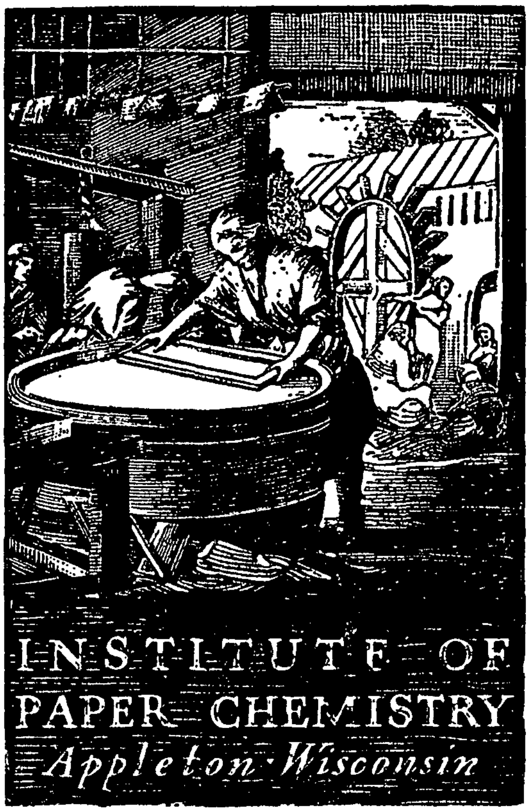

RELATIONSHIP BETWEEN SACK DROP AND SACK PAPER PROPERTIES

PART IV. MULTIPLE LINEAR CORRELATIONS BETWEEN BUTT DROP PERFORMANCE AND COMBINATIONS OF SACK PAPER PROPERTIES

Project 2033

Report Thirty-Seven

A Progress Report

to

MULTIWALL SHIPPING SACK PAPER MANUFACTURERS

June 10, 1966

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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SUMMARY OF RESULTS

During this contractual period, the policy committee requested that past data be reanalyzed so that the information may be utilized in practical applications directed toward improvement in sack paper manufacture and sack performance. Reports Twenty-Nine and Thirty-One discussed the relationships between individual sack paper properties and face and butt drop, respectively. Report Thirty-Four discussed the relationship between face drop performance and various combinations of sack paper properties using multiple correlation techniques.

In Report Thirty-One the best predictions of butt drop performance for the 50-lb. flat and extensible papers used in past studies were obtained with the properties shown in Table I.

Based on these results and on the difficulties in using fatigue-type tests in mill evaluation and control, the results in Report Thirty-One indicated that cross-machine T.E.A. is the best single property for the prediction of butt drop sack performance. However, 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.

This report discusses the linear relationship between face drop performance and combinations of sack paper properties. As in Report Thirty-One, the analysis was carried out separately for the flat kraft combinations of

TABLE I

INDIVIDUAL PROPERTIES BEST RELATED TO BUTT DROP

Property	Correlation Coefficient[a]	Av. Prediction Diff. %[b]
Flat Kraft – Study I ($\underline{N}$ = 20)		
1. T.E.A., cross	0.79	16.4
2. Impulse, cross	0.79	16.9
3. Frag, cross	0.75	17.8
4. T.E.A., combined	0.60	24.3
5. Stretch, cross	0.52[c]	24.9
Flat Kraft – Study II ($\underline{N}$ = 12)		
1. Frag, cross	0.93	7.7
2. T.E.A., combined	0.85	11.2
3. T.E.A., cross	0.83	12.1
4. Impulse, cross	0.76	14.4
5. Impulse, combined	0.77	15.4
Extensible Kraft – Study II ($\underline{N}$ = 14)		
1. Frag, in	0.91	12.0
2. Scattering coefficient	-0.87	12.8
3. Frag, combined	0.85	15.4
4. TA impact fatigue	0.83	16.2
5. T.E.A., cross	0.78	20.1
Combined Flat and Extensible Kraft ($\underline{N}$ = 46)		
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. TA impact fatigue	0.69	25.6

[a] Significant at the 1% level.
[b] Average difference in percent between observed and computed face drop based on the observed value as reference.
[c] Significant at the 5% level.

