INSTITUTE OF
PAPER CHEMISTRY
Appleton Wisconsin

CONTINUOUS EVALUATION OF CORRUGATING MEDIUM

Project 1108-17

Summary Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

April 1, 1956

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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OF

CORRUGATING MEDIUM

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The study known as the Continuous Evaluation of Corrugating
Medium was initiated by the Fourdrinier Kraft Board Institute at The
Institute of Paper Chemistry on October 1, 1955. The study has now
been in progress for a period of six months—namely, October, November,
and December, 1955; January, February, and March, 1956. The results
obtained during the first six months of the study are summarized in
this report.

During the first six months, rolls of corrugating medium were
submitted for evaluation from thirteen different paper machines. The
number of rolls submitted from each of these machines for each period,
the total number of rolls evaluated during each period, and the average
number of rolls from each machine per period are given in Table I. It
may be seen in Table I that the average number of rolls evaluated per
period was nearly 69 giving a grand total of 412 rolls evaluated during
the first six months of the study.

Each roll of corrugating medium was evaluated for basis weight,
caliper, Concora flat crush*, H. & D. flat crush (single-faced board)
and runability. Runability was measured by corrugating each roll under
standardized conditions on the Institute's corrugator into A-flute board

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* The Concora medium test results are calculated on the basis of pounds
of load per unit area rather than on the basis of the formula suggested
by the Concora manufacturer and are reported as Concora flat crush test
results.

TABLE I

TABULATION BY PERIODS OF THE NUMBER OF ROLLS OF CORRUGATING MEDIUM SUBMITTED FROM EACH MACHINE

Machines	1	2	3	Periods 4	5	6	Av.
A	--	--	2	--	---	2	0.7
B	6	8	7	8	9	9	7.8
C	--	2	6	9	7	9	5.5
D	5	8	8	9	8	7	7.5
E	--	5	7	10	8	6	6.0
F	--	1	1	--	--	--	0.3
G	6	8	8	7	9	8	7.7
H	--	1	7	10	8	9	5.8
I	4	7	9	9	9	8	7.7
J	6	8	8	9	8	8	7.8
K	4	9	5	10	8	10	7.7
L	--	1	1	1	--	--	0.5
M	2	2	4	8	4	2	3.7
Total	33	60	73	90	78	78	68.7

at 450 feet per minute. If unsatisfactory runability occurred at this
speed, the corrugator was slowed down in increments of 25 f.p.m. until
satisfactory runability was obtained—i.e., no ruptured flutes. To date,
all rolls submitted have exhibited satisfactory runability at 450 f.p.m.

The current F.K.I. averages for basis weight, caliper, Concora
flat crush, and single-face flat crush for the first six periods are
summarized in Table II and presented graphically in Figure 1. From an
inspection of these results, it may be noted that all tests have re-
mained relatively constant with only minor fluctuations being evident.
The average basis weight appears to be slightly higher—26.6 lb. for the
first period compared with 27.2 lb. for the sixth period. In summary,
the following observations may be made regarding the current F.K.I. av-
erages for the first six periods:

    1.   Basis weight has increased slightly.

    2.   Caliper has remained relatively constant.

    3.   Concora flat crush has not changed significantly.

    4.   Single-face flat crush has remained relatively constant.

In order to study the relationships between the various tests,
the current machine averages obtained for each machine for the first six
periods have been plotted for the following comparisons:

    1. Single-face flat crush vs. basis weight

    2. Single-face flat crush vs. caliper

    3. Single-face flat crush vs. apparent density

    4. Single-face flat crush vs. Concora flat crush

TABLE II

TABULATION OF CURRENT F.K.I. AVERAGES BY PERIODS

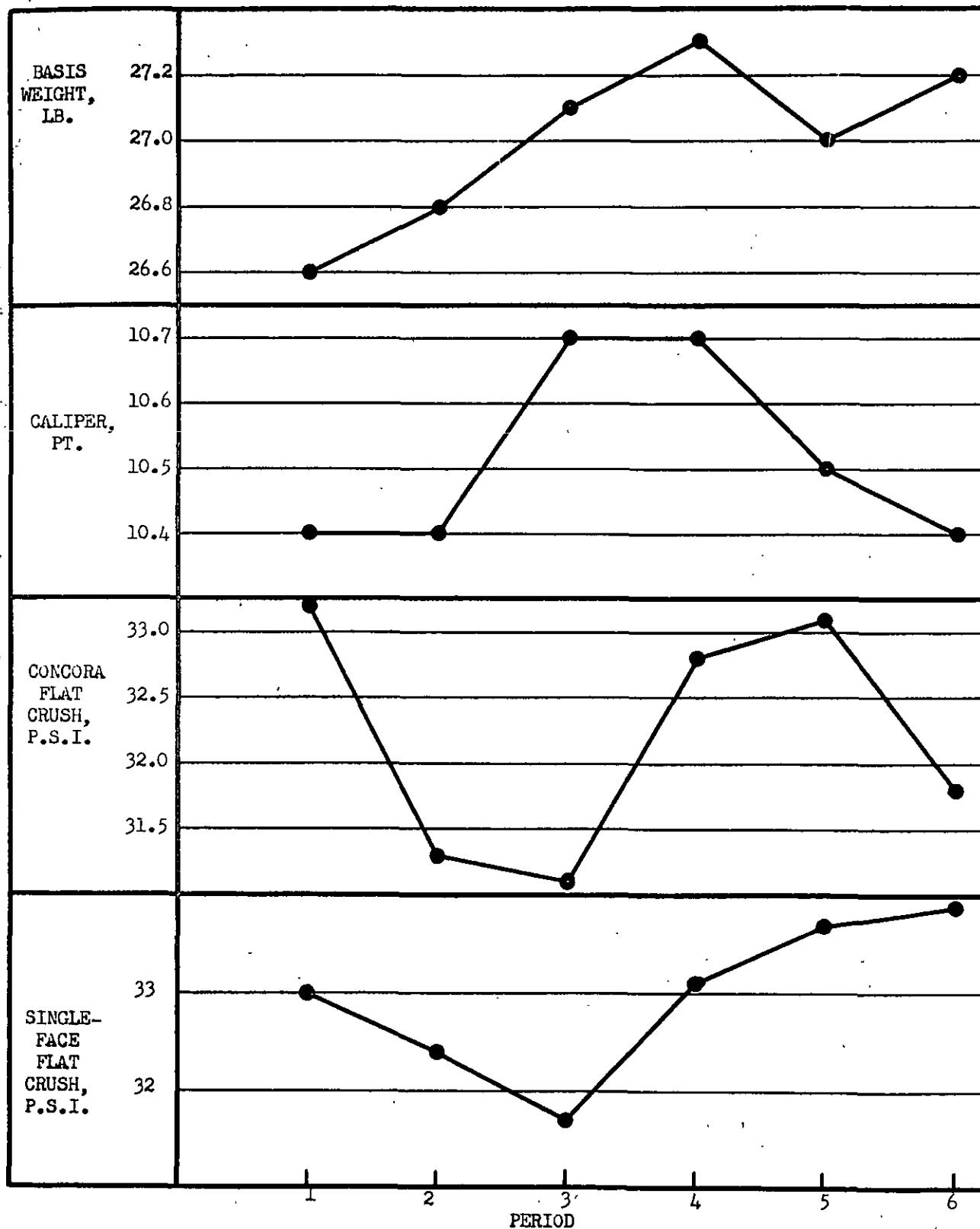| Period	Basis Weight, lb.	Caliper, Pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	26.6	10.4	33.2	33.0
2	26.8	10.4	31.3	32.4
3	27.1	10.7	31.1	31.7
4	27.3	10.7	32.8	33.1
5	27.0	10.5	33.1	33.7
6	27.2	10.4	31.8	33.9

Figure 1. Comparison of Current F.K.I. Averages by Periods

    5. Concora flat crush _vs._ basis weight

   6. Concora flat crush _vs._ caliper

The data used are given in the appendix of this report.

        The relationship between single-face flat crush and basis
weight is shown in Figure 2. It may be noted from an inspection of
Figure 2 that the relationship is obscure and that within this range
of basis weights, the magnitudes of the single-face flat crush results
do not appear to be dependent on the basis weights of the corrugating
mediums.

        Figure 3 shows the relationship between single-face flat crush
and caliper based on a plot of the current machine averages. It may be
observed in Figure 3 that in the caliper range of 10 to 11 points which
encompasses the majority of the data, the magnitude of the single-face
flat crush values varies from the lowest to the highest. Thus, it ap-
pears that caliper in the range of values encountered here does not de-
termine the magnitude of the single-face flat crush.

        The relationship between single-face flat crush and apparent
density is shown graphically in Figure 4. The apparent density was cal-
culated by dividing the basis weight result by the corresponding caliper
result. From a study of Figure 4 it appears that apparent density is
not directly related to single-face flat crush for the semichemical cor-
rugating mediums--i.e., low apparent density results are associated with
high flat crush results as often as with low flat crush results. However,
based on the rather limited results for the kraft corrugating mediums, a

