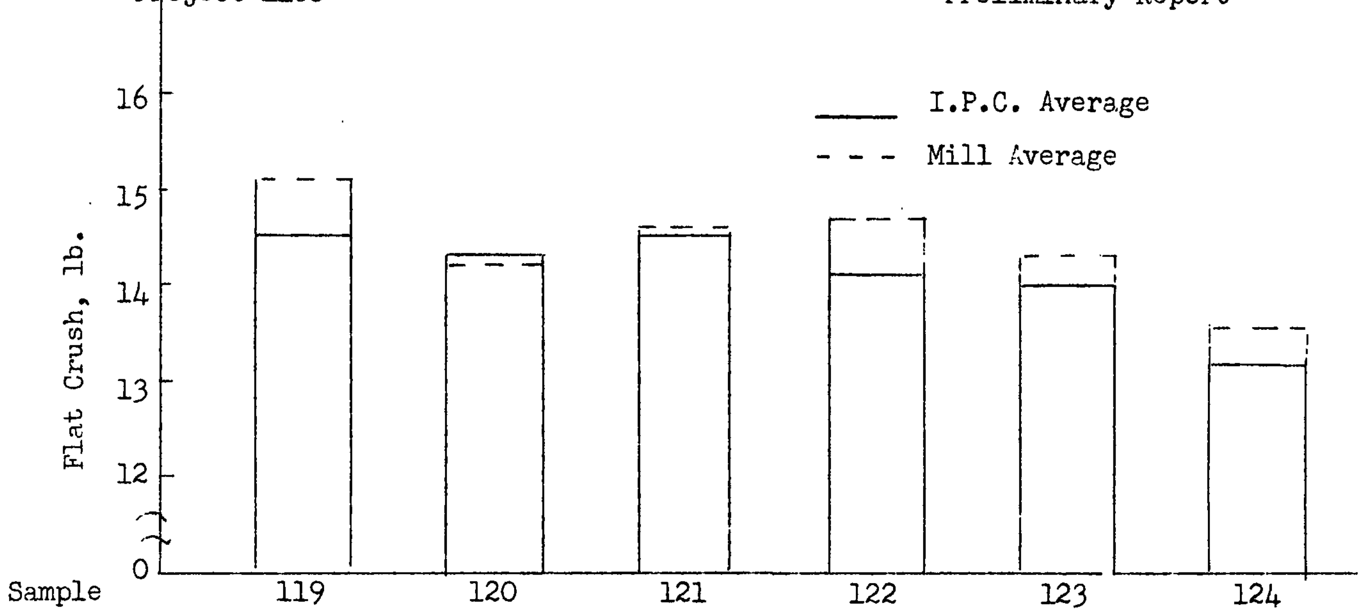

Figure 4

Mill O-1

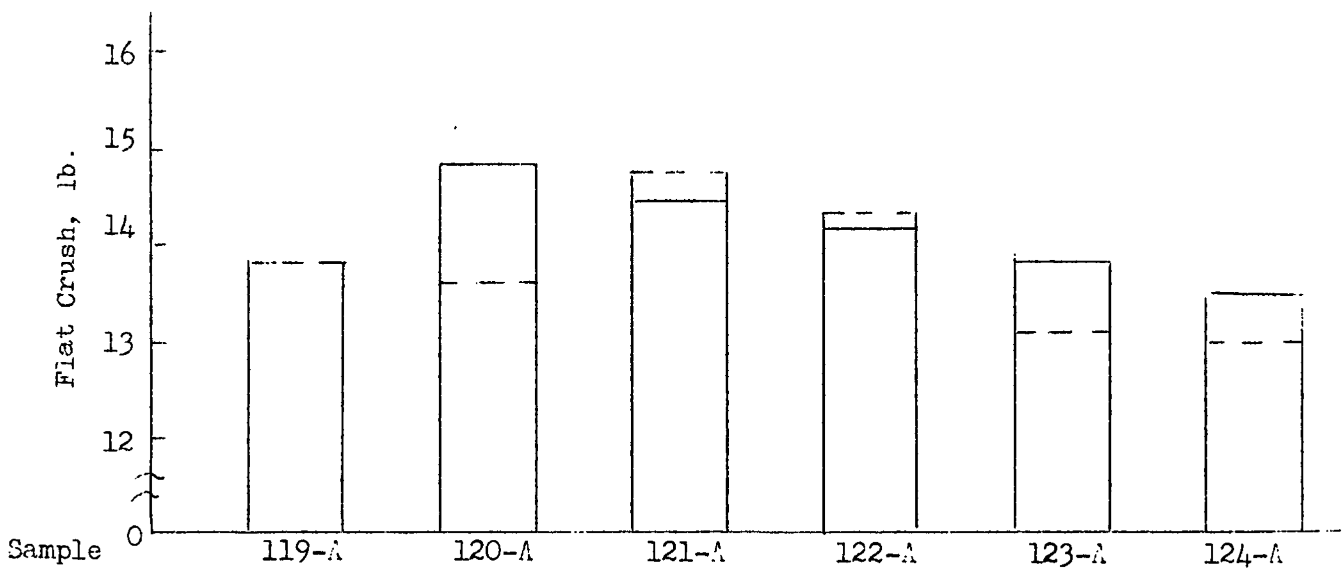

Figure 5

Mill O-2

COMPARISON OF SINGLE-FLUTE FLAT CRUSH RESULTS

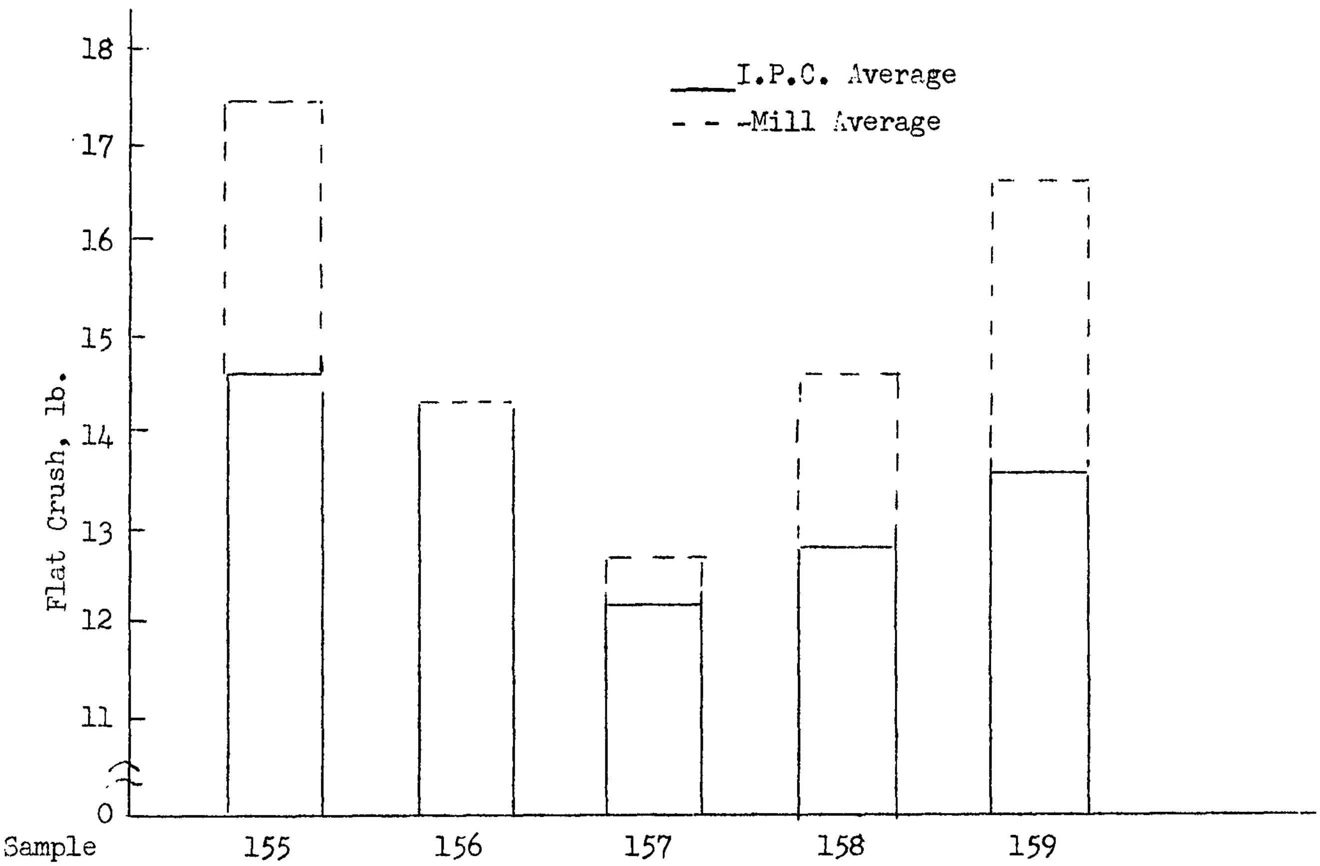

Figure 6

Mill P

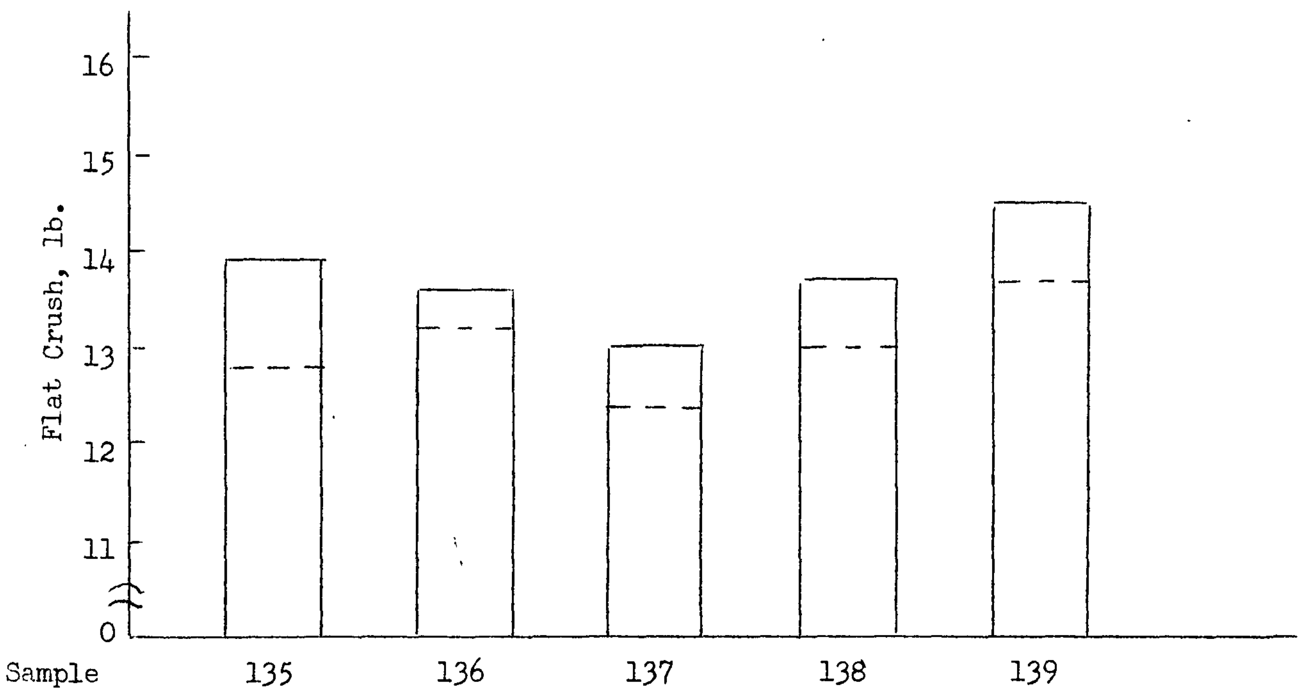

Figure 7

Mill Q-1

COMPARISON OF SINGLE-FLUTE FLAT CRUSH RESULTS

Variation as a result of material was minimized in the manner of cutting and distributing the specimens for testing. The variability resulting from the operation of the single-fluter, the pretest treatment of the specimens, and the compression tester would be minimized if the previously outlined procedure were followed rigidly. It is suggested that wherever the Institute and mill results differ significantly, an investigation should be performed to determine if any of the above factors might be causing such variability in results.

Appendix

The individual single-flute flat crush test results for each sample submitted are presented in Table IV, together with the differences between Institute and mill results. The following calculations are all based on the data given in Table IV.

For each sample submitted, 20 flat crush test results which had been obtained at the mill were compared with 20 such test results obtained at the Institute. It was desired to determine by significance of difference between averages whether the two testers compared favorably. The "t" test was used to determine whether the averages were significantly different. The following procedure was used to analyze the data for each sample submitted.

1. The average ($\bar{X}_M$) for mill test results was calculated from

$$\bar{X}_M = \frac{\Sigma X_M}{N_M}$$

where ΣX_M is the sum of the individual test results obtained at the mill and

N_M is the number of test results included in ΣX_M. (N_M was usually 20 except for samples where one or more test results were discarded because the specimen slipped in the specimen holder during the flat crush test.)

