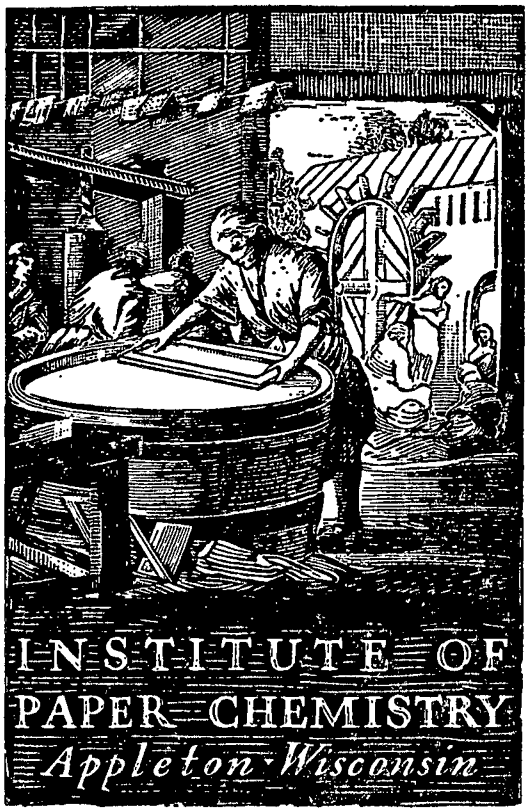

RELATIONSHIP BETWEEN SACK DROP AND SACK PAPER PROPERTIES
PART II. BUTT DROP PERFORMANCE

Project 2033

Report Thirty-One

A Progress Report

to

MULTIWALL SHIPPING SACK PAPER MANUFACTURERS

October 21, 1964

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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RELATIONSHIP BETWEEN SACK DROP AND SACK PAPER PROPERTIES

PART II. BUTT DROP PERFORMANCE

SUMMARY OF RESULTS

During the present contractural period, the policy committee requested that one phase of the program be devoted to an analyses and study of past data so that the information may be utilized in practical applications directed toward improvement in sack paper manufacture and sack performance. Report Twenty-nine was the first report in this series. It focussed attention on the degree to which face drop performance was related to the various sack paper tests. This report summarizes a similar analysis for butt drop performance at 50% R.H.

As in the face drop analyses, the primary basis for judging the merits of a given sack paper test was its ability to predict butt drop performance. However, other factors such as magnitude and sign of the correlation coefficient, general knowledge regarding sack and sack paper behavior, etc., were also considered. Properties evaluated in only one of the studies such as Instron fatigue, high rate tensile, etc., are included in the analysis but are not discussed in the summary because of their research nature and/or correlation with other properties. However, their relative effectiveness is noted in the main text. It should be mentioned in connection with the selection of tests that the difference in predictive ability between the "best" and "poorest" test was not much over 10-20%. Thus, replacement of the poorest by the best test would be expected to improve the prediction of sack quality only 10-20%.

FLAT KRAFT PAPERS

1. Averaging the predictive ability for Studies I and II (see Fig. 1) the five best sack paper tests (evaluated in both studies) for predicting sack performance are:

a) Frag, cross

b) T.E.A., cross

c) Impulse, cross

d) T.E.A., combined

e) Frag, combined

2. Based on testing ease and calibration considerations, T.E.A. is preferred for specification or control of flat kraft multiwall sack paper. The cross-machine orientation is the dominant direction because the stresses in butt drop are believed to be predominantly cross machine in direction. It is believed, however, that the machine-direction characteristics have a minor influence on butt drop. Therefore, if a major change is made in the machine-direction T.E.A., e.g., extensible kraft, some change in butt drop can be expected.

3. Among the paper tests which were found to be less well related (see Fig. 2) to butt drop performance were tensile and tearing strength.

EXTENSIBLE KRAFT PAPERS

The conclusions drawn herein are based on an analysis of the results obtained in Study II.

1. The five best tests for predicting butt drop performance of extensible paper sacks (see Fig. 1) arranged in order of decreasing predictive efficiency are:

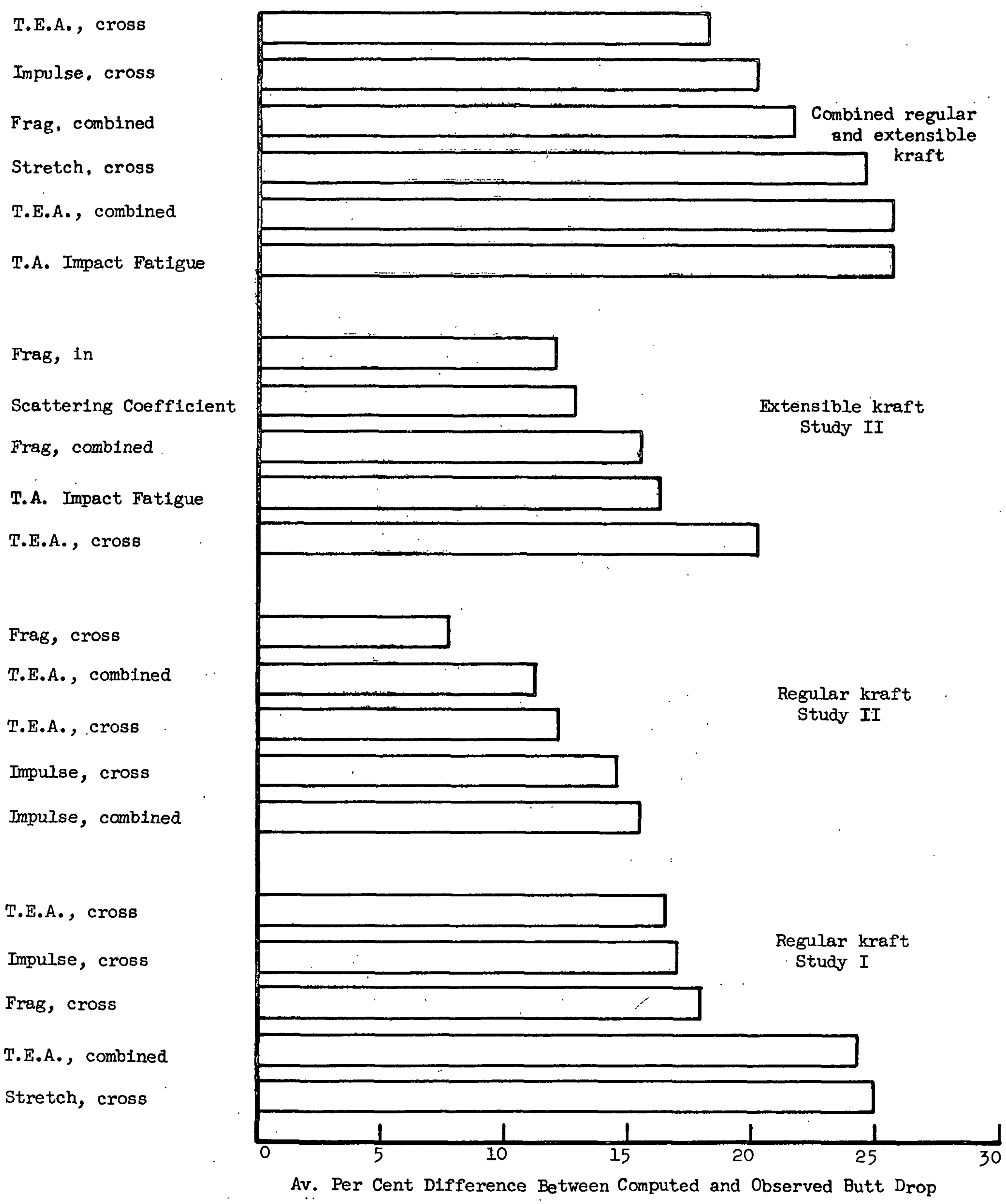

Figure 1. Comparison of Properties Giving the Best Predictions of Butt Drop Performance