Figure 2.   The Relationship Between Single-Face Flat Crush and Basis Weight
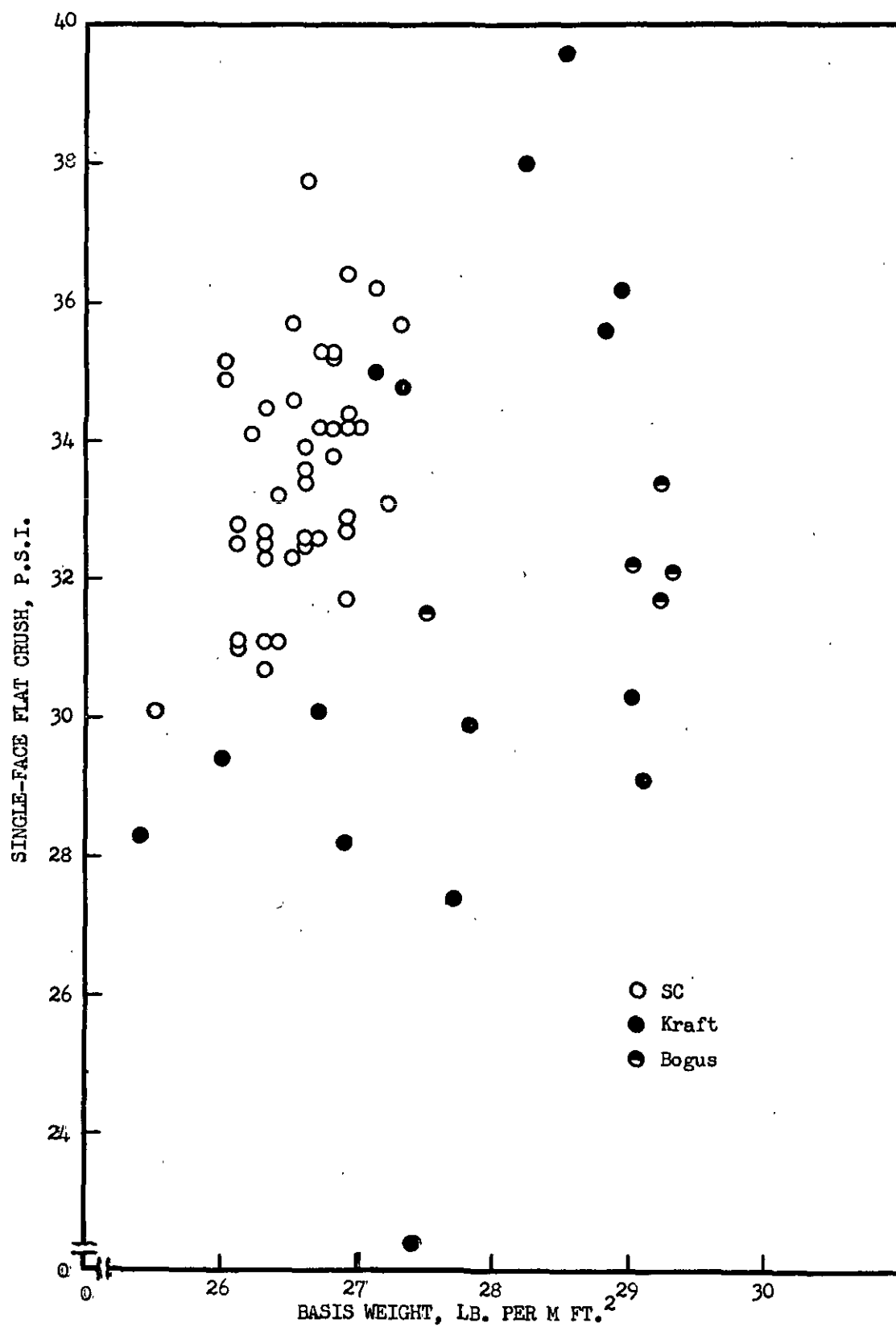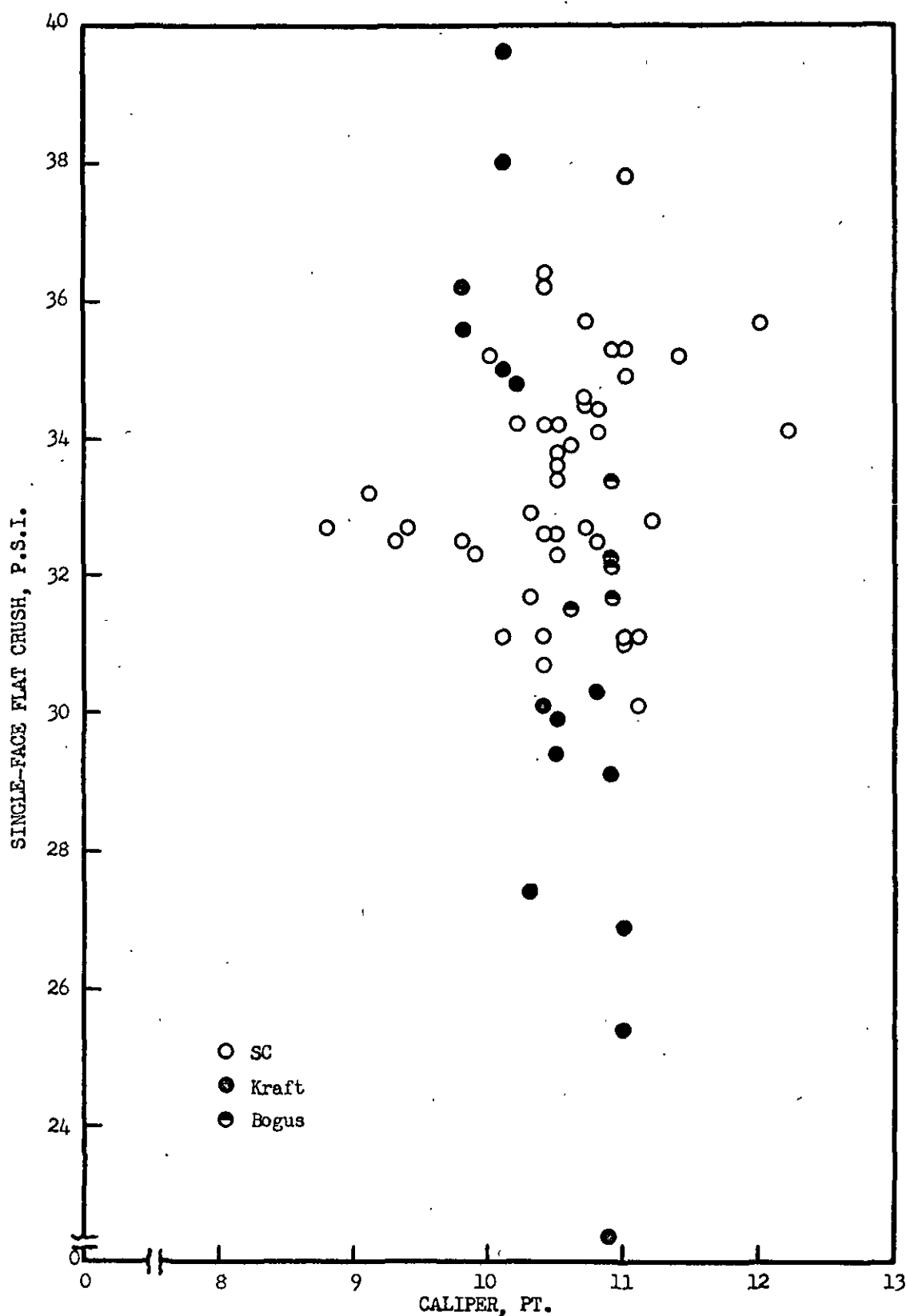
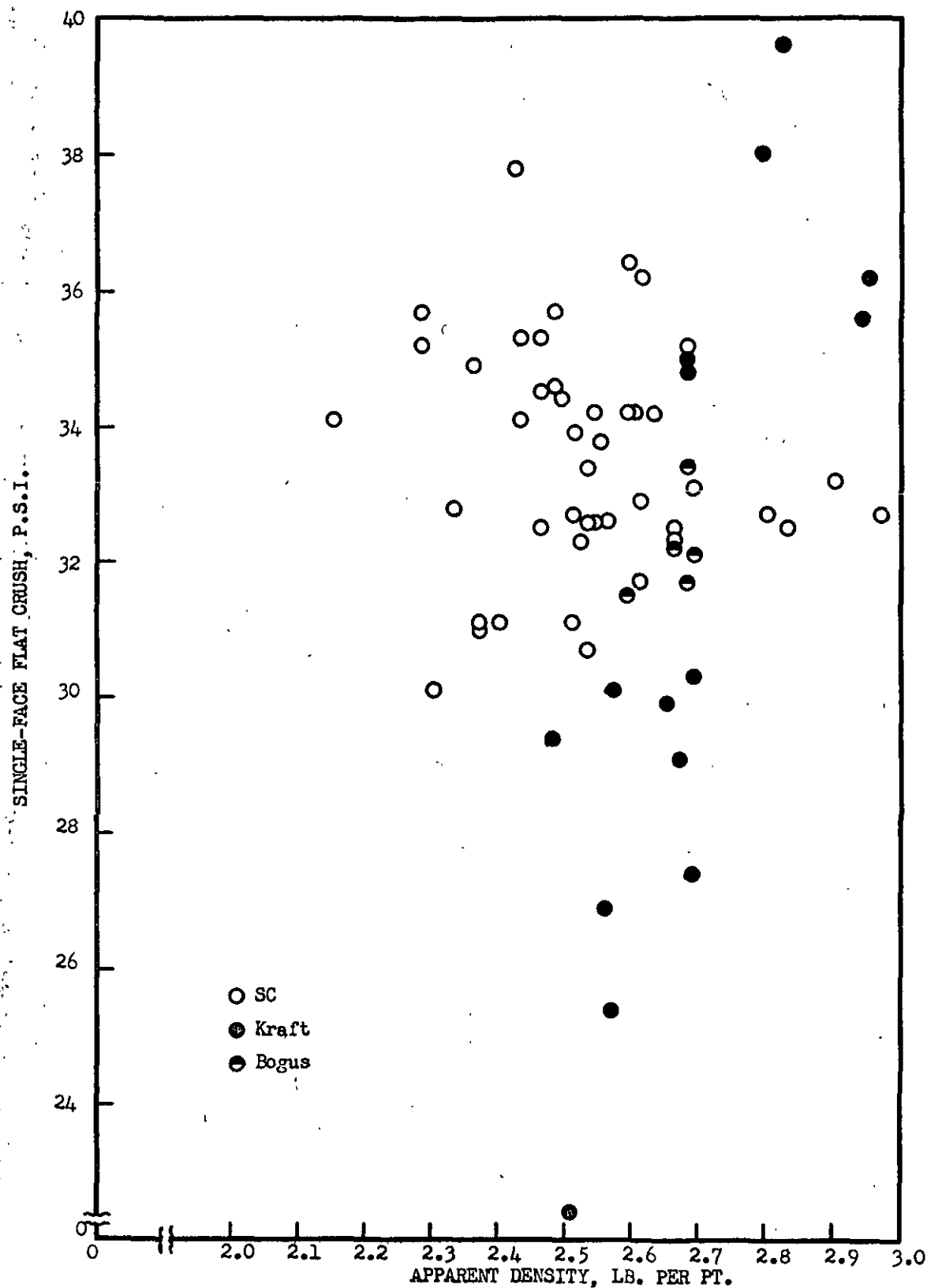Figure 3.   The Relationship Between Single-Face Flat Crush and Caliper

Figure 4.   The Relationship Between Single-Face Flat Crush and Apparent Density

direct relationship appears evident between the two tests--i.e., low

apparent density is generally associated with low flat crush and high

apparent density with high flat crush. The data for the bogus corru-

gating mediums are too limited to warrant any specific conclusions.

Figure 5 shows the relationship between single-face flat crush

and Concora flat crush. It appears quite evident from an inspection of

Figure 5 that a direct relationship exists between these two tests as

indicated by the fact that a straight line could be fitted to the group-

ing of the plotted points. A statistical technique called correlation

has been applied to these data to determine the intimacy of the relation-

ship. This technique involves the calculation of a coefficient known as

the "correlation coefficient" which has a magnitude ranging from 0.00

(no correlation) to 1.00 (perfect correlation) and either a plus sign

(direct correlation) or minus sign (inverse correlation). The correla-

tion coefficient calculated for the relationship between single-face flat

crush and Concora flat crush was found to be +0.87. A coefficient of

this magnitude indicates that a direct relationship exists between the

two tests and that they measure the same characteristics of the corrugat-

ing medium to a considerable degree.

Shown in Figure 6 is a graph of the relationship between

Concora flat crush and basis weight. The configuration of the plotted

data indicates that basis weight within the range noted does not have

a dominant influence on the magnitude of the Concora flat crush test re-
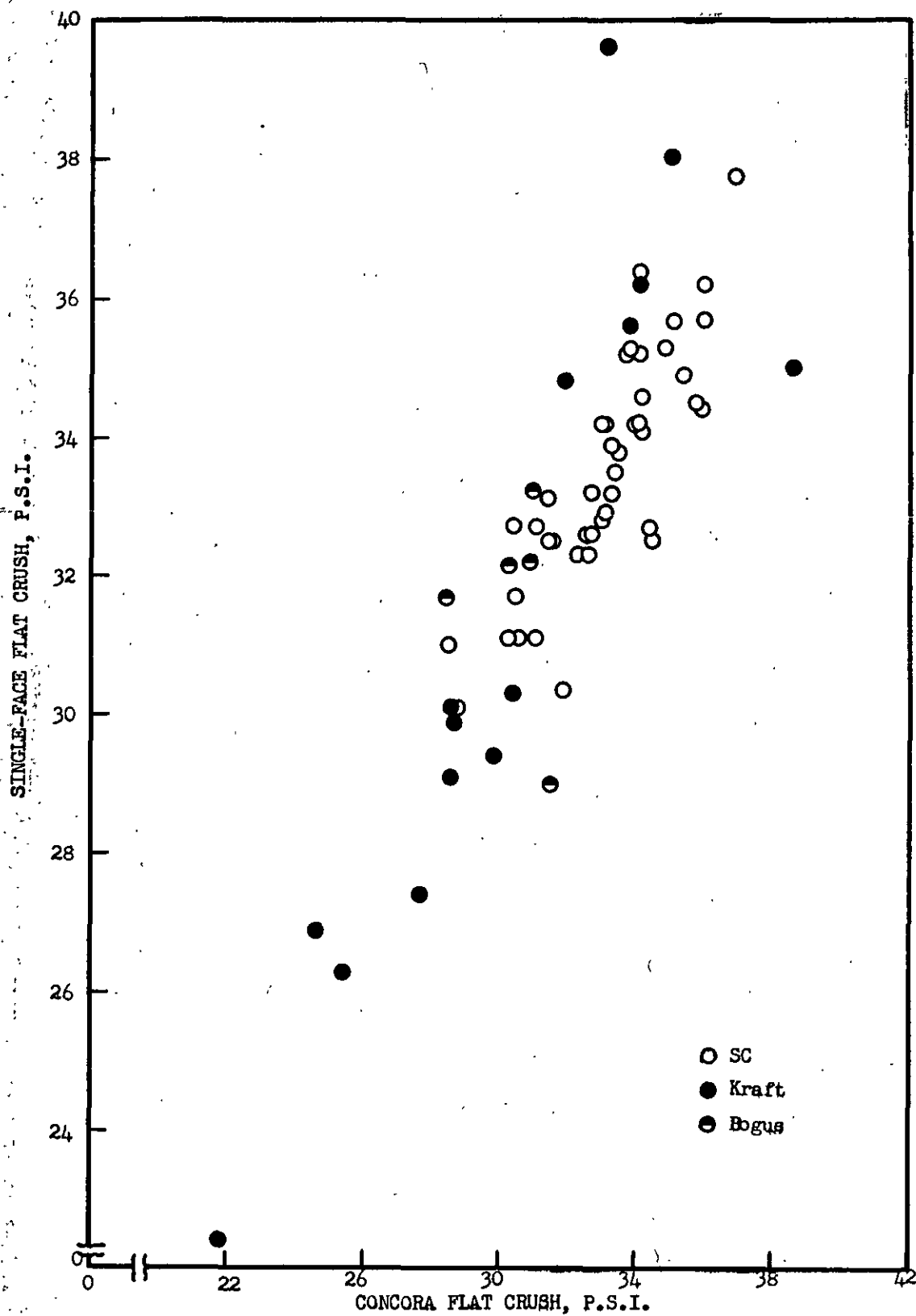
sults.