TABLE IV

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill D-1

	Sample 179 I.P.C.	Sample 180 I.P.C.	Sample 181 I.P.C.	Sample 182 I.P.C.	Sample 183 I.P.C.
	10.6	14.2	13.8	19.9	12.5
	12.3	14.1	16.0	18.0	12.4
	12.6	16.0	12.1	19.7	14.4
	13.3	12.3	15.3	17.9	11.9
	13.3	16.3	12.1	18.8	11.8
	11.1	13.0	14.5	18.0	13.8
	13.1	14.1	14.0	19.0	12.8
	13.0	13.0	12.0	18.4	14.5
	15.1	13.8	16.5	15.1	13.0
	10.2	14.3	11.2	22.2	12.8
	12.9	18.5	15.6	19.1	12.7
	12.2	15.2	17.5	17.1	12.9
	8.7	14.1	12.8	21.8	13.2
	11.5	13.2	12.1	20.3	13.7
	13.6	16.2	13.0	18.5	11.0
	11.5	13.4	13.9	17.8	14.3
	12.6	14.8	14.7	19.4	11.4
	11.2	13.4	12.6	19.1	13.1
	11.9	10.1	11.1	17.4	12.1
	13.8	13.6	10.7	19.0	12.4
Av.	12.2	14.2	13.6	18.8	12.8

No data were received from Mill D-1.

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill D-2

	Sample 184 I.P.C.	Sample 185 I.P.C.	Sample 186 I.P.C.	Sample 187 I.P.C.	Sample 188 I.P.C.
	15.6	14.5	13.5	17.0	10.0
	12.2	13.5	15.5	20.3	11.3
	13.2	15.5	14.3	16.3	9.8
	14.1	14.0	14.6	17.8	10.6
	14.9	11.8	16.0	18.0	10.3
	14.0	14.1	14.2	17.5	9.5
	14.2	13.5	14.7	16.5	12.2
	15.3	14.3	17.2	20.3	9.5
	13.0	13.8	14.7	20.4	7.8
	13.0	13.8	17.3	17.3	10.2
	13.1	16.2	13.2	17.0	10.3
	12.3	16.3	14.3	18.3	8.8
	12.2	16.4	15.6	17.3	12.1
	12.4	16.9	15.2	19.3	7.8
	13.9	11.8	17.2	19.6	12.3
	13.4	14.5	13.7	18.3	9.9
	11.1	15.4	16.5	19.8	10.2
	12.7	15.4	15.1	18.4	12.5
	13.1	15.2	14.9	18.8	9.0
	12.2	15.5	16.2	19.5	10.7
Av.	13.3	14.6	15.2	18.4	10.2

No data were received from D-2.

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill D-3

	Sample 189 I.P.C.	Sample 190 I.P.C.	Sample 191 I.P.C.	Sample 192 I.P.C.	Sample 193 I.P.C.
	11.4	14.5	17.7	18.1	12.0
	12.4	14.4	16.2	17.7	12.3
	12.8	14.5	17.9	--	13.3
	10.6	15.5	15.2	16.4	12.5
	12.4	15.0	15.0	--	12.6
	9.7	16.3	17.3	18.2	13.4
	12.6	12.8	15.7	18.0	12.1
	11.3	14.3	16.1	--	12.9
	8.9	17.2	15.0	19.1	12.8
	10.5	17.1	16.5	15.3	10.1
	8.6	15.0	17.7	14.9	12.5
	9.5	14.2	17.7	18.3	10.8
	10.3	14.0	17.7	17.2	13.7
	13.0	15.2	17.9	18.7	10.7
	8.4	14.3	15.0	17.1	12.8
	11.1	15.3	16.8	17.8	12.6
	10.6	16.0	16.4	--	12.5
	10.5	14.1	15.9	--	12.1
	10.7	15.5	16.9	18.5	15.1
	12.0	15.3	16.0	19.0	11.0
Av.	10.9	15.0	16.5	17.6	12.4

No data received from D-3.

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill F

	Sample 130 I.P.C.	Sample 131 I.P.C.	Sample 132 I.P.C.	Sample 133 I.P.C.	Sample 134 I.P.C.
	9.7	12.2	9.8	8.8	7.6
	8.3	10.5	10.1	7.6	10.1
	9.6	8.9	8.6	9.3	7.6
	10.5	11.3	9.0	9.5	7.0
	9.7	7.8	9.6	9.5	9.5
	8.5	9.3	6.9	10.0	8.6
	8.3	7.0	9.6	8.6	9.5
	8.5	9.4	11.1	9.0	7.0
	10.8	7.9	11.5	10.1	9.3
	10.7	10.2	10.8	10.2	8.3
	10.0	10.5	10.5	12.5	6.0
	9.9	9.1	9.8	9.3	11.6
	8.3	7.7	8.1	10.9	7.1
	10.0	9.8	8.2	10.6	9.1
	7.1	7.4	8.6	8.9	7.7
	9.8	8.7	9.3	10.6	7.6
	9.8	8.6	11.0	8.7	8.3
	8.6	11.2	10.1	11.0	8.8
	8.8	9.1	10.8	8.6	7.5
	9.1	9.3	9.0	10.7	9.5
Av.	9.3	9.3	9.6	9.7	8.4

No data received from Mill F.

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill H

	Sample 125			Sample 126			Sample 127			Sample 128			Sample 129		
	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.
	18.8	18.7	-0.1	14.9	15.4	+0.5	19.2	18.0	-1.2	16.0	16.5	+0.5	17.8	14.6	-3.2
	16.3	16.7	+0.4	16.0	16.4	+0.4	17.7	14.2	-3.5	16.3	16.4	+0.1	17.5	17.2	-0.3
	17.7	16.4	-1.3	16.3	16.4	+0.1	15.8	16.8	+1.0	16.0	14.7	-1.3	18.7	15.4	-3.3
	17.6	18.2	+0.6	15.3	16.2	+0.9	17.4	16.0	-1.4	16.2	16.3	+0.1	19.9	17.0	-2.9
	18.5	15.0	-3.5	18.9	16.2	-2.7	18.8	17.6	-1.2	15.6	16.3	+0.7	17.3	15.8	-1.5
	18.1	--	--	17.8	17.0	-0.8	17.5	16.4	-1.1	18.7	15.8	-2.9	18.9	15.8	-3.1
	16.6	17.6	+1.0	16.8	15.2	-1.6	16.6	15.0	-1.6	17.4	16.6	-0.8	16.3	14.7	-1.6
	17.0	16.6	-0.4	17.2	16.7	-0.5	16.5	15.4	-1.1	17.0	--	--	17.0	17.6	+0.6
	15.6	15.6	0.0	15.0	17.2	+2.2	18.8	16.0	-2.8	16.7	14.4	-2.3	19.3	17.0	-2.3
	17.0	13.8	-3.2	17.7	16.2	-1.5	17.7	17.5	-0.2	17.5	13.4	-4.1	18.4	16.1	-2.3
	19.5	16.4	-3.1	16.2	15.0	-1.2	17.8	17.0	-0.8	17.2	17.0	-0.2	18.6	18.5	-0.1
	17.8	15.8	-2.0	16.6	17.5	+0.9	15.5	17.9	+2.4	17.0	15.8	-1.2	17.5	14.2	-3.3
	16.9	14.8	-2.1	17.1	16.0	-1.1	18.0	18.2	+0.2	15.8	14.0	-1.8	19.8	--	--
	17.1	14.8	-2.3	11.9	16.6	+4.7	18.3	19.6	+1.3	14.9	17.4	+2.5	18.0	16.2	-1.8
	18.6	16.4	-2.2	20.0	17.8	-2.2	18.6	16.2	-2.4	16.3	15.6	-0.7	19.6	15.8	-3.8
	17.3	15.4	-1.9	17.8	17.8	0.0	14.8	18.4	+3.6	16.2	17.2	+1.0	18.2	17.3	-0.9
	16.7	18.0	+1.3	16.3	16.8	+0.5	16.0	15.1	-0.9	17.9	14.4	-3.5	19.9	16.8	-3.1
	18.7	16.4	-2.3	16.8	17.6	+0.8	18.8	15.4	-3.4	17.8	15.1	-2.7	19.0	16.3	-2.7
	16.0	14.2	-1.8	17.8	16.0	-1.8	17.3	--	--	19.0	17.0	-2.0	17.5	15.2	-2.3
	17.2	17.6	+0.4	16.9	17.0	+0.1	16.8	16.0	-0.8	14.0	16.6	+2.6	18.7	16.3	-2.4
Av.	17.4	16.2	-1.2	16.7	16.6	-0.1	17.4	16.7	-0.7	16.7	15.8	-0.9	18.4	16.2	-2.2