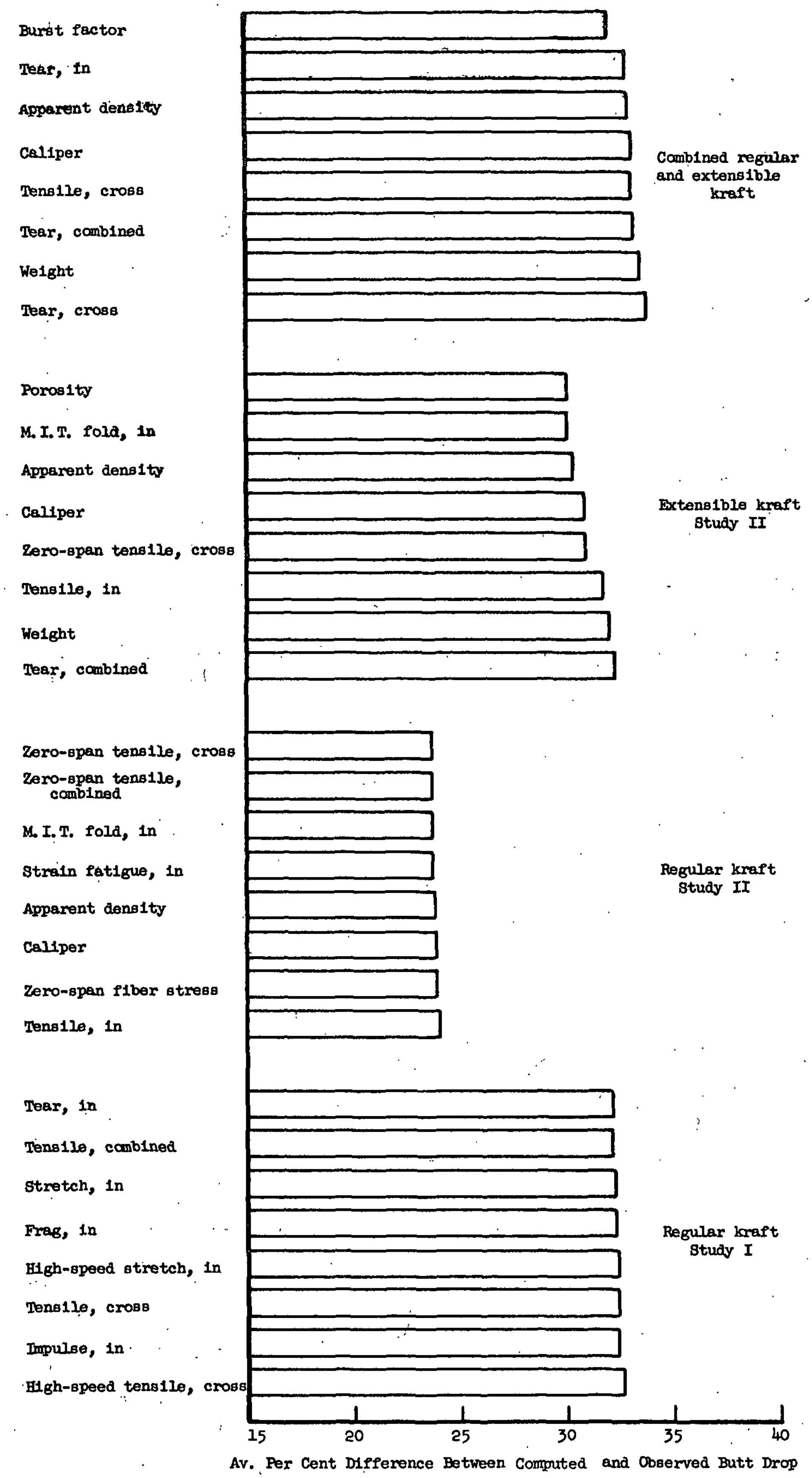

Figure 2. Comparison of Properties Giving the Poorest Predictions of Butt Drop Sack Performance

a) Frag, in

b) Scattering coefficient

c) Frag, combined

d) T.A. impact fatigue

e) T.E.A., cross

2. Although scattering coefficient, Frag, and T.A. impact fatigue are better related to butt drop performance than cross-machine T.E.A., it is believed that the latter is more amenable for use in control, etc.

3. Among the sack paper tests found to be poorly (see Fig. 2) related to butt drop performance were machine-direction tensile and combined tear.

EXTENSIBLE AND FLAT KRAFT SACK PAPERS

When the data were analyzed to determine the most appropriate sack paper tests to be used for both extensible and flat kraft sack paper, the following results were obtained:

1. The six best tests (see Fig. 1) arranged in order of decreasing prediction efficiency are:

a) T.E.A., cross

b) Impulse, cross

c) Frag, combined

d) Stretch, cross

e) T.E.A., combined

f) T.A. impact fatigue

2. Cross-machine T.E.A. is superior to combined T.E.A. (sum of in and cross) for butt drop prediction because the importance of in-machine T.E.A. is

overemphasized by the combined value (see Fig. 3 and 4). In Reference (2) a two factor multiple correlation gave the following equation:

$$B = -25.6 + 16.9W_x + 155.0W_y \tag{1}$$

where

B = butt drop, safe inch

W_x, W_y = in and cross-machine T.E.A., in lb./sq. in.

Equation (1) is also graphed in Fig. 3 and indicates that to produce equal effects on butt drop the change in machine-direction T.E.A. should be about 9 times greater than a change in cross-direction T.E.A.

3. Taking test cost, calibration, etc., into consideration, cross-machine T.E.A. is recommended as the best single property for butt drop prediction of extensible and flat kraft sack paper. The two factor Equation (1) above is probably slightly superior and will be discussed further in a future report.

GENERAL

The conclusions reached in this analysis of butt drop relationships to sack paper property are basically similar to those reached in Report Twenty-Nine for face drop, i.e., T.E.A. provides the best and most convenient estimates of drop test performance. For face drop, combined T.E.A. was recommended. For butt drop, cross-machine T.E.A. is the best single property for predictive purposes.

Cross-machine T.E.A. will not accurately predict the relative butt drop performance of all sack paper combinations. Also, large changes in machine-direction properties can be expected to significantly affect butt drop tests. The use of these tests should, therefore, be tempered by judgment and experience.

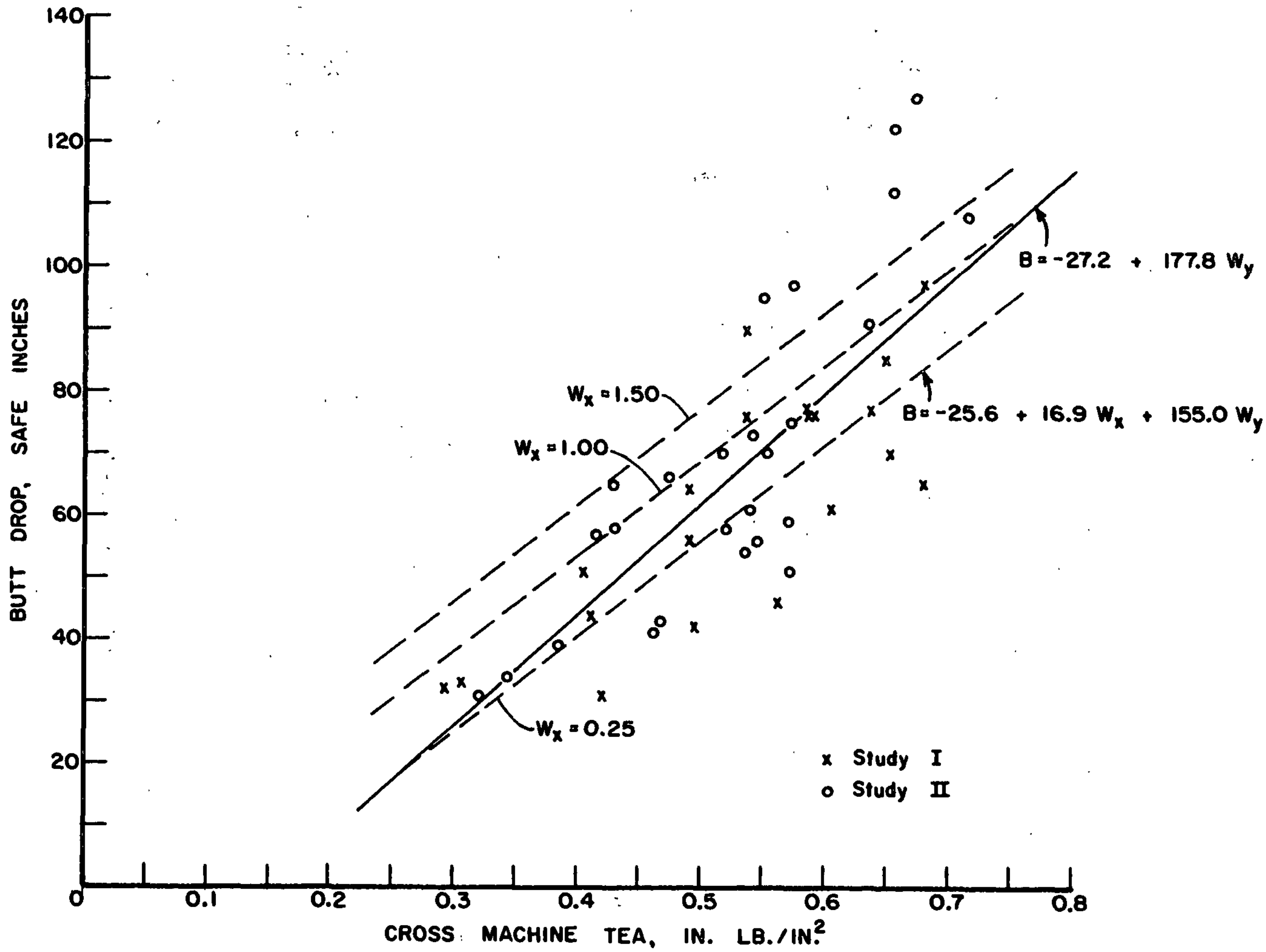

Figure 3. Relationship Between Butt Drop and Cross-Machine T.E.A.