Note: T.E.A. = Tensile energy absorption.

Studies I and II, for the extensible kraft combinations of Study II, and for the combined data. All data were obtained at 50% R.H.

The merits of the multiple linear regressions were judged in terms of the following:

1. The regression coefficients for the individual variables should be statistically significant at the 5% level.

2. The coefficient of multiple correlation (R) should be as high as reasonably possible in keeping with (1) above. Also, it should exhibit improvement over the simple correlation coefficients for the properties involved.

3. The selected properties should bear some logical relationship to butt drop performance and the sign of the regression coefficients (positive or negative) should be consistent with general experience.

For this summary, a number of the multiple factor relationships which were investigated in the study are shown for each data subdivision. The remainder of the relationships investigated are discussed in the main body of the text. In general, the relationships discussed in the summary exhibited some promise in one or more phases of this study or in the literature. Also, a few relationships were included to illustrate results obtained with properties in current sack paper specifications. In addition, the multiple factor relationships are compared with the properties exhibiting the greatest promise as single factors in Report Thirty-One.

FLAT KRAFT PAPERS

Comparisons of selected single and multiple factor relationships are shown in Tables II and III for the flat kraft sacks of Study I and II, respectively. Based on these results and the additional correlations discussed in later pages, the following conclusions may be reached.

1. Excluding fatigue properties, no relationships were found which fully met the above criteria for the data of both studies. However, comparing the multiple correlations with the results based on C.D. T.E.A. alone (Regressions 201 and 211), it may be noted that a modest improvement was obtained in Study I using C.D. tensile and C.D. T.E.A. (see Regression 28). A slight additional increase in correlation coefficient was obtained in the three-factor relationship (see Regression 27) utilizing M.D. tear, C.D. tensile and C.D. T.E.A. though M.D. tear failed to reach significance at the 5% level. However, in Study II only slight improvements in correlation were obtained with the same regressions.

Qualitatively, butt drop should depend on cross-machine properties. Thus, the slight improvements noted above when C.D. tensile, C.D. T.E.A., and M.D. tear (sack failure line progresses in M.D. for butt drop) are reasonable in terms of this argument.

T.E.A. is a measure of the energy under the load-deformation curve. A given value of T.E.A. could, theoretically, be obtained in many different ways — e.g., high tensile and low stretch and vice versa. It can be speculated that butt drop performance will depend not only on cross-direction T.E.A. but also, to some degree, on how the T.E.A. level is achieved — i.e., on the shape of the load-deformation curve and on the ultimate tensile and stretch values. The above might help explain why C.D. tensile and T.E.A. could give an improved

TABLE II

COMPARISON OF SIMPLE AND MULTIPLE CORRELATIONS FOR STUDY I

($\underline{N}$ = 20)

