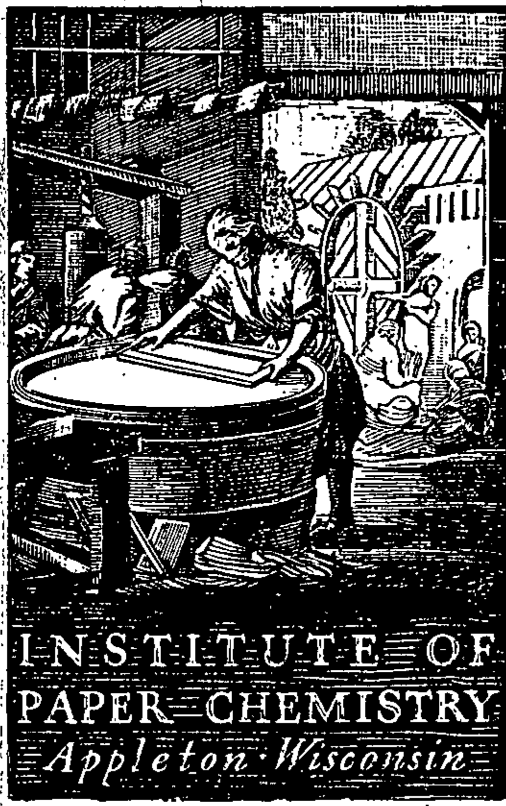

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INVESTIGATION OF CONCORA MEDIUM FLUTERS

Project 1108

Progress Report Nine

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

May 1, 1958

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

ABSTRACT

At the request of the Technical Committee of the Fourdrinier Kraft Board Institute, Inc., a round-robin study was made on the Concora medium test in order to compare results obtained between laboratories. For this purpose, five samples were forwarded to each participating laboratory or mill by The Institute of Paper Chemistry. A total of 18 Concora testers participated in the study and the following results were obtained.

1. No given mill retained the ranking relative to the other mills throughout all sample lots.

2. When the results obtained at The Institute of Paper Chemistry are used as an arbitrary reference level, the test results varied on an average from a +9.4% for Mill G to a -6.2% for Mill S.

3. Eleven of the seventeen mills exhibited composite averages which were within a ± 4% range of the composite averages obtained on the IPC tester. When a range of ± 2.5% is considered, only seven of the seventeen mills fell within that range.

After the above results were reviewed by the Technical committee, The Institute of Paper Chemistry forwarded additional samples to six of the mills participating in the first study. Samples were sent to the four mills (G, H, F and I) which exhibited particularly high results in the original study and to the two mills (B and S) which previously exhibited low results.

The Concora flat-crush results showed that Mills G, H and I, which exhibited high results in the original study, appeared to exhibit equally high

results in the second study. On the other hand, Mill F, which also was high in the original study, now reported results which were in reasonable agreement with the Institute results. The remaining two mills (B and S) also appeared to be in reasonable agreement with the Institute results.

The above indicates that appreciable differences in Concora test results may exist between mills. Because the variables causing such differences are not known, it suggests that care must be taken to check the performance of any given tester at frequent intervals.

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

INTRODUCTION

At a meeting of the Technical Committee of the Fourdrinier Kraft Board Institute early in 1957, it was requested that a round-robin study be made of the Concora medium fluter in order to determine the magnitude of differences existing in test results between mills. This study was prompted by the widespread concern as to the apparent lack of agreement between mills as well as the desire for more information on the effect of instrumental factors such as wear of the rolls, warpage of the plate, heat transfer, etc., associated with the Concora medium fluter.

It may be recalled that a similar study (1) of the single-fluter was made at the request of the Fourdrinier Kraft Board Institute in 1952. Using some of the techniques utilized in the single fluter study, a program was prepared which would allow samples to be prepared, formed, and tested in a standardized manner so that information could be developed concerning the current status of agreement between mills.

In the initial phase of the study, samples were evaluated by eighteen mills or laboratories. When the results were reviewed, it was found that eleven of the participating laboratories or mills exhibited composite averages within a ± 4% range of the Institute tester. Four mills (G, H, F, and I) exhibited particularly high results while two mills (B and S) exhibited results on the low side. After these results were reviewed by the Technical Committee, the Institute was requested to forward additional test samples to the above six mills to determine if the differences observed in the first study would persist.

Reports were rendered to the Technical Committee describing the results obtained in each phase of the investigation. This present report combines the results obtained in each phase. It should be emphasized that the results contained herein are merely representative of the differences in Concora test level at one given instance of time. Concora test results for each mill or laboratory may be expected to shift with time as such instrumental factors as slide and pressure roll lubrication, roll wear, heat transfer, etc., change. Thus, somewhat different results might be obtained each time such a study was performed.

It should also be noted that the Concora flat-crush results obtained in Phase I are reported in pounds. It was requested by the committee that the results in Phase II be reported in p.s.i. Some confusion may result; however, percentage differences remain the same in either system of units. For this reason, it was not thought necessary to convert Phase I results to a p.s.i. basis.

MATERIALS--PHASE I

Five sample lots of corrugating medium were selected at The Institute of Paper Chemistry and cut into test strips 1/2-inch wide and 6 inches long in the machine direction. The cut specimens were randomized and shuffled into samples containing 12 specimens in each sample. One sample of 12 specimens for each of the five sample lots was then sent to each participant in the round robin. By this method, each participant received specimens equally representative of the parent sample lot.

The sample lots selected were identified by code number and represent a range of flat crush as determined by the Concora medium fluter at The Institute of Paper Chemistry. The identify of these samples are tabulated in Table I.

TABLE I

MATERIALS USED

Sample Lot	Type of Medium	Weight, lb.	Caliper, pt.
K-1048	Kraft	27.8	9.2
K-1047	Semichemical	26.4	10.7
K-1058	Bogus	28.7	11.2
K-1045	Semichemical	27.4	11.0
K-1064	Semichemical	27.0	10.0

TESTING PROCEDURE--PHASE I

In order to restrict the study to differences in equipment and operation, the following instructions were enclosed with each set of sample and each participant was requested to make his evaluations under the following conditions:

1. After receipt of the samples, open each package so that the individual specimens are freely exposed to the atmosphere and condition them for at least 24 hours at 50 ± 2% relative humidity and 73 ± 3.5°F. prior to test.

2. Before performing any tests, measure (using a pyrometer) and adjust the temperature of the two corrugating rolls. The temperature for these tests should be 350° ± 25°F.; thus, the difference in temperature between the front and back rolls may not be greater than 50°F. Please record the measured temperatures in the appropriate location on the attached data sheets.

3. After adjusting the temperature of the rolls, obtain at least one pressure pattern using strips of pressure-sensitive paper (NCR) enclosed with the samples. Please mark the edge of the strip corresponding to the top of the roll and the side of the strip facing the pressure roll. Return it with the data sheets.

4. Before performing any tests, check the tines of forming comb or fork to insure they are straight and parallel.

5. Please have one operator test all samples. Ten specimens per sample are to be tested. It may be noted that each sample includes at least 12 specimens to allow for the possibility of accidental damage during shipment or testing. Any extra specimens may be discarded after 10 specimens are tested.

6. All specimens shall be conditioned at least 15 minutes and no longer than 45 minutes at 50% relative humidity and 73°F. after taping and prior to testing. This may be accomplished with little loss of time by fluting and taping a number of specimens and then testing them in consecutive order after the first taped specimen has conditioned at least 15 minutes.

In addition to the test procedure, a strip of NCR paper was enclosed with each set of samples. The NCR paper was for the purpose of obtaining a pressure pattern of the corrugator rolls and was to be obtained just prior to fluting the samples used in this study. Also, a compression tester questionnaire was sent to obtain information which might be of value in interpreting the data obtained. This questionnaire dealt with information concerning the type of machine used, the load range, testing speed, calibration method, type of platen surface, platen parallelism, and whether a lazy hand indicator was used.

MATERIALS--PHASE II

The four sample lots of corrugating medium to be used in this investigation were selected at The Institute of Paper Chemistry. These sample lots embrace a range of flat crush from 32 to 43 p.s.i. as determined by the Concora medium fluter at the Institute. The identity of these samples are tabulated in Table II.

TABLE II

MATERIALS USED

Sample Lot	Type of Medium	Weight, lb.	Caliper, pt.
1489	Semichemical	28.0	11.1
1492	Semichemical	27.4	10.2
1482	Semichemical	27.1	10.2
1494	Semichemical	26.7	10.0

The four sample lots of corrugating medium were cut into test strips 1/2-inch wide and 6 inches long in the machine direction. The sampling procedure is illustrated in Figure 1. It may be seen in Figure 1 that for each lot of material there were twelve samples of twenty-two specimens each. The samples for Lot 1489 were numbered from 1 through 12, those for Lot 1492 from 13 through 24, those for Lot 1482 from 25 through 36, and those for Lot 1494 from 37 through 48. The eleven even-numbered specimens in each sample were sent to one of the six participating mills. The mills were requested to test only ten of the eleven specimens with the results being identified according to specimen number. Since there were twelve samples per sample lot and six mills, the even-numbered specimens from the

Sample Number

Machine Direction ↓

Specimen Number

1	2	3	4	5	6	7	8	9	10	11	12
A-1	B-1	C-1	D-1	E-1	F-1	G-1	H-1	I-1	J-1	K-1	L-1
A-2	B-2	C-2	D-2	E-2	F-2	G-2	H-2	I-2	J-2	K-2	L-2
A-3	B-3	C-3	D-3	E-3	F-3	G-3	H-3	I-3	J-3	K-3	L-3
A-4	B-4	C-4	D-4	E-4	F-4	G-4	H-4	I-4	J-4	K-4	L-4
A-5	B-5	C-5	D-5	E-5	F-5	G-5	H-5	I-5	J-5	K-5	L-5
A-6	B-6	C-6	D-6	E-6	F-6	G-6	H-6	I-6	J-6	K-6	L-6
A-7	B-7	C-7	D-7	E-7	F-7	G-7	H-7	I-7	J-7	K-7	L-7
A-8	B-8	C-8	D-8	E-8	F-8	G-8	H-8	I-8	J-8	K-8	L-8
A-9	B-9	C-9	D-9	E-9	F-9	G-9	H-9	I-9	J-9	K-9	L-9
A-10	B-10	C-10	D-10	E-10	F-10	G-10	H-10	I-10	J-10	K-10	L-10
A-11	B-11	C-11	D-11	E-11	F-11	G-11	H-11	I-11	J-11	K-11	L-11
A-12	B-12	C-12	D-12	E-12	F-12	G-12	H-12	I-12	J-12	K-12	L-12
A-13	B-13	C-13	D-13	E-13	F-13	G-13	H-13	I-13	J-13	K-13	L-13
A-14	B-14	C-14	D-14	E-14	F-14	G-14	H-14	I-14	J-14	K-14	L-14
A-15	B-15	C-15	D-15	E-15	F-15	G-15	H-15	I-15	J-15	K-15	L-15
A-16	B-16	C-16	D-16	E-16	F-16	G-16	H-16	I-16	J-16	K-16	L-16
A-17	B-17	C-17	D-17	E-17	F-17	G-17	H-17	I-17	J-17	K-17	L-17
A-18	B-18	C-18	D-18	E-18	F-18	G-18	H-18	I-18	J-18	K-18	L-18
A-19	B-19	C-19	D-19	E-19	F-19	G-19	H-19	I-19	J-19	K-19	L-19
A-20	B-20	C-20	D-20	E-20	F-20	G-20	H-20	I-20	J-20	K-20	L-20
A-21	B-21	C-21	D-21	E-21	F-21	G-21	H-21	I-21	J-21	K-21	L-21
A-22	B-22	C-22	D-22	E-22	F-22	G-22	H-22	I-22	J-22	K-22	L-22

Figure 1

Sampling Procedure for Each Lot of Material first and seventh samples in each lot were sent to one mill, the second and eighth samples to another, and so on. Thus, each mill tested two samples of ten specimens from each lot of material. The eleven odd-numbered specimens in each sample were retained and tested at The Institute of Paper Chemistry. Thus, the Institute tested twelve samples of 10 specimens from each lot of material.

TESTING PROCEDURE--PHASE II

The testing procedure used in this investigation was the same as that used in the initial round-robin study. In addition, each mill was requested to make measurements of flute height or caliper of the taped specimen prior to fluting. For this purpose, a short length of 1/8-inch drill rod was included with the samples sent to each mill. It was requested that the flute height measurements be made by placing the drill rod at the bottom of one of the central flutes, laying a micrometer depth gage over the fluted strip and measuring the distance from the top of the flute to the top of the drill rod section. These measurements were requested because it was reasoned that differences in flute height might be one cause for differences in readings--i.e., the higher the flute, the lower the readings.

DISCUSSION OF RESULTS

Phase I

As previously mentioned, the purpose of this study was to develop information concerning the agreement in test results obtained between mills using the Concora medium fluter. Five sample lots of corrugating medium embracing a range of flat crush from 25 to 40 p.s.i. were used in this study. The specimens were selected, shuffled, and precut to test size by The Institute of Paper Chemistry and then sent to the individual mills for fluting and testing. The mills fluted and tested ten specimens of each sample lot and returned a record of the individual test readings to the Institute for analysis. Table III presents a tabulation of the test averages obtained by each mill for the five sample lots tested. Bar charts indicating the range of test averages for each sample lot are illustrated in Figures 2 through 6. It may be noted that these charts are plotted in order of decreasing test average. The test average obtained at The Institute of Paper Chemistry (Mill C) is presented as a solid line across the entire chart for purposes of comparison.

For purposes of comparison, the results tabulated in Table III have been retabulated in Table IV to show the distribution of the results per sample about the Institute results taken as an arbitrary reference point. In the case of Sample Lot K-1048, the results ranged from a plus 5.4% (see Table III) for Mill G to a minus 11.5% for Mill S. For Sample K-1047 the range was from +10.3% to minus 5.5% for Mills H and A, respectively. When the results for Sample Lot K-1058 are considered, it may be seen that the range was from +12.3% for Mill G to -4.9% for Mill S. Similarly for Sample Lot 1064, the range was +14.5% for

TABLE III

CONCORA FLAT CRUSH RESULTS

Sample No.	Flat-Crush Results K-1048		K-1047		K-1058		K-1045		K-1064		Av. diff., %*
Mill	lb.	diff., %*	lb.	diff., %*	lb.	diff., %*	lb.	diff., %*	lb.	diff., %*	
A	45.8	-7.8	51.2	-5.5	62.5	+1.3	72.0	-1.1	64.7	-4.6	-3.5
B	45.1	-9.3	52.6	-3.0	59.5	-3.6	66.0	-9.3	66.7	-1.6	-5.4
C*	49.7		54.2		61.7		72.8		67.8		
D	46.3	-6.8	55.4	+2.2	62.0	+0.5	73.0	+0.3	74.4	+9.7	+1.2
E	51.6	+3.8	53.9	-0.6	64.0	+3.7	69.6	-4.4	69.0	+1.8	+0.9
F	47.6	-4.2	59.3	+9.4	65.4	+6.0	76.5	+5.1	76.3	+12.5	+5.8
G	52.4	+5.4	58.3	+7.6	69.3	+12.3	77.9	+7.0	77.7	+14.6	+9.4
H	49.9	+0.4	59.8	+10.3	67.9	+10.0	78.5	+7.8	74.2	+9.4	+7.6
I	49.5	-0.4	59.2	+9.2	64.7	+4.9	77.8	+6.9	73.5	+8.4	+5.[illegible]
J	45.8	-7.8	54.4	0.4	62.9	+1.9	69.4	4.7	67.3	-0.7	-2.2
K	49.6	0.2	54.[illegible]	1.3	63.6	+3.1	70.3	3.4	70.6	4.1	+1.[illegible]
L	[illegible]	[illegible]	53.3	1.7	59.6	-3.4	69.1	-5.1	69.5	+2.5	-2.7
M	45.9	-7.6	53.5	-1.3	63.1	+2.3	70.5	-3.2	69.7	+2.8	[illegible]
N	47.3	-4.8	54.6	+0.7	63.8	+3.4	71.8	-1.4	73.2	+8.0	+1.2
O	47.2	-5.0	53.7	-0.9	60.1	-2.6	66.2	[illegible]	66.7	-1.6	-3.[illegible]
P	46.7	-6.0	54.7	-0.9	60.7	-1.6	71.6	-1.6	66.3	-2.2	-2.1
R	47.4	-4.6	56.9	[illegible]	64.2	+4.1	74.5	+2.3	72.7	+7.2	+2.[illegible]
S	44.0	-11.5	52.1	-3.9	58.7	-4.9	67.9	[illegible]	65.1	-4.0	-6.2

*Institute of Paper Chemistry tester, Mill C, used as reference.