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill N-1

	Sample 145 I.P.C.	Sample 146 I.P.C.	Sample 147 I.P.C.	Sample 148 I.P.C.	Sample 149 I.P.C.
	15.2	12.6	15.6	17.2	16.5
	18.3	15.9	16.2	15.9	17.4
	15.5	13.3	15.8	16.0	16.5
	16.7	14.8	15.7	15.8	15.9
	15.6	14.8	15.8	14.5	13.8
	15.8	16.0	16.8	19.0	17.8
	15.1	15.0	16.1	15.1	15.3
	17.2	12.5	14.9	16.1	16.0
	13.5	14.7	15.7	15.5	14.6
	14.9	14.3	14.2	14.8	15.0
	15.7	15.7	15.9	16.9	15.2
	16.9	13.5	18.1	17.0	17.1
	16.8	14.4	17.0	15.8	15.2
	15.2	14.2	18.8	18.9	15.2
	15.2	12.9	15.8	16.0	16.0
	16.8	14.0	16.9	14.8	15.2
	16.5	13.6	16.1	15.8	15.8
	18.1	14.7	15.1	17.0	13.7
	14.6	13.6	15.3	15.6	15.2
	15.2	14.4	15.5	14.6	15.9
Av.	15.9	14.2	16.1	16.1	15.7

No data received from Mill N-1.

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill N-2

Sample 150			Sample 151			Sample 152			Sample 153			Sample 154		
I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.
15.2	12.8	-2.4	15.7	15.2	-0.5	15.0	14.1	-0.9	16.1	12.1	-4.0	15.1	12.6	-2.5
16.2	14.0	-2.2	17.4	14.0	-3.4	14.7	13.6	-1.1	15.7	13.7	-2.0	15.1	13.8	-1.3
16.0	13.5	-2.5	15.7	13.7	-2.0	14.2	14.2	0.0	13.7	13.0	-0.7	14.9	12.1	-2.8
14.9	13.1	-1.8	16.3	15.1	-1.2	14.8	15.2	+0.4	16.2	13.9	-2.3	15.2	12.8	-2.4
14.5	12.7	-1.8	17.1	14.4	-2.7	16.1	13.6	-2.5	15.2	13.6	-1.6	16.4	15.0	-1.4
14.6	12.0	-2.6	16.7	16.4	-0.3	13.5	11.4	-2.1	14.7	14.8	+0.1	16.2	12.6	-3.6
14.9	11.9	-3.0	17.2	17.5	+0.3	15.7	13.1	-2.6	15.4	14.2	-1.2	14.0	13.6	-0.4
15.0	13.4	-1.6	15.5	14.7	-0.8	16.8	12.1	-4.7	14.6	14.6	0.0	15.2	12.4	-2.8
14.6	14.4	-0.2	17.8	15.2	-2.6	14.2	13.0	-1.2	14.6	13.0	-1.6	14.2	13.6	-0.6
15.1	12.6	-2.5	15.4	15.1	-0.3	17.5	14.6	-3.0	15.9	13.0	-2.9	16.5	12.8	-3.7
15.5	12.3	-3.2	15.5	15.2	-0.3	15.5	12.8	-2.7	15.5	15.0	-0.5	16.3	12.7	-3.6
16.0	12.8	-3.2	17.3	15.8	-1.5	14.6	12.5	-2.1	15.2	12.6	-2.6	15.6	11.6	-4.0
15.2	13.5	-1.7	15.1	16.4	+1.3	14.5	13.0	-1.5	--	12.5	--	14.9	13.7	-1.2
14.2	13.9	-0.3	15.1	15.8	+0.7	15.1	15.1	0.0	16.8	12.8	-4.0	15.0	13.2	-1.8
15.3	11.0	-4.3	15.3	14.0	-1.3	17.7	14.7	-3.0	--	12.6	--	16.5	11.3	-5.2
15.3	11.5	-3.8	--	16.4	--	16.1	12.6	-3.5	16.2	10.4	-5.8	14.6	12.4	-2.2
13.5	15.3	+1.8	14.3	15.5	+1.2	16.9	13.4	-3.5	14.6	11.3	-3.3	14.9	13.4	-1.5
14.4	14.2	-0.2	15.3	12.4	-2.9	14.0	12.8	-1.2	15.6	13.0	-2.6	14.0	13.4	-0.6
16.2	12.1	-4.1	15.5	16.0	+0.5	14.6	13.6	-1.0	15.4	15.0	-0.4	14.0	14.0	0.0
12.9	15.2	+2.3	18.3	16.3	-2.0	18.6	12.4	-6.2	16.9	13.4	-3.5	16.4	14.3	-2.1
Av. 15.0	13.1	-1.9	16.1	15.3	-0.8	15.5	13.4	-2.1	15.5	13.2	-2.3	15.2	13.1	-2.1