No.	Regression Equation	Regression Significance ($\underline{F}$ Test)	Significant Variables 5% Level	Significant Variables 1% Level	Correlation Coefficient	Correlation Coefficient for Individual Tests Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[c]
	Single-Factor Relationships[d]								
200	B = 0.1145 FC - 5.9	--	FC	FC	0.75[b]	0.75	--	--	17.8
201	B = 134.7 WC - 8.9	--	WC	WC	0.79[b]	0.79	--	--	16.4
202	B = 9.453 IC - 23.1	--	IC	IC	0.79[b]	0.79	--	--	16.9
203	B = 89.97 WT - 17.1	--	WT	WT	0.60[b]	0.60	--	--	24.3
204	B = 0.0542 FT + 8.2	--	FT	--	0.54[a]	0.54	--	--	26.1
	Multiple Factor Relationships Excluding Fatigue Properties								
2	B = 1.06 TC - 0.606 EC + 121.8	1.67	None	None	0.41	0.25	-0.39	--	29.1
3	B = -0.604 TT - 0.251 ET + 158.3	0.47	None	None	0.23	-0.07	-0.21	--	30.9
4	B = 99.3 WT + 0.141 ET - 61.3	5.01[a]	WT	WT	0.61	0.60	-0.21	--	24.2
5	B = 143 WC + 0.136 ET - 47.7	14.50[b]	WC	WC	0.79	0.79	-0.21	--	16.8
6	B = 142 WC + 0.436 EI - 66.1	16.65[b]	WC	WC	0.81	0.79	0.07	--	15.8
28	B = 139 WC + 2.56 TC - 60.2	21.61[b]	TC,WC	WC	0.85	0.79	0.25	--	13.7
27	B = 145 WC + 2.45 TC + 0.391 EI - 109.2	16.24[b]	TC,WC	WC	0.87	0.79	0.25	0.07	14.7
29	B = 20.8 SC + 6.69 TC - 144.9	23.48[b]	TC,SC	TC,SC	0.86	0.52	0.25	--	14.0
30	B = -34.8 WI + 133.4 WC + 4.1	14.69[b]	WC	WC	0.80	-0.17	0.79	--	15.6
	Multiple Factor Relationships Including Fatigue Properties								
32	B = -0.096 FI + 0.15 FC + 10.3	20.96[b]	FI,FC	FI,FC	0.84	0.10	0.75	--	--
13	B = -0.074 FI + 0.11 FC + 48.7 WC + 0.7	14.89[b]	FC	None	0.86	0.10	0.75	0.79	--
12	B = 134 WC + 0.109 TA - 10.8	13.85[b]	WC	WC	0.79	0.79	0.23	--	--

[a]Significant at the 5% level.
[b]Significant at the 1% level.
[c]The average difference between predicted and observed butt drop using the given regression equation.
[d]The relationships shown gave the best butt drop predictions in Report Thirty-One.

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
T.A. fatigue	--	--	--	TA
Scattering coefficient	--	--	--	BA

TABLE III

COMPARISON OF SIMPLE AND MULTIPLE CORRELATIONS FOR THE FLAT KRAFT SACKS OF STUDY II

($\underline{N}$ = 12)

No.	Regression Equation	Regression Significance ($\underline{F}$ Test)	Significant Variables 5% Level	Significant Variables 1% Level	Correlation Coefficient ($\underline{R}$)	Correlation Coefficient for Individual Tests Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[c]
	Single-Factor Relationships[d]								
210	B = 0.1357 FC - 12.6	--	FC	FC	0.93[b]	0.93	--	--	7.7
211	B = 132.8 WC - 8.9	--	WC	WC	0.83[b]	0.83	--	--	12.1
212	B = 11.62 IC - 32.8	--	IC	IC	0.76[b]	0.76	--	--	14.4
213	B = 102.5 WT - 28.4	--	WT	WT	0.85[b]	0.85	--	--	11.2
214	B = 0.059 FT + 1.9	--	FT	FT	0.75[b]	0.75	--	--	15.8
	Multiple Factor Relationships Excluding Fatigue Properties								
2	B = 5.60 TC + 0.614 EC - 133.3	2.00	None	None	0.56	0.52	-0.30	--	17.2
3	B = 1.13 TT - 0.009 ET - 4.2	0.62	None	None	0.35	0.35	-0.27	--	22.3
4	B = 104 WT + 0.035 ET - 38.9	11.72[b]	WT	WT	0.85	0.85	-0.27	--	10.9
5	B = 133 WC + 0.0005 ET - 9.0	10.00[b]	WC	WC	0.83	0.83	-0.27	--	12.2
6	B = 131 WC - 0.050 EI - 2.1	10.08[b]	WC	WC	0.83	0.83	-0.23	--	11.8
28	B = 120 WC + 1.21 TC - 26.0	11.11[b]	WC	WC	0.84	0.83	0.52	--	11.5
27	B = 115 WC + 2.43 TC + 0.239 EI - 75.9	7.07[a]	WC	WC	0.85	0.83	0.52	-0.23	10.7
29	B = 16.3 SC + 4.37 TC - 84.2	10.55[b]	SC,TC	SC,TC	0.84	0.58	0.52	--	11.2
30	B = 64.0 WI + 121 WC - 24.4	13.23[b]	WC	WC	0.86	0.47	0.83	--	10.5
	Multiple Factor Relationships Including Fatigue Properties								
32	B = -0.031 FI + 0.15 FC - 10.4	42.46[b]	FC	FC	0.95	0.42	0.93	--	--
13	B = 0.017 FI + 0.03 FC + 84.0 WC - 6.3	9.04[b]	None	None	0.88	0.42	0.93	0.88	--
12	B = 114 WC + 0.63 TA - 10.3	18.10[b]	WC,TA	WC	0.90	0.83	0.59	--	--