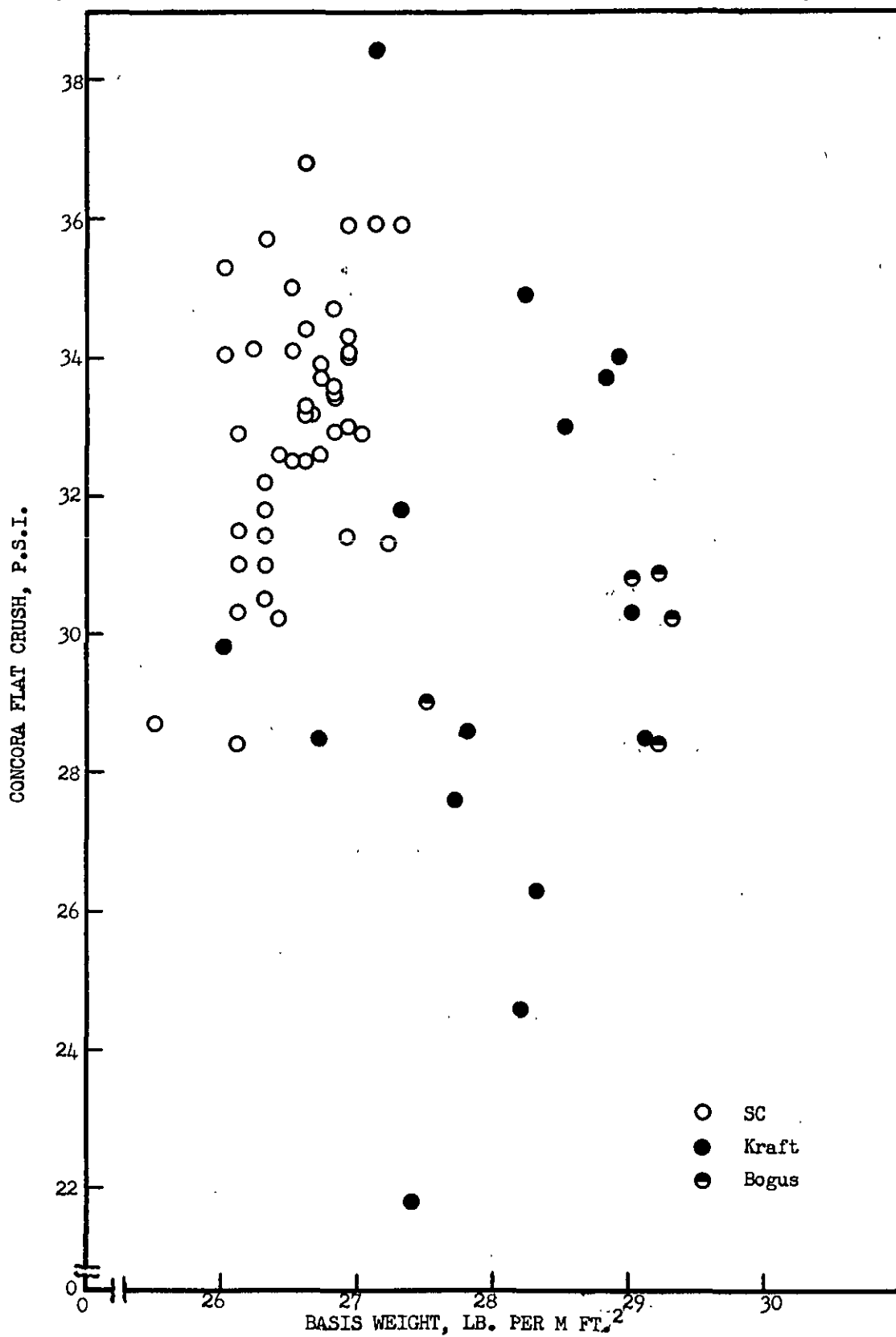Figure 5.   The Relationship Between Single-Face Flat Crush and Concora Flat Crush

Figure 6. The Relationship Between Concora Flat Crush and Basis Weight

The relationship between Concora flat crush and caliper is
shown graphically in Figure 7. An inspection of the plotted data in
Figure 7 indicates that caliper is not directly related to Concora flat
crush—i.e., low caliper values are associated about as often with high
Concora flat crush values as they are with low Concora flat crush values.

The current machine averages obtained for each test and each
machine during the first six periods of this study have been summarized
in individual tables and corresponding figures which are presented and
discussed in alphabetical order on the pages of this report that follow.
In considering these results from period to period, the reader should
bear in mind that some of the current machine averages are based on the
results for a greater number of rolls of corrugating medium than are some
others, and this has an influence on how reliably a given average reflects
the quality of product which a particular machine is producing. For ex-
ample, if the average for period 1 is based on the testing of 2 rolls and
that for period 2 on the testing of 8-rolls, it would be concluded that the
average for period 8 was more reliable in representing the true quality
level for that particular machine, other factors being equal. This fact
is mentioned to emphasize the importance of testing an adequate number
of rolls in order to obtain a reliable indication of quality.

Table III presents the current averages by periods for Machine A.
These results are shown by graphic means in Figure 8 where it may be seen
that data are available for only two periods and, therefore, any trends
which may be evident could not be considered significant.
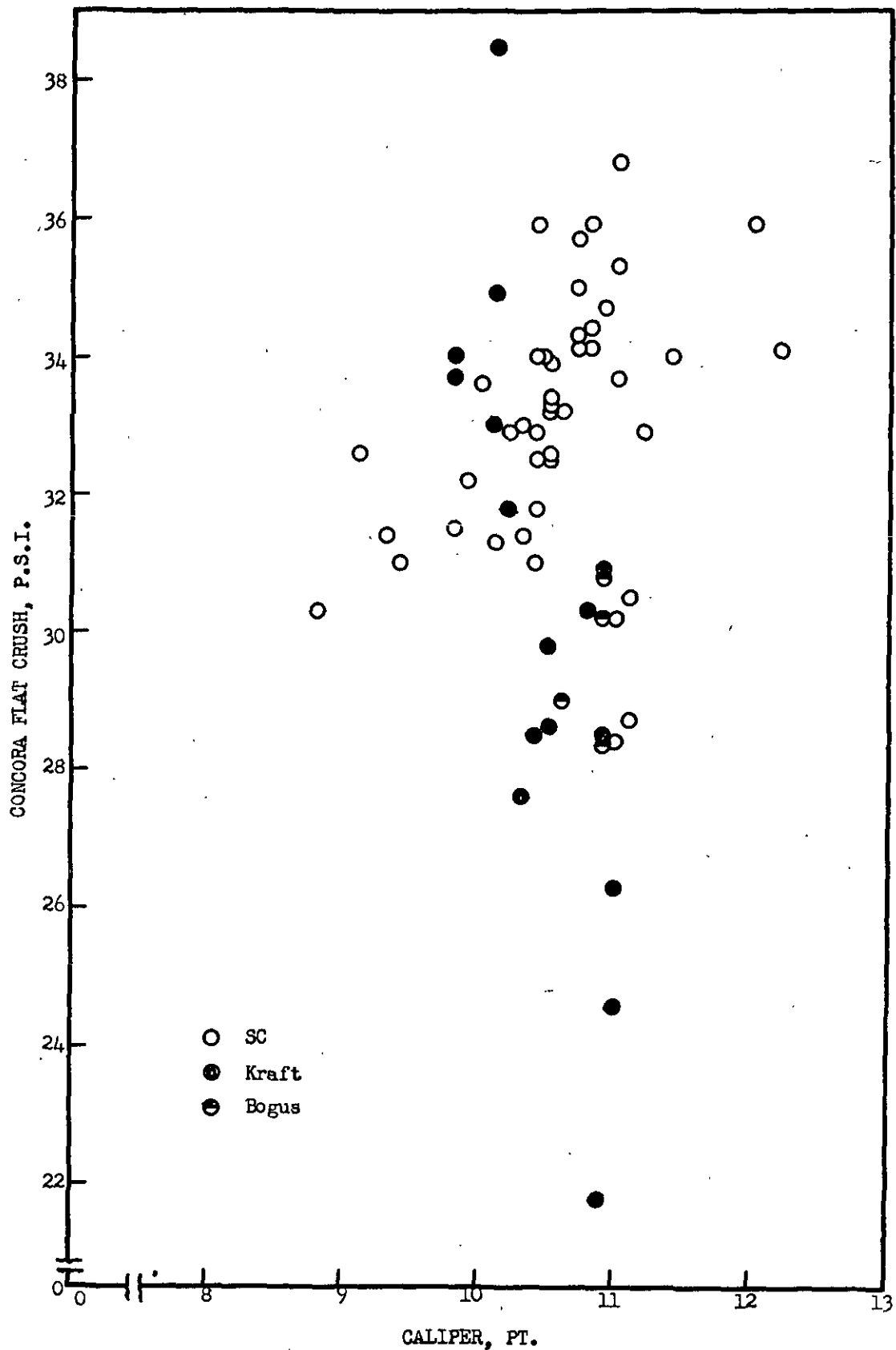
Figure 7. The Relationship Between Concora Flat Crush and Caliper
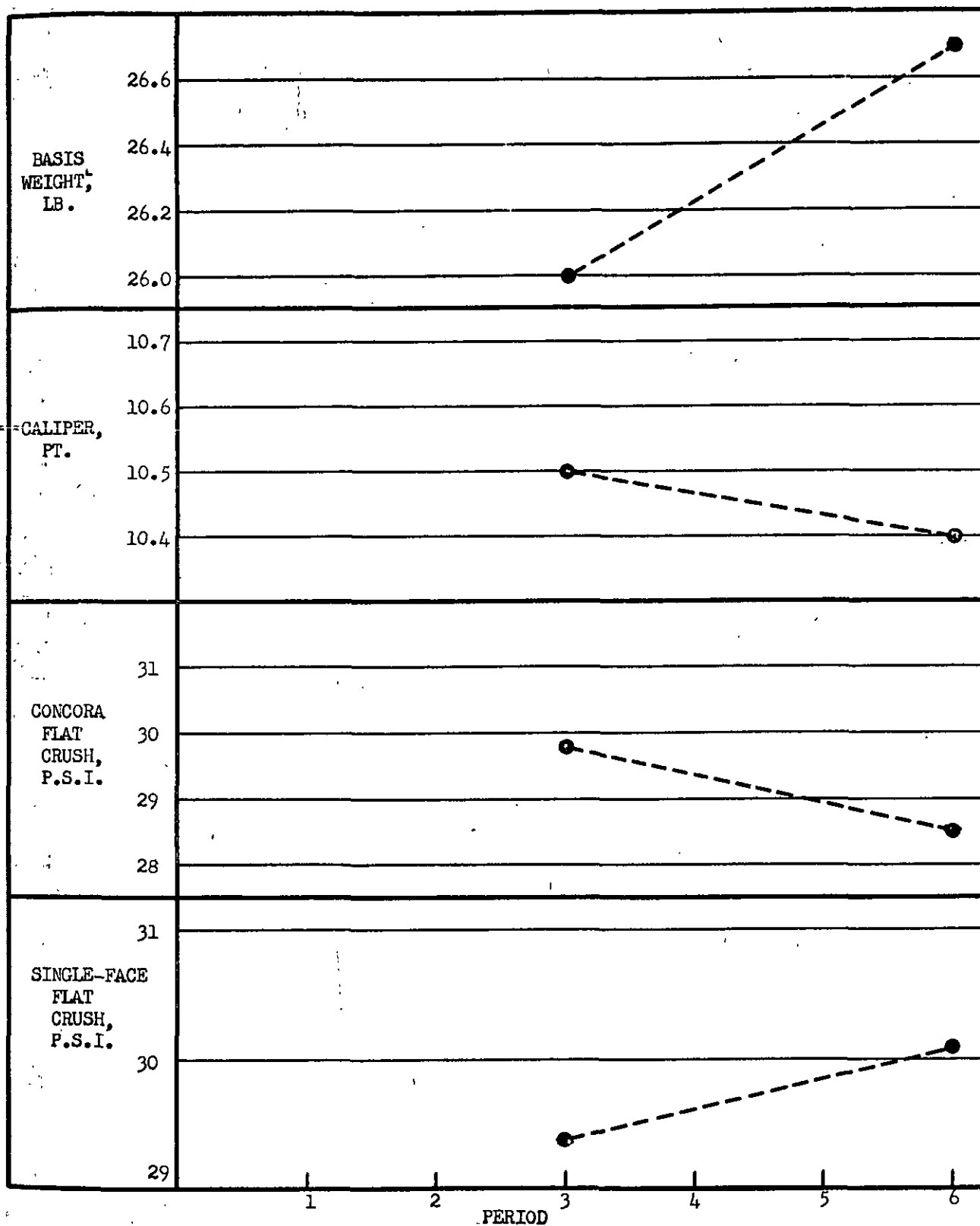
Figure 8. Comparison of Current Averages by Periods for Machine A