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill O-1

	Sample 119			Sample 120			Sample 121			Sample 122			Sample 123			Sample 124		
	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.
	15.5	15.4	-0.1	15.6	14.4	-1.2	15.7	15.3	-0.4	12.5	16.2	+3.7	14.8	14.2	-0.6	13.8	--	--
	15.2	--	--	13.3	13.5	+0.2	15.9	13.8	-2.1	15.7	12.6	-3.1	16.0	13.8	-2.2	16.1	--	--
	16.8	15.1	-1.7	15.5	14.6	-0.9	16.3	13.2	-3.1	13.5	14.2	+0.7	14.4	15.3	+0.9	11.1	14.6	+3.5
	15.6	15.4	-0.2	13.0	15.4	+2.4	13.1	13.4	+0.3	15.3	13.3	-2.0	15.9	15.6	-0.3	14.5	13.8	-0.7
	12.3	15.2	+2.9	15.5	15.0	-0.5	15.2	15.4	+0.2	15.4	15.2	-0.2	14.0	15.4	+1.4	14.7	14.5	-0.2
	14.2	15.2	+1.0	13.7	15.6	+1.9	15.3	14.4	-0.9	11.1	19.6	+8.5	12.3	14.2	+1.9	10.8	--	--
	16.1	16.6	+0.5	14.2	14.6	+0.4	14.0	13.6	-0.4	14.5	13.9	-0.6	13.3	13.0	-0.3	12.5	--	--
	14.4	15.4	+1.0	14.5	14.1	-0.4	14.8	13.7	-1.1	12.4	15.6	+3.2	11.2	15.3	+4.1	12.3	12.0	-0.3
	14.1	13.9	-0.2	13.8	11.3	-2.5	12.6	15.8	+3.2	14.2	16.8	+2.6	13.9	16.8	+2.9	14.7	12.6	-2.1
	13.2	13.7	+0.5	16.3	14.8	-1.5	13.6	12.6	-1.0	14.4	15.1	+0.7	14.7	14.8	+0.1	14.6	15.5	+0.9
	15.0	15.8	+0.8	14.2	14.7	+0.5	17.3	14.7	-2.6	15.4	13.0	-2.4	13.2	11.7	-1.5	12.8	11.6	-1.2
	15.7	14.3	-1.4	15.9	11.8	-4.1	15.4	17.6	+2.2	13.2	13.5	+0.3	13.2	12.7	-0.5	12.5	11.5	+1.0
	14.4	15.8	+1.4	14.3	14.8	+0.5	13.8	16.6	+2.8	14.2	15.0	+0.8	15.3	13.9	-1.4	13.3	13.4	+0.1
	13.7	13.4	-0.3	13.7	15.6	+1.9	15.1	--	--	15.5	15.4	-0.1	16.0	13.8	-2.2	11.8	--	--
	12.0	13.5	+1.5	14.8	14.8	0.0	10.9	12.4	+1.5	14.7	16.4	+1.7	12.8	15.0	+2.2	12.6	17.0	+4.4
	14.1	--	--	13.0	16.6	+3.6	15.0	15.4	+0.4	14.8	14.0	-0.8	10.3	13.6	+3.3	13.0	--	--
	15.8	16.4	+0.6	14.1	13.3	-0.8	13.1	13.8	+0.7	13.5	14.8	+1.3	14.1	12.6	-1.5	13.1	13.8	+0.7
	14.1	15.5	+1.4	13.3	14.4	+1.1	14.8	--	--	13.5	13.3	-0.2	14.8	13.9	-0.9	11.7	12.3	+0.6
	14.0	15.5	+1.5	14.2	12.9	-1.3	14.1	14.9	+0.8	13.3	13.6	+0.3	14.9	13.7	-1.2	13.4	14.5	+1.1
	13.8	--	--	13.8	12.0	-1.8	13.5	16.0	+2.5	14.8	12.9	-1.9	14.0	16.4	+2.4	15.3	12.6	-2.7
Av.	14.5	15.1	+0.6	14.3	14.2	-0.1	14.5	14.6	+0.1	14.1	14.7	+0.6	14.0	14.3	+0.3	13.2	13.6	+0.4

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill O-2

Sample 119-A			Sample 120-A			Sample 121-A			Sample 122-A			Sample 123-A			Sample 124-A		
I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.
14.3	12.1	-2.2	16.0	--	--	16.8	16.6	-0.2	12.3	14.3	+2.0	12.5	--	--	13.8	12.5	-1.3
14.5	10.8	-3.7	13.4	15.2	+1.8	12.2	11.5	-0.7	14.8	13.4	-1.4	13.9	12.5	-1.4	11.7	12.8	+1.1
14.0	--	--	16.4	14.2	-2.2	12.8	15.2	+2.4	16.1	11.1	-5.0	13.8	13.6	-0.2	16.1	13.6	-2.5
13.8	15.1	+1.3	13.5	14.8	+1.3	15.0	--	--	15.7	18.4	+2.7	16.3	15.5	-0.8	14.4	13.2	-1.2
12.4	14.7	+2.3	16.2	14.1	-2.1	16.5	12.7	-3.8	13.1	18.1	+5.0	14.9	14.8	-0.1	12.3	--	--
12.5	13.6	+1.1	14.6	13.3	-1.3	14.9	--	--	11.8	13.3	+1.5	13.7	12.6	-1.1	13.4	11.2	-2.2
15.1	--	--	17.0	--	--	15.9	15.7	-0.2	14.4	13.0	-1.4	13.3	10.7	-2.6	13.0	12.4	-0.6
14.9	15.2	+0.3	14.7	15.3	+0.6	16.0	12.6	-3.4	15.2	12.6	-2.6	13.8	14.9	+1.1	12.7	14.2	+1.5
10.1	17.6	+7.5	15.1	--	--	14.3	15.4	+1.1	13.4	12.6	-0.8	15.8	11.5	-4.3	11.7	13.1	+1.4
14.0	--	--	15.2	16.1	+0.9	16.0	15.5	-0.5	13.2	14.2	+1.0	14.0	--	--	15.2	13.5	-1.7
15.4	10.3	-5.1	13.5	--	--	13.4	15.0	+1.6	--	13.8	--	12.8	11.4	-1.4	12.2	12.5	+0.3
15.3	14.4	-0.9	15.7	12.7	-3.0	12.7	13.4	+0.7	13.9	16.2	+2.3	13.2	--	--	12.6	13.9	+1.3
15.0	14.8	-0.2	15.7	11.5	-4.2	12.2	20.2	+8.0	17.0	13.0	-4.0	14.0	14.0	0.0	13.9	13.4	-0.5
15.7	14.0	-1.7	13.8	13.2	-0.6	14.7	13.7	-1.0	12.8	15.5	+2.7	13.4	13.1	-0.3	12.9	12.8	-0.1
12.6	--	--	14.8	12.5	-2.3	14.4	16.3	+1.9	14.5	--	--	15.8	13.2	-2.6	13.2	11.9	-1.3
13.1	15.6	+2.5	14.2	12.7	-1.5	12.6	14.3	+1.7	12.9	14.7	+1.8	14.9	--	--	14.0	12.6	-1.4
16.0	12.8	-3.2	13.7	12.1	-1.6	13.4	12.9	-0.5	14.2	14.7	+0.5	12.0	--	--	13.5	13.4	-0.1
11.7	12.4	+0.7	17.0	12.6	-4.4	14.0	14.7	+0.7	13.8	13.5	-0.3	12.0	15.9	+3.9	14.0	--	--
13.6	13.8	+0.2	12.1	--	--	14.6	15.1	+0.5	14.7	14.6	-0.1	15.0	12.3	-2.7	14.2	13.6	-0.6
12.0	13.1	+1.1	13.7	13.3	-0.4	14.8	14.1	-0.7	13.3	--	--	11.4	11.0	-0.4	13.5	13.4	-0.1
Av. 13.8	13.8	0.0	14.8	13.6	-1.2	14.4	14.7	+0.3	14.1	14.3	+0.2	13.8	13.1	-0.7	13.4	13.0	-0.4