[a]Significant at the 5% level.
[b]Significant at the 1% level.
[c]The average difference between predicted and observed butt drop using the given regression equation.
[d]The relationships shown gave the best butt drop predictions in Report Thirty-One.

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
T.A. fatigue	--	--	--	TA
Scattering coefficient	--	--	--	BA

correlation such as in Study I. This matter could be investigated in terms of the fatigue theory advanced in Report Eighteen.

2. Combinations of C.D. T.E.A. with tearing strength (M.D., C.D., or combined) gave little or no improvement in correlation as compared to C.D. T.E.A. alone.

3. The combination of M.D. and C.D. T.E.A. was little better than C.D. T.E.A. alone as noted in Report Twenty-One. Apparently, relatively large changes in M.D. T.E.A. are required to produce a noticeable change in butt drop performance.

4. Variations in crease strength must influence butt drop performance to some extent. Since the tests used in this analysis were carried out on the parent papers, variations in crease strength due to fabrication would not be accounted for and this would increase the error of prediction.

EXTENSIBLE KRAFT PAPERS

A summary of the extensible kraft results is tabulated in Table IV. The following conclusions may be drawn:

1. Excluding fatigue properties, the following relationships appeared to meet the three criteria mentioned earlier:

No.	Equation	Correlation Coefficient	Av. Prediction Diff., %
6	B = 254 WC + 1.68 EI - 270.4	0.89	13.3
15	B = 140 WC - 0.99 BA + 245.7	0.94	--
29	B = 27.65 SC + 9.11 TC - 193.2	0.77	20.0

TABLE IV

COMPARISON OF SELECTED SIMPLE AND MULTIPLE CORRELATIONS FOR THE EXTENSIBLE KRAFT SACKS OF STUDY II

(N = 14)

No.	Regression Equation	Regression Significance (F Test)	Significant Variables		Correlation Coefficient (R)	Correlation Coefficient for Individual Tests			Av. Prediction Diff., %[c]
			5% Level	1% Level		Prop. 1	Prop. 2	Prop. 3	
			Single-Factor Relationships[d]						
220	B = 0.2180 FI - 68.1	--	FI	FI	0.91[b]	0.91	--	--	12.0
221	B = -1.370 BA + 418.9	--	BA	BA	-0.87[b]	-0.87	--	--	12.8
222	B = 0.1402 FT - 76.8	--	FT	FT	0.85[b]	0.85	--	--	15.4
223	B = 1.670 TA - 6.8	--	TA	TA	0.83[b]	0.83	--	--	16.2
224	B = 251.9 WC - 61.0	--	WC	WC	0.78[b]	0.78	--	--	20.1
			Multiple Factor Relationships Excluding Fatigue Properties						
2	B = 9.81 TC + 0.367 EC - 131.8	3.43	TC	None	0.62	0.60	-0.17	--	22.0
3	B = 3.26 TT + 0.167 ET - 84.5	0.70	None	None	0.34	0.32	0.03	--	29.0
4	B = 85.7 WT - 0.379 ET + 32.3	4.56[a]	WT	None	0.67	0.63	0.03	--	20.8
5	B = 288 WC + 0.503 ET - 220.4	13.78[b]	WC	WC	0.84	0.78	0.03	--	15.0
6	B = 254 WC + 1.68 EI - 270.4	20.98[b]	WC,EI	WC	0.89	0.78	0.41	--	13.3
15	B = 140 WC - 0.99 BA + 245.7	45.75[b]	WC,BA	WC,BA	0.94	0.78	-0.87	--	--
28	B = 222 WC + 2.01 TC - 76.4	9.24[b]	WC	None	0.79	0.78	0.60	--	19.4
27	B = 241 WC + 0.862 TC + 1.65 EI - 273.7	12.86[b]	EI,WC	WC	0.89	0.78	0.60	0.41	13.5
29	B = 27.6 SC + 9.11 TC - 193.2	7.96[b]	SC,TC	TC	0.77	0.43	0.60	--	20.0
30	B = 31.9 WI + 233.4 WC - 90.4	10.94[b]	WC	WC	0.82	0.41	0.78	--	17.8
			Multiple Factor Relationships Including Fatigue Properties						
32	B = 0.22 FI + 0.0033 FC - 68.8	26.75[b]	FI	FI	0.91	0.91	0.49	--	--
13	B = 0.182 FI - 0.021 FC + 74.4 WC - 76.8	18.66[b]	FI	FI	0.92	0.91	0.49	0.78	--
12	B = 137 WC + 1.12 TA - 55.6	21.82[b]	WC,TA	TA	0.89	0.78	0.83	--	--
26A	B = 6.76 TC + 1.51 TA - 108.6	56.34[b]	TC,TA	TC,TA	0.96	0.60	0.83	--	--