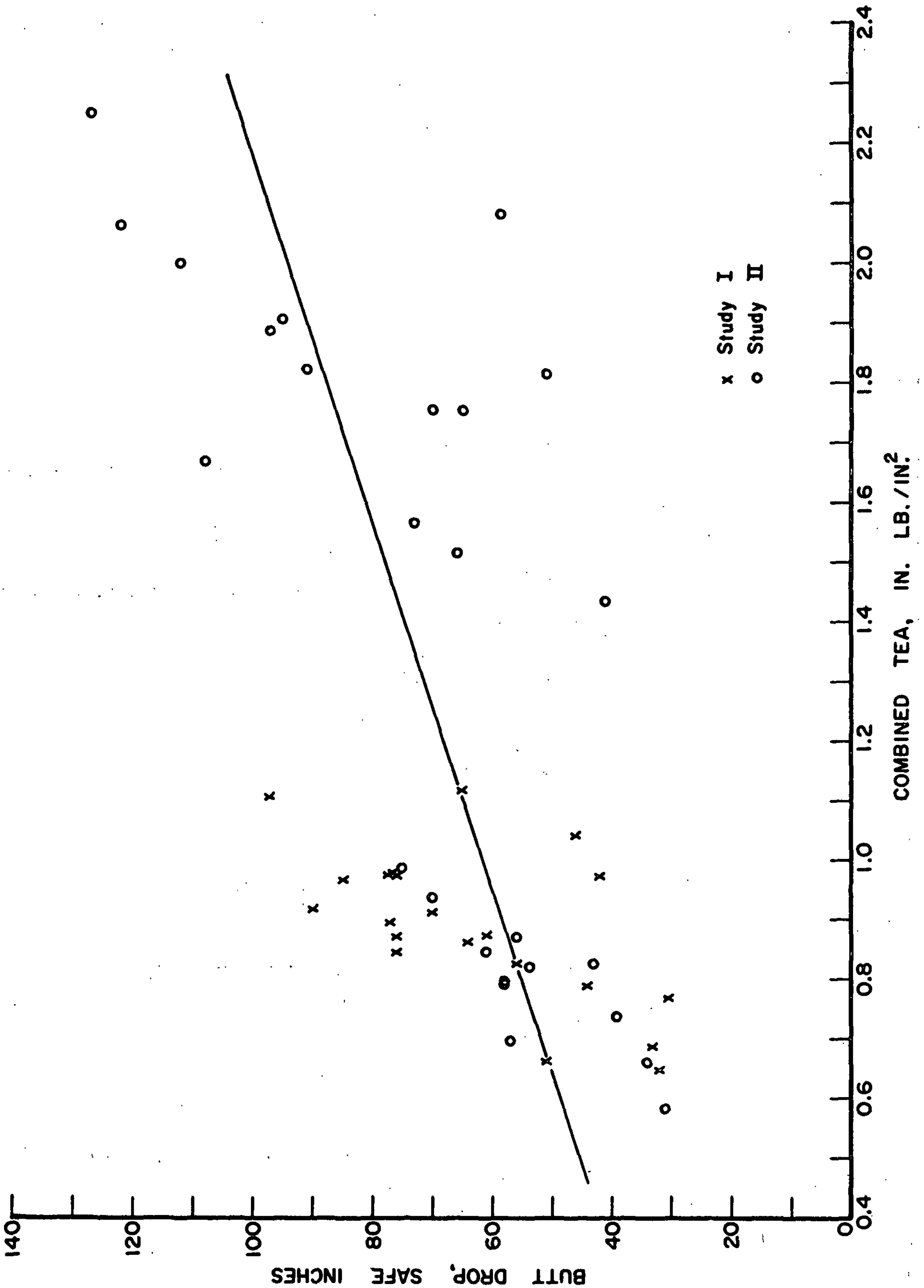

Figure 4. Relationship Between Butt Drop and Combined T.E.A.

The equation relating butt drop performance of 3-ply cement size pasted sacks to cross-machine T.E.A. is given below and illustrated in Fig. 3.

$$B = -27.2 + 177.8W_y \tag{2}$$

where

$\underline{B}$ = butt drop at 50% R.H., safe inch

$\underline{W_y}$ = cross-machine T.E.A., in lb./sq. in.

Equations (1) and (2) should not be used for general predictions of butt drop performance since they strictly hold only for the particular construction and evaluation conditions. The predictions are expected to hold, however, on a relative basis under many conditions.

In order to illustrate the effect which small changes in T.E.A. may have on the performance of sacks of the style and size used in the study, sack performance has been calculated using Equations (1) and (2). The results are tabulated in Table I and show that changes of about 10% in stretch introduce changes in T.E.A. equivalent to about 20% change in butt drop.

A succeeding report will discuss the correlation of combinations of properties to face and butt drop.

LITERATURE CITED

1. Progress Report Twelve, Feb. 8, 1960.

2. Progress Report Twenty-One, Oct. 1, 1962.

THE INSTITUTE OF PAPER CHEMISTRY

William J. Whitsitt, Research Aide

R. C. McKee, Chairman, Container Section

TABLE I

EFFECT OF CHANGES IN T.E.A. ON BUTT DROP AT 50% R.H.

No.	Change in Stretch, % M.D.	Change in Stretch, % C.D.	T.E.A., in lb./sq.in. M.D.	T.E.A., in lb./sq.in. C.D.	Butt Drop Performance Equation (1) Safe Inch	Equation (1) %	Equation (2) Safe Inch	Equation (2) %
				Flat Kraft				
1	+20.4	+19.1	0.4417	0.618	78	+42	83	+43
2	+10.2	+9.6	0.3883	0.549	66	+20	70	+21
3	0.0	0.0	0.3375	0.482	55	--	58	--
4	-10.2	-9.6	0.2898	0.420	44	-20	48	-17
5	-20.4	-19.1	0.2415	0.361	34	-38	37	-36
6	-30.6	-28.7	0.1942	0.301	24	-56	26	-55
				Extensible Kraft				
7	+10.2	+10.0	1.748	0.6927	111	+18	96	+19
8	+5.1	+5.0	1.608	0.6535	103	+10	89	+10
9	0.0	0.0	1.478	0.6085	94	--	81	--
10	-5.1	-5.0	1.366	0.5595	84	-11	72	-11
11	-10.0	-10.0	1.255	0.5228	77	-18	66	-19

Note: Equation (1) $\underline{B} = -25.6 + 16.9\,\underline{W}_{\underline{x}} + 155.0\,\underline{W}_{\underline{y}}$

Equation (2) $\underline{B} = -27.2 + 177.8\,\underline{W}_{\underline{y}}$.

APPENDIX I

PROCEDURES

The data for the statistical analyses were taken from the following reports of Project 2033.

Report No.	Report Date
12	Feb. 8, 1960
21	Oct. 1, 1962
22	Aug. 31, 1962
23	Oct. 16, 1962
24	July 22, 1962
25	Oct. 31, 1962

Information on test procedures, etc., may be found in the same reports.

Separate analyses were made for each of the following data subdivisions:

a) Study I, regular kraft sacks — N = 20

b) Study II, regular kraft sacks — N = 12

c) Study II, extensible kraft sacks — N = 14

The butt drop test results were expressed in safe inches of drop.

Forty-eight properties of the sack paper were evaluated for each study, although in some instances properties were evaluated in one study and not the other. Tests evaluated in one study included:

1.	Van der Korput energy	Study I only
2.	High-speed tensile	Study I only
3.	High-speed stretch	Study I only
4.	High-speed work	Study I only
5.	Zero-span tensile	Study II only
6.	M.I.T. fold	Study II only
7.	Instron strain fatigue	Study II only
8.	Instron energy fatigue	Study II only

As mentioned in Report Twenty-Nine, van der Korput energy and high-speed tensile, stretch and work tests correlate well with Instron tests at conventional test rates (1, 2). Therefore, tests on the Instron should be an adequate substitute for the van der Korput or high-speed tests. The remaining tests (5-8 above) were considered to be research tools and undesirable for control or specification purposes. Therefore, they are not considered further in the discussion.

APPENDIX II

ANALYSES

For this report the simple linear correlations between butt drop and the physical characteristics of the sack papers were reviewed for the two major studies carried out in the past. The detailed tables of statistical data are shown in Appendix III, Tables VII through X. Tables XI through XIV in Appendix III show the test properties arranged in order of their average prediction difference, together with the corresponding correlation coefficient. The average prediction difference is the average difference in per cent between computed and observed sack drop values based on the selected sack paper property. These data are graphed in Fig. 5 through 8.

REGULAR SACKS – STUDIES I AND II

For the flat kraft data graphed in Fig. 5 and 6, the best properties for predictive purposes in each study are compared in Table II. It may be noted that:

1. Four properties were common to both studies; namely, cross-machine T.E.A., impulse and Frag and combined (in plus cross) T.E.A. The two properties not appearing in both lists were cross-machine stretch and combined (in plus cross) impulse.

2. The correlation coefficients were significant at the 1% level for all properties except cross-machine stretch where the coefficient was significant at the 5% level.