TABLE III

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE A

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	--	--	--	--
2	--	--	--	--
3	26.0	10.5	29.8	29.4
4	---	--	--	--
5	--	--	--	--
6	26.7	10.4	28.5	30.1

The current averages for Machine B shown in Table IV and graphically illustrated in Figure 9 indicate that basis weight and caliper have remained relatively constant--weight slightly above 26-lb. and caliper near 11 pt. Concora flat crush and single-face flat crush have increased somewhat.

TABLE IV

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE B

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	26.1	11.0	28.4	31.0
2	26.4	11.0	30.2	31.1
3	25.5	11.1	28.7	30.1
4	26.3	11.1	30.5	31.1
5	26.1	11.2	32.9	32.8
6	26.7	11.0	33.7	35.3

Figure 9. Comparison of Current Averages by Periods for Machine B

A graphical presentation of the current averages for Machine C

given in Table V is shown in Figure 10. Data are available for five of the

six periods. Basis weight and caliper appear to be relatively constant

but Concora flat crush and single-face flat crush have declined to some

extent.

TABLE V

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE C

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	--	--	--	--
2	27.1	10.4	35.9	36.2
3	26.9	10.3	33.0	32.9
4	26.7	10.5	32.6	32.6
5	26.9	10.7	34.3	32.7
6	27.2	10.1	31.3	33.1

From an inspection of the current averages given in Table VI

for Machine D and graphically presented in Figure 11, it may be noted

that all tests have exhibited a trend to higher levels.

TABLE VI

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE D

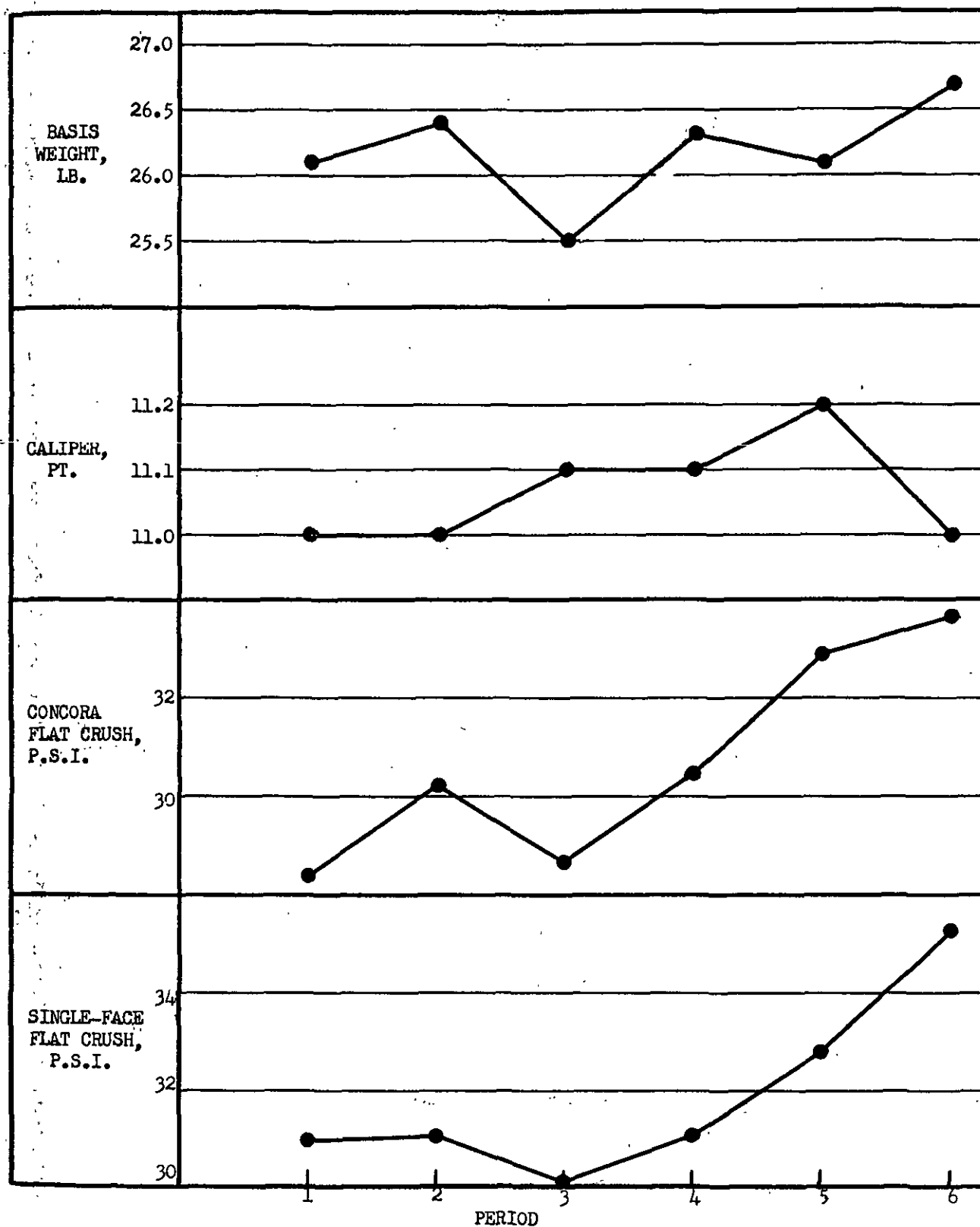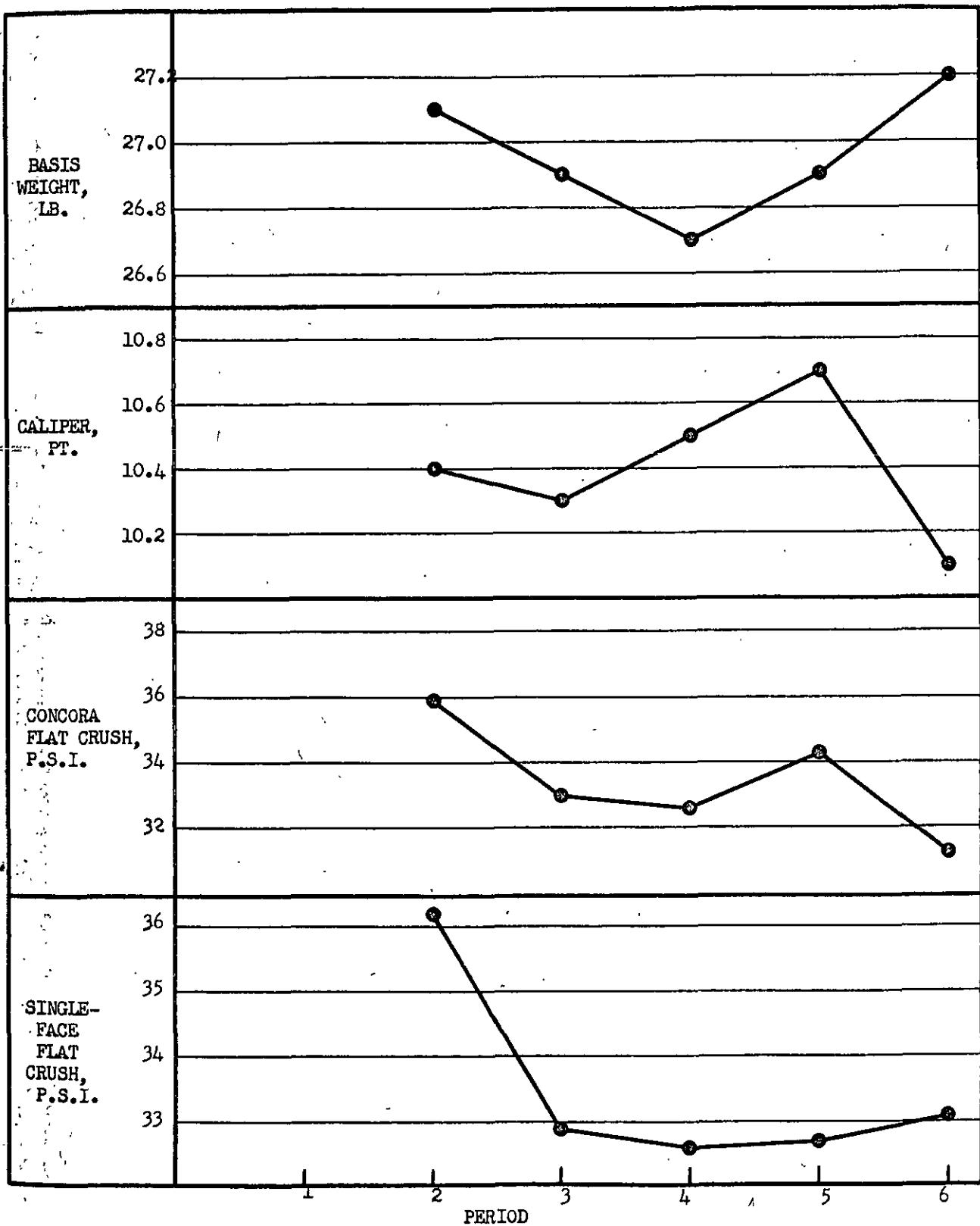| Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	26.3	10.4	31.8	30.7
2	26.1	10.4	31.0	31.1
3	26.9	10.3	31.4	31.7
4	26.5	10.5	32.5	32.3
5	26.9	10.4	34.0	34.2
6	26.8	10.5	33.4	33.8