[a]Significant at the 5% level.
[b]Significant at the 1% level.
[c]The average difference between computed and observed values of butt drop using the given regression equation.
[d]The relationships shown gave the best butt drop predictions in Report Thirty-One.

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
T.A. fatigue	--	--	--	TA
Scattering coefficient	--	--	--	BA

where $\underline{B}$ = Butt drop
$\overline{WC}$ = C.D. T.E.A.
$\overline{EI}$ = M.D. Elmendorf tear
$\overline{BA}$ = Scattering coefficient
$\overline{SC}$ = C.D. stretch
$\overline{TC}$ = C.D. tensile

Regression 29 is inferior to 6 or 15 and predictions of butt drop performance based on 29 are no better than those obtained using C.D. T.E.A. (see Regression 224). Predictions based on Regressions 6 or 15 were considerably better than those obtained using C.D. T.E.A. alone. They were about equal to the prediction accuracy achieved with M.D. frag or scattering coefficient alone (see Regressions 220 and 221).

2. Efforts to improve number six by incorporating C.D. tensile as a third factor were not successful (see Regression 27).

3. The combination of M.D. and C.D. T.E.A. was somewhat better than C.D. T.E.A. alone although the M.D. factor failed to reach significance at the 5% level.

4. Excluding fatigue properties, it appears that two-factor relationships using C.D. T.E.A. and M.D. tear or C.D. T.E.A. and scattering coefficient offer a significant improvement in predictive accuracy as compared to C.D. T.E.A. for these 50-lb. extensible pasted sacks.

5. When fatigue properties are considered, a two-factor relationship utilizing C.D. tensile and the T.A. impact fatigue test gave quite favorable results.

COMBINED DATA FOR FLAT AND EXTENSIBLE KRAFT PAPERS

A summary of the results obtained with the combined data is shown in Table V. Based on these results and the additional correlations described in later pages, the following conclusions may be reached.

1. Omitting fatigue properties, the following relationships exhibited some improvement relative to cross-direction T.E.A. alone (Regression 230).

No.	Equation	Corr. Coeff.	Av. Prediction Diff., %
230	B = 177.8 WC - 27.2	0.79	18.1
30	B = 316.9 WI + 155.0 WC - 25.6	0.84	16.5
24	B = 26.4 SC + 8.35 TC + 0.72 EC - 288.8	0.84	--
20	B = 189 WC + 2.42 TC + 0.47 ET - 200.4	0.86	17.3
21	B = 187 WC + 3.14 TC + 0.74 EC - 190.9	0.86	17.3

Note: Symbols defined as follows:

	M.D.	C.D.	Combined
Tensile	TI	TC	--
Stretch	SI	SC	--
T.E.A.	WI	WC	--
Tear	EI	EC	ET

As may be noted, Regression 30 which utilized in and cross-machine T.E.A. gave the best average prediction accuracy. Regressions 21 and 20 which utilized cross-machine T.E.A., cross-machine tensile, and either cross-machine tear or combined tear gave slightly higher correlation coefficients but the average prediction accuracy was slightly inferior to that obtained with Regression 30.