TABLE IV

DISTRIBUTION OF MILL RESULTS

	K-1048	K-1047	K-1058	K 1045	K-1064	Composite Average*
+14 to 14.9					G	
+13 to 13.9						
+12 to 12.9			G		F	
+11 to 11.9						
+10 to 10.9		H	H			
+ 9 to 9.9		F, I			D, H	G$^{9.4}$
+ 8 to 8.9					I, N	
+ 7 to 7.9		G		G, H	R	H$^{7.6}$
+ 6 to 6.9			F	I		
+ 5 to 5.9	G	R		F		F$^{5.8}$, I$^{5.8}$
+ 4 to 4.9			I, R		K	
+ 3 to 3.9	E		E, K, N			
+ 2 to 2.9		D	M	R	L, M	R$^{2.8}$
+ 1 to 1.9		K	A, J		E	D$^{1.2}$, K$^{1.0}$, [illegible]$^{1.2}$
+ 0 to 0.9	H	N, P, J	D	D		E$^{0.9}$
- 0 to 0.9	I, K	E, O			J	
- 1 to 1.9		L, M	P	A, N, P	B, O	[illegible]$^{1.4}$
- 2 to 2.9			O		P	J$^{2.2}$, L$^{2.7}$, P$^{2.1}$
- 3 to 3.9		B, S	B, L	K, M		A$^{3.5}$, O$^{3.[illegible]}$
- 4 to 4.9	F, N, R		S	E, I	A, S	
-5 to 5.9	L, O	A		I		B$^{5.4}$
- 6 to 6.9	D, P			S		S$^{6.2}$
- 7 to 7.9	J, M, A					
- 8 to 8.9						
- 9 to 9.9	B			B, O		
-10 to 10.9						
-11 to 11.9	S					
-12 to 12.9						
-13 to 13.9						
-14 to 14.9						

* Exponent represents composite average percentage difference from Mill C results.