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill P

	Sample 155			Sample 156			Sample 157			Sample 158			Sample 159	
I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.
14.2	16.5	+2.3	11.8	13.4	+1.6	11.6	13.0	+1.4	14.1	16.5	+2.4	14.7	15.0	+0.3
14.6	16.0	+1.4	16.2	13.0	-3.2	12.2	12.0	-0.2	13.8	14.0	+0.2	10.5	15.0	+4.5
13.0	17.0	+4.0	14.7	10.2	-4.5	12.1	13.0	+0.9	12.6	14.0	+1.4	13.3	17.0	+3.7
15.5	14.5	-1.0	15.3	14.5	-0.8	10.9	15.0	+4.1	10.8	13.0	+2.2	13.8	16.0	+2.2
15.5	20.0	+4.5	13.4	13.5	+0.1	13.7	14.0	+0.3	12.1	14.0	+1.9	14.6	15.0	+0.4
14.9	20.0	+5.1	12.2	16.0	+3.8	14.2	12.0	-2.2	12.7	14.5	+1.8	11.8	16.0	+4.2
13.4	18.0	+4.6	13.3	14.0	+0.7	12.1	12.2	+0.1	13.7	15.0	+1.3	15.6	16.0	+0.4
13.6	16.2	+2.6	14.5	13.0	-1.5	12.5	12.0	-0.5	12.3	15.0	+2.7	13.1	17.0	+3.9
13.5	18.0	+4.5	14.8	16.0	+1.2	12.4	12.5	+0.1	11.3	--	--	11.3	15.0	+3.7
16.2	17.0	+0.8	14.2	15.5	+1.3	14.3	14.0	-0.3	13.2	14.5	+1.3	12.0	19.0	+7.0
15.0	16.0	+1.0	13.6	15.0	+1.4	13.0	15.0	+2.0	14.3	15.0	+0.7	14.4	20.5	+6.1
17.1	18.0	+0.9	13.7	15.0	+1.3	12.1	11.0	-1.1	13.6	14.0	+0.4	16.5	16.2	-0.3
15.0	19.0	+4.0	16.2	14.5	-1.7	10.6	12.0	+1.4	12.3	15.0	+2.7	14.3	17.0	+2.7
13.8	18.0	+4.2	13.5	15.0	+1.5	11.0	11.0	0.0	12.6	16.5	+3.9	14.1	16.5	+2.4
13.8	18.5	+4.7	13.3	12.5	-0.8	14.3	13.5	-0.8	13.8	15.0	+1.2	15.2	15.5	+0.3
16.2	--	--	15.5	15.0	-0.5	12.3	13.0	+0.7	13.4	15.0	+1.6	14.5	16.0	+1.5
13.2	17.0	+3.8	15.0	17.0	+2.0	12.4	11.0	-1.4	13.4	14.5	+1.1	14.8	18.0	+3.2
14.4	17.0	+2.6	15.0	15.0	0.0	12.2	11.0	-1.2	12.3	13.0	+0.7	14.7	18.2	+3.5
13.5	16.5	+3.0	16.7	15.5	-1.2	9.3	13.0	+3.7	13.6	14.5	+0.9	10.0	18.5	+8.5
14.8	17.0	+2.2	12.3	12.5	+0.2	11.4	14.5	+3.1	11.0	15.0	+4.0	12.9	15.0	+2.1
Av. 14.6	17.4	+2.8	14.3	14.3	0.0	12.2	12.7	+0.5	12.8	14.6	+1.8	13.6	16.6	+3.0

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill Q-1

Sample 135			Sample 136			Sample 137			Sample 138			Sample 139		
I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.	I.P.C.	Mill	Diff.
15.1	13.4	-1.7	13.7	13.4	-0.3	13.9	12.7	-1.2	14.3	12.4	-1.9	14.9	14.1	-0.8
14.7	13.7	-1.0	13.4	12.9	-0.5	13.5	11.3	-2.2	14.9	13.7	-1.2	16.2	13.6	-2.6
15.2	11.9	-3.3	14.2	13.4	-0.8	14.7	12.3	-2.4	13.5	12.2	-1.3	13.3	13.8	+0.5
14.3	14.1	-0.2	13.2	14.5	+1.3	12.3	13.6	+1.3	13.8	13.3	-0.5	14.1	13.1	-1.0
16.2	13.4	-2.8	17.0	14.0	-3.0	12.8	13.5	+0.7	13.2	14.0	+0.8	13.8	13.3	-0.5
12.7	13.7	+1.0	11.2	11.1	-0.1	12.2	11.6	-0.6	14.3	13.5	-0.8	14.4	13.4	-1.0
13.6	13.0	-0.6	12.1	14.1	+2.0	12.8	12.5	-0.3	14.1	12.9	-1.2	14.0	13.1	-0.9
15.7	13.0	-2.7	13.8	12.0	-1.8	13.1	12.4	-0.7	14.6	11.9	-2.7	13.8	14.5	+0.7
16.1	14.1	-2.0	13.8	13.9	+0.1	14.8	13.8	-1.0	12.3	--	--	14.2	13.2	-1.0
12.4	12.6	+0.2	13.0	12.4	-0.6	12.5	15.7	+3.2	14.8	11.5	-3.3	16.2	15.1	-1.1
15.2	13.8	-1.4	14.0	12.6	-1.4	12.7	11.8	-0.9	13.6	13.1	-0.5	14.2	14.1	-0.1
13.3	12.6	-0.7	13.8	12.0	-1.8	11.0	11.4	+0.4	14.2	14.3	+0.1	15.5	13.6	-1.9
14.0	11.6	-2.4	13.7	14.0	+0.3	12.6	11.9	-0.7	13.5	13.5	0.0	13.4	13.0	-0.4
13.5	--	--	14.9	14.0	-0.9	12.5	12.7	+0.2	13.0	13.4	+0.4	14.9	14.0	-0.9
13.4	--	--	14.8	14.0	-0.8	13.4	12.7	-0.7	12.3	13.5	+1.2	15.2	12.2	-3.0
12.9	10.7	-2.2	14.2	12.7	-1.5	13.6	13.2	-0.4	12.9	12.7	-0.2	13.1	14.6	+1.5
11.7	--	--	11.8	13.3	+1.5	11.1	11.0	-0.1	14.0	--	--	14.4	14.1	-0.3
11.4	11.8	+0.4	12.2	13.2	+1.0	13.2	10.7	-2.5	14.3	--	--	16.0	--	--
14.1	12.3	-1.8	13.2	12.3	-0.9	13.5	12.2	-1.3	13.2	--	--	14.3	--	--
12.2	12.1	-0.1	14.7	14.0	-0.7	13.1	11.2	-1.9	13.4	12.1	-1.3	13.6	13.7	+0.1
Av. 13.9	12.8	-1.1	13.6	13.2	-0.4	13.0	12.4	-0.6	13.7	13.0	-0.7	14.5	13.7	-0.8