Figure 10.   Comparison of Current Averages by Periods for Machine C
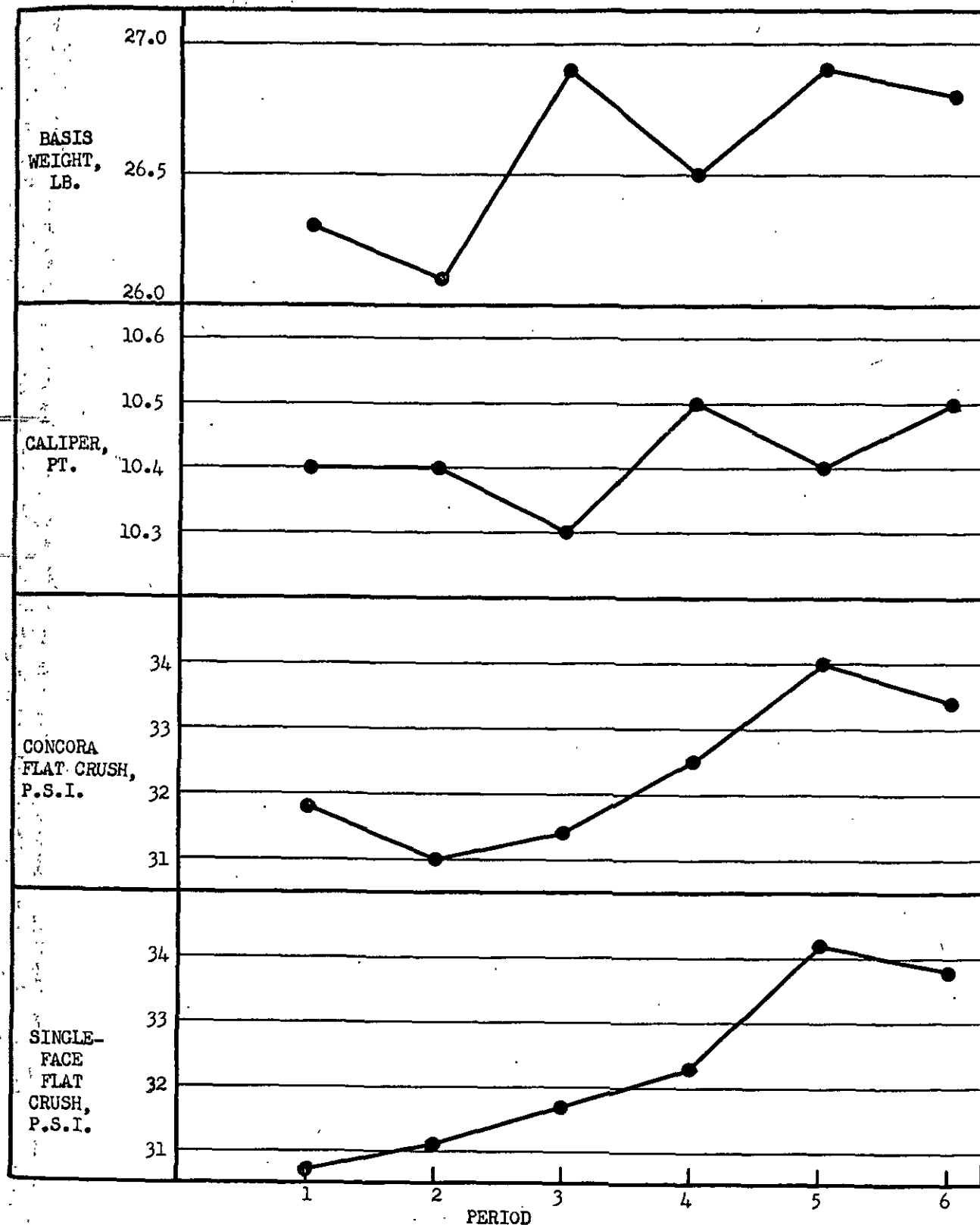
Figure 11. Comparison of Current Averages by Periods for Machine D

.The current averages for Machine E which are given in Table VII

and shown graphically in Figure 12 exhibit no definite trends with regard.

to basis weight although caliper has increased and flat crush (both Concora

and single-face) has decreased somewhat from previous levels.

TABLE VII

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE E

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	--	--	--	--
2	27.7	10.3	27.6	27.4
3	29.0	10.8	30.3	30.3
4	29.1	10.9	28.5	29.1
5	27.8	10.5	28.6	29.9
6	28.2	11.0	24.6	26.9

Illustrated graphically in Figure 13 are the current averages

shown in Table VIII for Machine F. Data are available for only two of

the first six periods and no observations that could be made would have

much significance.

TABLE VIII

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE F

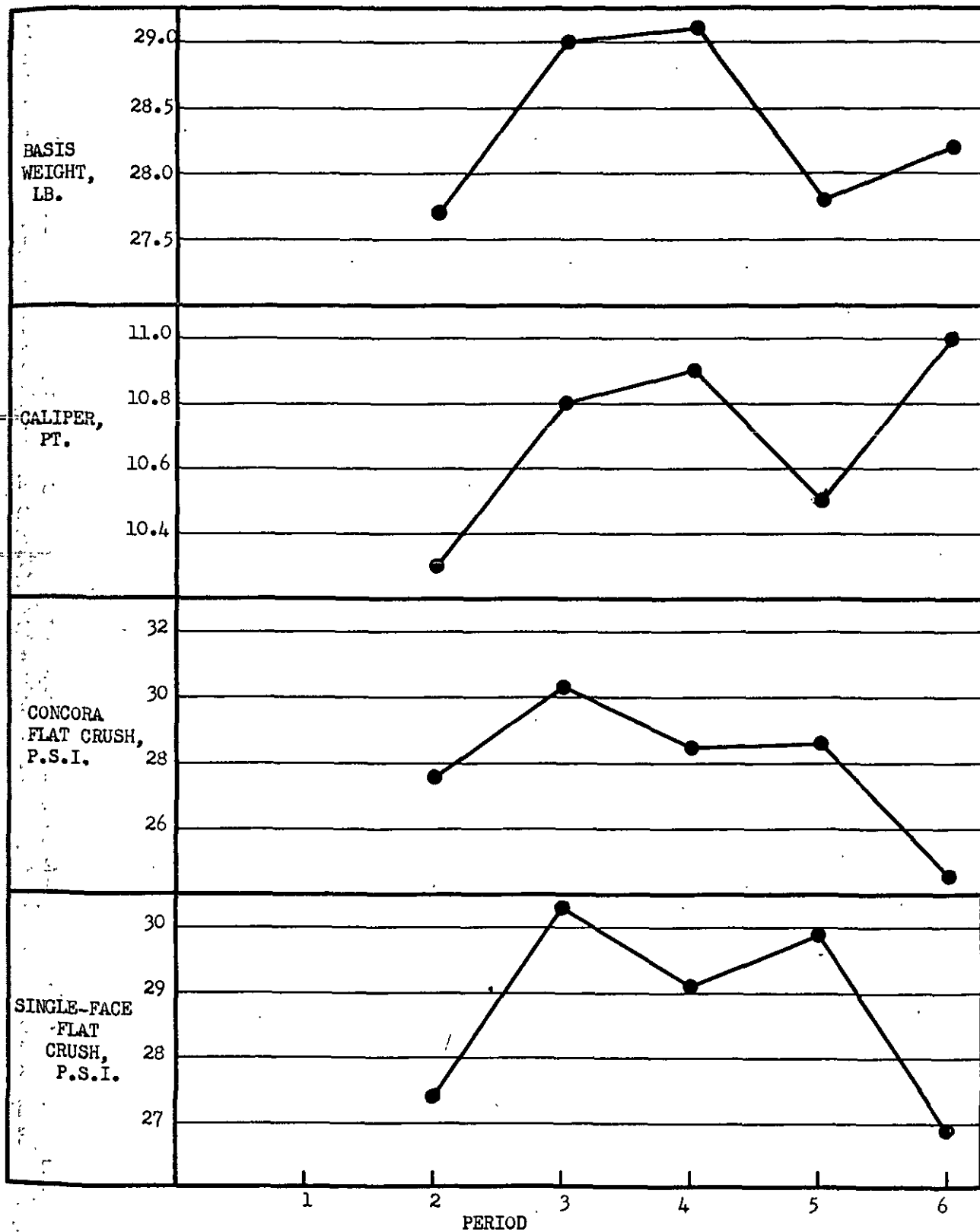| Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	--	--	--	--
2	28.3	11.0	26.3	25.4
3	27.4	10.9	21.8	22.4
4	--	--	--	--
5	--	--	--	--
6	--	--	--	--

Figure 12. Comparison of Current Averages by Periods for Machine E
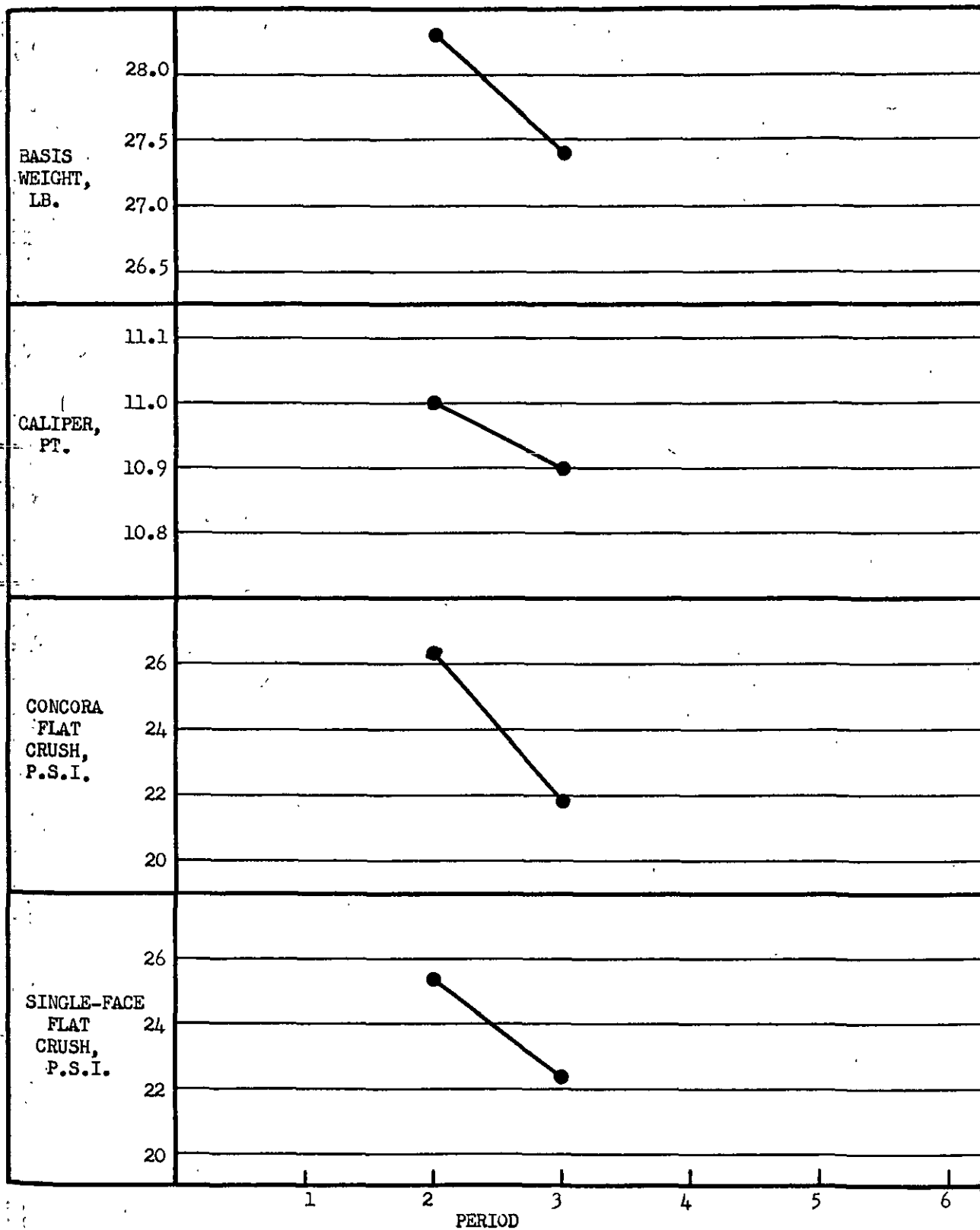
Figure 13. Comparison of Current Averages by Periods for Machine F

The current averages for Machine G are given in Table IX and
shown graphically in Figure 14. In general it appears that basis weight
and caliper have not changed appreciably. Concora and single-face flat
crush are currently at higher levels than they were when the study was
initiated.