2. Therefore, for the 50-lb. flat and extensible kraft sacks of this study, cross-direction T.E.A. seems to be the most important variable governing butt drop performance. Small improvements in prediction accuracy are

TABLE V

COMPARISON OF SELECTED SIMPLE AND MULTIPLE CORRELATIONS FOR THE COMBINED DATA

($\underline{N}$ = 46)

No.	Regression Equation	Regression Significance ($\underline{F}$ Test)	Significant Variables 5% Level	Significant Variables 1% Level	Multiple Correlation Coefficient ($\underline{R}$)	Correlation Coefficient for Individual Tests Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[c]
	Single-Factor Relationships[d]								
230	B = 177.8 WC - 27.2	--	WC	WC	0.79	0.79	--	--	18.1
231	B = 11.26 IC - 32.3	--	IC	IC	0.74	0.74	--	--	21.6
232	B = 0.086 FT - 20.0	--	FT	FT	0.74	0.74	--	--	21.6
233	B = 16.75 SC + 0.76	--	SC	SC	0.62	0.62	--	--	24.6
234	B = 32.71 WT + 29.1	--	WT	WT	0.65	0.65	--	--	25.6
235	B = 0.883 TA + 39.6	--	TA	TA	0.69	0.69	--	--	25.6
	Multiple Factor Relationships Excluding Fatigue Properties								
2	B = 2.34 TC + 0.518 EC - 47.2	1.31	None	None	0.24	0.05	0.15	--	33.1
3	B = 1.34 TT - 0.109 ET + 159.7	3.85[a]	TT	None	0.39	-0.38	0.16	--	31.3
4	B = 36.4 WT - 0.199 ET + 76.7	17.62[b]	WT	WT	0.67	0.65	0.16	--	25.0
5	B = 185 WC + 0.315 ET - 113.1	46.78[b]	WC,ET	WC,ET	0.83	0.79	0.16	--	18.2
6	B = 184 WC + 0.565 EI - 99.9	42.33[b]	WC,EI	WC	0.81	0.79	0.12	--	18.5
7	B = 183 WC + 0.388 EC - 82.9	43.51[b]	WC,EC	WC	0.82	0.79	0.15	--	18.4
17	B = 168 WC + 1.14 BG - 68.6	43.54[b]	WC,BG	WC	0.82	0.79	0.37	--	--
28	B = 178 WC + 0.43 TC - 35.1	34.99[b]	WC	WC	0.79	0.79	0.05	--	17.9
27	B = 183 WC + 0.77 TC + 0.60 EI - 118.3	28.34[b]	WC,EI	WC	0.82	0.79	0.05	0.12	18.1
20	B = 189 WC + 2.42 TC + 0.47 ET - 200.4	37.90[b]	WC,TC,ET	WC,ET	0.86	0.79	0.05	0.16	17.3
21	B = 187 WC + 3.14 TC + 0.74 EC - 190.9	38.04[b]	WC,TC,EC	WC,TC,EC	0.86	0.79	0.05	0.15	17.3
29	B = 25.2 SC + 5.47 TC - 132.4	32.69[b]	SC,TC	SC,TC	0.78	0.62	0.05	--	18.0
24	B = 26.4 SC + 8.35 TC + 0.72 EC - 288.8	34.19[b]	SC,TC,EC	SC,TC,EC	0.84	0.62	0.05	0.15	--
30	B = 16.9 WI + 155.0 WC - 25.6	50.40[b]	WI,WC	WI,WC	0.84	0.53	0.79	--	16.5
31	B = 0.92 II + 9.43 IC - 27.9	35.77[b]	II,IC	II,IC	0.79	0.55	0.74	--	--
35	B = 1.91 SI + 12.5 SC + 9.9	17.27[b]	SI,SC	SC	0.67	0.54	0.62	--	--
	Multiple Factor Relationships Including Fatigue Properties								
32	B = 0.093 FI + 0.071 FC - 16.0	27.67[b]	FI,FC	FI,FC	0.75	0.65	0.34	--	--
13	B = 138 WC + 0.053 FI + 0.021 FC - 33.4	38.12[b]	WC,FI	WC,FI	0.86	0.79	0.65	0.34	--
12	B = 134 WC + 0.534 TA - 20.7	66.24[b]	WC,TA	WC,TA	0.87	0.79	0.69	--	--
26	B = 118 WC + 2.76 TC + 0.73 TA - 68.7	62.86[b]	WC,TA,TC	WC,TA,TC	0.90	0.79	0.05	0.69	--
25	B = 16.8 SC + 6.16 TC + 0.75 TA - 134.8	61.83[b]	SC,TA,TC	SC,TA,TC	0.90	0.62	0.05	0.69	--