TABLE IV (Continued)

SINGLE-FLUTE TEST RESULTS

Summary of Individual Sample Lots
Institute Data versus Mill Data

Mill Q-2

Sample 140 I.P.C.	Sample 141 I.P.C.	Sample 142 I.P.C.	Sample 143 I.P.C.	Sample 144 I.P.C.
13.1	12.9	13.6	14.2	12.5
11.3	13.9	14.5	15.3	13.1
12.4	14.3	13.1	13.9	13.5
12.2	13.6	15.0	14.8	13.8
11.3	11.9	12.3	15.4	13.3
13.5	11.4	13.4	14.2	13.2
14.1	12.3	13.4	13.3	13.7
12.0	13.5	14.5	13.7	14.4
11.5	12.3	12.0	16.1	13.8
14.5	14.1	12.6	16.8	12.2
14.0	13.9	12.7	14.3	14.2
15.6	12.7	13.6	15.8	13.3
12.3	12.7	12.9	13.1	15.1
--	12.8	11.5	13.3	13.2
13.3	14.0	11.2	14.4	14.3
14.0	13.2	13.2	14.1	14.1
14.3	14.0	14.2	13.6	14.4
13.3	13.2	11.5	15.2	13.8
13.7	14.7	12.2	13.1	14.6
13.4	15.9	14.0	13.6	15.0
Av. 13.1	13.4	13.1	14.4	13.8

No data received from Mill Q-2

2. The average ($\bar{X}_I$) for Institute test results was found in the same manner as (1) above.

3. The sample variance (s^2_M) for mill test results was calculated as follows:

$$s^2_M = \frac{\Sigma X_M^2}{N_M} - \bar{X}_M^2$$

where ΣX_M^2 is the sum of the squares of the individual test results,

$\bar{X}_M^2$ is the square of the average of the individual test results, and

N_M is the number of individual test results included in the average.

4. The sample variance (s_I^2) for Institute test results was calculated in the same manner as (3) above.

5. The "t" test, which is a test of the significance of differences between averages, was performed on the data for each sample submitted. The formula for "t" is

$$t = \frac{\bar{X}_M - \bar{X}_I}{\sqrt{\frac{s_M^2}{N_M - 1} + \frac{s_I^2}{N_I - 1}}}$$

where $\bar{X}_M$ is the average of the individual flat crush values obtained at the mill,

$\bar{X}_I$ is the average of the individual flat crush values obtained at the Institute,

s_M^2 is the sample variance of the mill data,

s_I^2 is the sample variance of the Institute data,

N_M is the number of individual test results included in the average of the mill data, and

N_I is the number of individual test results included in the average of the Institute data.

6. The number of degrees of freedom associated with the value calculated for "t" is equal to $(N_M - 1) + (N_I - 1)$.

7. If the value calculated for "t" is 2.02 or less for approximately 38 degrees of freedom, it may be concluded that there is at least one chance in 20 that such an observed difference between means might occur by chance and that there is no clear evidence that the difference is significant. If "t" exceeds 2.02, there is less than one chance in 20 that such an observed difference between means might occur by chance and, thus, it is concluded that the two averages probably did not come from the same population. If the value of "t" is greater than 2.70, it may be concluded that there is less than one chance in 100 that such an observed difference between means might occur simply by chance. In such a case, the difference would surely be considered significant.

The results of the foregoing calculations pertaining to the "t" test of significance are presented in Table V for each sample submitted.

The formula for calculating the 95% confidence limits which are presented in Table III is

$$+L = \bar{X} + t_{0.05}\frac{s}{\sqrt{n - 1}}$$

$$-L = \bar{X} - t_{0.05}\frac{s}{\sqrt{n - 1}}$$

where +L and -L are the upper and lower confidence limits, respectively,

$\bar{X}$ is the average of the sample,

$t_{0.05}$ is the value of t at the 5% level of significance for n - 1 degrees of freedom, and

$s/\sqrt{n - 1}$ is an estimate of the standard deviation of the population mean.

It was previously mentioned that analyses of variance were performed to separate machine variability from material variability in those instances where the "t" test showed a significant difference between mill and Institute results. The data for Sample 150 will be used to illustrate the procedure employed.

1. The twenty mill flat crush results were divided into five subgroups of four each in numerical order.

2. The twenty Institute flat crush results were divided into five subgroups of four each in numerical order.

TABLE V

SUMMARY OF VALUES RELEVANT TO "t" TEST

Mill Code	Sample Number	No. of Specimens Mill	No. of Specimens I.P.C.	Variance, s^2 Mill	Variance, s^2 I.P.C.	Standard Deviation, s Mill	Standard Deviation, s I.P.C.	"t"	Degrees of Freedom	Is Difference Significant?
D-1	179		20		1.985		1.409			
D-1	180		20		2.882		1.698			
D-1	181		20		3.515		1.875			
D-1	182		20		2.366		1.538			
D-1	183		20		0.885		0.941			
D-2	184		20		1.253		1.120			
D-2	185		20		1.867		1.366			
D-2	186		20		1.435		1.198			
D-2	187		20		1.625		1.275			
D-2	188		20		1.755		1.325			
D-3	189		20		1.844		1.358			
D-3	190		20		1.089		1.043			
D-3	191		20		1.025		1.012			
D-3	192		15		1.464		1.210			
D-3	193		20		1.226		1.107			
F	130		20		0.890		0.943			
F	131		20		1.836		1.355			
F	132		20		1.320		1.149			
F	133		20		1.213		1.101			
F	134		20		1.643		1.282			
H	125	19	20	1.788	0.984	1.337	0.992	3.133	37	Yes
H	126	20	20	0.630	2.650	0.794	1.628	0.277	38	No
H	127	19	20	1.861	1.439	1.364	1.200	1.717	37	No
H	128	19	20	1.293	1.392	1.137	1.180	2.255	37	Yes
H	129	19	20	1.161	1.005	1.078	1.003	6.405	37	Yes
M	206									
M	207									
M	208									
M	209									
M	210									

TABLE V (Continued)