TABLE IX

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE G

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	26.8	10.9	34.7	35.3
2	26.5	10.7	35.0	35.7
3	26.2	10.8	34.1	34.1
4	26.3	10.7	35.7	34.5
5	26.0	11.0	35.3	34.9
6	26.6	11.0	36.8	37.8

Shown in Table X are the current averages for Machine H. Figure
15 presents these results graphically. From an inspection of these data,
it may be seen that basis weight has maintained a level of approximately
29 lb. and caliper a level of 10.9 pt. for the last four of the five periods
for which data are available. Flat crush (both Concora and single-face)
appears to have increased.

The current averages for Machine I are given in Table XI and
presented graphically in Figure 16. The results for the six periods
indicate that all tests have remained relatively constant.

Pictured graphically in Figure 17 are the current averages for
Machine J. These results are also shown in Table XII. In general there

TABLE X

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE H

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	--	--	--	---
2	27.5	10.6	29.0	31.5
3	29.2	10.9	28.4	31.7
4	29.3	10.9	30.2	32.1
5	29.0	10.9	30.8	32.2
6	29.2	10.9	30.9	33.4

TABLE XI

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE I

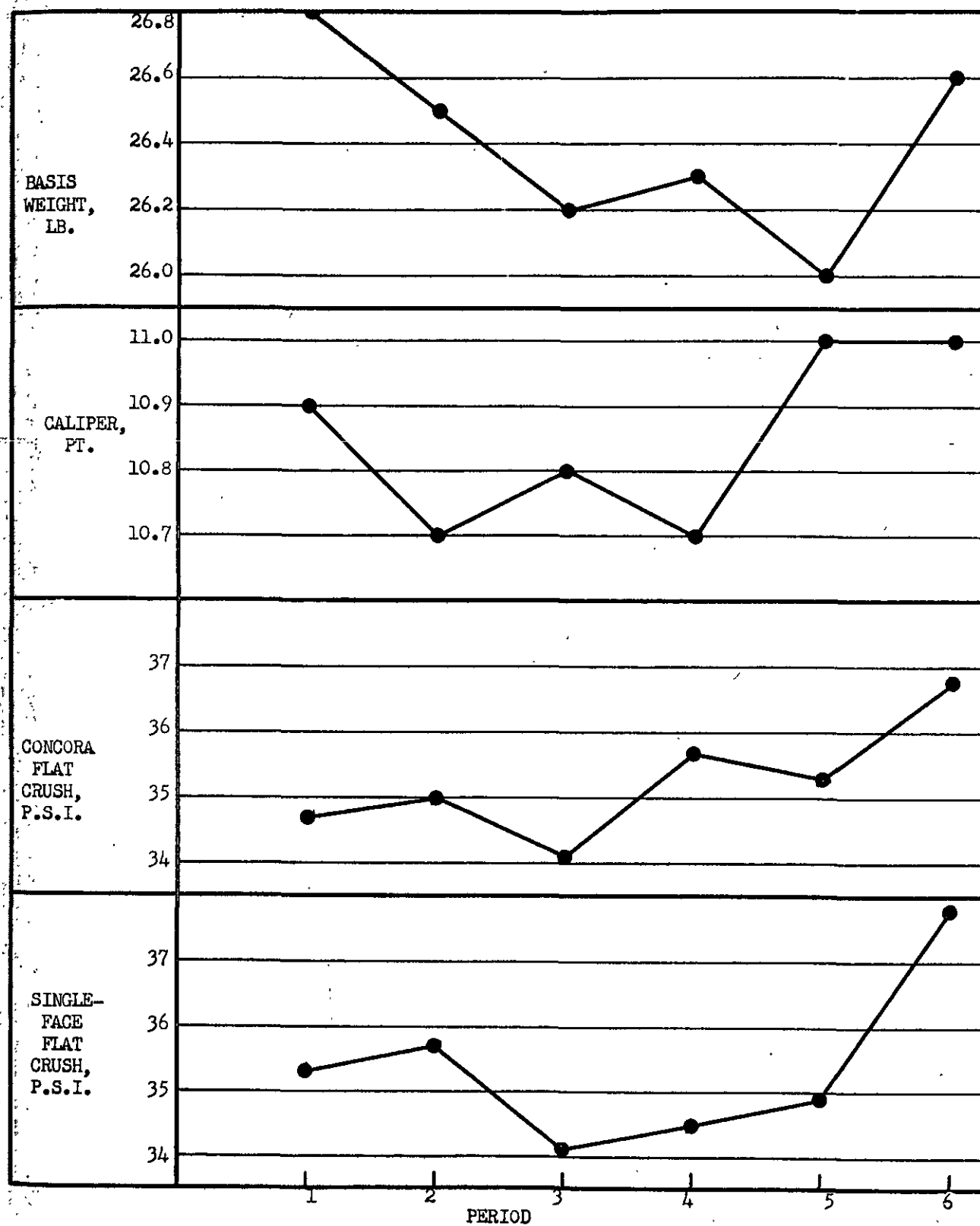| Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	26.8	10.2	32.9	34.2
2	26.8	10.0	33.6	35.2
3	27.0	10.4	32.9	34.2
4	26.6	10.5	33.2	33.4
5	26.7	10.5	33.9	34.2
6	26.9	10.4	34.0	36.4

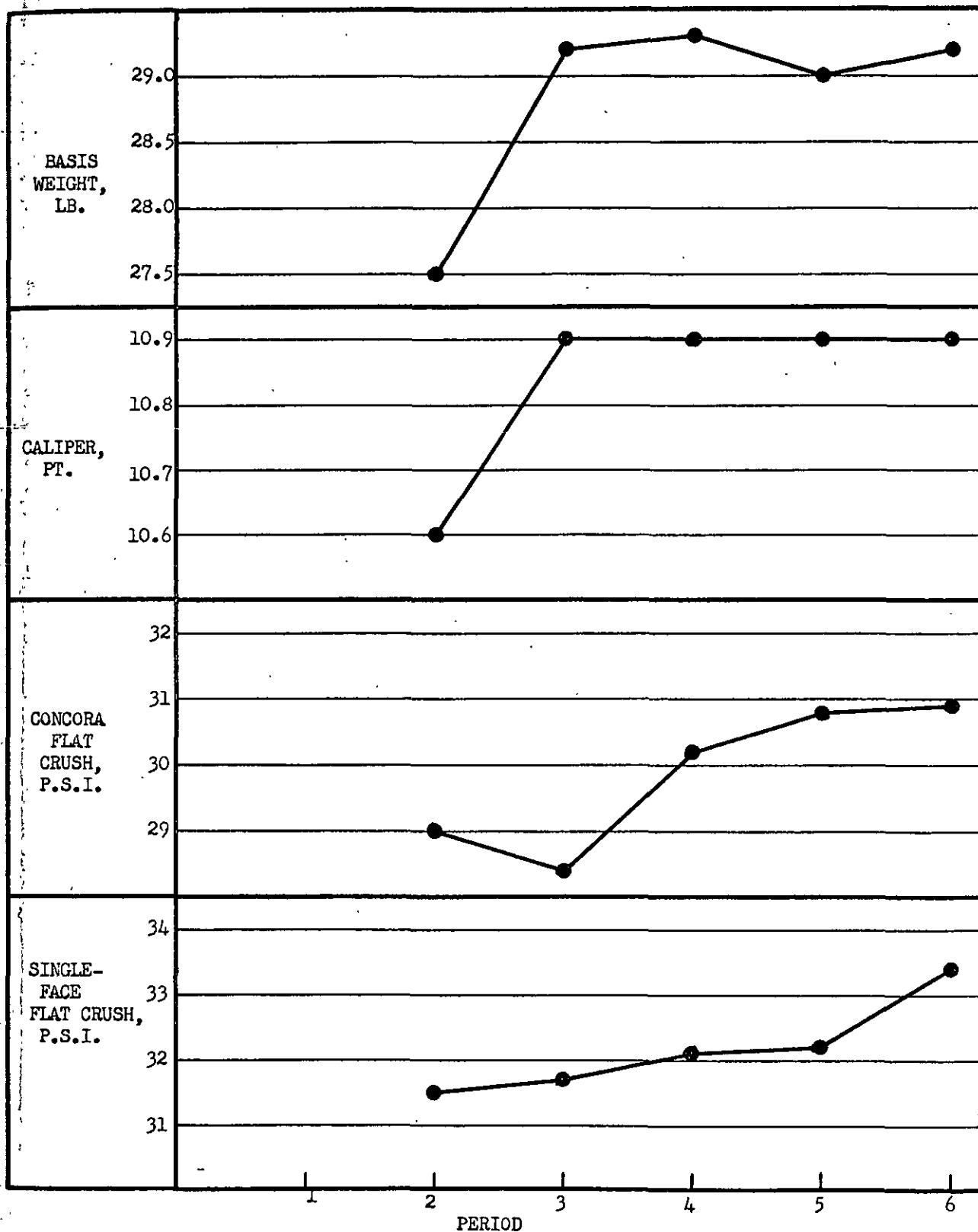Figure 14. Comparison of Current Averages by Periods for Machine G

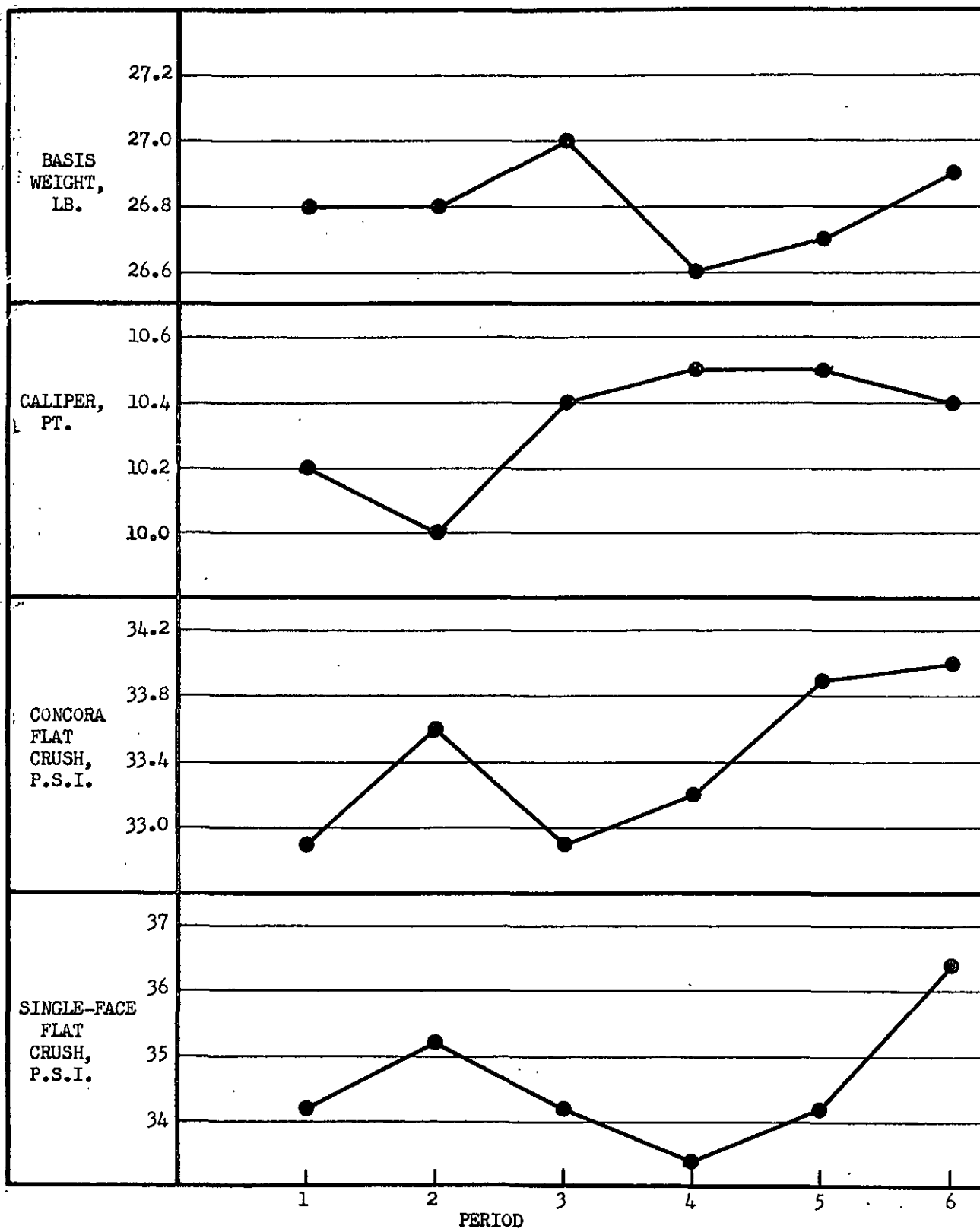Figure 15. Comparison of Current Averages by Periods for Machine H