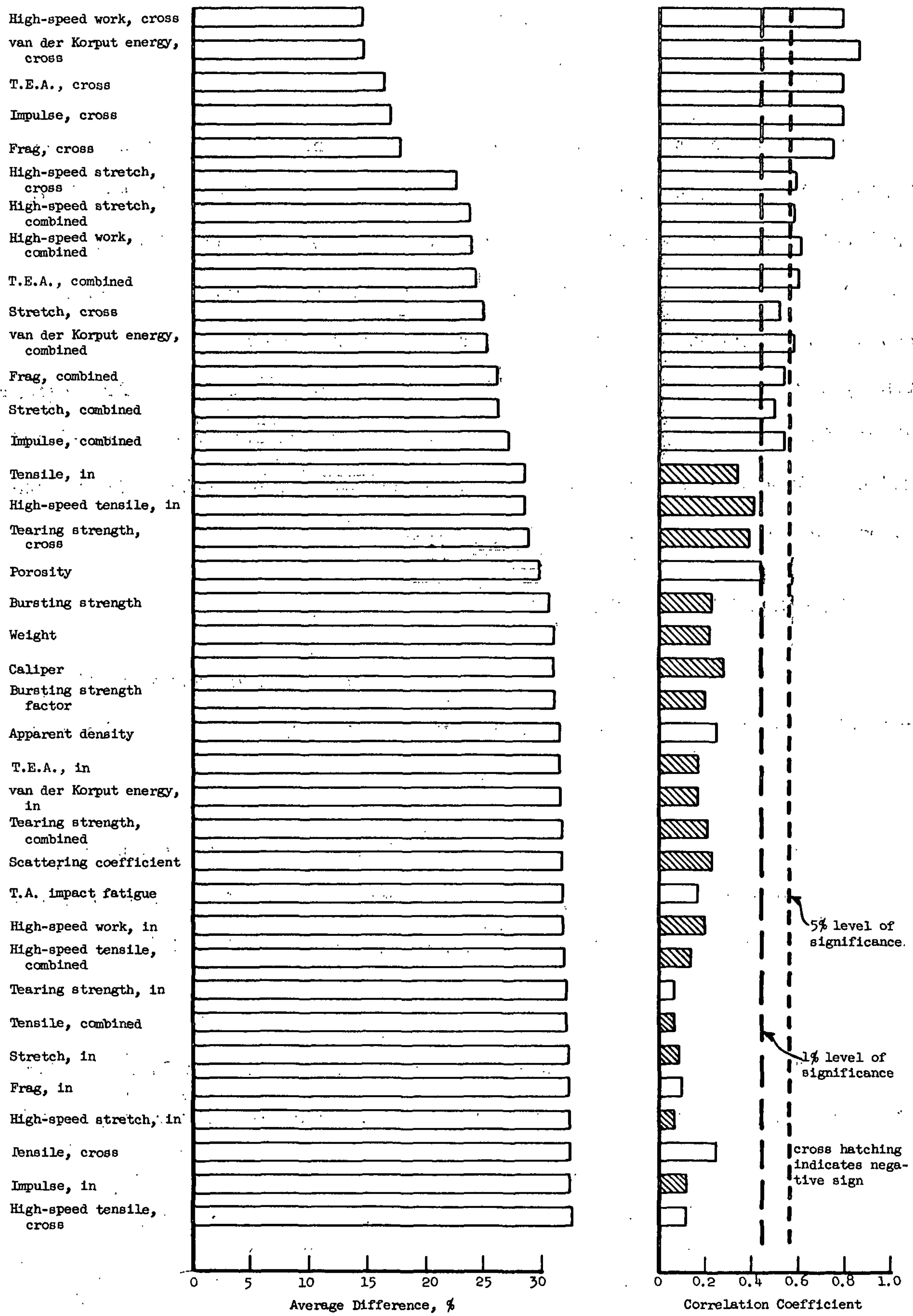

Figure 5. Comparative Ranking of Sack Paper Properties Based on Butt Drop Predictive Ability for Regular Kraft Materials from Study I

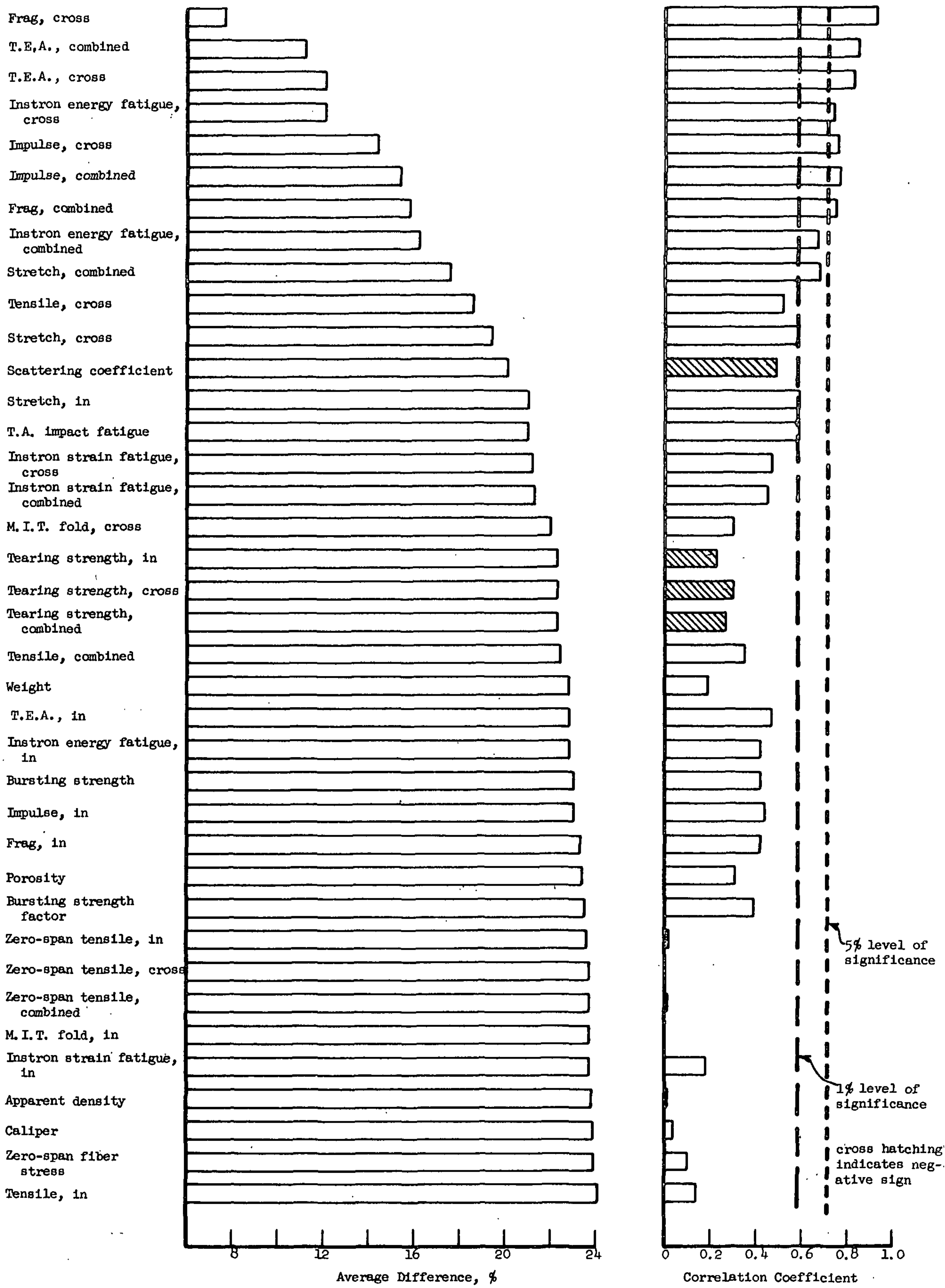

Figure 6. Comparative Ranking of Sack Paper Properties Based on Butt Drop Predictive Ability for Regular Kraft Materials from Study II

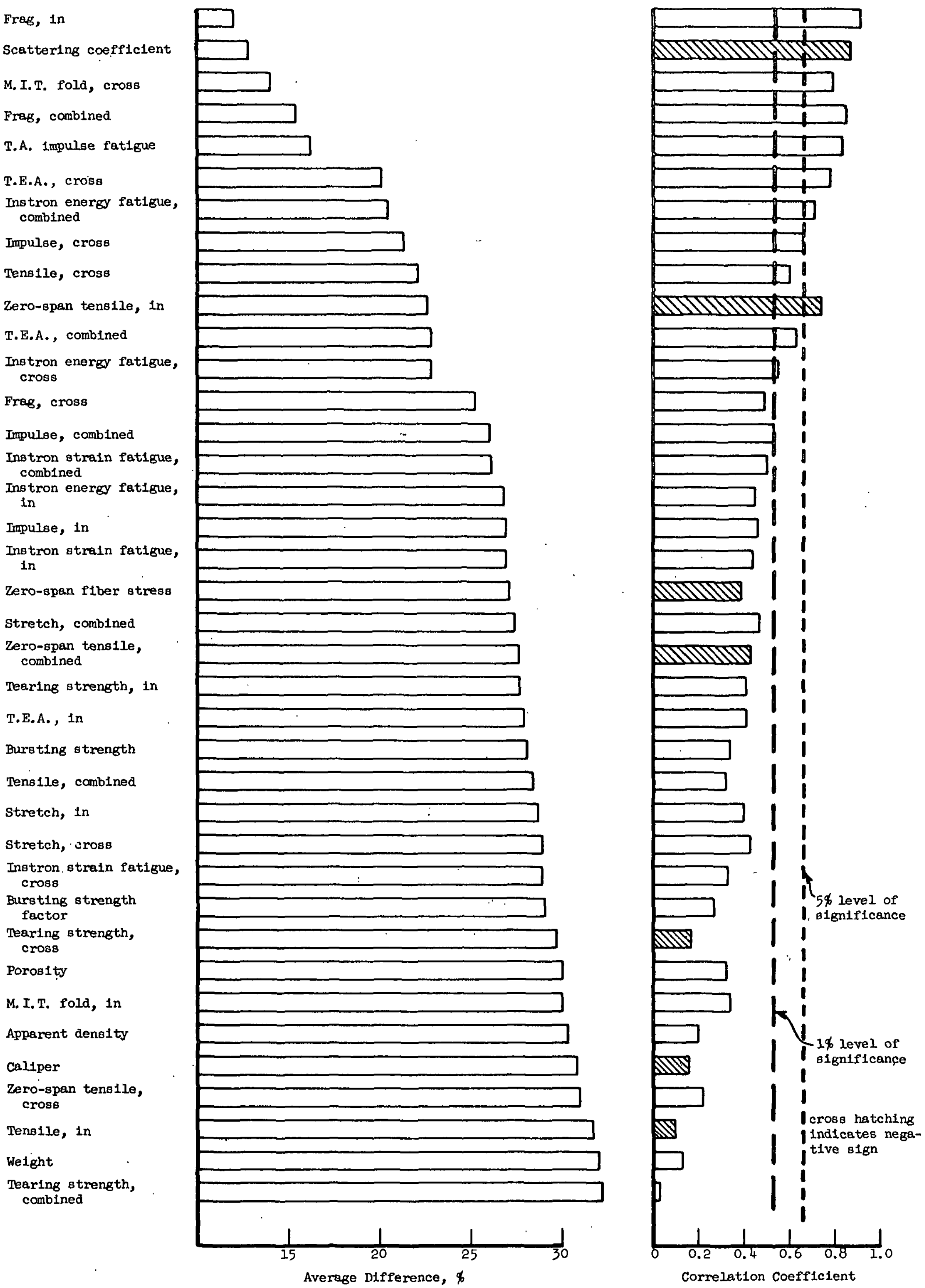

Figure 7. Comparative Ranking of Sack Paper Properties Based on Butt Drop Predictive Ability for Extensible Kraft Materials from Study II