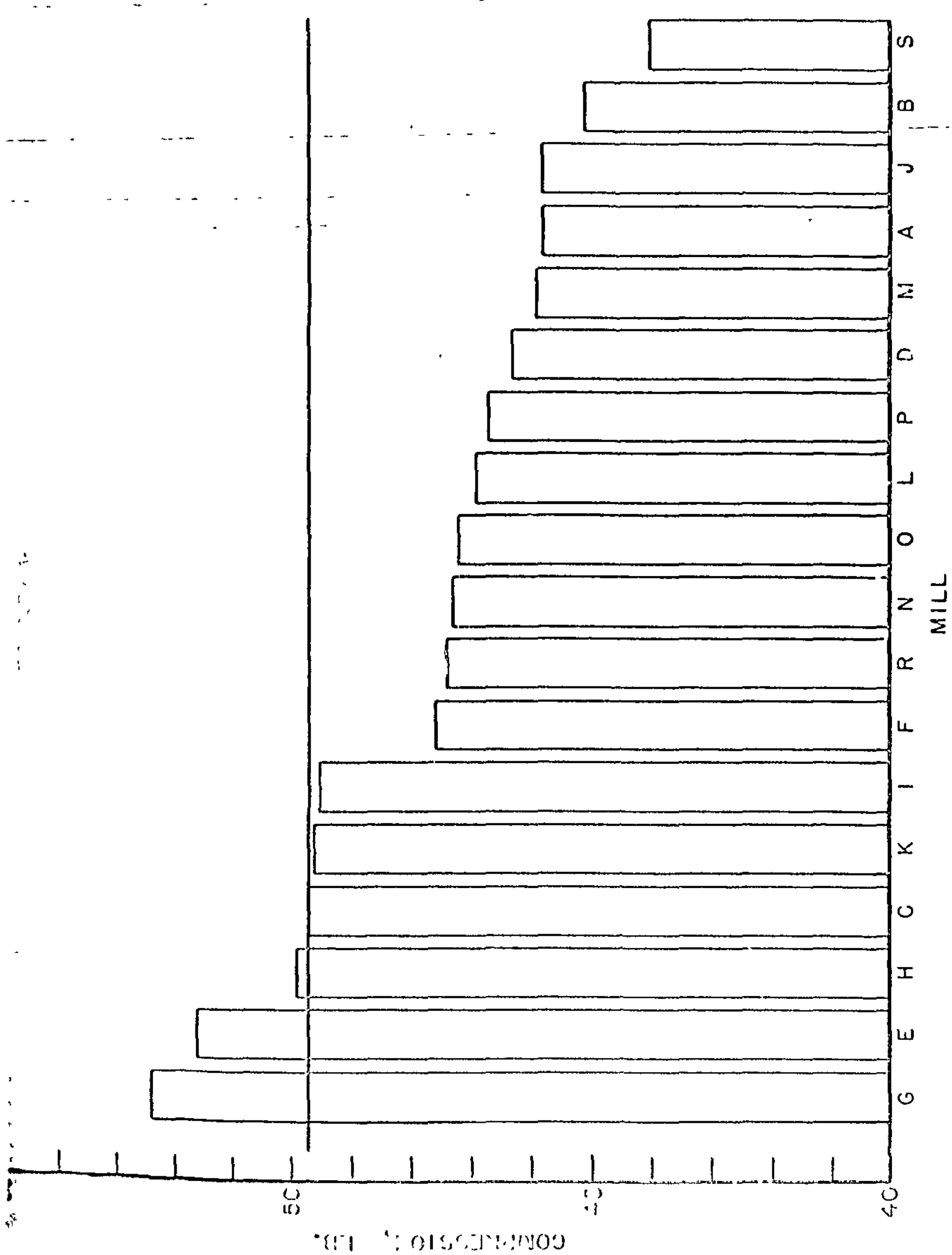

Figure 2

Concora Flat-Crush Averages Obtained on Sample Lot K-104S

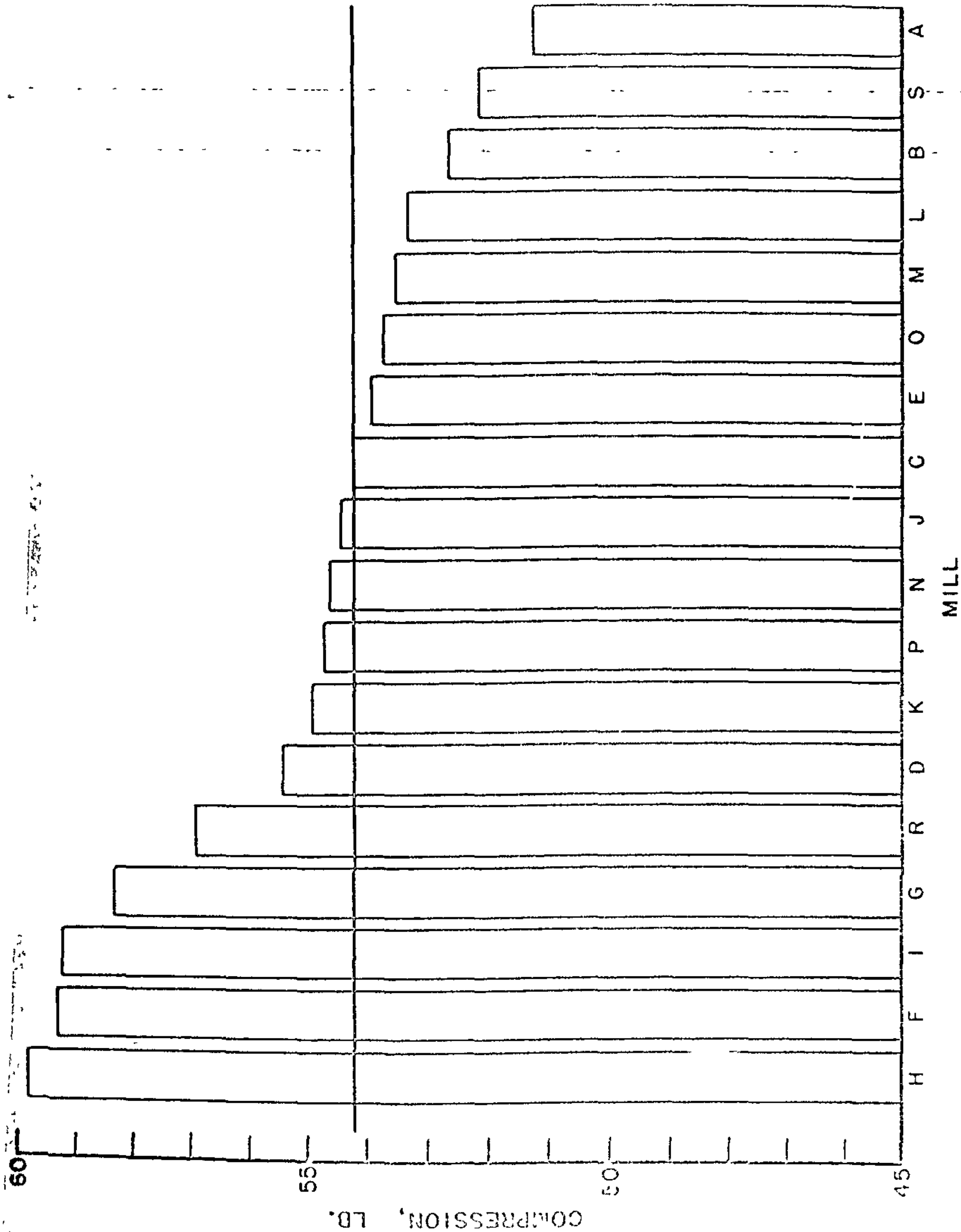

Figure 3

Concora Flat-Crush Averages Obtained on Sample Lot K-1047

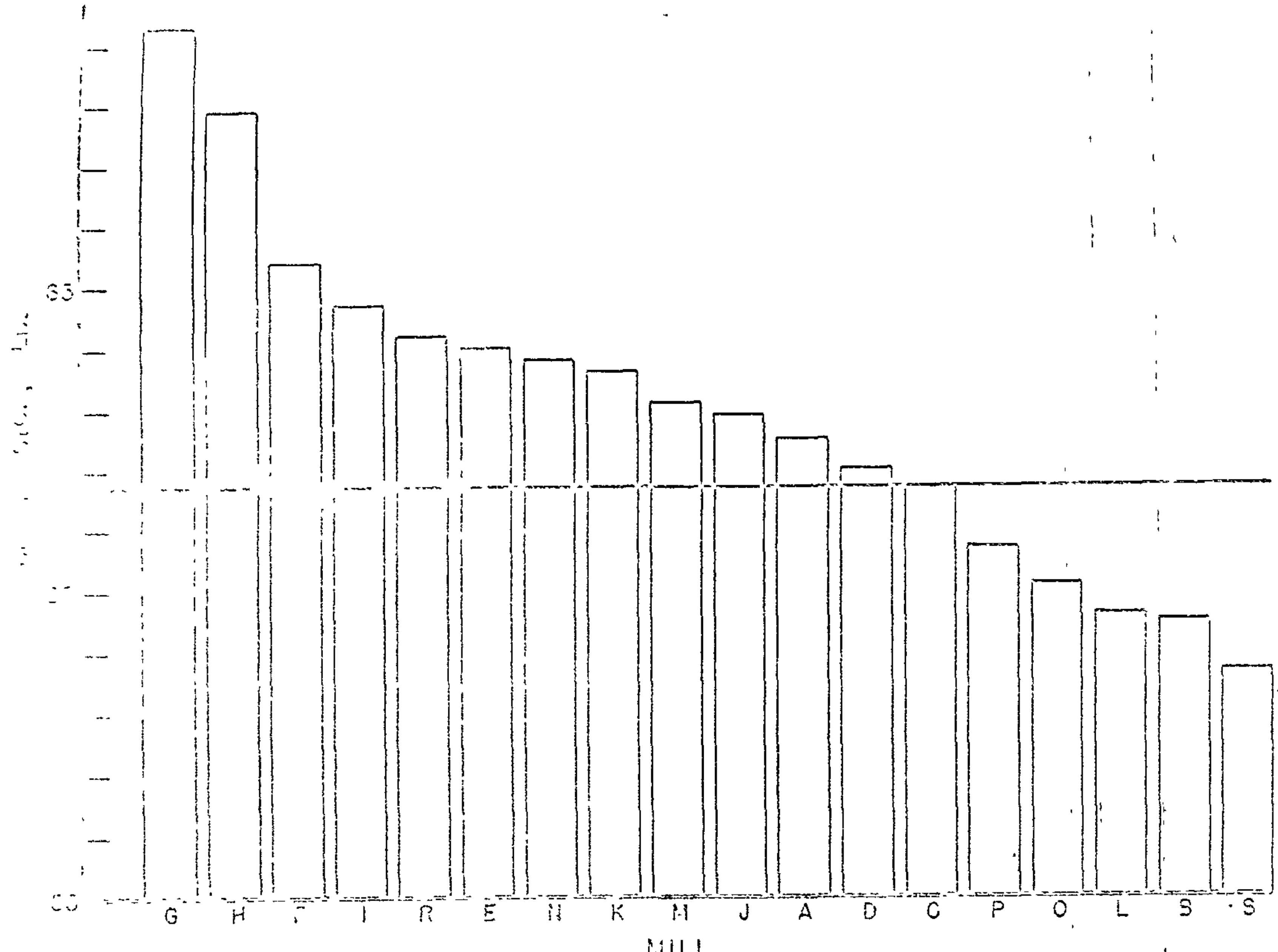

Figure 4

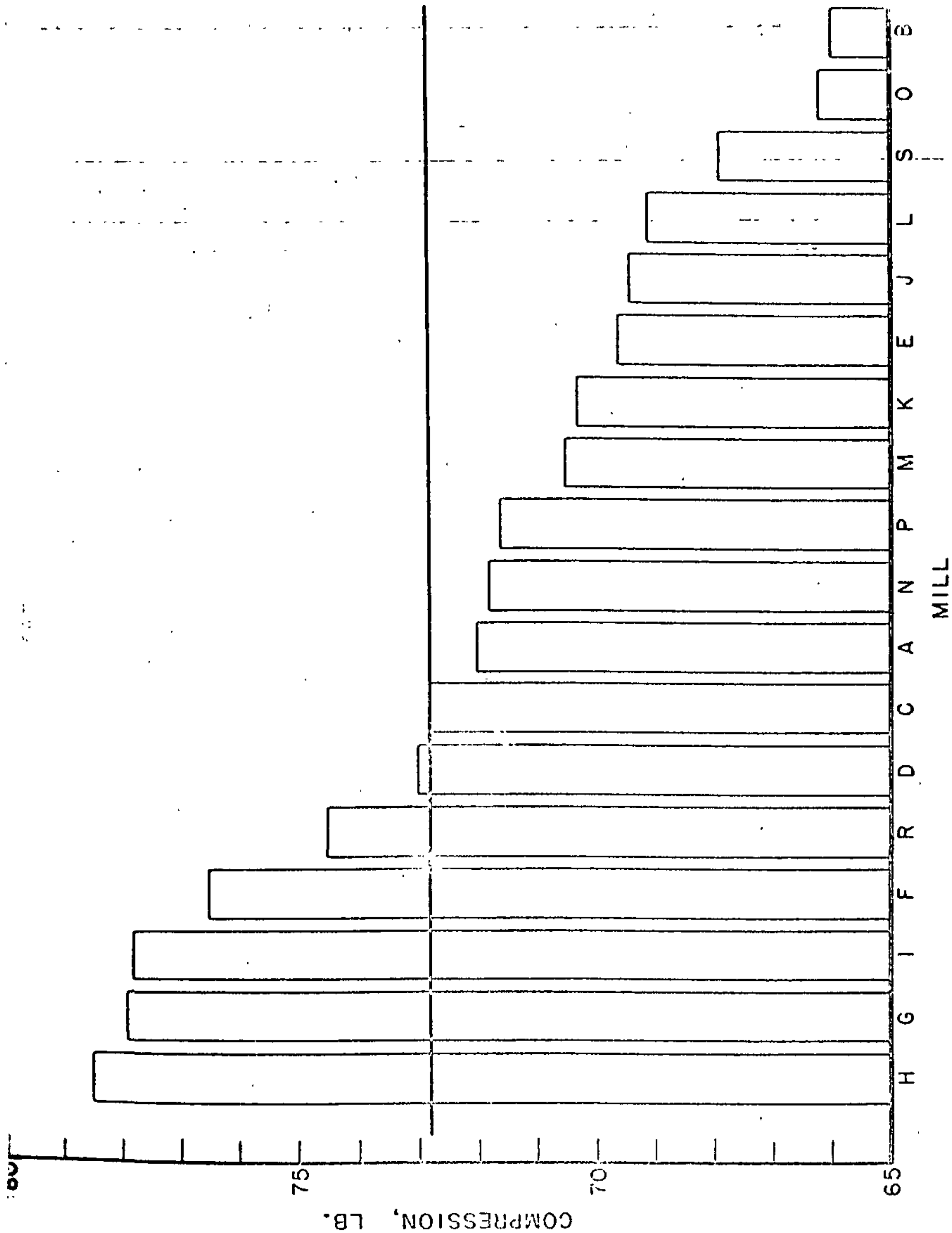

Figure 5

Concora Flat-Crush Averages Obtained on Sample Lot K-1045

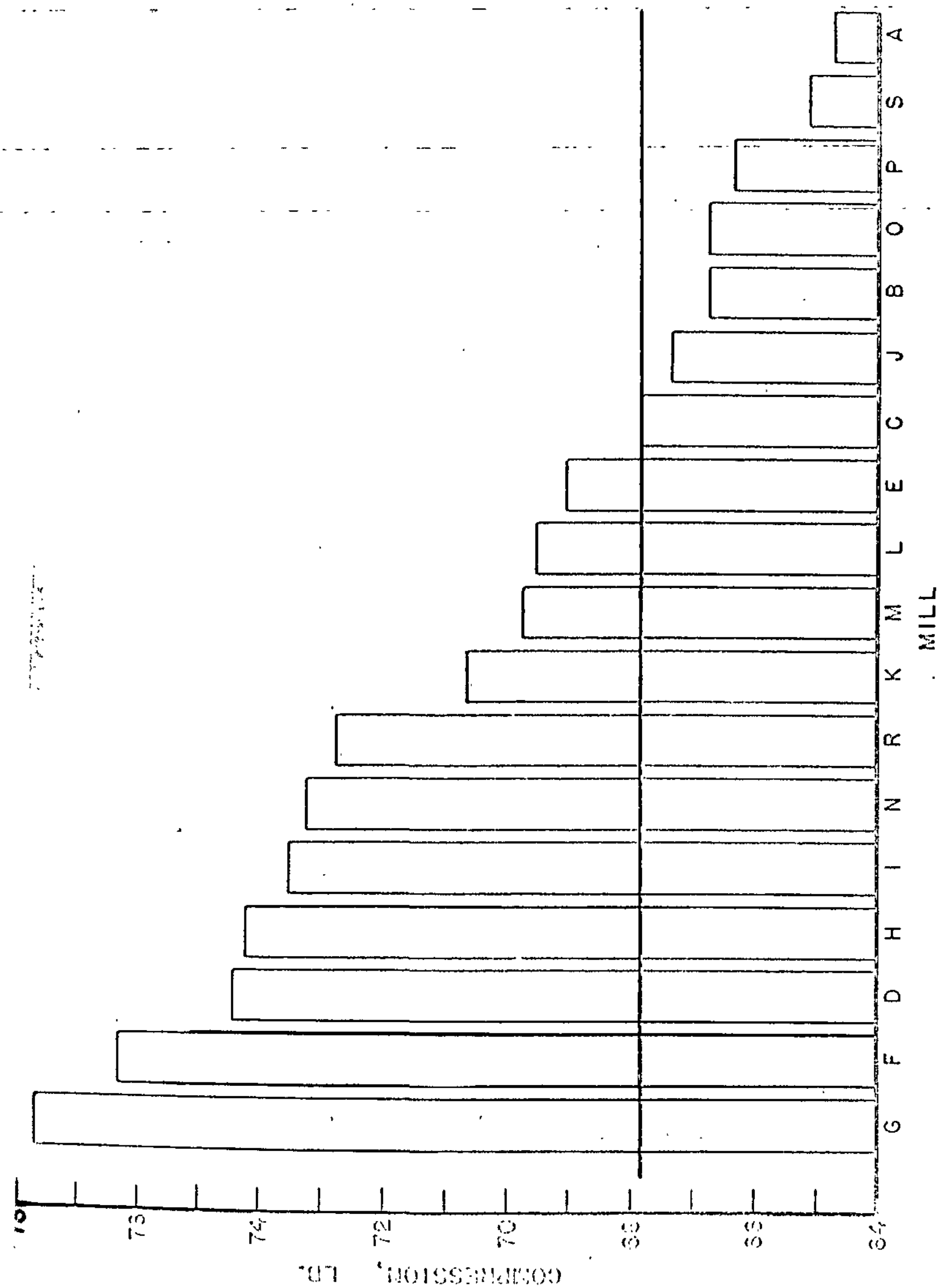

Figure 6

Concora Flat-Crush Averages Obtained on Sample Lot K-1034

Mill G to -4.0% for Mill S. For Sample Lot 1045, the range was +7.8% for Mill H to -9.3% for Mill B.

When the data are considered in terms of the composite average deviation from Mill C results, it may be seen (see Tables III and IV) that the results of Mills G, H, F and I averaged from 5.8 to 9.4% higher with the 9.4 being associated with Mill G. On the other hand, Mill B exhibited results which averaged 5.4% lower than Mill C and Mill S exhibited results which averaged 6.2% lower than Mill C. Eleven of the seventeen mills exhibited composite averages which were within a ± 4% range of Mill C results. When a range of ± 2.5% is considered, only seven of the seventeen fell within this range. These were Mills E, K, D, N, M, P and J. On the basis of a cursory statistical study (3) carried out previously on the data obtained from 78 samples of corrugating medium, it was estimated that the reproducibility of sample averages at the 95% level was approximately ± 4% for specimen size 10 which was the size used in this study.

In order to determine whether the data as a whole yielded significant differences between mills or between sample lots of material, an analysis of variance technique was first performed on the test results from all five sample lots of material.

From the design of the test program it would, of course, be expected that there would be a significant difference between the sample lots of material. The real question is to determine if there is a significant difference in the results obtained by the different mills. The data from all mills were included in this analysis with the exception of the test results for Mill S which were received after the analysis had been completed. However, subsequent analysis indicated that the over-all results would not have been affected significantly had the results of Mill S been included. The results of this analysis of variance are presented in Table V.

TABLE V

ANALYSIS OF VARIANCE OF COMPOSITE DATA

Source of Variance	Degrees of Freedom	Square	F
Between mills	16	350.125	11.124**
Between sample lots of material	4	17,970.365	570.923**
Mill x sample lot interaction	64	31.476	3.601**
Residual (error)	765	8.742	
Total	849		

** Significant at 1% level--i.e., likelihood of obtaining F values of above magnitude by chance alone is less than 1 in 100.

It may be noted in Table V that a significant mill x sample lot interaction exists. This means that a given mill does not retain the same test order relative to the other mills throughout all sample lots of materials. Figures 2 through 6 indicate this same fact inasmuch as no mill retained the same relative ranking (from highest to lowest) for all five sample lots of material. Because the mill x sample lot interaction was significant, the mean squares due to the variation between mills and between sample lots of materials were tested against the mill x sample lot interaction mean square. Significant differences between mills and between sample lots of material were noted.

In order to analyze the differences between mills without considering the differences between sample lots of material, analyses of variance were performed on each sample lot of material separately. The results of these analyses are presented in Table VI. It may be seen in Table VI that a significant difference between mills is noted for each sample lot of material.

The analyses of variance which have been performed indicate only that significant differences between test results from the various mills do exist--i.e., that the mill averages as a whole differ significantly amongst themselves. However, these analyses do not indicate which mills differ significantly. Because the analyses of variance yielded significant differences between mills, the t-test was applied as a further aid to interpret the results of these analyses and to determine the magnitude of the difference between two means (in this case, between sample averages from two mills) which would be required for significance at the 5% and 1% level.

The data obtained at The Institute of Paper Chemistry (Mill C) were taken as an arbitrary reference point. It was possible, then, to determine which mill averages were significantly different from The Institute of Paper Chemistry average.

The difference between two means which is required for significance at both the 5% and 1% levels have been calculated for each sample lot of material and are presented in Table VI. Differences as great or greater than those presented in Table VII for 5% level would be expected strictly by chance only one in twenty times. Differences as great or greater than those presented in Table VII for 1% level would be expected strictly by chance only one in a hundred times.

TABLE VI

ANALYSIS OF VARIANCE

Source of Variance	Degrees of Freedom	K-1048 Mean Square	K-1048 F	K-1047 Mean Square	K-1047 F	K-1058 Mean Square	K-1058 F	K-1045 Mean Square	K-1045 F	K-1064 Mean Square	K-1064 F
Between mills	16	45.919	7.130**	63.699	7.126**	72.074	8.396**	146.268	16.152**	148.068	13.851**
Within mills (error)	153	6.440		8.939		8.584		9.056		10.690	
Total	169										

** Significant at 1% level.

TABLE VII

DIFFERENCE BETWEEN MILL AVERAGES REQUIRED FOR SIGNIFICANCE, LB.*

Sample Lot	5% Level	1% Level
K-1048	2.2	2.9
K-1047	2.6	3.4
K-1058	2.6	3.4
K-1045	2.6	3.5
K-1064	2.9	3.8

* Obtained from analysis of variance data.

Note: Above should be multiplied by 0.6 to convert to p.s.i.

The differences between the Institute (Mill C) and mill averages are presented in Table VIII. Also shown are the levels at which the differences are significant.

The data tabulated in Table VIII has been retabulated in Table IX to indicate the number of sample averages which differed significantly at 5% level from Mill C results for each mill.