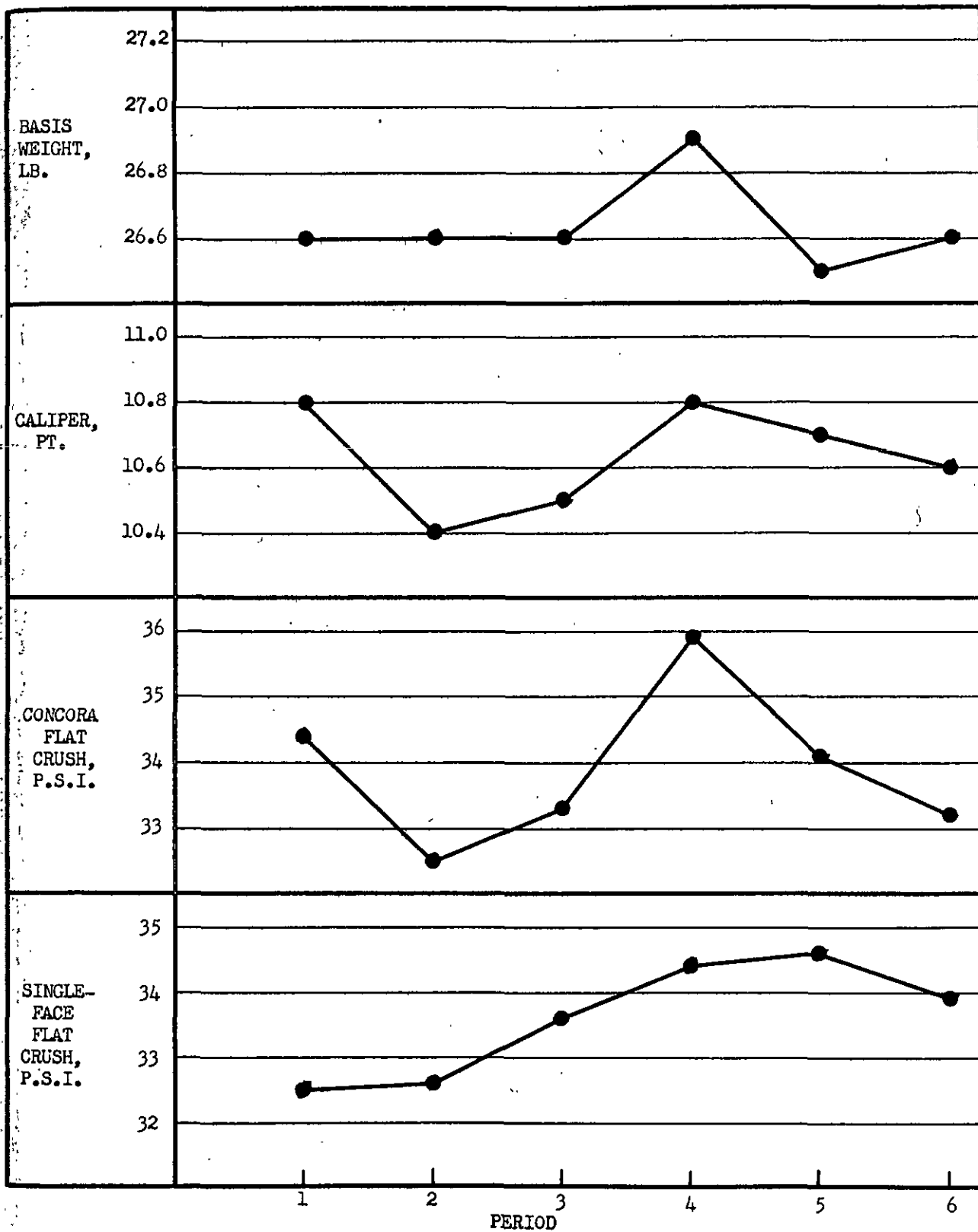Figure 16.   Comparison of Current Averages by Periods for Machine I

Figure 17.   Comparison of Current Averages by Periods for Machine J

TABLE XII

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE J

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	26.6	10.8	34.4	32.5
2	26.6	10.4	32.5	32.6
3	26.6	10.5	33.3	33.6
4	26.9	10.8	35.9	34.4
5	26.5	10.7	34.1	34.6
6	26.6	10.6	33.2	33.9

appear to be no clear-cut trends for any of the tests, all of which have remained relatively constant.

Table XIII presents the current averages for Machine K and Figure 18 illustrates them graphically. It may be noted in Figure 18 that basis weight has not changed appreciably; caliper reached a high of 9.9 points during the third period but since then has declined to its current level of 8.8 points; and flat crush has not changed significantly.

TABLE XIII

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE K

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	26.3	9.3	31.4	32.5
2	26.3	9.4	31.0	32.7
3	26.3	9.9	32.2	32.3
4	26.1	9.8	31.5	32.5
5	26.4	9.1	32.6	33.2
6	26.1	8.8	30.3	32.7
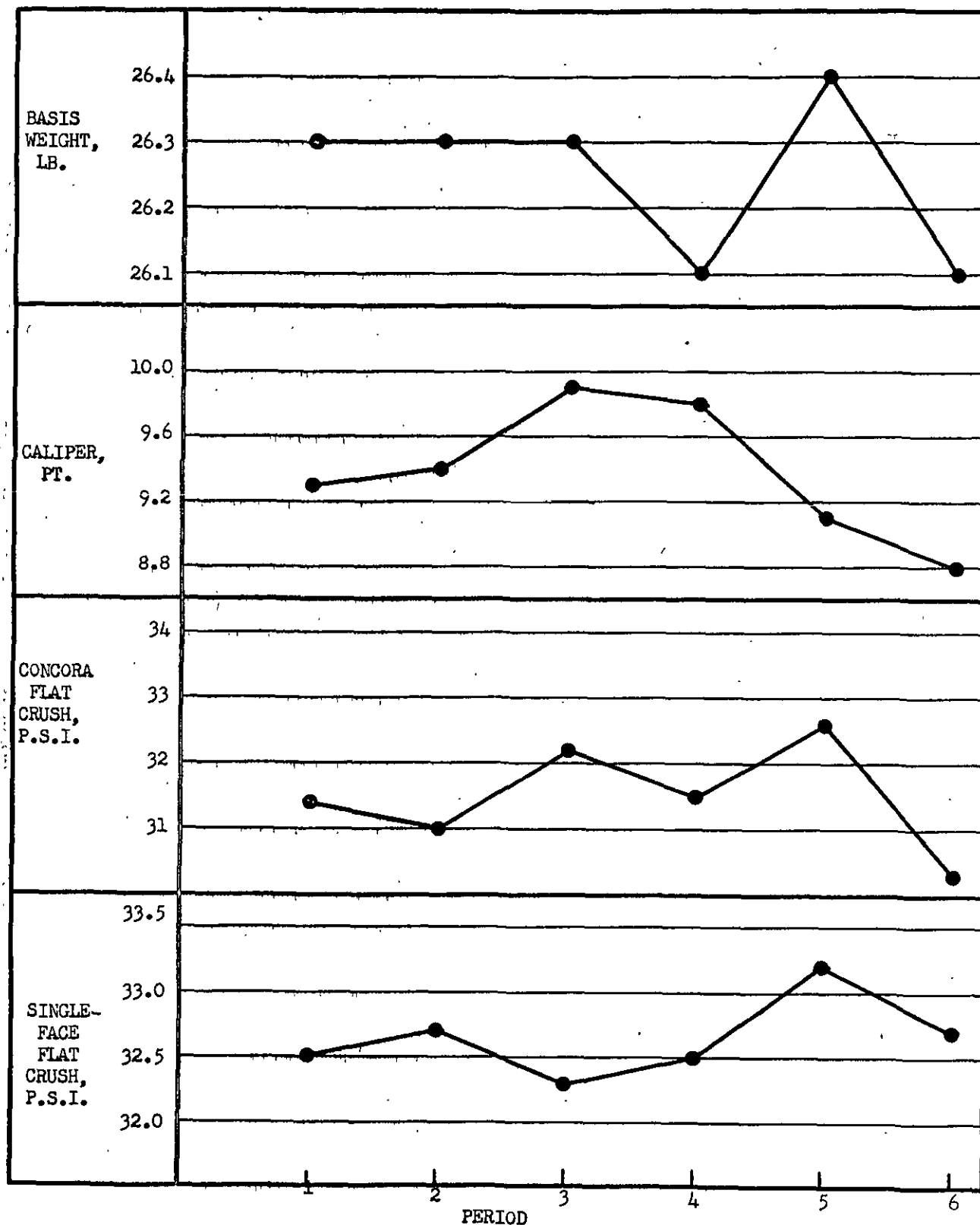
Figure 18. Comparison of Current Averages by Periods for Machine K

The current averages for Machine L are given in Table XIV and presented graphically in Figure 19. It may be noted that data are available for only three of the six periods, and any observations based on this amount of data would not have much significance.

TABLE XIV

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE L

Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	--	--	--	--
2	26.0	11.4	34.0	35.2
3	26.2	12.2	34.1	34.1
4	27.3	12.0	35.9	35.7
5	--	--	--	--
6	--	--	--	--

A graphical presentation of the current averages for Machine M given in Table XV is shown in Figure 20. From an inspection of these results it appears that basis weight has increased from its initial level; caliper has not changed appreciably; Concora flat crush and single-face flat crush have maintained relatively constant levels with some evidence of a current upswing in single-face flat crush.