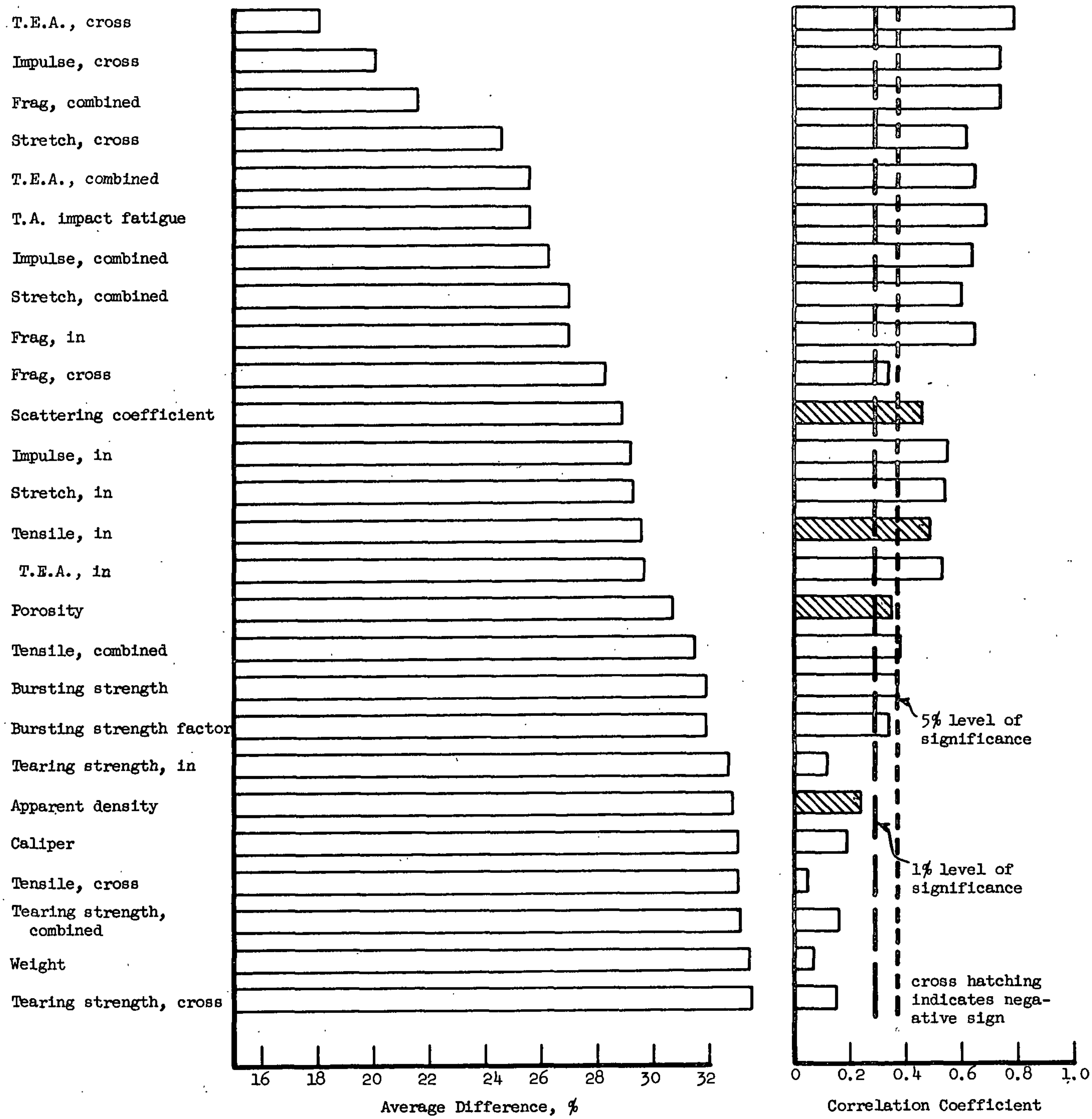

Figure 8. Comparative Ranking of Sack Paper Properties Based on Butt Drop Predictive Ability for Regular and Extensible Kraft Materials

TABLE II

COMPARISON OF FIVE PROPERTIES GIVING THE BEST PREDICTIONS
OF BUTT DROP PERFORMANCE FOR THE REGULAR KRAFT SACKS
OF STUDIES I AND II

Study I				Study II		
Property	Corr. Coeff.	Av. Diff., %		Property	Corr. Coeff.	Av. Diff., %
1. T.E.A., cross	0.79[a]	16.4		1. Frag, cross	0.93[a]	7.7
2. Impulse, cross	0.79[a]	16.9		2. T.E.A., combined	0.85[a]	11.2
3. Frag, cross	0.75[a]	17.8		3. T.E.A., cross	0.83[a]	12.1
4. T.E.A., combined	0.60[a]	24.3		4. Impulse, cross	0.76[a]	14.4
5. Stretch, cross	0.52[b]	24.9		5. Impulse, combined	0.77[a]	15.4

[a]Significant at 1% level.

[b]Significant at 5% level.

Note: Only properties evaluated in both studies were included in the tabulation.

3. In terms of agreement between predicted and observed butt drop values, cross-machine T.E.A. ranked first in Study I and cross-machine Frag ranked first in Study II.

4. The favorable correlations of cross-machine properties apparently occur because the predominant stresses in butt drop are in the cross-machine direction.

The T.E.A., Impulse, and Frag tests were discussed in Report Twenty-Nine as they also gave favorable correlations with face drop. [Note: Combined, in plus cross, values were better correlated with face drop.] In general, for face drop it was concluded that combined T.E.A. would be the most favorable property for specification or control purposes. For the same reasons it appears that cross-machine T.E.A. would be the most suitable single property where butt drop performance of flat kraft is concerned.

Properties exhibiting the least predictive ability for butt drop performance of flat kraft sacks were as follows:

	Study I			Study II		
	Property	Corr. Coeff.	Av. Prediction Diff., %	Property	Corr. Coeff.	Av. Prediction Diff., %
1.	High-speed work, in	-0.20	31.8	Bursting strength factor	0.39	23.5
2.	High-speed tensile, combined	-0.14	31.9	Zero-span tensile, in	-0.02	23.6
3.	Tearing strength, in	0.07	32.1	Zero-span tensile, cross	0.00	23.7
4.	Tensile, combined	-0.07	32.1	Zero-span tensile, combined	-0.01	23.7
5.	Stretch, in	-0.09	32.3	M.I.T. fold, in	0.00	23.7
6.	Frag, in	0.10	32.3	Instron strain fatigue, in	0.18	23.7
7.	High-speed stretch, in	-0.07	32.4	Apparent density	-0.01	23.8
8.	Tensile, cross	0.25	32.4	Caliper	0.04	23.9
9.	Impulse, in	-0.12	32.4	Zero-span fiber stress	0.10	23.9
10.	High-speed tensile, cross	0.12	32.6	Tensile, in	0.14	24.1

EXTENSIBLE SACK PERFORMANCE – STUDY II

Figure 7 shows the ranking of the various physical characteristics of the sack paper for the extensible papers of Study II. Omitting properties not evaluated in both studies, the five best properties for predictive purposes were as shown in Table III.

TABLE III

PROPERTIES EXHIBITING THE BEST PREDICTIONS OF THE BUTT DROP PERFORMANCE OF EXTENSIBLE SACKS

Property	Corr. Coeff.[a]	Av. Prediction Diff., %
1. Frag, in	0.91	12.0
2. Scattering coefficient	-0.87	12.8
3. Frag, combined	0.85	15.4
4. T.A. impact fatigue	0.83	16.2
5. T.E.A., cross	0.78	20.1

[a]Significant at the 1% level.

In-machine Frag and the scattering coefficient gave better estimates of the butt drop performance than the other properties. Combined Frag, T.A. impact fatigue and cross-machine T.E.A. followed in that order. The same properties were of importance to face drop as discussed in Report Twenty-Nine.

Scattering coefficient as a measure of the unbonded area is indirectly related to the bonded area — one of the basic factors in sheet strength. While not usually considered suitable for specification, as a nondestructive property it could be useful in automatic control applications.

If the fatigue tests — Frag and T.A. impact fatigue — are considered unsuitable for control or specifications, the properties giving the more favorable predictions of extensible sack performance are (1) scattering coefficient and (2) cross-machine T.E.A.

The properties giving the poorer predictions of extensible sack butt drop are shown in Table IV. As may be noted, combined tear, cross-machine tear, and machine-direction tensile were among the properties giving the poorest predictions of butt drop performance.

TABLE IV

PROPERTIES GIVING POOREST PREDICTIONS OF
EXTENSIBLE SACK PERFORMANCE

	Property	Corr. Coeff.	Av. Prediction Diff., %
1.	Bursting strength factor	0.27	29.3
2.	Tearing strength, cross	-0.17	29.7
3.	Porosity	0.32	30.0
4.	M.I.T. fold, in	0.34	30.0
5.	Apparent density	0.20	30.3
6.	Caliper	-0.16	30.8
7.	Zero-span tensile, cross	0.22	30.9
8.	Tensile, in	-0.10	31.7
9.	Weight	0.13	32.0
10.	Tearing strength, combined	0.03	32.2

COMBINED REGULAR AND EXTENSIBLE SACK DATA

For the combined data, the correlation and prediction percentage differences are illustrated in Fig. 8. Because of the greater range covered by the combined data, many properties exhibited highly significant correlations. The six best properties in terms of face drop prediction are shown in Table V.

TABLE V

PROPERTIES EXHIBITING THE BEST PREDICTIONS OF BUTT DROP PERFORMANCE FOR THE COMBINED REGULAR AND EXTENSIBLE DATA

	Property	Corr. Coeff.[a]	Av. Prediction Diff., %
1.	T.E.A., cross	0.79	18.1
2.	Impulse, cross	0.74	20.1
3.	Frag, combined	0.74	21.6
4.	Stretch, cross	0.62	24.6
5.	T.E.A., combined	0.65	25.6
6.	T.A. impact fatigue	0.69	25.6

[a]Significant at the 1% level.