It may be observed from Table IX that only one mill, namely, Mill K, did not differ significantly from Mill C results on any of the samples. Mill G on the other hand differed significantly on all five samples and Mills F, H, and I on four out of five samples. If Mill C results are a practical reference, then it would appear that attention should be focused on Mills G, F, H, and I to determine the reasons for their apparent nonconformity.

TABLE VIII

DIFFERENCES BETWEEN I.P.C. AND MILL AVERAGES

Mill	K-1048	K-1047	K-1058	K-1045	[illegible]
A	-3.9**	-3.0*	+0.8	-0.8	[illegible]
B	-4.6**	-1.6	-2.2	-6.8**	[illegible]
D	-3.4**	+1.2	+0.3	+0.2	[illegible]
E	+1.9	-0.3	+2.3	-3.2*	[illegible]
F	-2.1	+5.1**	+3.7**	+3.7**	[illegible]
G	+2.7*	+4.1**	+7.6**	+5.1**	[illegible]
H	+0.2	+5.6**	+6.2**	+5.7**	[illegible]
I	-0.2	+5.0**	+3.0*	+5.0**	[illegible]
J	-3.9**	+0.2	+1.2	-3.4*	[illegible]
K	-0.1	+0.7	+1.9	-2.5	[illegible]
L	-2.8*	-0.9	-2.1	-3.7**	[illegible]
M	-3.8**	-0.7	+1.4	-2.3	[illegible]
N	-2.4*	+0.4	+2.1	-1.0	[illegible]
O	-2.5*	-0.5	-1.6	-6.0**	[illegible]
P	-3.0**	+0.5	-1.0	-1.2	[illegible]
R	-2.3*	+2.7*	+2.5	+1.7	[illegible]
S	-5.7**	-2.1	-3.0*	-4.9**	[illegible]

* Significant at 5% level.

** Significant at 1% level.

TABLE IX

DISTRIBUTION OF MILLS BASED ON SIGNIFICANT DIFFERENCES

No. Averages Differing Significantly*					
0	1	2	3	4	5
K	P	O	S	I	G
	M	N	R	H	
	E	L	A	F	
		J			
		D			
		B			

* Mill C used as reference.

It has been mentioned previously that each mill tested one sample of ten specimens for each sample lot of material. It seemed desirable to obtain an idea of the range in which such sample averages might fall for each mill. In dealing with large size samples, the sample means would vary $\pm$ 2 standard errors ($\sigma_{\bar{x}}$) or more from the population mean in about 5 sample averages out of 100. However, in considering samples of ten specimens (9 degrees of freedom), sample averages will vary $\pm 2.3\ \sigma_{\bar{x}}$ or more from the population mean in about 5 samples out of 100. It may be concluded, then, that 95% of the sample averages would be expected to fall in the range $\bar{\bar{x}} \pm 2.3\ \sigma_{\bar{x}}$. The probability is also 95 out of 100 that the population mean falls within this range.

The standard errors and 95% limits for averages are presented in Table X for each mill or each sample lot of material. These limits

TABLE X

STANDARD ERRORS AND 95% RANGE FOR SAMPLE AVERAGES

	Sample Lot									
	K-1048		K-1047		K-1058		K-1045		K-1064	
	$\sigma_{\bar{X}}$	Range	$\sigma_{\bar{X}}$	Range	$\sigma_{\bar{X}}$	Range	$\sigma_{\bar{X}}$	Range	$\sigma_{\bar{X}}$	Range
A	1.083	43.3-48.3	0.998	48.9-53.5	0.734	60.8-64.2	1.155	69.3-74.7	0.989	62.4-67.0
B	0.737	43.4-46.8	0.909	50.5-54.7	0.342	58.7-60.3	1.247	63.1-68.9	1.096	64.2-69.2
C	0.989	47.4-52.0	0.772	52.4-56.0	1.535	58.2-65.2	1.062	70.4-75.2	1.200	65.0-70.6
D	0.423	45.3-47.3	0.957	53.2-57.6	0.745	60.3-63.7	0.931	70.9-75.1	1.077	71.9-76.9
E	0.718	49.9-53.3	0.674	52.3-55.5	1.075	61.5-66.5	1.035	67.2-72.0	1.686	65.1-72.9
F	0.819	45.7-49.5	0.989	57.0-61.6	1.107	62.9-67.9	1.222	73.7-79.3	1.044	73.9-78.7
G	0.819	50.5-54.3	1.023	55.9-60.7	1.055	66.9-71.7	0.752	76.2-79.6	1.350	74.6-80.8
H	0.752	48.2-51.6	1.272	56.9-62.7	0.809	66.0-69.8	0.847	76.6-80.4	0.863	72.2-76.2
I	0.582	48.2-50.8	1.020	56.9-61.5	0.831	62.8-66.6	1.031	75.4-80.2	1.267	70.6-76.4
J	0.987	43.5-48.1	0.957	52.2-56.6	0.737	61.2-64.6	0.897	67.3-71.5	0.746	65.6-69.0
K	1.024	47.2-52.0	0.994	52.6-57.2	1.266	60.7-66.5	0.667	68.8-71.8	0.921	68.5-72.7
L	0.547	45.6-48.2	0.844	51.4-55.2	0.933	57.5-61.7	0.836	67.2-71.0	0.957	67.3-71.7
M	0.547	44.6-47.2	0.847	51.6-55.4	0.737	61.4-64.8	0.860	68.5-72.5	0.907	67.6-71.8
N	0.331	45.4-49.2	0.670	53.1-56.1	0.646	62.3-65.3	0.327	71.0-72.6	0.853	71.2-75.2
O	0.879	45.2-49.2	1.165	51.0-56.4	0.567	58.8-61.4	0.646	64.7-67.7	0.260	66.1-67.3
P	0.775	44.9-48.5	1.065	52.3-57.1	0.989	58.4-63.0	1.077	69.1-74.1	0.684	64.7-67.9
R	0.792	45.6-49.2	0.674	55.3-58.5	0.952	62.0-66.4	1.108	72.0-77.0	0.943	70.5-74.9
S	0.558	42.7-45.3	0.875	50.1-54.1	0.817	56.8-60.6	0.640	66.4-69.4	0.948	62.9-67.3

for each mill are graphically presented in Figures 7 through 11 for each sample lot of material.

As previously mentioned, each participant was forwarded a strip of NCR paper to enable a pressure pattern to be made of the corrugator roll contact prior to the evaluation of the test samples. The pressure patterns so obtained were returned and examined to determine whether there was any correspondence between test results and corrugator pattern. Figure 12 illustrates sections of the roll pattern obtained by the participating mills. Patterns were examined and placed in categories of good uniform pattern, heavy but uniform pressure lines, heavy intermittent pressure lines, excessive pressure along one edge of the pattern strip, and light pressure lines. There was no consistent agreement found between the type of pressure pattern and the ranking of the samples. It was noted, however, that all mills having very low test values submitted uniform or good print patterns and all mills having exceptionally high test values submitted uneven or distorted print patterns. This criteria was not infallible, however, because some of the mills in the central test value range had uneven patterns and some had uniform patterns.

Examination of the compression tester characteristics such as platen parallelism, testing speed, and calibration accuracy which were submitted by the participating mills gave no clue as to the reason for differences in test results. Table XI presents a summary of the compression tester data obtained.

TABLE XI

INSTRUMENTAL MEASUREMENTS

Mill	Average Fluting Temp., °F.	Load Range, lb.	Compression Tester Test Speed, in./min.	Platen Parallelism, 0.001 inch
A	350	500	1.78	0.1
B	349	500	0.89	3.4
C	360	200	1.00	2.1
D	350	500	1.43	0.4
E	370	500	1.71	6.0
F	355	100	1.62	3.0
G	350	500	1.62	0.5
H	362	500	1.56	15.6
I	340	300	3.00	2.0
J	340	500	0.90	5.0
K	340	500	0.85	3.0
L	349	500	0.99	5.0
M	356	500	1.67	4.0
N	345	500	0.90	0.5
O	345	100	1.71	1.8
P	352	500	1.71	9.0
R	354	500	1.62	3.0
S	367	500	1.80	19.7

Notes: All but Mill C used H and D compression tester.
All mills used abrasive paper on loading platen.
All but Mill L used maximum indicating load dial.