TABLE XV

TABULATION OF CURRENT AVERAGES BY PERIODS FOR MACHINE M

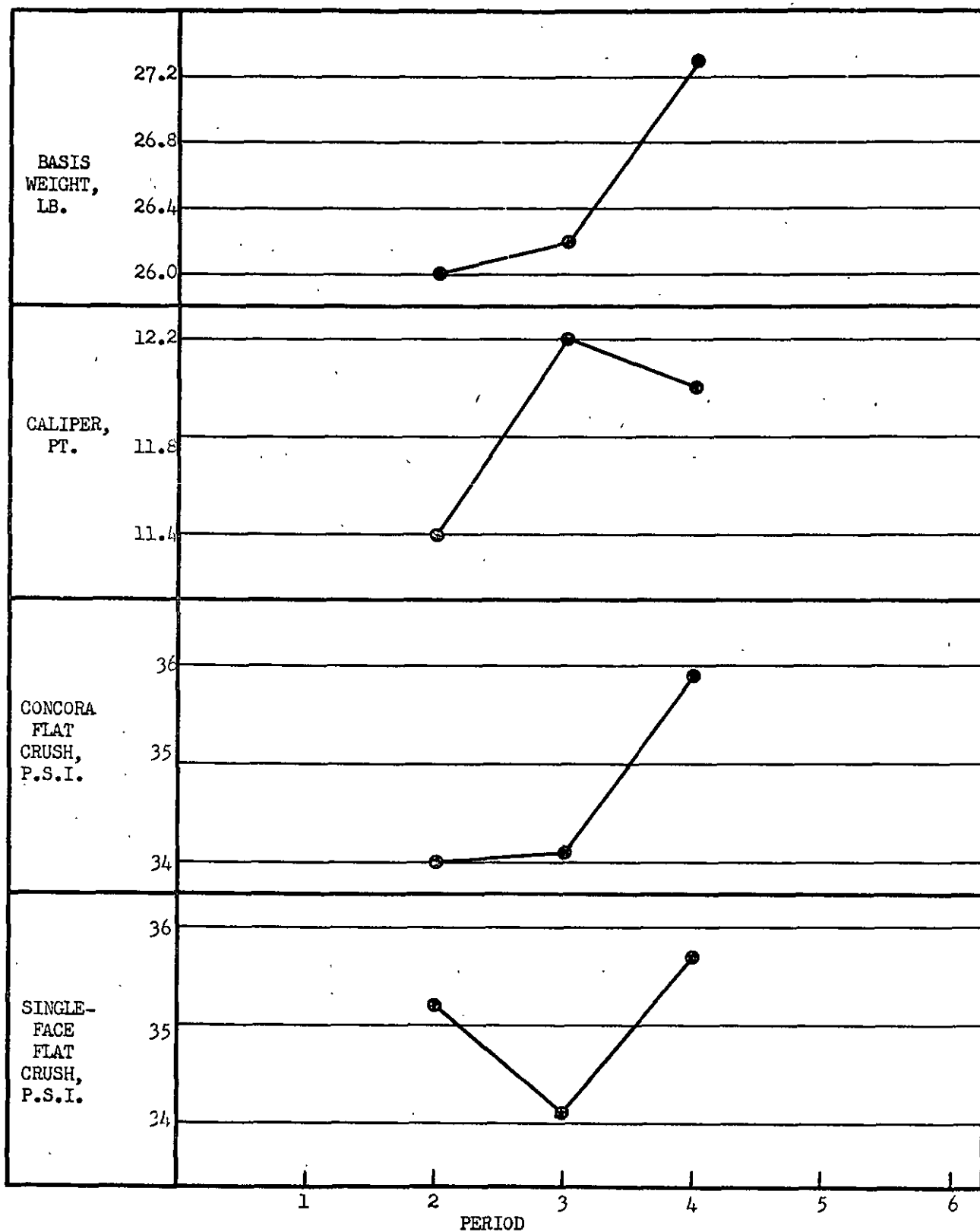| Period	Basis Weight, lb.	Caliper, pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
1	27.1	10.1	38.5	35.0
2	27.3	10.2	31.8	34.8
3	28.8	9.8	33.7	35.6
4	28.9	9.8	34.0	36.2
5	28.2	10.1	34.9	38.0
6	28.5	10.1	33.0	39.6

Figure 19. Comparison of Current Averages by Periods for Machine L
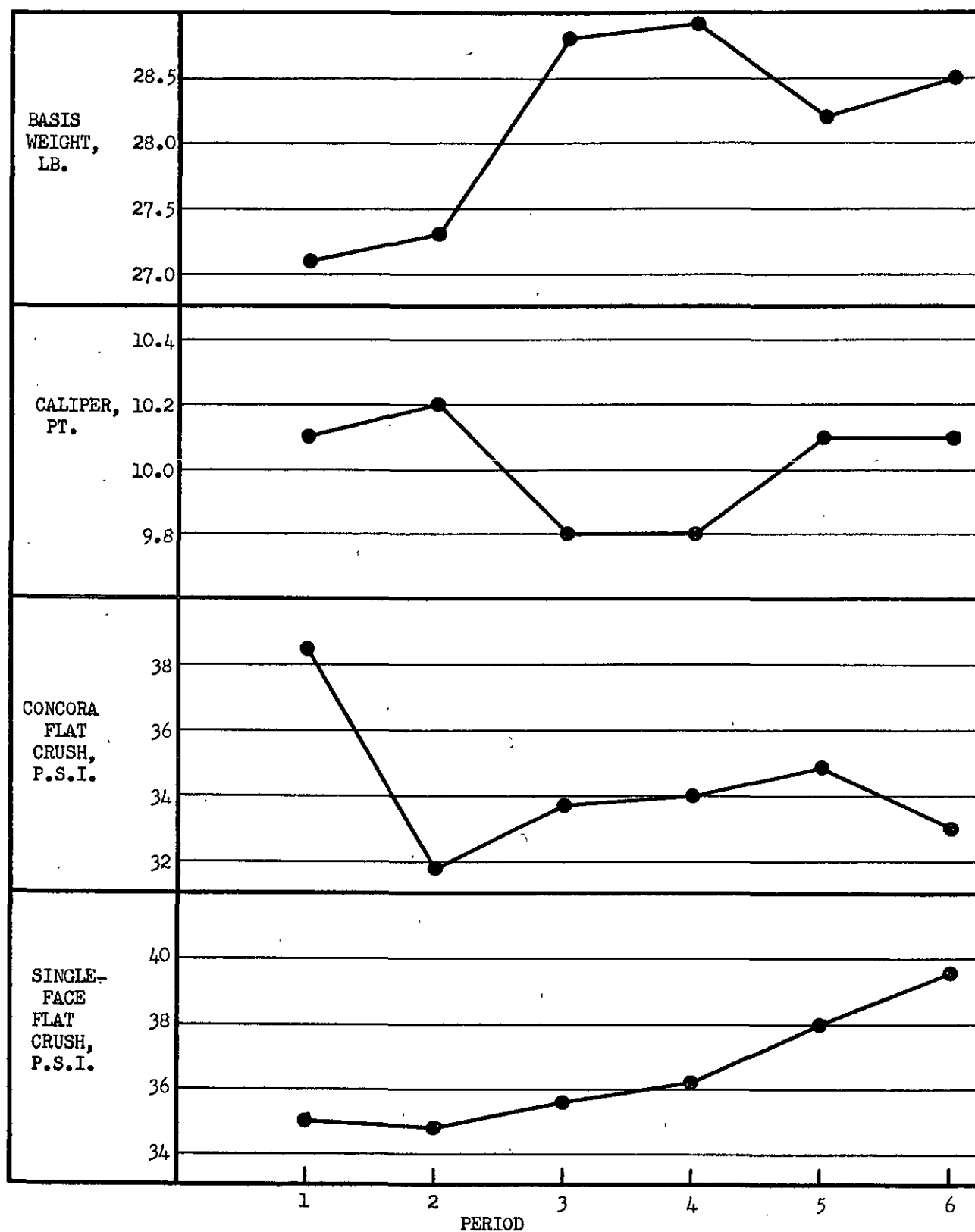
Figure 20. Comparison of Current Averages by Periods for Machine M

APPENDIX

TABULATION OF CURRENT MACHINE AVERAGES PLOTTED IN
FIGURES 2 THROUGH 7

Mill Code and Period	Basis Weight, lb.	Caliper, pt.	Apparent Density, lb./pt.	Concora Flat-Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
A-1	--	--	--	--	--
-2	--	--	--	--	--
-3	26.0	10.5	2.48	29.8	29.4
-4	--	--ᵎ	--	--	--
-5	--	--	--	--	--
-6	26.7	10.4	2.57	28.5	30.1
B-1	26.1	11.0	2.37	28.4	31.0
-2	26.4	11.0	2.40	30.2	31.1
-3	25.5	11.1	2.30	28.7	30.1
-4	26.3	11.1	2.37	30.5	31.1
-5	26.1	11.2	2.33	32.9	32.8
-6	26.7	11.0	2.43	33.7	35.3
C-1	---	--	--	--	--
-2	27.1	10.4	2.61	35.9	36.2
-3	26.9	10.3	2.61	33.0	32.9
-4	26.7	10.5	2.54	32.6	32.6
-5	26.9	10.7	2.51	34.3	32.7
-6	27.2	10.1	2.69	31.3	33.1
D-1	26.3	10.4	2.53	31.8	30.7
-2	26.1	10.4	2.51	31.0	31.1
-3	26.9	10.3	2.61	31.4	31.7
-4	26.5	10.5	2.52	32.5	32.3
-5	26.9	10.4	2.59	34.0	34.2
-6	26.8	10.5	2.55	33.4	33.8
E-1	--	--	--	--	--
-2	27.7	10.3	2.69	27.6	27.4
-3	29.0	10.8	2.69	30.3	30.3
-4	29.1	10.9	2.67	28.5	29.1
-5	27.8	10.5	2.65	28.6	29.9
-6	28.2	11.0	2.56	24.6	26.9
F-1	--	--	--	--	--
-2	28.3	11.0	2.57	26.3	25.4
-3	27.4	10.9	2.51	21.8	22.4
-4	--	--	---	--	--
-5	--	--	--	--	--
-6	--	--	--	--	--

APPENDIX--2

TABULATION OF CURRENT MACHINE AVERAGES PLOTTED IN
FIGURES 2 THROUGH 7

Mill Code and Period	Basis Weight, lb.	Caliper, pt.	Apparent Density, lb./pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
G-1	26.8	10.9	2.46	34.7	35.3
-2	26.5	10.7	2.48	35.0	35.7
-3	26.2	10.8	2.43	34.1	34.1
-4	26.3	10.7	2.46	35.7	34.5
-5	26.0	11.0	2.36	35.3	34.9
-6	26.6	11.0	2.42	36.8	37.8
H-1	--	--	---	---	--
-2	27.5	10.6	2.59	29.0	31.5
-3	29.2	10.9	2.68	28.4	31.7
-4	29.3	10.9	2.69	30.2	32.1
-5	29.0	10.9	2.66	30.8	32.2
-6	29.2	10.9	2.68	30.9	33.4
I-1	26.8	10.2	2.63	32.9	34.2
-2	26.8	10.0	2.68	33.6	35.2
-3	27.0	10.4	2.60	32.9	34.2
-4	26.6	10.5	2.53	33.2	33.4
-5	26.7	10.5	2.54	33.9	34.2
-6	26.9	10.4	2.59	34.0	36.4
J-1	26.6	10.8	2.46	34.4	32.5
-2	26.6	10.4	2.56	32.5	32.6
-3	26.6	10.5	2.53	33.3	33.6
-4	26.9	10.8	2.49	35.9	34.4
-5	26.5	10.7	2.48	34.1	34.6
-6	26.6	10.6	2.51	33.2	33.9
K-1	26.3	9.3	2.83	31.4	32.5
-2	26.3	9.4	2.80	31.0	32.7
-3	26.3	9.9	2.66	32.2	32.3
-4	26.1	9.8	2.66	31.5	32.5
-5	26.4	9.1	2.90	32.6	33.2
-6	26.1	8.8	2.97	30.3	32.7
L-1	--	--	---	--	--
-2	26.0	11.4	2.28	34.0	35.2
-3	26.2	12.2	2.15	34.1	34.1
-4	27.3	12.0	2.28	35.9	35.7
-5	--	--	--	--	--
-6	--	--	---	--	--

TABULATION OF CURRENT MACHINE AVERAGES PLOTTED IN
FIGURES 2 THROUGH 7

Mill Code and Period	Basis Weight, lb.	Caliper, pt.	Apparent Density, lb./pt.	Concora Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i.
M-1	27.1	10.1	2.68	38.5	35.0
-2	27.3	10.2	2.68	31.8	34.8
-3	28.8	9.8	2.94	33.7	35.6
-4	28.9	9.8	2.95	34.0	36.2
-5	28.2	10.1	2.79	34.9	38.0
-6	28.5	10.1	2.82	33.0	39.6