The properties in Table V are nearly the same as those listed for the flat kraft sack data above.

A comparative ranking of the better properties for butt drop prediction is shown in Table VI. On an over-all basis the data indicate that properties giving the best prediction of face drop performance are as follows:

1. T.E.A., cross
2. Impulse, cross
3. Frag, combined
4. T.E.A., combined
5. Frag, cross

TABLE VI

COMPARATIVE RANKING WITH REGARD TO BUTT DROP PREDICTION

Property	Rank[a] Regular Sacks Study I	Study II	Extensible Sacks	Combined Data	Composite Rank
T.E.A., cross	1	3	5	1	10
Impulse, cross	2	4	6	2	14
Frag, cross	3	1	9	10	23
T.E.A., combined	4	2	8	5	19
Stretch, cross	5	9	18	4	36
Impulse, combined	8	5	10	7	30
Frag, combined	6	6	3	3	18
Stretch, combined	7	7	12	8	34
Tensile, cross	25	8	7	23	63
Frag, in	24	21	1	9	55
Scattering coeff.	19	10	2	11	42
T.A. impact fatigue	20	12	4	6	42

[a]Based on average percentage prediction difference.

The accent on cross-machine properties can be attributed to the high cross-direction stresses induced in butt drop. In this analysis the cross-machine properties give better predictions than the sum of in and cross directions. This is because the sum gives equal weight to both directions. The two factor correlations carried out in Reference (2) indicate that slight improvements in prediction are obtained using both in and cross T.E.A., however, the regression constants give major weight to cross-direction T.E.A.

If the Frag fatigue test is omitted because of its variability and other weaknesses, the best properties for butt drop prediction are cross-machine T.E.A. and impulse and combined T.E.A. The regression equations for the combined data are given below:

1. T.E.A., cross: $B = -27.2 + 177.8\ W_y$ (1)

3. Impulse, cross: $B = -32.3 + 11.3\ I_y$ (2)

2. T.E.A., combined: $B = 29.1 + 32.7\ [W_x + W_y]$ (3)

where

$\underline{B}$ = butt drop, safe inch

$\underline{W_x}$, $\underline{W_y}$ = T.E.A., in and cross

$\underline{I_y}$ = Impulse, cross

To improve butt drop performance by 10% at a level of 60 safe inches, Equations (1), (2), and (3) imply that the cross-machine T.E.A. must be increased by about 7%, cross-machine impulse by about 7%, or combined T.E.A. by about 20%.

TABLE VII

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND BUTT DROP OF PASTED VALVE SACKS

(Study I – 20 regular kraft samples)

	Variable	Regression Constants[a] Intercept	Regression Constants[a] Slope	Corr. Coeff.	Av. Diff.,[b] %	Per Cent of Comparisons Within ± 10%	± 15%	± 25%
1.	Weight	274.3	-4.134(4.4)	-0.22	31.0	20.0	25.0	55.0
2.	Caliper	129.7	-12.22 (9.9)	-0.28	31.0	15.0	30.0	60.0
3.	Apparent density	7.2	5.902(5.4)	0.25	31.5	15.0	30.0	60.0
4.	Bursting strength	105.1	-1.084(1.1)	-0.23	30.6	20.0	30.0	55.0
5.	Bursting strength factor	98.9	-47.41(55.5)	-0.20	31.1	15.0	30.0	55.0
6.	Tearing strength, in	45.8	0.1353(0.48)	0.07	32.1	20.0	30.0	50.0
7.	Tearing strength, cross	153.1	-0.6905(0.39)	-0.39	28.8	20.0	30.0	55.0
8.	Tearing strength, combined	121.8	-0.2329(0.26)	-0.21	31.7	20.0	20.0	55.0
9.	Tensile, in	156.1	-2.785 (1.8)	-0.34	28.5	20.0	35.0	60.0
10.	Tensile, cross	23.2	2.047 (1.8)	0.25	32.4	25.0	30.0	50.0
11.	Tensile, combined	83.6	-0.3995(1.4)	-0.07	32.1	20.0	25.0	60.0
12.	Stretch, in	75.0	-7.792(20.3)	-0.09	32.3	20.0	30.0	50.0
13.	Stretch, cross	21.1	10.92 (4.2)	0.52	24.9	25.0	45.0	60.0
14.	Stretch, combined	7.6	10.15 (4.2)	0.50	26.2	25.0	40.0	60.0
15.	T.E.A., in	79.3	-47.45(65.3)	-0.17	31.5	15.0	35.0	60.0
16.	T.E.A., cross	-8.9	134.7 (24.9)	0.79	16.4	45.0	65.0	75.0
17.	T.E.A., combined	-17.1	89.97(28.3)	0.60	24.3	30.0	30.0	65.0
18.	Frag, in	54.3	0.0202(0.05)	0.10	32.3	15.0	30.0	55.0
19.	Frag, cross	-5.9	0.1145(0.02)	0.75	17.8	35.0	60.0	75.0
20.	Frag, combined	8.2	0.0542(0.02)	0.54	26.1	20.0	40.0	55.0
21.	Impulse, in	76.5	-1.702(3.3)	-0.12	32.4	20.0	30.0	50.0
22.	Impulse, cross	-23.1	9.453(1.7)	0.79	16.9	35.0	50.0	80.0
23.	Impulse, combined	-23.1	4.947(1.8)	0.54	27.1	20.0	30.0	60.0
24.	T.A. impact fatigue	52.2	0.4536(0.64)	0.17	31.8	15.0	30.0	55.0
25.	Porosity	52.2	0.7775(0.37)	0.44	29.7	30.0	40.0	60.0
26.	Scattering coefficient	114.0	-0.2090(0.21)	-0.23	31.7	20.0	25.0	55.0
27.	van der Korput energy, in	78.0	-8.127(10.9)	-0.17	31.6	15.0	35.0	60.0
28.	van der Korput energy, cross	-18.2	31.88 (4.5)	0.86	14.6	40.0	60.0	85.0
29.	van der Korput energy, combined	-13.6	17.14 (5.7)	0.58	25.2	25.0	35.0	65.0
30.	High-speed tensile, in	205.7	-5.090(2.7)	-0.41	28.5	25.0	40.0	50.0
31.	High-speed tensile, cross	41.9	1.131(2.1)	0.12	32.6	15.0	30.0	50.0
32.	High-speed tensile, combined	109.2	-1.010(1.7)	-0.14	31.9	20.0	35.0	60.0
33.	High-speed stretch, in	74.7	-7.3181(23.6)	-0.07	32.4	20.0	25.0	50.0
34.	High-speed stretch, cross	8.6	16.18 (5.2)	0.59	22.6	25.0	45.0	60.0
35.	High-speed stretch, combined	-17.2	15.93 (5.3)	0.58	23.7	30.0	35.0	55.0
36.	High-speed work, in	87.5	-69.87 (82.4)	-0.20	31.8	15.0	35.0	55.0
37.	High-speed work, cross	-19.1	162.6 (29.3)	0.79	14.5	60.0	60.0	80.0
38.	High-speed work, combined	-32.1	109.8 (34.1)	0.61	23.9	30.0	40.0	55.0

[a]Butt drop expressed in safe inches.
[b]Based on observed value as reference.

TABLE VIII

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND BUTT DROP OF PASTED VALVE SACKS

(Study II - 12 regular kraft samples)

	Variable	Regression Constants[a] Intercept	Regression Constants[a] Slope	Corr. Coeff.	Av. Diff., %[b]	Per Cent of Comparisons Within ± 10%	± 15%	± 25%
1.	Weight	-94.8	2.895(4.8)	0.19	22.8	33.3	50.0	58.3
2.	Caliper	46.1	1.137(8.7)	0.04	23.9	41.7	50.0	66.7
3.	Apparent density	55.2	-0.2571(6.4)	-0.01	23.8	41.7	50.0	66.7
4.	Bursting strength	-6.9	1.556(1.1)	0.42	23.0	25.0	50.0	75.0
5.	Bursting strength factor	-1.7	72.45(54.1)	0.39	23.5	25.0	41.7	75.0
6.	Tearing strength, in	87.4	-0.2804(0.38)	-0.23	22.3	33.3	41.7	66.7
7.	Tearing strength, cross	129.9	-0.5904(0.59)	-0.30	22.3	33.3	41.7	66.7
8.	Tearing strength, combined	105.2	-0.2064(0.24)	-0.27	22.3	33.3	41.7	66.7
9.	Tensile, in	33.6	0.5812(1.3)	0.14	24.1	33.3	41.7	66.7
10.	Tensile, cross	-18.6	3.771 (2.0)	0.52	18.6	33.3	50.0	58.3
11.	Tensile, combined	-7.8	1.1609(0.99)	0.35	22.4	33.3	33.3	66.7
12.	Stretch, in	-24.9	51.64(22.3)	0.59	21.0	25.0	33.3	75.0
13.	Stretch, cross	4.9	14.5 (6.3)	0.58	19.4	25.0	25.0	75.0
14.	Stretch, combined	-20.6	15.2 (5.2)	0.68	17.6	25.0	41.7	83.3
15.	T.E.A., in	13.0	121.9 (71.7)	0.47	22.8	25.0	33.3	66.7
16.	T.E.A., cross	-8.9	132.8 (28.2)	0.83	12.1	41.7	66.7	100.0
17.	T.E.A., combined	-28.4	102.5 (20.2)	0.85	11.2	58.3	66.7	91.7
18.	Frag, in	31.1	0.0577(0.04)	0.42	23.3	25.0	41.7	75.0
19.	Frag, cross	-12.6	0.1357(0.02)	0.93	7.7	66.7	83.3	100.0
20.	Frag, combined	1.9	0.0593(0.02)	0.75	15.8	41.7	50.0	83.3
21.	Impulse, in	-7.8	7.876(5.1)	0.44	23.0	33.3	33.3	75.0
22.	Impulse, cross	-32.8	11.62 (3.2)	0.76	14.4	50.0	58.3	66.7
23.	Impulse, combined	-66.3	7.899(2.1)	0.77	15.4	33.3	50.0	75.0
24.	Impact fatigue	36.4	1.051(0.46)	0.59	21.0	25.0	33.3	75.0
25.	Porosity	44.3	0.9869(0.95)	0.31	23.4	16.7	50.0	58.3
26.	Scattering coefficient	202.0	-0.5991(0.34)	-0.49	20.1	50.0	50.0	66.7
27.	Zero-span tensile, in	57.0	-0.0562(0.97)	-0.02	23.6	41.7	50.0	66.7
28.	Zero-span tensile, cross	51.5	0.0264(1.7)	0.00	23.7	41.7	50.0	66.7
29.	Zero-span tensile, combined	58.1	-0.0399(0.9)	-0.01	23.7	41.7	50.0	66.7
30.	Zero span, fiber stress	14.6	0.6781(2.0)	0.10	23.9	25.0	50.0	66.7
31.	M.I.T. fold, in	53.0	0.00003(0.03)	0.00	23.7	41.7	50.0	66.7
32.	M.I.T. fold, cross	34.6	0.0418 (0.04)	0.30	22.0	41.7	50.0	66.7
33.	Instron strain fatigue, in	35.8	4.502(7.9)	0.18	23.7	25.0	41.7	66.7
34.	Instron strain fatigue, cross	8.2	10.07 (6.0)	0.47	21.2	25.0	33.3	66.7
35.	Instron strain fatigue, total	-5.5	7.071(4.4)	0.45	21.3	33.3	41.7	66.7
36.	Instron energy fatigue, in	30.0	4.086(2.8)	0.42	22.8	25.0	33.3	75.0
37.	Instron energy fatigue, cross	-7.5	11.14 (3.2)	0.74	12.1	58.3	58.3	91.7
38.	Instron energy fatigue, total	-0.3	4.819(1.7)	0.67	16.2	33.3	58.3	91.7