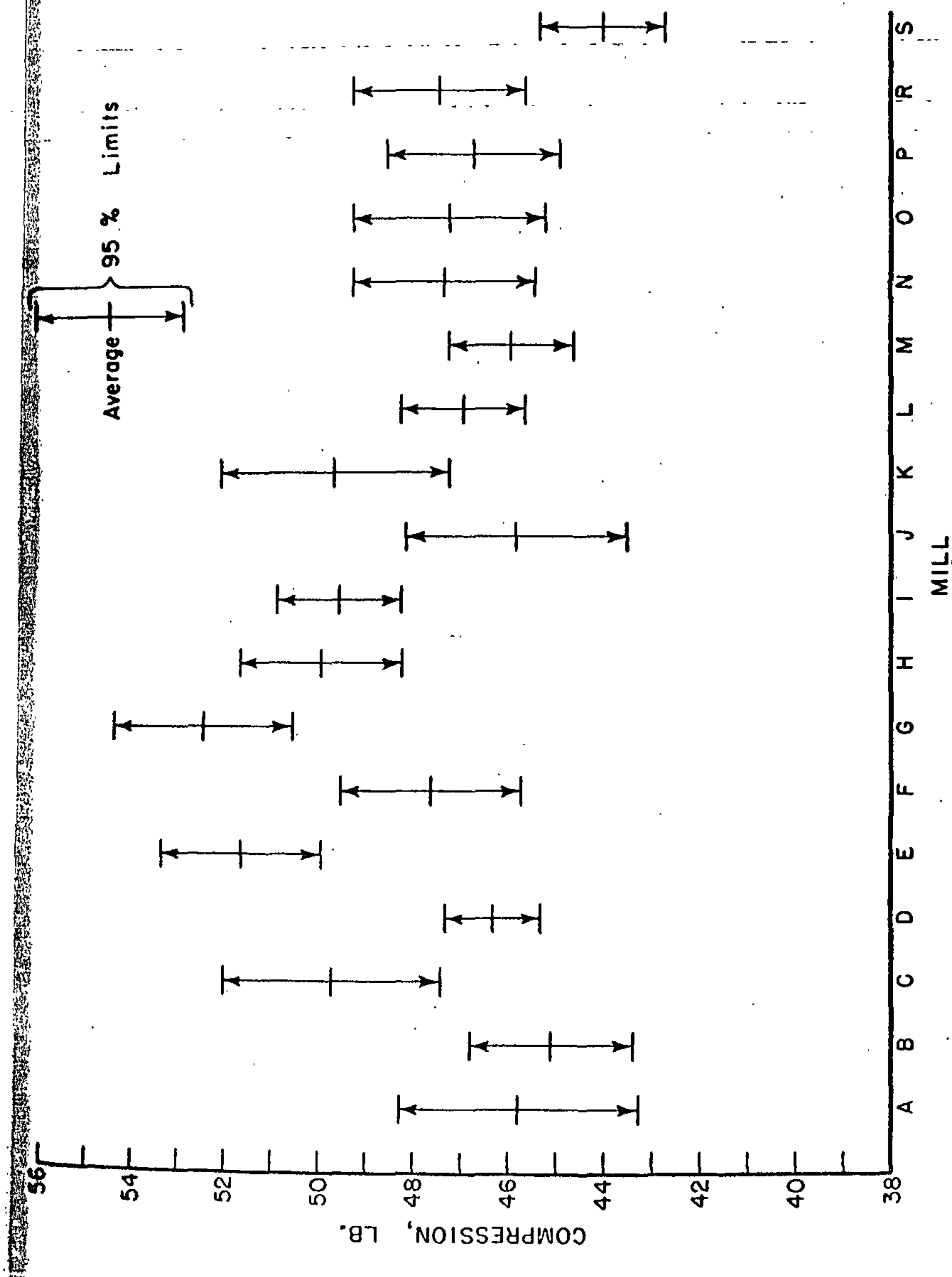

Figure 7

95% Range for Sample Averages of Individual Mills on Sample Lot K-1048

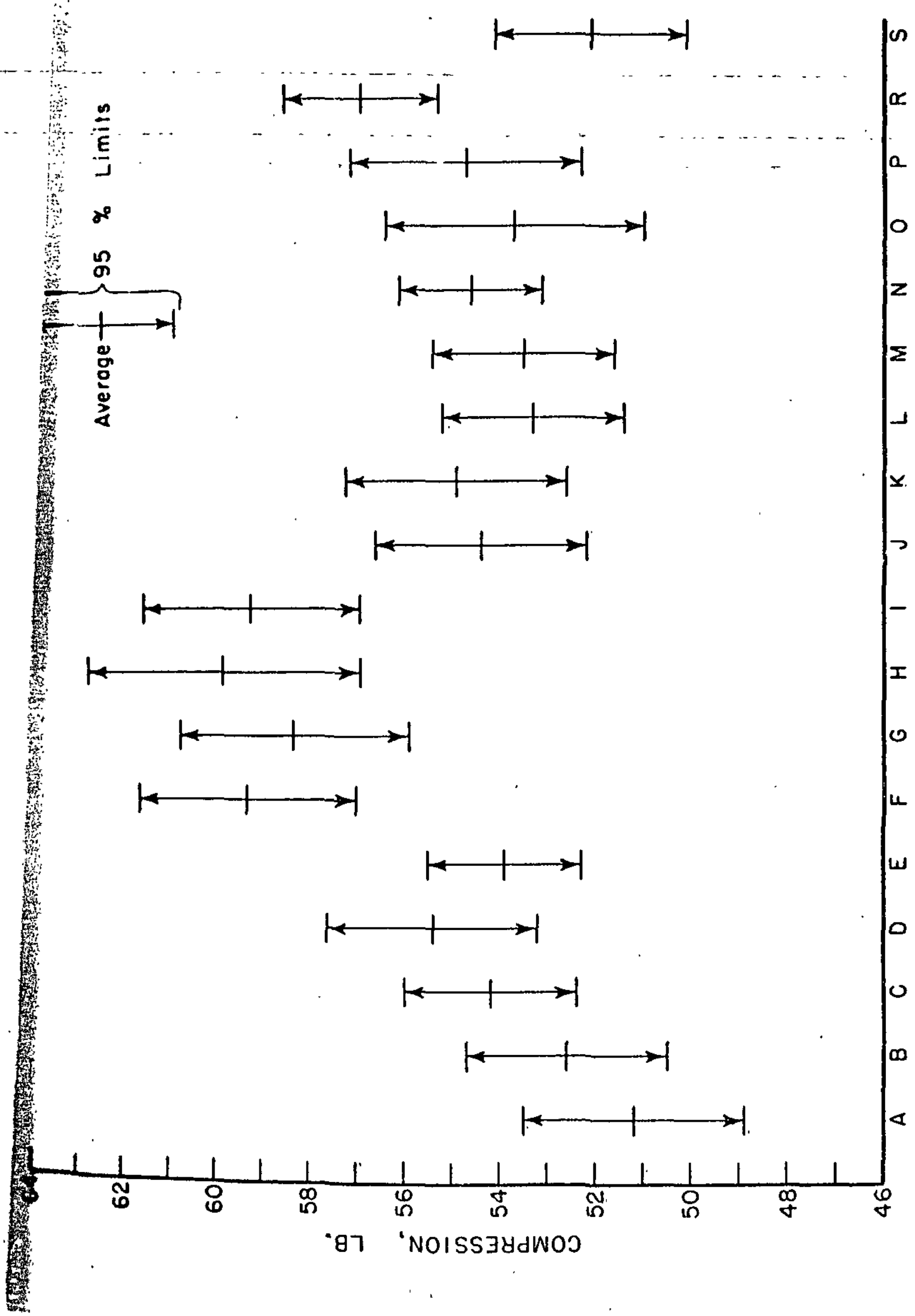

Figure 8

95% Range for Sample Averages of Individual Mills on Sample Lot K-1047

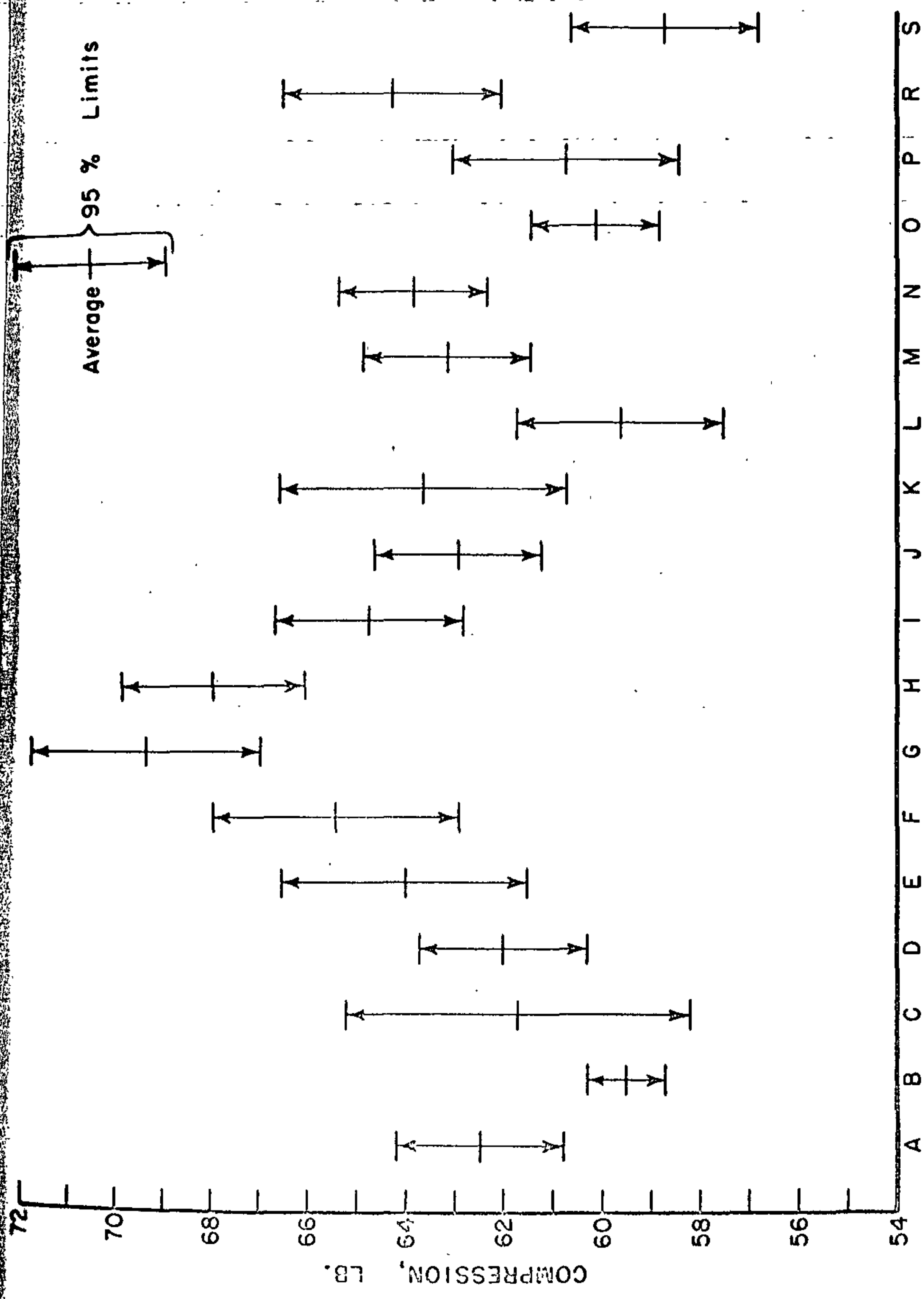

Figure 9

95% Range for Sample Averages of Individual Mills on Sample Lot K-1058

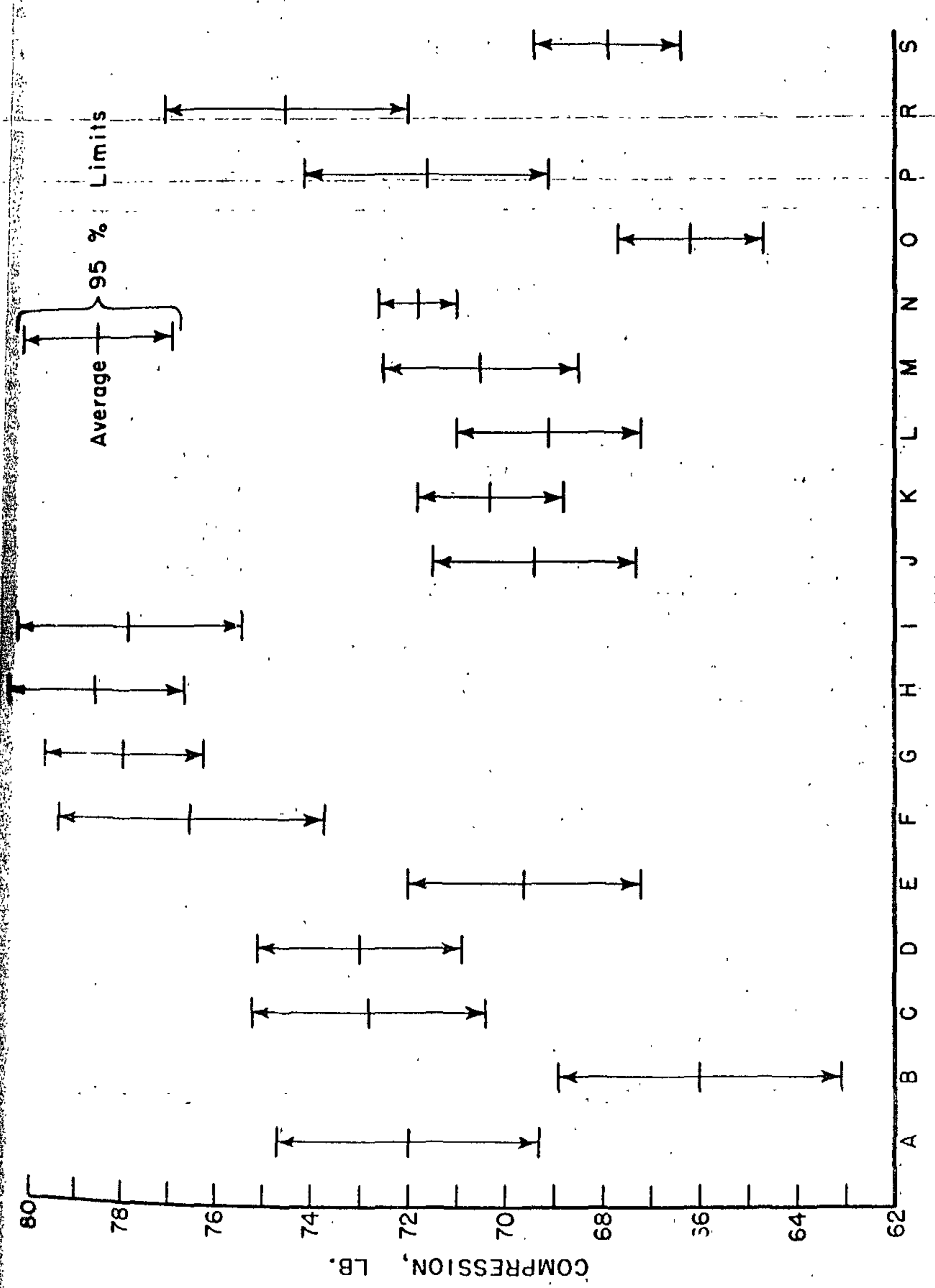

Figure 10

95% Range for Sample Averages of Individual Mills on Sample Lot K-1045

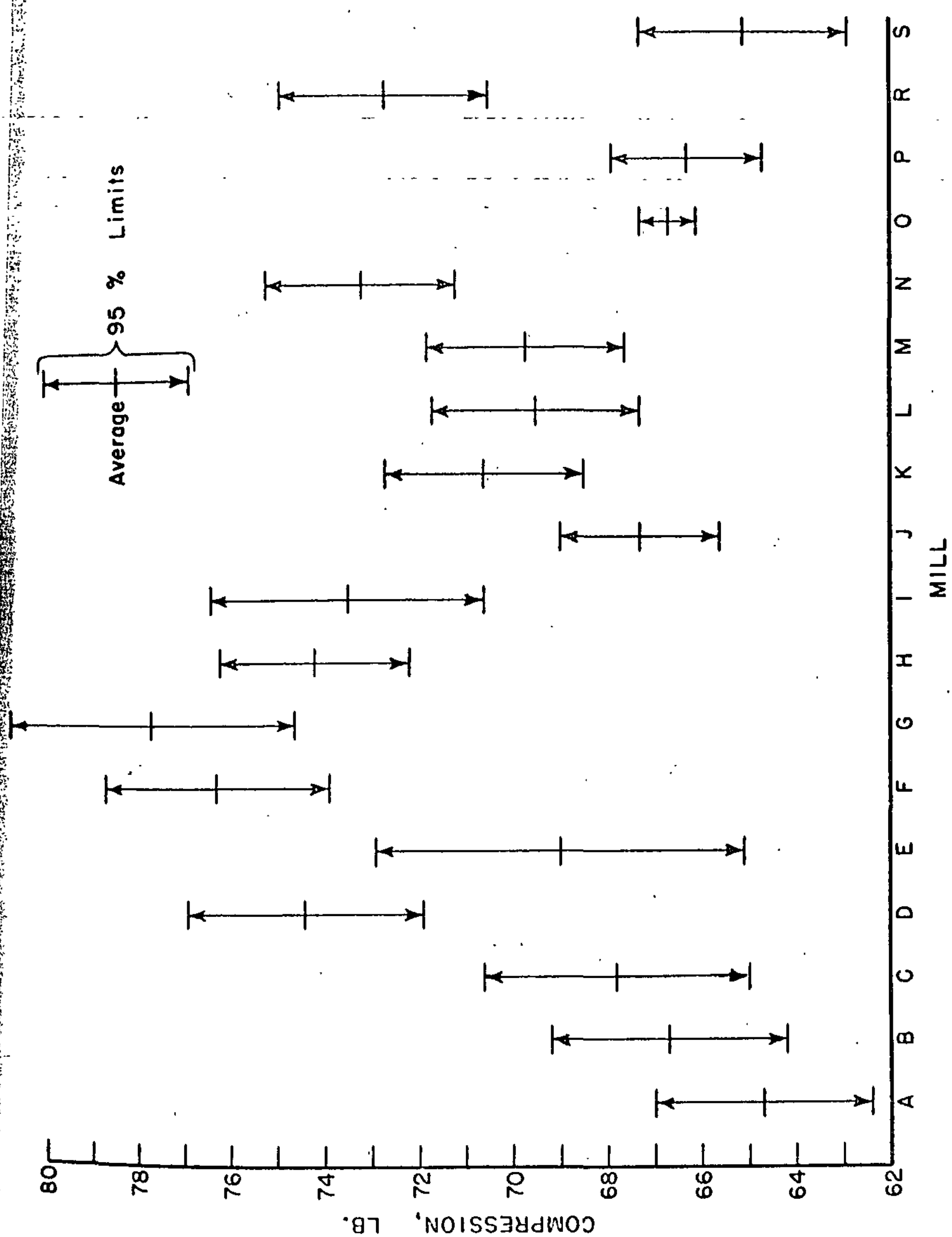

Figure 11

95% Range for Sample Averages of Individual Mills on Sample Lot K-1064

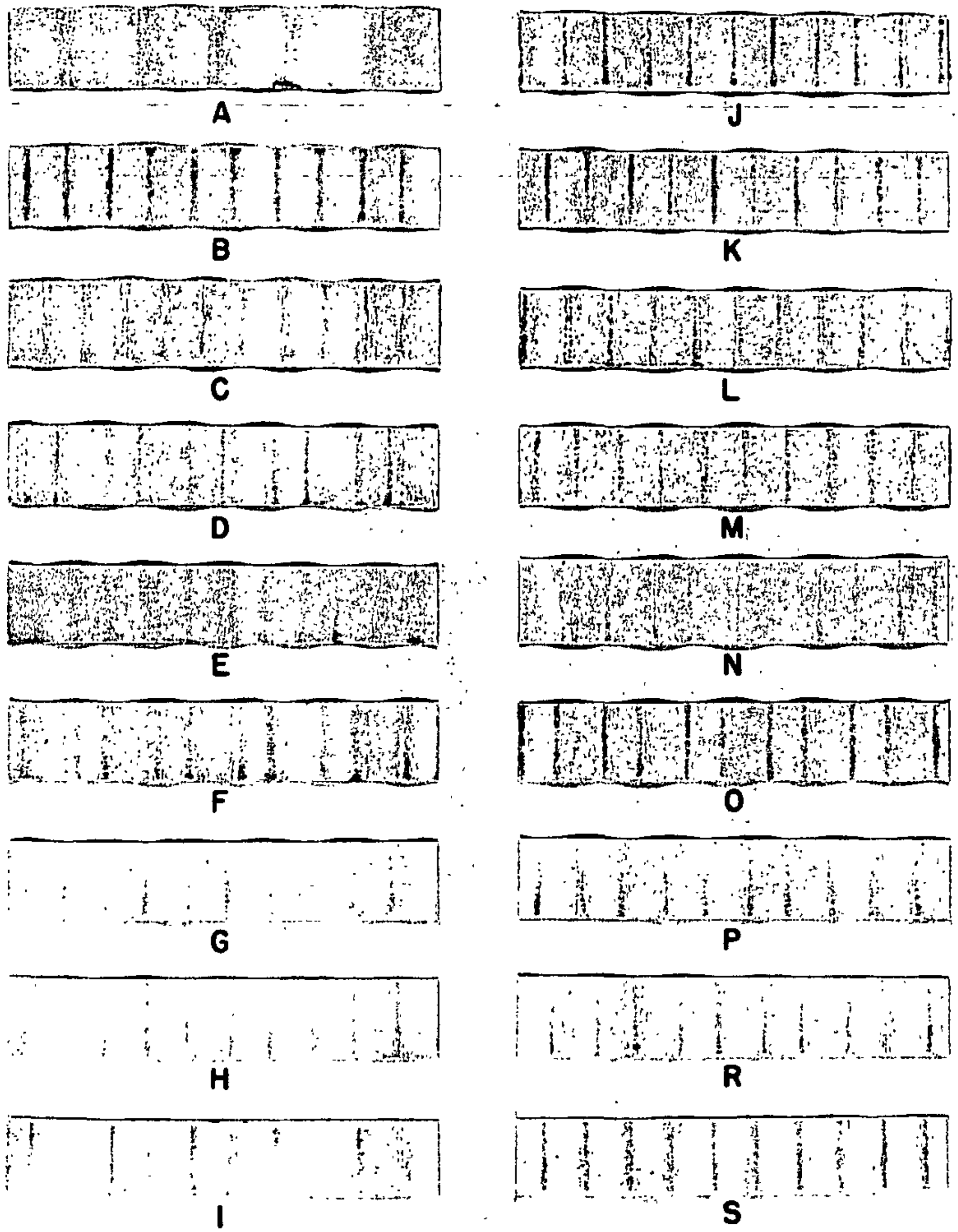

Figure 12

Pressure Pattern of Corrugating Rolls

One test variable which was not explored in Phase I was the height or caliper of the fluted specimen as prepared for the compression test. There is some evidence that the flute height obtained when using the Concora medium fluter may influence the magnitude of the test value. In general, the lower the flute height, the higher the test value obtained. This phenomena was first noticed in an instrumentation study of the Concora medium fluter (2) when tension was placed on the strip fed through the corrugating rolls. This tension tended to displace the pressure roll slightly so that the full depth of flute was not realized. Under these conditions, higher test values were obtained than when no tension was applied. A second bit of evidence was the increased flat crush obtained when the spring tension on the pressure roll was reduced so that the corrugating rolls did not mesh fully when a specimen was fed through the rolls. It is thought that some of the mills obtaining excessively high test values may have Concora medium fluters in which the pressure roll slide may stick slightly when hot so that the full pressure is applied to the rolls.

Those mills experiencing low compression results may have medium fluters in which the corrugating rolls have exceptional freedom to seat fully so that the flute is formed to the full depth. A second cause for low test values could be insufficient temperature transfer to the medium which may come about as a result of dirty teeth on the rolls or inaccurate determination of roll temperature. A third possibility for low test values could lie in the backing operation where the fluted medium is placed in the reforming rack, held in place by its comb, and pressure-sensitive tape applied. If all flutes are not adhered to the tape, the specimen could fail at a lower load because of inadequate flute support. It should be emphasized that the foregoing are purely speculative and should be so interpreted. There are many variables which need to be considered.

DISCUSSION OF RESULTS

Phase II

As previously mentioned, the purpose of this second phase was to compare Concora medium fluter test results obtained by those mills exhibiting high or low results in Phase I with results obtained at The Institute of Paper Chemistry. Results from the four highest (G, H, F, and I) and two lowest (B and S) mills were analyzed using four sample lots of corrugating medium embracing a range of flat crush from 32 to 43 p.s.i. The specimens were precut to test size by The Institute of Paper Chemistry according to the method previously described and each mill fluted and tested two samples (ten specimens per sample) from each of the four lots of material. The Institute tested twelve samples (ten specimens per sample) from each sample lot of material.

It should be noted that the Concora flat crush results discussed in Phase I were reported in pounds. It was requested by the committee that the results of the current investigation should be reported in p.s.i. Also, it should be noted that the code letters used in this section of the report are the same as those used in the previous section.

A comparison of test averages obtained by each mill with those obtained at The Institute of Paper Chemistry is presented in tabular form in Table XII and graphically in Figures 13 through 18. The averages obtained at

TABLE XII

COMPARISON OF INSTITUTE AND MILL AVERAGES AND VARIANCES

Concora Flat Crush, p.s.i.

Mill	Sample Lot	Sample	Institute Average	Mill Average	Diff.	% Diff.[a]	t	Institute Variance	Mill Variance	F
E	1489	4	34.5	35.3	+0.8	+2.3	0.929 N.S.	3.7000	3.5343	1.047 N.S.
		10	35.8	36.9	+1.1	+3.1	1.310 N.S.	4.5640	1.7449	2.616 N.S.
	1492	16	35.3	35.9	+0.6	+1.7	0.644 N.S.	2.8360	4.4532	1.574 N.S.
		22	35.6	36.1	+0.5	+1.4	0.565 N.S.	3.8440	4.3210	1.124 N.S.
	1482	23	40.9	41.7	+0.8	+2.0	1.256 N.S.	1.8240	1.9343	1.060 N.S.
		34	40.2	43.1	+2.9	+7.2	3.804 **	2.8800	2.8462	1.012 N.S.
	1494	40	35.0	34.8	-0.2	-0.6	0.417 N.S.	2.4160	1.1783	2.050 N.S.
		46	34.5	34.3	-0.2	-0.6	0.234 N.S.	3.3000	3.9800	1.206 N.S.
F	1489	6	35.0	34.3	-0.7	-2.0	0.730 N.S.	6.4960	4.9160	1.321 N.S.
		12	34.4	34.7	+0.3	+0.9	0.395 N.S.	2.8040	2.9440	1.050 N.S.
	1492	18	34.9	35.3	+0.4	+1.1	0.556 N.S.	2.4640	3.2360	1.313 N.S.
		24	35.1	36.7	+1.6	+4.6	2.318 *	3.3800	1.1560	2.924 N.S.
	1482	30	39.8	41.6	+1.8	+4.5	1.808 N.S.	5.4440	5.1360	1.060 N.S.
		36	41.5	41.5	0.0	0.0	0.078 N.S.	2.7840	3.0760	1.105 N.S.
	1494	42	34.4	36.8	+2.4	+7.0	3.614 **	2.4040	2.0040	1.200 N.S.
		43	34.3	35.6	+1.3	+3.8	1.903 N.S.	2.6240	1.7640	1.488 N.S.
G	1489	1	33.8	37.0	+3.2	+9.5	2.702 *	5.1360	8.7240	1.699 N.S.
		7	33.1	37.4	+4.3	+13.0	4.387 **	2.9440	6.4840	2.202 N.S.
	1492	13	34.2	39.2	+5.0	+14.6	6.073 **	2.1600	4.5640	2.113 N.S.
		19	35.0	38.5	+3.5	+10.0	5.421 **	1.0440	3.0760	2.946 N.S.
	1482	25	41.4	47.6	+6.2	+15.0	7.237 **	2.8000	4.4840	1.601 N.S.
		31	40.3	46.3	+6.0	+14.9	7.157 **	2.0640	4.8360	2.343 N.S.
	1494	37	35.1	38.5	+3.4	+9.7	3.709 **	3.8600	4.3560	1.128 N.S.
		43	34.0	38.5	+4.5	+13.2	7.138 **	2.6440	1.2360	2.139 N.S.

TABLE XII (Continued)

COMPARISON OF INSTITUTE AND MILL AVERAGES AND VARIANCES

Concora Flat Crush, p.s.i.

Mill	Sample Lot	Sample	Institute Average	Average	Diff.	% Diff.[a]	t	Institute Variance	Mill Variance	F
H	1489	2	32.6	35.6	+3.0	+9.2	3.181 **	4.0960	4.3360	1.059 N.S.
		8	34.2	35.0	+0.8	+2.3	0.707 N.S.	8.3200	3.8440	2.164 N.S.
	1492	14	35.3	38.2	+2.9	+8.2	3.134 **	3.3960	5.0440	1.485 N.S.
		20	35.1	38.0	+2.9	+8.3	5.765 **	1.3000	1.2960	1.003 N.S.
	1482	26	40.1	47.7	+7.6	+19.0	7.713 **	3.5040	6.2600	1.787 N.S.
		32	40.3	47.8	+7.5	+18.6	6.917 **	4.9960	6.9640	1.394 N.S.
	1494	38	34.6	38.4	+3.8	+11.0	4.505 **	2.6440	4.4000	1.664 N.S.
		44	33.8	38.6	+4.8	+14.2	5.670 **	2.4160	4.5640	1.889 N.S.
I	1489	3	35.4	35.5	+0.1	+0.3	0.058 N.S.	7.4400	3.3160	2.244 N.S.
		9	36.0	35.8	-0.2	-0.6	0.382 N.S.	1.1200	2.8160	2.514 N.S.
	1492	15	35.9	38.0	+2.1	+5.8	2.345 *	0.3040	8.1760	26.895 **
		21	35.1	38.3	+3.2	+9.1	4.337 **	2.2600	3.3160	1.467 N.S.
	1482	27	40.7	42.9	+2.2	+5.4	2.581 *	1.5560	5.4600	3.509 *
		33	41.1	44.0	+2.9	+7.1	4.298 **	1.7000	2.9760	1.751 N.S.
	1494	39	33.4	37.0	+3.6	+10.8	5.531 **	1.8440	2.2560	1.223 N.S.
		45	33.8	36.2	+2.4	+7.1	3.019 **	2.4840	3.8440	1.549 N.S.
S	1489	5	35.6	37.4	+1.8	+5.1	1.434 N.S.	8.7240	7.0440	1.239 N.S.
		11	35.2	37.0	+1.8	+5.1	1.580 N.S.	2.5640	10.4040	4.058 *
	1492	17	36.0	37.0	+1.0	+2.8	1.330 N.S.	2.9600	2.2560	1.312 N.S.
		23	35.8	37.3	+1.5	+4.2	1.648 N.S.	1.9240	5.7160	2.971 N.S.
	1482	29	39.9	42.0	+2.1	+5.3	2.473 *	4.1800	3.0400	1.375 N.S.
		35	41.7	42.2	+0.5	+1.2	0.599 N.S.	1.7000	4.7240	2.779 N.S.
	1494	41	35.7	36.3	+0.6	+1.7	0.748 N.S.	3.8600	2.5800	1.496 N.S.
		47	34.4	36.2	+1.8	+5.2	2.962 **	2.4840	1.4560	1.706 N.S.

[a] Based on Institute results
N.S. Not significant

* Significant at 5% level.
** Significant at 1% level.