SUMMARY OF VALUES RELEVANT TO "t" TEST

Mill Code	Sample Number	No. of Specimens Mill	No. of Specimens I.P.C.	Variance, s^2 Mill	Variance, s^2 I.P.C.	Standard Deviation, s Mill	Standard Deviation, s I.P.C.	"t"	Degrees of Freedom	Is Difference Significant?
N-1	145		20		1.361		1.167			
N-1	146		20		0.974		0.987			
N-1	147		20		1.057		1.028			
N-1	148		20		1.492		1.222			
N-1	149		20		1.075		1.037			
N-2	150	20	20	1.293	0.682	1.137	0.826	5.785	38	Yes
N-2	151	20	19	1.304	1.137	1.142	1.066	2.415	37	Yes
N-2	152	20	20	0.989	1.853	0.994	1.361	5.482	38	Yes
N-2	153	20	18	1.356	0.652	1.164	0.808	6.749	36	Yes
N-2	154	20	20	0.784	0.730	0.886	0.854	7.740	38	Yes
O-1	119	17	20	0.873	1.434	0.935	1.197	1.567	35	No
O-1	120	20	20	1.775	0.903	1.332	0.950	0.333	38	No
O-1	121	18	20	1.866	2.020	1.366	1.421	0.245	36	No
O-1	122	20	20	2.693	1.396	1.641	1.182	1.347	38	No
O-1	123	20	20	1.594	2.182	1.263	1.477	0.740	38	No
O-1	124	14	20	2.324	1.905	1.524	1.380	0.606	32	No
O-2	119-A	16	20	3.190	2.269	1.786	1.506	0.054	34	No
O-2	120-A	15	20	1.647	1.698	1.283	1.303	2.730	33	Yes
O-2	121-A	18	20	3.554	1.947	1.885	1.395	0.640	36	No
O-2	122-A	18	19	3.261	1.681	1.806	1.296	0.412	35	No
O-2	123-A	15	20	2.519	1.695	1.587	1.302	1.334	33	No
O-2	124-A	18	20	0.517	1.166	0.719	1.080	1.370	36	No
P	155	19	20	1.836	1.213	1.355	1.102	6.923	37	Yes
P	156	20	20	2.334	1.789	1.528	1.338	0.097	38	No
P	157	20	20	1.599	1.550	1.265	1.245	1.240	38	No
P	158	19	20	0.773	0.984	0.879	0.992	5.806	37	Yes
P	159	20	20	2.260	2.827	1.503	1.682	5.827	38	Yes

TABLE V (Continued)

SUMMARY OF VALUES RELEVANT TO "t" TEST

Mill Code	Sample Number	No. of Specimens Mill	No. of Specimens I.P.C.	Variance, s^2 Mill	Variance, s^2 I.P.C.	Standard Deviation, s Mill	Standard Deviation, s I.P.C.	"t"	Degrees of Freedom	Is Difference Significant?
Q-1	135	17	20	0.893	1.928	0.945	1.389	2.705	35	Yes
Q-1	136	20	20	0.786	1.541	0.887	1.241	1.271	38	No
Q-1	137	20	20	1.311	0.878	1.145	0.937	1.635	38	No
Q-1	138	16	20	0.597	0.539	0.773	0.734	2.719	34	Yes
Q-1	139	18	20	0.455	0.844	0.674	0.919	2.927	36	Yes
Q-2	140		19		1.331		1.154			
Q-2	141		20		1.041		1.020			
Q-2	142		20		1.103		1.050			
Q-2	143		20		1.061		1.030			
Q-2	144		20		0.552		0.743			
R	160									
R	161									
R	162									
R	163									
R	164									

Table VI presents the data broken down into subgroups, together with the various sums employed in the analysis of variance.

TABLE VI

DATA FOR SAMPLE 150 DIVIDED INTO SUBGROUPS

Machines	Subgroup 1	2	3	4	5	Σ
Mill	12.8	12.7	14.4	13.5	15.3	
	14.0	12.0	12.6	13.9	14.2	
	13.5	11.9	12.3	11.0	12.1	
	13.1	13.4	12.8	11.5	15.2	
	53.4	50.0	52.1	49.9	56.8	262.2
I.P.C.	15.2	14.5	14.6	15.2	13.5	
	16.2	14.6	15.1	14.2	14.4	
	16.0	14.9	15.5	15.3	16.2	
	14.9	15.0	16.0	15.3	12.9	
	62.3	59.0	61.2	60.0	57.0	299.5
	115.7	109.0	113.3	109.9	113.8	561.7

3. ΣI^2 = sum of the squares of the 40 individual values = 7961.95

4. T^2/N = sum of the 40 individual values squared divided by the number of values = $(561.7)^2/40$ = 7887.67

5. $\Sigma s^2/N$ = sum of the squares of the five subgroup totals divided by the number of individuals in each total =

   $[(115.7)^2 + (109.0)^2 + (113.3)^2 + (109.9)^2 + (113.8)^2]/8$ =

   63,132.83/8 = 7891.60

6. $\Sigma M^2/N$ = sum of the squares of the two machine totals divided by the number of individuals in each total =

   $[(262.2)^2 + (299.5)^2]/20$ = 158,449.09/20 = 7922.45

7. $\Sigma(c^2)/N$ = sum of the squares of the cell totals divided by the number of individuals in each cell = $[(53.4)^2 + (50.0)^2 + (52.1)^2 + (49.9)^2 + (56.8)^2 + (62.3)^2 + (59.0)^2 + (61.2)^2 + (60.0)^2 + (57.0)^2]/4 = 31{,}738.95/4 = 7934.74$.

Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Between machines	(6)-(4) =34.78	1	34.78	33.25
Between subgroups	(5)-(4) = 3.93	4	0.9825	0.939
Machine subgroup Interaction	8.36 } 35.57	4 } 34	2.09 } 1.046	2.304
Residual	27.21	30	0.9070	
Total	(3)-(4) =74.28	39		

8. Sum of squares for machine x sample interaction is equal to (7)-(4) minus the sums of squares for between machines and between subgroups.

9. Sum of squares for residual is equal to total sum of squares minus the sums of squares for between machines, between subgroups, and interaction.

10. The degrees of freedom for machines equals the number of machines being compared minus one = 2 - 1 = 1.

11. The degrees of freedom for subgroups equals the number of subgroups minus one = 5 - 1 = 4.

12. The degrees of freedom for the interaction equals degrees of freedom for machines times degrees of freedom for subgroups = 4 x 1 = 4.

13. The total degrees of freedom equals the total number of individual test values minus one = 40 - 1 = 39.

14. The degrees of freedom for residual equals the total degrees of freedom minus the degrees of freedom for between machines, between subgroups and interaction.

15. The mean squares are equal to the sums of squares divided by the degrees of freedom.

16. Next, test the interaction mean square against the residual mean square equals 2.09/0.9070 = 2.304. Consulting a table of values of F, it is found that, at the 5% level of significance for 4 and 30 degrees of freedom, F may not exceed 2.69. Thus, the value of 2.304 is not significant. Therefore, the interaction sum of squares and degrees of freedom are combined with those for the residual and a new residual mean square is calculated.

17. The mean square for machines is tested against the new residual mean square = 34.78/1.046 = 33.25. This F value is significant beyond the 1% level. Therefore, it is concluded that there is a significant difference between machines.

18. The mean square for subgroups is tested against the new residual mean square = 0.9825/1.046 = 0.939. This F value is not significant at the 5% level. Thus, it is concluded that there is no difference between subgroups and, therefore, no difference in the material.