[a]Butt drop expressed in safe inches.
[b]Based on observed value as reference.

TABLE IX

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND BUTT DROP OF PASTED VALVE SACKS

(Study II — 14 extensible kraft samples)

	Variable	Regression Constants[a] Intercept	Regression Constants[a] Slope	Corr. Coeff.	Av. Diff.,[b] %	Per Cent of Comparisons Within ± 10%	± 15%	± 25%
1.	Weight	-56.4	2.730(6.1)	0.13	32.0	14.3	21.4	50.0
2.	Caliper	115.9	-5.590(10.0)	-0.16	30.8	21.4	28.6	50.0
3.	Apparent density	25.7	6.398(8.9)	0.20	30.3	21.4	28.6	50.0
4.	Bursting strength	-15.9	2.214(1.8)	0.34	28.1	28.6	28.6	57.1
5.	Bursting strength factor	10.9	83.30 (84.6)	0.27	29.3	21.4	28.6	57.1
6.	Tearing strength, in	-118.0	1.627(1.1)	0.41	27.7	14.3	28.6	50.0
7.	Tearing strength, cross	139.7	-0.3680(0.60)	-0.17	29.7	14.3	42.9	57.1
8.	Tearing strength, combined	71.6	0.0454(0.43)	0.03	32.2	7.1	28.6	50.0
9.	Tensile, in	109.0	-1.173(3.3)	-0.10	31.7	14.3	28.6	42.9
10.	Tensile, cross	-55.9	8.560(3.3)	0.60	22.1	28.6	35.7	57.1
11.	Tensile, combined	-29.1	3.013(2.6)	0.32	28.4	21.4	35.7	64.3
12.	Stretch, in	33.8	5.473(3.6)	0.40	28.7	14.3	28.6	64.3
13.	Stretch, cross	-30.7	24.72 (15.0)	0.43	28.9	7.1	28.6	64.3
14.	Stretch, combined	-0.35	6.102(3.3)	0.47	27.4	14.3	35.7	64.3
15.	T.E.A., in	13.6	56.64(36.7)	0.41	27.9	28.6	35.7	64.3
16.	T.E.A., cross	-61.0	251.9 (57.4)	0.78	20.1	21.4	64.3	71.4
17.	T.E.A., combined	-51.1	74.27(26.3)	0.63	22.8	35.7	57.1	71.4
18.	Frag, in	-68.1	0.2180(0.03)	0.91	12.0	50.0	78.6	92.9
19.	Frag, cross	0.90	0.1850(0.09)	0.49	25.2	35.7	42.9	64.3
20.	Frag, combined	-76.8	0.1402(0.03)	0.85	15.4	42.9	50.0	78.6
21.	Impulse, in	22.0	2.634(1.5)	0.46	26.9	21.4	50.0	64.3
22.	Impulse, cross	-63.1	15.37 (5.1)	0.66	21.3	35.7	57.1	71.4
23.	Impulse, combined	-2.5	2.612(1.2)	0.53	26.0	21.4	42.9	64.3
24.	T.A. impact fatigue	-6.8	1.670(0.32)	0.83	16.2	35.7	50.0	78.6
25.	Porosity	66.0	1.460(1.3)	0.32	30.0	14.3	35.7	50.0
26.	Scattering coefficient	418.9	-1.370(0.22)	-0.87	12.8	42.9	57.1	100.0
27.	Zero-span tensile, in	311.2	-4.243(1.1)	-0.74	22.6	7.1	35.7	71.4
28.	Zero-span tensile, cross	9.4	1.468(1.9)	0.22	30.9	7.1	21.4	42.9
29.	Zero-span tensile, combined	288.1	-1.955(1.2)	-0.43	27.6	21.4	42.9	57.1
30.	Zero span, fiber stress	256.0	-3.749(2.6)	-0.39	27.1	42.9	42.9	42.9
31.	M.I.T. fold, in	48.4	0.0522(0.04)	0.34	30.0	7.1	21.4	50.0
32.	M.I.T. fold, cross	3.3	0.2094(0.05)	0.79	14.0	42.9	64.3	92.9
33.	Instron strain fatigue, in	-6.7	6.657(3.9)	0.44	26.9	28.6	28.6	50.0
34.	Instron strain fatigue, cross	-7.3	15.35(12.7)	0.33	28.9	21.4	35.7	57.1
35.	Instron strain fatigue, combined	-54.3	7.069(3.5)	0.50	26.1	21.4	35.7	57.1
36.	Instron energy fatigue, in	-29.9	10.48(5.9)	0.45	26.8	42.9	50.0	64.3
37.	Instron energy fatigue, cross	-6.6	14.77(6.5)	0.55	22.8	42.9	50.0	71.4
38.	Instron energy fatigue, combined	-126.3	12.37(3.6)	0.71	20.4	28.6	64.3	78.6

[a]Butt drop expressed in safe inches.
[b]Based on observed value as reference.

TABLE X

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND BUTT DROP OF PASTED VALVE SACKS

(Combined studies — 32 regular plus 14 extensible samples)

	Variable	Regression Constants[a] Intercept	Regression Constants[a] Slope	Corr. Coeff.	Av. Diff., %[b]	Per Cent of Comparisons Within ± 10%	± 15%	± 25%
1.	Weight	-14.4	1.579(3.4)	0.07	33.4	15.2	37.0	52.2
2.	Caliper	110.2	-7.647(5.9)	-0.19	33.0	26.1	32.6	47.8
3.	Apparent density	7.0	6.569(4.1)	0.24	32.8	23.9	30.4	47.8
4.	Bursting strength	-6.8	1.794(0.69)	0.37	31.9	26.1	37.0	56.5
5.	Bursting strength factor	-1.4	85.14 (35.0)	0.34	31.9	23.9	37.0	56.5
6.	Tearing strength, in	28.4	0.3091(0.39)	0.12	32.7	21.7	43.5	54.3
7.	Tearing strength, cross	31.4	0.2566(0.25)	0.15	33.5	19.6	34.8	54.3
8.	Tearing strength, combined	16.0	0.1942(0.18)	0.16	33.1	21.7	34.8	52.2
9.	Tensile, in	122.4	-1.872(0.50)	-0.49	29.6	23.9	30.4	54.3
10.	Tensile, cross	58.3	0.4509(1.5)	0.05	33.0	21.7	34.8	50.0
11.	Tensile, combined	123.3	-1.179(0.43)	-0.38	31.5	17.4	28.3	54.3
12.	Stretch, in	52.9	3.497(0.82)	0.54	29.3	28.3	32.6	56.5
13.	Stretch, cross	0.76	16.75 (3.2)	0.62	24.6	26.1	34.8	63.0
14.	Stretch, combined	40.0	3.400(0.68)	0.60	27.0	30.4	32.6	56.5
15.	T.E.A., in	48.4	29.33(7.0)	0.53	29.7	30.4	34.8	52.2
16.	T.E.A., cross	-27.2	177.8(21.1)	0.79	18.1	37.0	52.2	69.6
17.	T.E.A., combined	29.1	32.71(5.7)	0.65	25.6	30.4	34.8	63.0
18.	Frag, in	22.4	0.0908(0.02)	0.65	27.0	30.4	39.1	58.7
19.	Frag, cross	32.3	0.0656(0.03)	0.34	28.3	26.1	39.1	56.5
20.	Frag, combined	-20.0	0.086 (0.01)	0.74	21.6	19.6	41.3	69.6
21.	Impulse, in	44.7	1.711(0.39)	0.55	29.2	28.3	37.0	56.5
22.	Impulse, cross	-32.3	11.26 (1.5)	0.74	20.1	26.1	41.3	67.4
23.	Impulse, combined	27.7	1.806(0.33)	0.64	26.3	28.3	39.1	58.7
24.	T.A. impact fatigue	39.6	0.8834(0.14)	0.69	25.6	28.3	37.0	60.9
25.	Porosity	54.7	1.008 (0.40)	0.35	30.7	26.1	34.8	56.5
26.	Scattering coefficient	218.6	-0.6169(0.18)	-0.46	28.9	21.7	34.8	52.2

[a] Butt drop expressed in safe inches.
[b] Based on observed value as reference.