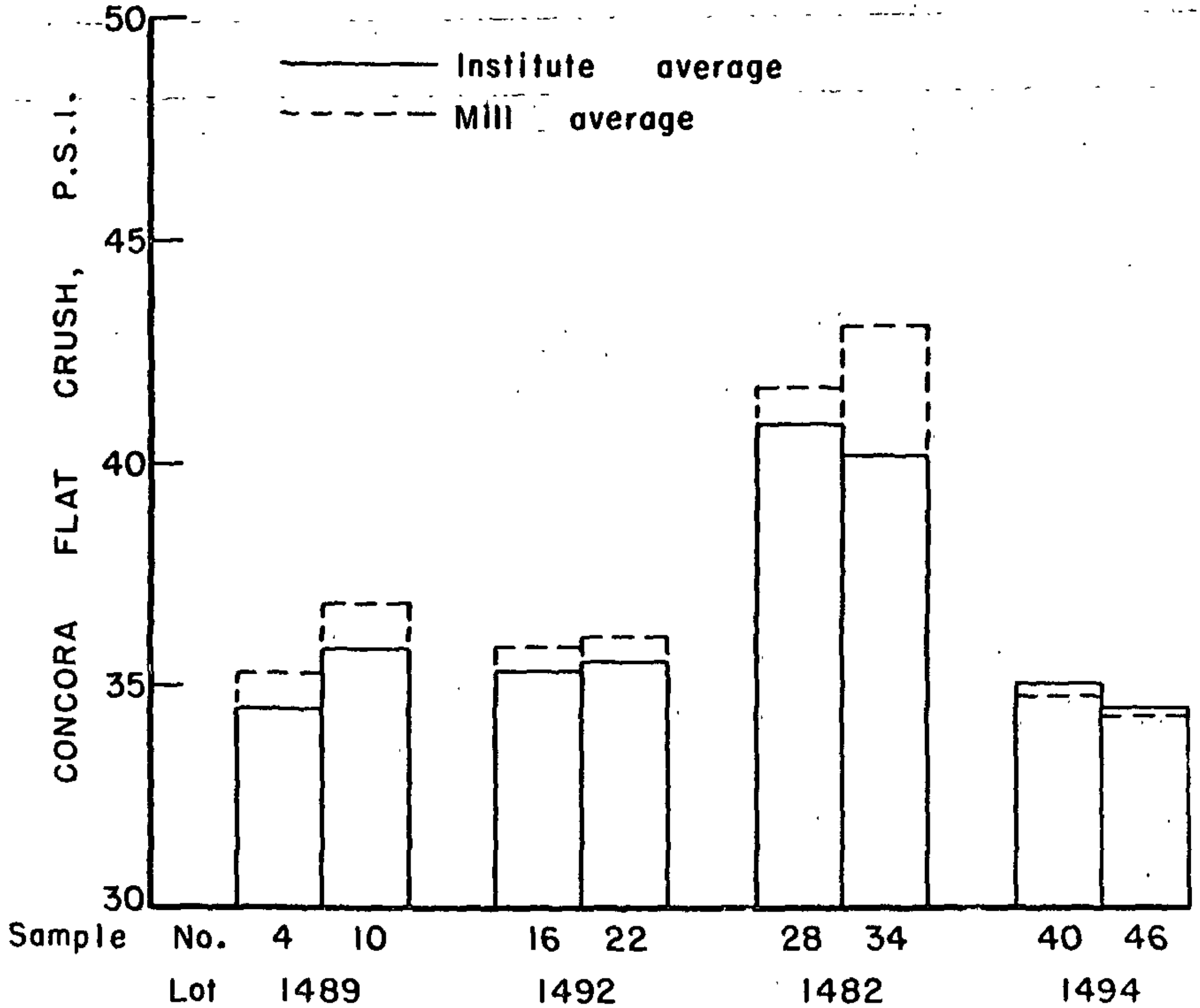

Figure 13

Comparison of Institute and Mill Results for Mill B

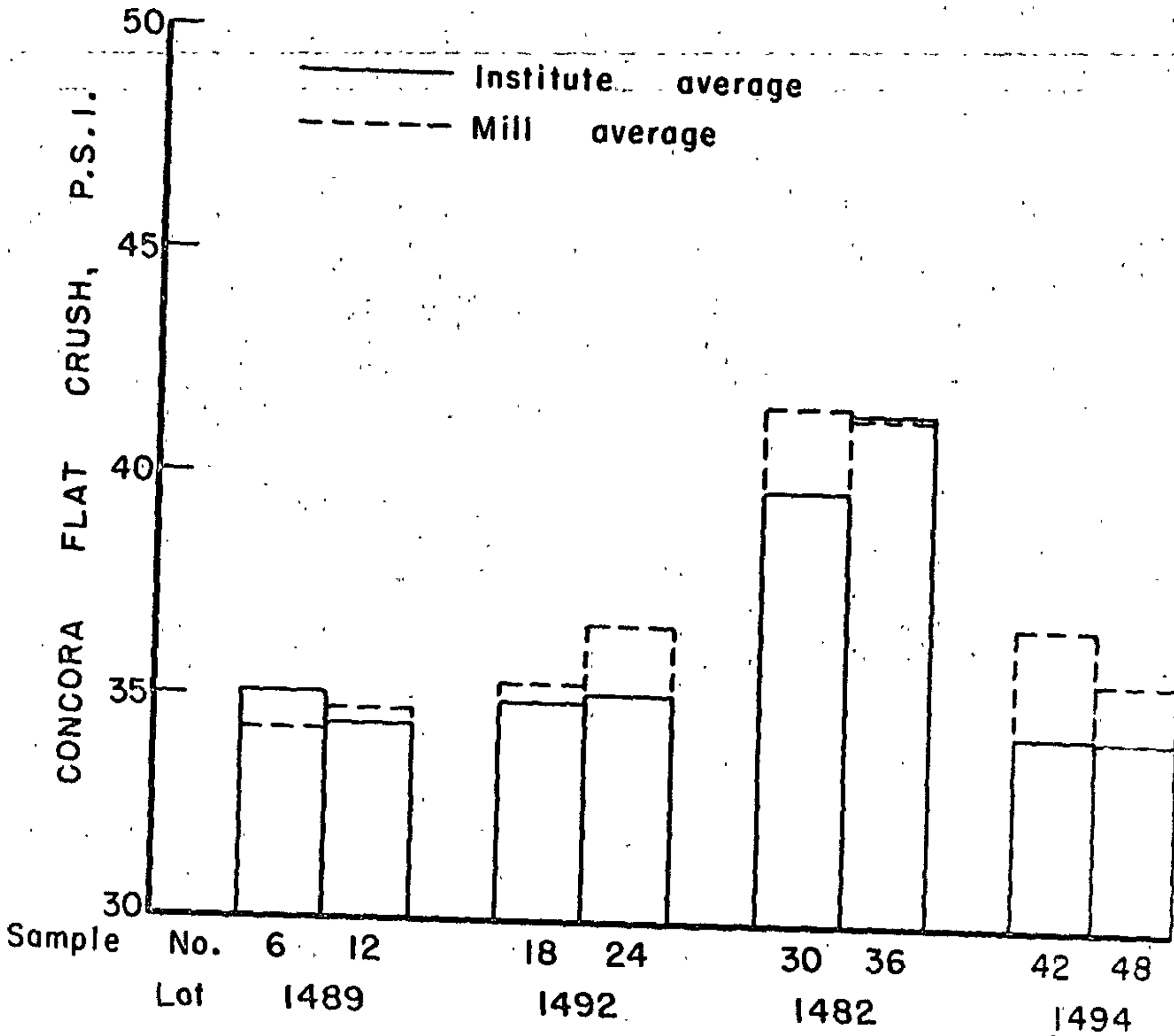

Figure 14

Comparison of Institute and Mill Results for Mill F

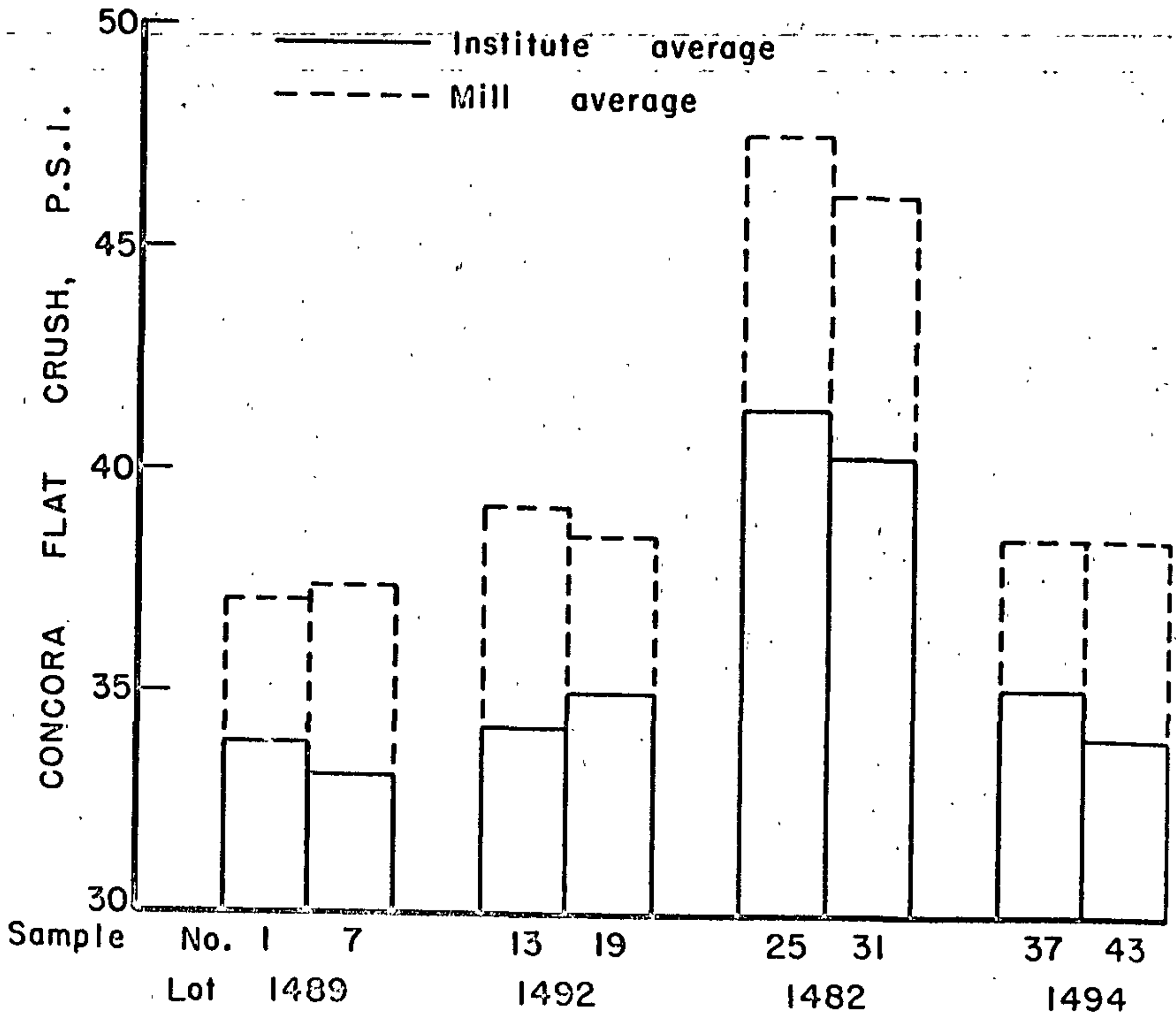

Figure 15

Comparison of Institute and Mill Results for Mill G

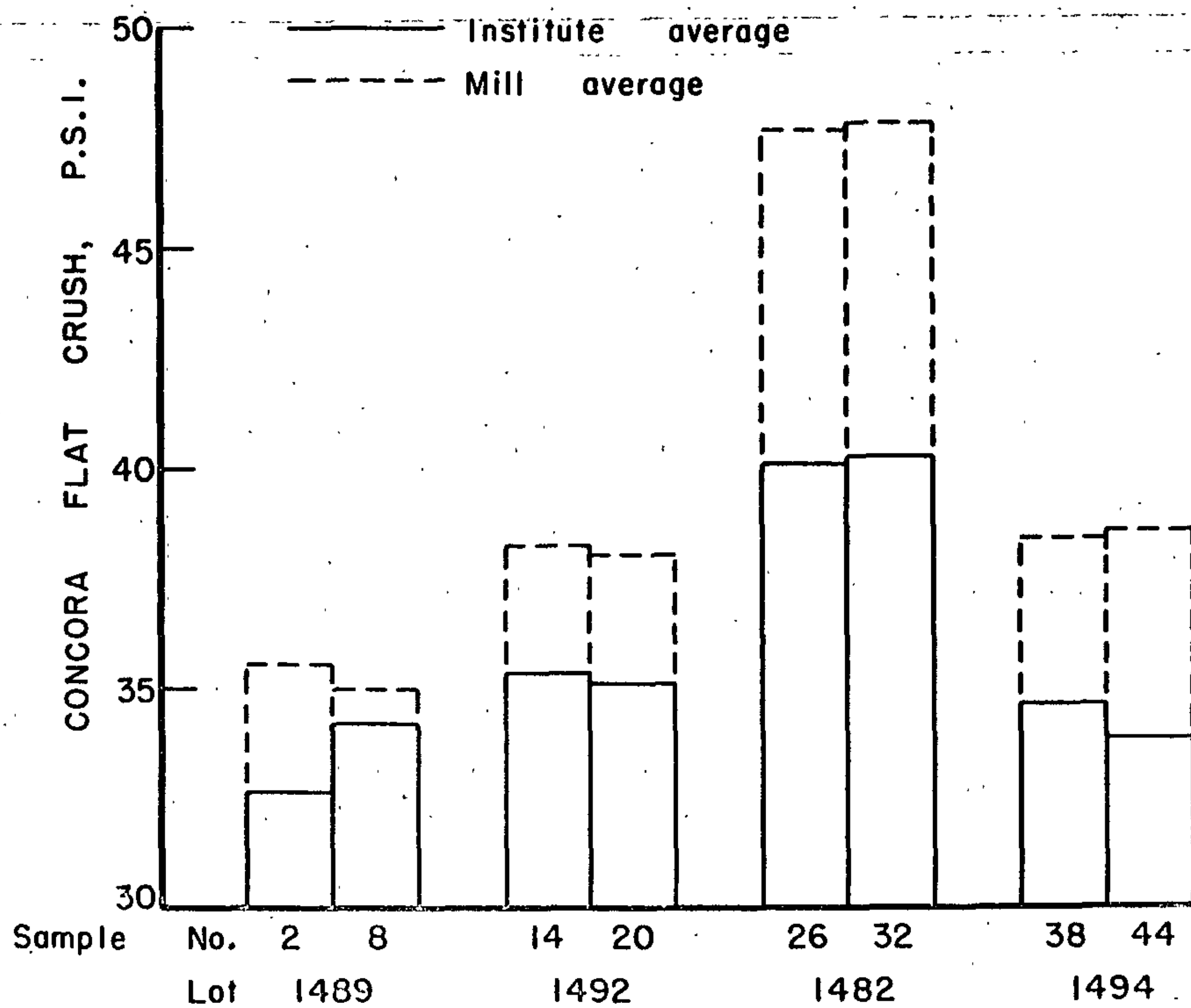

Figure 16
Comparison of Institute and Mill Results for Mill H

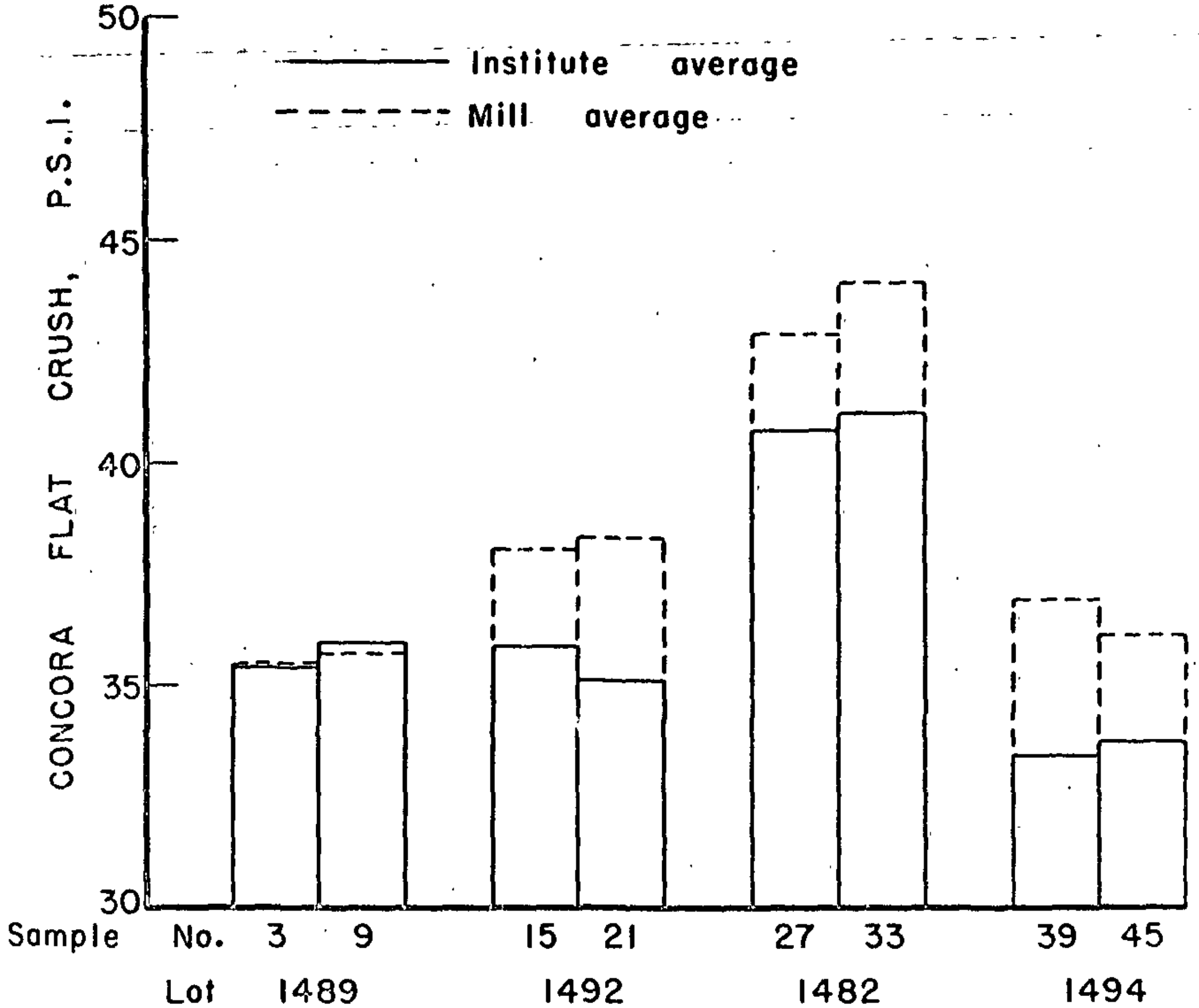

Figure 17

Comparison of Institute and Mill Results for Mill I

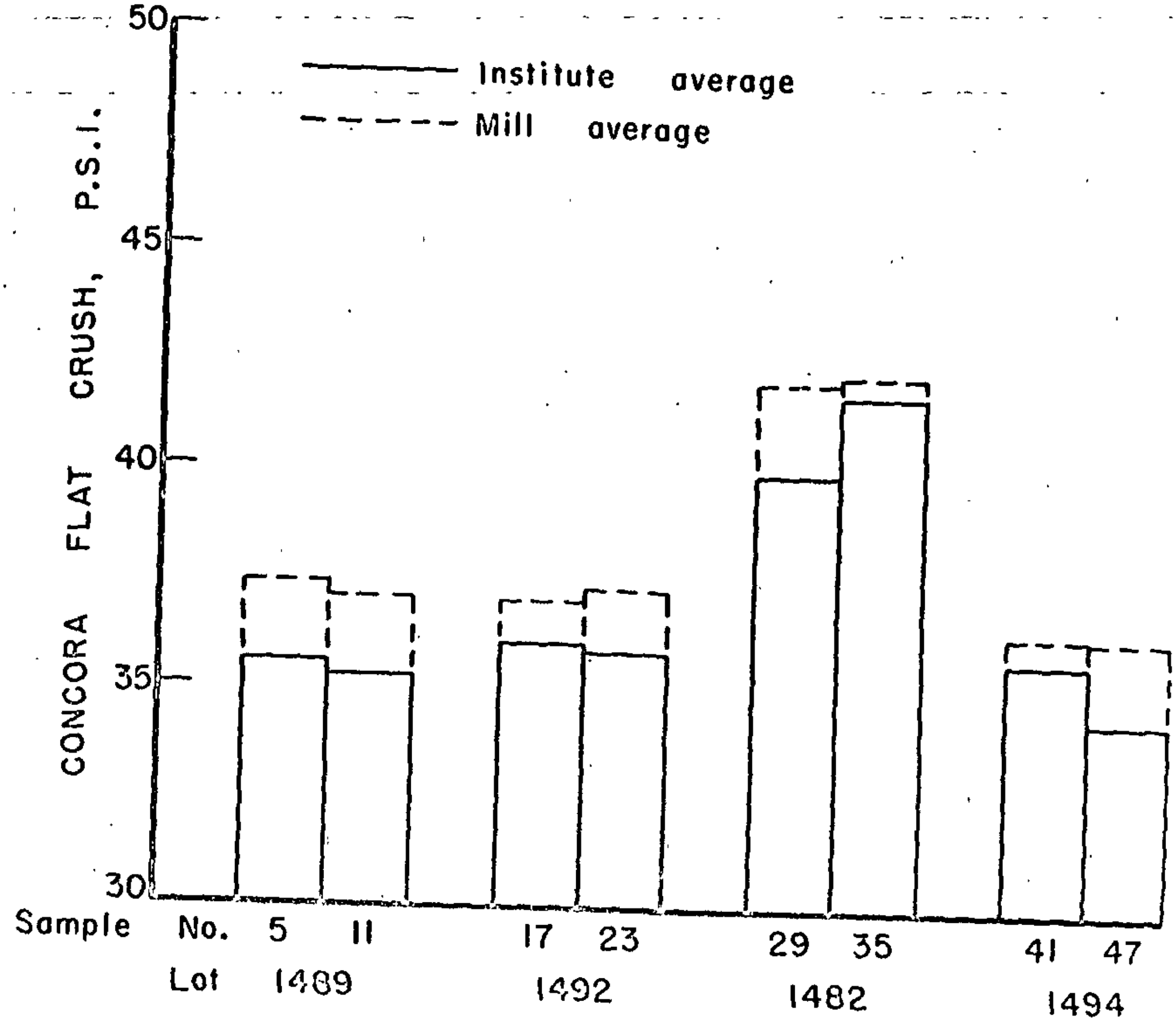

Figure 18

Comparison of Institute and Mill Results for Mill S each mill on two samples from each of the four sample lots are compared with averages of similar samples tested at The Institute of Paper Chemistry. The differences and per cent differences between the Institute and mill averages are based on the Institute results.

The "t" values presented in Table XII were used to ascertain the significance of the differences between the sample averages. The "t" value represents the ratio of the difference between two means to the standard error of the difference between two means. Therefore,

$$t = \frac{\bar{X}_{IPC} - \bar{X}_{MILL}}{\sigma_{\bar{X}_{IPC} - \bar{X}_{MILL}}}$$

where

$$\sigma_{\bar{X}_{IPC} - \bar{X}_{MILL}} = \sqrt{\frac{\sigma^2_{IPC}}{N} + \frac{\sigma^2_{MILL}}{N}}$$

The variances, σ^2, needed to determine the standard error of the difference are also presented in Table XII. The estimated population variance, σ^2, is calculated from

$$\sigma^2 = \frac{N\sum X^2 - (\sum X)^2}{N(N-1)}$$

It should be noted that two factors influence the "t" test--first, the difference between sample averages, and second, the variability within the samples.

$(N_{IPC} - 1) + (N_{MILL} - 1)$ degrees of freedom are available for the "t" test. Therefore, in this study, with 18 degrees of freedom, a "t" value greater than 2.101 indicates significance at the 5% level--i.e., such a difference between averages could be found, strictly by chance, less than 5% of the time (one in twenty times). A "t" value greater than 2.878 indicates that ... great a difference between averages could be observed, by chance alone, ... than 1% of the time.

It may be seen in Table XII that for Mill B, only ... sample yielded a significant difference between the mill and Institute aver... This sample, from Lot 1482, yielded a difference of + 7.2%. It may be no... ...the difference obtained on the other sample from this lot was only ... and was not significant. The differences between Institute and mill aver... ...tained on the other samples varied from -0.6 to + 3.1%. The mill aver... ... higher than the Institute averages for all samples except those fro... ... where the Institute results were only slightly higher. In the firs... ..., this mill was lower than the Institute on all five samples with result... ... samples being significantly lower by -9.3%. Other differences range... ... to -3.6%. Thus, it appears that the results for this mill now ... ...ite favorably with Institute results.

Two samples tested at Mill F yielded averages whic... ...ifi... cantly different from averages obtained at the Institute. O... from Lot 1492 yielded a significant difference between averages of ... one sample from Lot 1494 yielded a significant difference of +7.... ferences observed for the other samples varied from zero to ... mill averages were higher than the Institute averages except for ... Previously, Mill F was significantly higher than the Institut... five samples. Those differences ranged from +5.1 to +12.5%, ... ference which was not significant was -4.2%. It appears tha... ...results now compare quite favorably with the Institute results although they are generally slightly higher.

It may be seen in Table XII that all the sample averages obtained by Mill G are significantly higher than the averages obtained at The Institute of Paper Chemistry. The differences range from +9.5 to +15.0%. In the first round-robin study, the results from Mill G were also significantly higher than the Institute results on all five samples. The differences ranged from +5.4 to +14.6%.

Regarding Mill H, all the mill averages except one are significantly higher than the Institute averages. The significant differences range from +8.2 to +19.0%. The sample difference which is not significant is +2.3%. Results from the first round-robin study indicated that this mill yielded significantly higher results than the Institute on four of five samples. In that study, the significant differences ranged from +7.8 to +10.3%, while the difference which was not significant was +0.4%.

The sample averages obtained at Mill I are significantly higher than the Institute averages for all samples except the two obtained on Lot 1489. The significant differences ranged from +5.4 to +10.8%. Lot 1489 yielded sample differences of +0.3 and -0.6%. This mill was significantly higher than the Institute on four of five samples tested in the initial round-robin study. In that study, the significant differences ranged from +4.9 to +9.2%. The difference which was not significant was -0.4%.

Only two samples tested at Mill S yielded averages which were significantly different from those obtained at the Institute. One sample from Lot 1482 yielded a significant difference between averages of +5.3% and one sample from Lot 1494 yielded a significant difference of +5.2%. The differences between averages observed on the other samples ranged from +1.2 to +5.1%. The mill averages were higher for all samples. In the previous study, this mill was lower than the Institute on all five samples--significantly lower on three samples (-4.9 to -11.5%). Other differences were about -4%. It appears that the results for this mill now compare quite favorably with the Institute results. Whereas the mill results were previously significantly lower than the Institute, they are now slightly higher.

By comparing the results of this study with those of the initial round-robin study, it may be noted that Mills G and I, as before, yielded results significantly higher than the Institute results with differences of approximately the same magnitude as those previously obtained. The results from Mill H are also significantly higher than Institute results as before; however, the current differences appear to be greater than those noted previously. The results for Mill F now appear to compare quite favorably with Institute results as the mill results are only slightly higher than those obtained at the Institute. While the previous results (first round-robin) for Mills B and S were generally significantly lower than the results obtained at the Institute, the results from these mills now agree favorably with Institute results. The results for both mills were found to be slightly higher than the Institute results. Thus, it appears that Mills G, H and I are still yielding Concora flat-crush results significantly different from Institute results, while Mills B, S and F are in reasonable agreement with the Institute results.

The "F" values presented in Table II are used to ascertain significant differences between the estimated population variances. The variance ratio, F, is determined from σ_1^2/σ_2^2 where σ_1^2 is the greater variance and σ_2^2 is the smaller variance. As mentioned previously, the population variances are estimated from

$$\sigma^2 = \frac{N \Sigma X^2 - (\Sigma X)^2}{N\ (N-1)}$$

It may be seen in Table II that no significant differences between estimated population variances obtained at the mill and those obtained at the Institute were noted for Mills B, F, G and H. The variability obtained by Mills G and H was generally greater than the variability obtained at the Institute, though not significantly so. No clearly defined trends were noted for Mills B and F.

The variances on two samples tested at Mill I (one sample from Lot 1492 and one from Lot 1482) were significantly greater than those obtained at the Institute on the same two samples. The variability obtained at Mill I was generally greater than that obtained at the Institute, though not significantly so.

One sample tested at Mill S yielded a significantly greater variance than that obtained at the Institute. This sample was from Lot 1489. The variability obtained by Mill S was greater than the Institute variability on three of the eight samples tested.

In general, then, the variability obtained on samples tested at the mills agreed very well with the variability obtained at The Institute of Paper Chemistry.

As mentioned previously, each participant in this second round-robin study was requested to measure the caliper (flute height) of the fluted specimens. This measurement was requested because it was thought that differences in flute height could cause differences in test results. Thus, it might be reasoned that the lower the flute height or caliper, the higher the flat crush.

A comparison of the caliper and Concora results is presented in Table XIII. Reviewing those results, it may be noted that differences in flute height were related to differences in Concora results in the expected manner for three of the mills--namely, B, F, and G. No correlation between the results was found for Mills H and S and Mill I did not report caliper readings, so no comparison is possible in this case. The results, therefore, do not conclusively indicate that differences in flute height are related to Concora differences. However, there is the suggestion that, at least under some circumstances, differences in flute height may cause differences in Concora readings. Until these results can be confirmed, measurement of pressure on the idler roll and <u>frequent inspection of the slider for sticking are recommended</u>.

It may be further remarked that the procedure used in measuring flute height in this study was not ideal--it was primarily selected because it could readily be carried out by the participating mills. Because the broad base of the depth micrometer will be supported by the two highest flutes, the measured depth corresponds to neither the greatest nor the least flute height. Individual flute heights cannot be determined by this method. In an effort to determine differences in flute height and to relate such

TABLE XIII

COMPARISON OF CONCORA FLAT CRUSH AND FLUTE HEIGHT RESULTS

Mill	Concora Flat Crush, p.s.i. I.P.C.	Mill	Diff.,[b] %	Caliper, in.[a] I.P.C.	Mill	Diff.,[b] %
			Composite Averages			
B	36.5	37.3	+2.2	0.061	0.059	-3.3
F	36.2	37.1	+2.5	0.063	0.061	-3.2
G	35.9	40.4	+12.5	0.062	0.057	-8.1
H	35.7	39.9	+11.8	0.061	0.061	0.0
I	36.4	38.5	+5.8	0.061	--	--
S	36.8	38.2	+3.8	0.062	0.062	0.0

a Indicated caliper plus 1/8 inch equals flute height.

b Based on I.P.C. results as reference.

differences to test results, a device has been constructed along the lines of a paper micrometer. This device is being used to measure flute heights at both ends and middle of the fluted specimens in connection with an instrumentation study being conducted at the present time.

The remaining information requested in the questionnaires is tabulated in Table XIV. As may be noted in the table, only Mill S reported any change in equipment--a new weighing beam in their H and D compression tester.

As in the previous study, pressure patterns were taken by the participating mills and returned to the IPC together with the test results. The pressure patterns are illustrated in Figure 19 and may be compared with the patterns illustrated in the previous reports. While some changes in pressure pattern are evident--see Mills G and I for example--it appears difficult to relate the patterns to the observed differences in flat-crush results.

TABLE XIV

INSTRUMENTAL MEASUREMENTS

Mill	Av. Fluting Temp., °F.	Load Range, lb.	Test Speed, in./min.	Platen Parallelism, 0.001 in.	Equipment Changes
B	340	500	0.91	0.5	None
F	350	100	1.62	4.0	None
G	345	100*	1.59	1.0	--
H	350	500	1.67	31	--
I	345	300	3.00	3.0	--
S	350	500	1.69	1.5	**

* In the previous round-robin, the load range or weighing beam used was reported as 500 lb.

**A new calibrated beam had been installed in the compression machine.

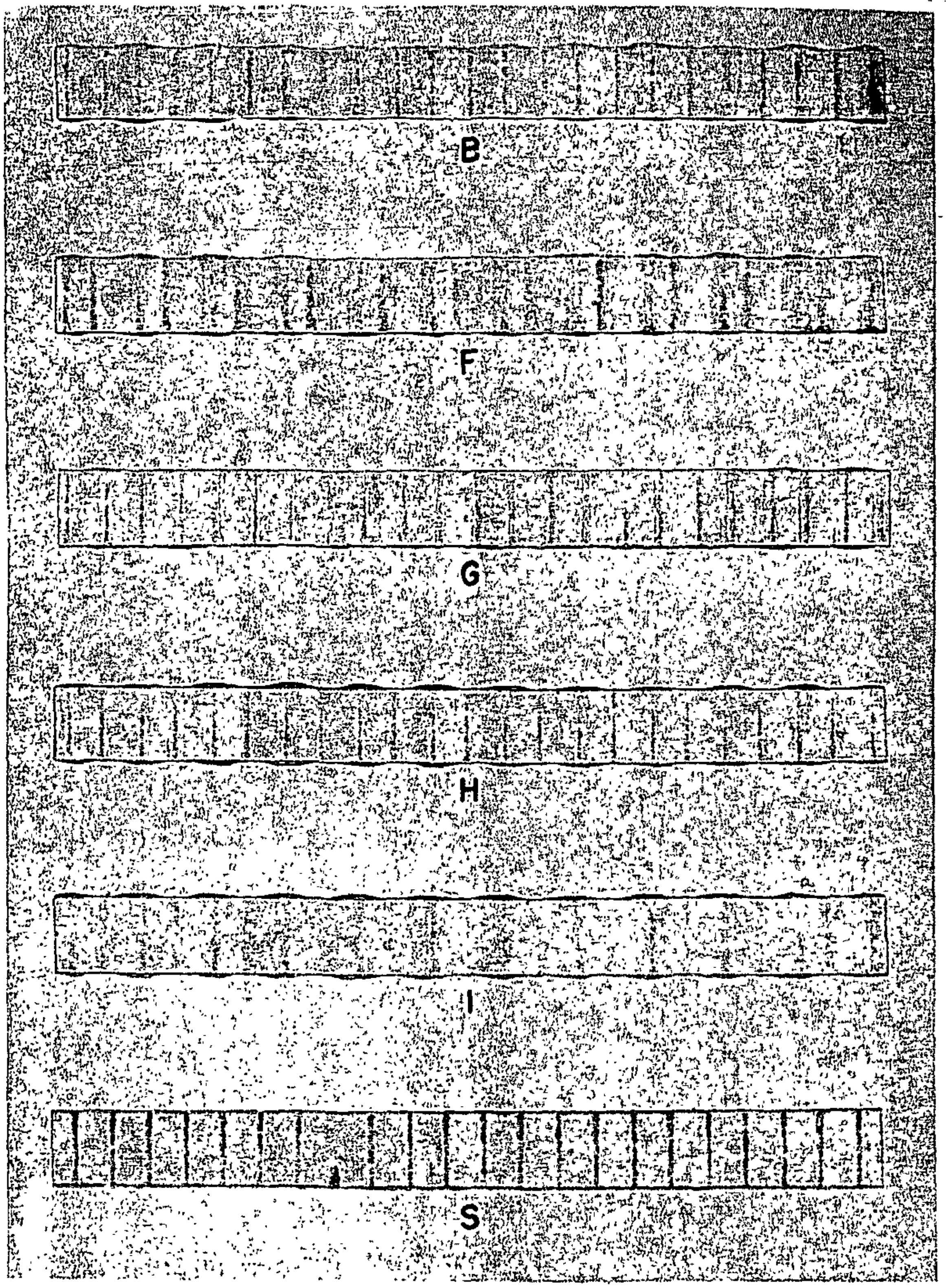

Figure 19

Pressure Pattern of Corrugating Rolls

The above study indicates that there may be substantial differences in test results between mills when using the Concora medium fluter under the conditions existing. It would seem desirable that those mills obtaining extremes in test results examine their machines and test procedure critically to determine whether these test results could be brought more nearly in line with the other mills participating in the round-robin test program.