TABLE XI

COMPARATIVE RANKING OF SACK PAPER TESTS BASED ON BUTT DROP PREDICTIVE ABILITY FOR THE REGULAR KRAFT SAMPLES OF STUDY I

	Test Property	Corr. Coeff.	Av. Diff., %[c]
			26.9[d]
1.	High-speed work, cross	0.79[b]	14.5
2.	van der Korput energy, cross	0.86[b]	14.6
3.	T.E.A., cross	0.79[b]	16.4
4.	Impulse, cross	0.79[b]	16.9
5.	Frag, cross	0.75[b]	17.8
6.	High-speed stretch, cross	0.59[b]	22.6
7.	High-speed stretch, combined	0.58[b]	23.7
8.	High-speed work, combined	0.61[b]	23.9
9.	T.E.A., combined	0.60[b]	24.3
10.	Stretch, cross	0.52[a]	24.9
11.	van der Korput energy, combined	0.58[b]	25.2
12.	Frag, combined	0.54[a]	26.1
13.	Stretch, combined	0.50[a]	26.2
14.	Impulse, combined	0.54[a]	27.1
15.	Tensile, in	-0.34	28.5
16.	High-speed tensile, in	-0.41	28.5
17.	Tearing strength, cross	-0.39	28.8
18.	Porosity	0.44	29.7
19.	Bursting strength	-0.23	30.6
20.	Weight	-0.22	31.0
21.	Caliper	-0.28	31.0
22.	Bursting strength factor	-0.20	31.1
23.	Apparent density	0.25	31.5
24.	T.E.A., in	-0.17	31.5
25.	van der Korput energy, in	-0.17	31.6
26.	Tearing strength, combined	-0.21	31.7
27.	Scattering coefficient	-0.23	31.7
28.	T.A. impact fatigue	0.17	31.8
29.	High-speed work, in	-0.20	31.8
30.	High-speed tensile, combined	-0.14	31.9
31.	Tearing strength, in	0.07	32.1
32.	Tensile, combined	-0.07	32.1
33.	Stretch, in	-0.09	32.3
34.	Frag, in	0.10	32.3
35.	High-speed stretch, in	-0.07	32.4
36.	Tensile, cross	0.25	32.4
37.	Impulse, in	-0.12	32.4
38.	High-speed tensile, cross	0.12	32.6

[a] Significant at 05 level.
[b] Significant at 01 level.
[c] The average difference between computed and observed butt drop values in safe inches.
[d] Average percentage difference of face drop values about their own average.

TABLE XII

COMPARATIVE RANKING OF SACK PAPER TESTS BASED ON BUTT DROP PREDICTIVE ABILITY FOR THE REGULAR KRAFT SAMPLES OF STUDY II

	Test Property	Corr. Coeff.	Av. Diff., %[c]
			20.4[d]
1.	Frag, cross	0.93[b]	7.7
2.	T.E.A., combined	0.85[b]	11.2
3.	T.E.A., cross	0.83[b]	12.1
4.	Instron energy fatigue, cross	0.74[b]	12.1
5.	Impulse, cross	0.76[b]	14.4
6.	Impulse, combined	0.77[b]	15.4
7.	Frag, combined	0.75[b]	15.8
8.	Instron energy fatigue, combined	0.67[a]	16.2
9.	Stretch, combined	0.68[a]	17.6
10.	Tensile, cross	0.52	18.6
11.	Stretch, cross	0.58[a]	19.4
12.	Scattering coefficient	-0.49	20.1
13.	Stretch, in	0.59[a]	21.0
14.	T.A. impact fatigue	0.59[a]	21.0
15.	Instron strain fatigue, cross	0.47	21.2
16.	Instron strain fatigue, combined	0.45	21.3
17.	M.I.T. fold, cross	0.30	22.0
18.	Tearing strength, in	-0.23	22.3
19.	Tearing strength, cross	-0.30	22.3
20.	Tearing strength, combined	-0.27	22.3
21.	Tensile, combined	0.35	22.4
22.	Weight	0.19	22.8
23.	T.E.A., in	0.47	22.8
24.	Instron energy fatigue, in	0.42	22.8
25.	Bursting strength	0.42	23.0
26.	Impulse, in	0.44	23.0
27.	Frag, in	0.42	23.3
28.	Porosity	0.31	23.4
29.	Bursting strength factor	0.39	23.5
30.	Zero-span tensile, in	-0.02	23.6
31.	Zero-span tensile, cross	0.00	23.7
32.	Zero-span tensile, combined	-0.01	23.7
23.	M.I.T. fold, in	0.00	23.7
34.	Instron strain fatigue, in	0.18	23.7
35.	Apparent density	-0.01	23.8
36.	Caliper	0.04	23.9
37.	Zero-span fiber stress	0.10	23.9
38.	Tensile, in	0.14	24.1

[a]Significant at 05 level.
[b]Significant at 01 level.
[c]The average difference between computed and observed butt drop values in safe inches.
[d]Average percentage difference of face drop values about their own average.

TABLE XIII

COMPARATIVE RANKING OF SACK PAPER TESTS BASED ON BUTT DROP PREDICTIVE ABILITY FOR THE EXTENSIBLE KRAFT MATERIALS FROM STUDY II

	Test Property	Corr. Coeff.	Av. Diff., %[c]
			27.8[d]
1.	Frag, in	0.91[b]	12.0
2.	Scattering coefficient	-0.87[b]	12.8
3.	M.I.T. fold, cross	0.79[b]	14.0
4.	Frag, combined	0.85[b]	15.4
5.	T.A. impact fatigue	0.83[b]	16.2
6.	T.E.A., cross	0.78[b]	20.1
7.	Instron energy fatigue, combined	0.71[b]	20.4
8.	Impulse, cross	0.66[b]	21.3
9.	Tensile, cross	0.60[a]	22.1
10.	Zero-span tensile, in	-0.74[b]	22.6
11.	T.E.A., combined	0.63[a]	22.8
12.	Instron energy fatigue, cross	0.55[a]	22.8
13.	Frag, cross	0.49	25.2
14.	Impulse, combined	0.53[a]	26.0
15.	Instron strain fatigue, combined	0.50	26.1
16.	Instron energy fatigue, in	0.45	26.8
17.	Impulse, in	0.46	26.9
18.	Instron strain fatigue, in	0.44	26.9
19.	Zero-span fiber stress	-0.39	27.1
20.	Stretch, combined	0.47	27.4
21.	Zero-span tensile, combined	-0.43	27.6
22.	Tearing strength, in	0.41	27.7
23.	T.E.A., in	0.41	27.9
24.	Bursting strength	0.34	28.1
25.	Tensile, combined	0.32	28.4
26.	Stretch, in	0.40	28.7
27.	Stretch, cross	0.43	28.9
28.	Instron strain fatigue, cross	0.33	28.9
29.	Bursting strength factor	0.27	29.3
30.	Tearing strength, cross	-0.17	29.7
31.	Porosity	0.32	30.0
32.	M.I.T. fold, in	0.34	30.0
33.	Apparent density	0.20	30.3
34.	Caliper	-0.16	30.8
35.	Zero-span tensile, cross	0.22	30.9
36.	Tensile, in	-0.10	31.7
37.	Weight	0.13	32.0
38.	Tearing strength, combined	0.03	32.2

[a]Significant at the 05 level.
[b]Significant at the 01 level.
[c]The average difference between computed and observed butt drop values in safe inches.
[d]Average percentage difference of butt drop values about their own average.

TABLE XIV

COMPARATIVE RANKING OF SACK PAPER TESTS BASED ON ~~FACE~~ Butt DROP PREDICTIVE ABILITY FOR THE COMBINED STUDIES INVOLVING REGULAR AND EXTENSIBLE MATERIAL

	Test Property	Corr. Coeff.	Av. Diff., %[c]
			29.0[d]
1.	T.E.A., cross	0.79[b]	18.1
2.	Impulse, cross	0.74[b]	20.1
3.	Frag, combined	0.74[b]	21.6
4.	Stretch, cross	0.62[b]	24.6
5.	T.E.A., combined	0.65[b]	25.6
6.	T.A. impact fatigue	0.69[b]	25.6
7.	Impulse, combined	0.64[b]	26.3
8.	Stretch, combined	0.60[b]	27.0
9.	Frag, in	0.65[b]	27.0
10.	Frag, cross	0.34[a]	28.3
11.	Scattering coefficient	-0.46[b]	28.9
12.	Impulse, in	0.55[b]	29.2
13.	Stretch, in	0.54[b]	29.3
14.	Tensile, in	-0.49[b]	29.6
15.	T.E.A., in	0.53[b]	29.7
16.	Porosity	0.35[a]	30.7
17.	Tensile, combined	-0.38[b]	31.5
18.	Bursting strength	0.37[a]	31.9
19.	Bursting strength factor	0.34[a]	31.9
20.	Tearing strength, in	0.12	32.7
21.	Apparent density	0.24	32.8
22.	Caliper	-0.19	33.0
23.	Tensile, cross	0.05	33.0
24.	Tearing strength, combined	0.16	33.1
25.	Weight	0.07	33.4
26.	Tearing strength, cross	0.15	33.5

[a] Significant at 05 level.
[b] Significant at 01 level.
[c] The average difference between computed and observed butt drop values in safe inches.
[d] Average percentage difference of face drop values about their own averages.