It should be emphasized that the Concora results are obtained only after the test specimens have been subjected to a sequence of events involving different pieces of equipment--i.e., fluter, rack and comb, compression tester, etc. Further, that instrumental and operational variables are undoubtedly associated with each operation and equipment. Therefore, it is to be expected that the Concora test will exhibit a variability higher than obtained on conventional tests such as bursting strength, tensile, tear, etc.

An instrumentation study has been initiated at The Institute of Paper Chemistry with the objective of determining mechanical or operational factors that cause differences in Concora test machine performance. It is hoped that the results of this study will make possible the establishment of a calibration procedure which, if adhered to, will permit the maintenance of all Concora testers within a given specified calibration range or tolerance. In addition, the study should provide information as to how the test level of a given Concora may be changed to bring it into calibration with another. Such a calibration procedure is necessary before the establishment of specifications or standards for medium based on Concora values. An instrument has been loaned to The Institute of Paper Chemistry for this study by the instrument manufacturer, Liberty Engineering Co., Beloit, Wis. Among the variables being studied are the following:

I. Preparation of fluted mediums for testing

A. Condition of rack and comb

B. Methods of taping

C. Removal of specimen from rack

II. Concora operation

A. Roll temperature—uniform and nonuniform

B. Pressure roll assembly

1. Sticking slider

2. Spring pressure

3. Uneven pressure

4. Roll worn into hot-plate surface

5. Warped plater

C. Drive roll assembly

D. Roller bearings

E. General

1. Dry lubricants

2. Fluid lubricants

SUMMARY

At the request of the technical committee of the Fourdrinier Kraft Board Institute, a round-robin study was made of the Concora medium fluter in order to determine the magnitude of difference existing in test results obtained between laboratories. Five samples of corrugating mediums were selected by The Institute of Paper Chemistry, cut, randomized, and sent to each participating mill laboratory, together with instructions for forming and testing. A questionnaire was also sent so that information could be obtained covering the physical adjustments of the test equipment which might be of value in interpreting the test results.

A total of eighteen Concora testers participated in this study. The results indicated the following:

1. No given mill retained the same test order relative to the other mills throughout all sample lots.

2. When the results obtained on The Institute of Paper Chemistry Concora tester are used as an arbitrary reference level, the test results varied on an average for all sample lots from a +9.4% for Mill G to a -6.2% for Mill S.

3. Eleven of the seventeen mills exhibited composite averages which were within a ± 4% range of the composite average obtained on The Institute of Paper Chemistry tester (identified as Mill C). When a range of ± 2.5% is concerned, only seven of the seventeen mills fell within that range. These were Mills E, K, D, N, M, P, and J.

4. A statistical analysis based on the t-test was used to

determine whether the differences in test results were significant. The following results were obtained.

a. The results obtained by Mill K were not significantly different from the corresponding results obtained on The Institute of Paper Chemistry tester.

b. The results obtained by Mills E, M, and P differed significantly from The Institute of Paper Chemistry results in one instance out of five for each mill.

c. Mills B, D, J, L, N, and O exhibited significant differences in two out of five cases; Mills A, R, and S three out of five.

d. Mill G differed significantly from The Institute of Paper Chemistry results on all five samples, whereas Mills F, H, and I differed significantly on four out of the five samples. This indicates that if The Institute of Paper Chemistry results have any significance as a reference level, then it would appear that attention should be focused on Mills G, F, H, and I to try to bring them into calibration with the reference since they are the farthest out based on the results of this study.

5. No correlation was found to exist between Concora corrugating roll pressure pattern and the test results except that in general the mills exhibiting exceptionally high results also exhibited uneven pressure patterns whereas low results were associated with normal or uniform pressure patterns.

After the above results were reviewed by the Technical committee of the Fourdrinier Kraft Board Institute, The Institute of Paper Chemistry sent additional test samples to six of the mills which had participated in the first round-robin study of the Concora medium tester. Samples were sent to the four mills (G, H, F, and I) which had exhibited particularly high Concora flat-crush results in the original study and to the two mills (B and S) which had previously exhibited results on the low side. Four sample lots of corrugating medium were carefully sampled and two samples of ten specimens from each lot were sent to each mill. Duplicate samples were retained and tested at The Institute of Paper Chemistry. No changes in test procedure were made; however, each mill was requested to make measurements of flute height or caliper of the taped specimen prior to fluting.

In general, the variability obtained on samples tested at the mills agreed very well with the variability obtained at The Institute of Paper Chemistry.

The Concora flat-crush results showed that Mills G, H, and I, which exhibited high results in the original study, appeared to exhibit equally high results in this investigation. On the other hand, Mill F, which also was high in the original study, now reported results which were in reasonable agreement with the Institute results. The remaining two mills (B and S) which reported lower results than the Institute in the original study now also appear to be in reasonably good agreement with the Institute.

A comparison of the caliper and Concora results showed that differences in flute height were related to differences in Concora results in the expected manner for three of the mills--namely, B, F, and G. No correlation between the results was found for Mills H and S. Mill I did not report caliper readings, so no comparison was possible. While these results do not conclusively indicate that differences in flute height are related to Concora differences, there is a possibility that, at least under some circumstances, differences in flute height may cause differences in Concora readings.

It is recommended that attention be given to machine and operational characteristics of each sequence in the Concora test, especially those mills which exhibited the most divergent results in order to see if these testers can be brought into proper agreement or calibration. For this purpose, an outline of calibration and test procedure is appended to this report.

LITERATURE CITED

1. Instrumental and Operational Factors Influencing Single-Fluter Test Results, Compression Report 29, April 1, 1952.

2. The Concora Medium Fluter Compression Report 48, Sept. 3, 1954.

3. An Investigation of Variables Influencing the Test Results Obtained in Pursuance of the Continuous Evaluation of Corrugating Mediums. Report 8. Technical Committee of Fourdrinier Kraft Board Institute, Inc.

4. Effect of After Fluting Conditioning Time on Concora Flat Crush. Compression Report 53, May 19, 1955.

CONCORA MEDIUM FLUTER OPERATIONAL PROCEDURE

PREFACE

The precision of the Concora medium test is influenced by material, instrumental, and operational variables. Specifically, these variables consist of the variability associated with the sample, the variability due to sample preparation, the variability associated with the Concora medium fluter, the variability associated with the rack and comb facing operation, the conditioning procedure between the facing and testing operation, the variability associated with the compression tester, and the variability associated with the operation of the compression tester. The following procedure is recommended as a guide for reducing the variables except those associated with the sample itself. The procedure is composed of sections dealing with each phase of the testing operation in sequence from sample preparation to the reporting of the compression values obtained.

PROCEDURE

SAMPLE PREPARATION

A. Specimen Size

The fluter was designed to test a backed strip containing ten flute tips. This requires eleven lines of attachment between the corrugated medium and the pressure-sensitive backing tape. Thus, specimen length does not appear to be critical as long as eleven lines of attachment are obtained. Based on a 1% tolerance in area, the specimen width should be cut 0.5 ± 0.005 inch, with the sides straight and parallel to one part in one thousand. Specimen length is recommended as six inches.

B. Conditioning

Moisture content of the test specimen prior to corrugating does not appear to be critical as judged by a change of less than 1.5% in test results between samples conditioned at 25% relative humidity and samples conditioned at 85% relative humidity (2,3). Unless a sample is noticeably moist, exposure in a 50% atmosphere for 1/2 hour normally is sufficient conditioning prior to forming.

II. *THE CONCORA MEDIUM FLUTER*

A. Fluting Temperature

The temperature of the corrugating rolls should be 350 ± 25°F. when measured by an accurate contact pyrometer with the rolls stationary. If the difference between the two rolls exceeds 50°F., remove the rolls and check the temperature of the hot plate under the rolls. The pressure roll may be removed after backing off the plate on the side of the hot plate to remove the spring tension on the roll and then removing the cap screw over the bearing. Before lifting the roll, marks should be made on the teeth to permit replacing with the same teeth in mesh. The driving roll may be removed by removing the screws holding the upper yoke and carefully lifting the yoke vertically. The removal of both rolls is facilitated by inserting screws in the two threaded holes in each roll. Under no circumstances should the rolls be pried away from the hot plate because burrs can easily be raised which prevent adequate contact between the rolls and the hot plate.

1. If the hot plate temperature appears to be uniform, check for the reasons for poor heat transfer to the rolls. This may be due to caking of the dry lubricant, too much dry lubricant, or rolls not seating properly on the hot plate due to:

a. Warped hot plate. Check by placing straight edge on surface of clean hot plate. If light can be seen between hot plate and straight edge, it indicates that the plate is warped and should either be straightened or replaced with a flat plate.

b. Gear box spindle not at right angles to hot plate. If the hot plate is not warped, the alignment of the gear can be checked by inserting a feeler gage between the driving corrugating roll and the hot plate. If there is clearance on one side but not on the other, the assembly should be realigned. The equivalent normally can be accomplished by shifting the gear box slightly.

c. If a feeler gage can be inserted between the hot plate and the entire periphery of the driving corrugating roll, the collar on the gear box shaft may be holding the shaft so high that the driving corrugating roll cannot fully seat on the hot plate. This may be remedied by raising the collar slightly.

d. If a feeler gage can be inserted between driven corrugating roll and the hot plate, the roll is not seating correctly. This indicates that the pressure spindle may be cocked or the corrugating roll is too tight on the spindle.

2. If a temperature difference exists on the hot plate, check the electrical resistance of the individual heating elements with an ohm-

meter capable of reading 50 to 55 ohms. If high resistance elements correspond with the cool region, shift the elements to balance total resistance under each roll area or replace elements. Elements may also be interchanged as required to balance the heat. If there is no relationship between the resistance of the elements and the temperature of the hot plate, look for poor thermal contact between the heating element and the hot plate. Bend, clean or adjust element as needed to provide good contact.

B. The Pressure on the Corrugator Idler Roll (Driven Roll) Should Be 20 to 24 Pounds

A convenient way to check this is by the use of a spring scale, capable of measuring force in one-pound increments. The scale is attached to the central screw of the idler roll and the maximum force required to just cause a separation of the corrugating rolls is noted. A sticking slide on the idler roll can greatly influence the magnitude of test values (2). If the force exceeds the above range, remove the pressure spring and move the pressure roll by hand to determine whether there is any sticking of the slide. If sticking is apparent, or if much resistance is encountered, the slide should be freed up and relubricated with a small amount of dry lubricant. It also may be desirable to remove the pressure roll and try to move the slide while tilting it slightly to see whether binding occurs.

C. Roller Bearings on Corrugating Roll Mounts

Because of the heat, these bearings are difficult to maintain in good condition. It is suggested that the bearings be cleaned periodically and, when reinstalling the bearings in the pressure roll, tighten the cap screw "finger tight." The drive roll seems to perform best when there is a little play vertically between the roll and its shaft. Under this condition, the two corrugating rolls have a little freedom to orient themselves on the hot plate to give the best intermeshing of the teeth.

D. Use of NCR Paper for Cursory Examination of Concora

It has been found practical to use NCR paper as a coarse check on the condition of the corrugator. For this purpose, a sandwich of the two matings--i.e., CB and CF-sheets of NCR paper is prepared one-half inch wide by thirty inches long and fed into the guide of the Concora. The resulting pressure pattern is then examined to determine the distribution and intensity of the pressure in the nip of the corrugating rolls. If the pressure pattern so obtained indicates an uneven distribution of the pressure in the area of the flute tips, the following items should be checked:

1. Warpage of hot plate--check item II, A 1a.
2. Gear box drive not allowing rolls to seat fully--Check items II A 1b, C, and d.
3. Uneven pressure on corrugator idler roll--check item II B.
4. Faulty roller bearings--check item II C.

E. Warpage of Corrugated Test Strip

If the test strip is started in the guide plate too high or tipped, curvature of the test strip could occur which results in distortion when backing. A distorted strip will not take the compression load uniformly.

III. Facing

A. The comb used to reshape the specimen in the rack is quite fragile and the teeth may easily be bent or distorted. The free ends of the comb should be placed against a straight edge to determine if all teeth touch the straight edge. Bending the teeth with the fingers will usually suffice to straighten them if required. After straightening the teeth, a scale should be placed on the flats to determine whether the teeth are equally spaced. If adjustment is required, they should be rechecked with a straight edge.

B. Pressure-Sensitive Tape. It has been noted that different lots of pressure-sensitive tape No. 400 may have different adhesive characteristics. If a roll is used which does not adhere readily, warming the tape slightly will sometimes improve the adhesion. Under ideal conditions, the tape may be applied by finger pressure; however, to insure adequate adhesion, it is recommended that a rubber roller be fabricated from a large (No. 12 or larger) rubber stopper so that pressure can be brought to bear on the flute tips by rolling the tape after it has been applied.

C. Re-forming the fluted medium in the rack and taping with facing tape should be done with care to insure that the specimen does not curve in the rack. A curved specimen cannot be loaded uniformly and will result in a lowered test.

IV. CONDITIONING

A. The heat applied during the forming operation tends to drive moisture out of the specimen. During the first few minutes after forming, both the moisture content and the temperature of the specimen changes most rapidly. Investigations (4) have shown that there is a marked change in test results with small changes in time interval between forming and testing. The test value will decrease as the specimen cools and moisture content is regained until equilibrium is reached.

B. If tests must be made within a short time lapse, it is recommended that the requisite number of specimens in the sample be formed and taped in a sequence and then tested in the same sequence so that not less than 15 nor more than 45 minutes elapse between forming and testing.

V. COMPRESSION TESTING

A. Instrumental Precautions

1. Platen Parallelism. The surfaces of the platen shall be flat and parallel to each other within one part in two thousand throughout the test and shall be so mounted as to have no more than 0.002-inch movement parallel to the surfaces of the platens.

2. Load Indicating Device. The load-indicating device should be capable of registering the greatest compression load, in pounds, with an accuracy of 0.5 pound. If a more sensitive weighing beam is used, consideration should be given to the possibility that differences in speed of loading will occur so that results obtained with a sensitive machine may not be identical with results obtained with the normal machine. Speed of loading should be 900 ± 300 pounds per minute with the platens in contact with each other.

B. Operational Procedure

1. The specimen should be inserted on the platens in a reproducible manner oriented so that advantage is taken of the maximum rigidity of the platens.

2. With some types of compression machine it is necessary to use abrasive paper on the platens to minimize slippage or roll of the specimen.

VI. REPORT

The maximum peak load shall be observed and recorded for each test specimen. The average compressive load value for the sample shall be reported to three significant figures.

The area of the test specimen in terms of corrugated board is approximately 1-2/3 square inches. Accordingly, the maximum compressive load in pounds may be converted to unit load (p.s.i.) by dividing by 1-2/3 or more conveniently by multiplying by the reciprocal or 0.6.

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