[a]Significant at the 5% level.
[b]Significant at the 1% level.
[c]The average difference between predicted and observed butt drop using the given regression equation.
[d]The relationships shown gave the best butt drop predictions in Report Thirty-One.

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Elmendorf tear	EI	EC	ET	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
Bursting strength	--	--	--	BG
T.A. fatigue	--	--	--	TA

achieved by also considering machine-direction T.E.A. or cross-direction tensile and tearing strength. It is evident, however, that none of the relationships will accurately predict the relative butt drop performance of all 50-lb. sack paper combinations.

3. In some instances, loss of strength in the creased zones of the sacks may be responsible for low butt drop sack performance, and, consequently, poor prediction accuracy. It is speculated that if the degradation in the tensile load-deformation curve in the creased zones could be properly evaluated, significant improvements in the relationships studied herein might be obtained.

4. In addition to the above conclusions, it may be noted that the two-factor relationships based on tensile and tearing strength (see Regressions 2 and 3) gave relatively poor correlation coefficients and prediction accuracy for these 50-lb. kraft sack papers.

GENERAL CONCLUSIONS

Considering the results as a whole, it appears that predictions of butt drop based on C.D. T.E.A. can be slightly improved using three-factor relationships based on C.D. T.E.A., C.D. tensile and combined or C.D. tearing strength. As an alternative, a two-factor relationship using in- and cross-machine T.E.A. also gave slightly better butt drop predictions as compared to C.D. T.E.A. alone.

The slight improvements mentioned above when C.D. tear is combined with C.D. tensile and T.E.A. do not appear entirely logical because the direction of the rupture in the butt drop test proceeds generally in the machine direction. Perhaps, if a three-factor relationship is used it would be preferable to employ combined tear since it will depend, in part, on M.D. tear.

Butt drop must depend, in part, on crease strength because failures frequently occur along the side crease. With flat kraft papers some improvement in correlation was obtained using C.D. T.E.A. measured in creased areas. Evidently, the sacks in a number of the runs exhibited low crease strength and this was responsible for their low butt drop performance. Better methods of measuring crease strength degradation would be helpful for the regular kraft papers. However, properties measured in the crease areas gave little or no improvement for the extensible kraft runs. Other factors may be responsible for the poor predictions obtained for a few of the extensible kraft runs.

For the combined flat and extensible papers, frequency distributions of the percentage differences between computed and observed butt drop values are shown below for three of the regression equations.

Percent of Predictions with Indicated Percentage Range

Prediction Range, %	Predictions Based on C.D. T.E.A. (Regression No. 230)	Predictions Based on M.D. and C.D. T.E.A. (Regression No. 30)	Predictions Based on C.D. Tensile, Tear, T.E.A. (Regression No. 21)
0-10	37.0	41.3	37.0
10.1-20	19.6	37.0	30.4
20.1-30	28.3	6.5	19.6
30.1- -	15.2	15.2	13.0

Approximately 57% of the predictions were within ± 20% of the observed value using C.D. T.E.A.; 78% were within ± 20% using M.D. and C.D. T.E.A.; and 67% were within ± 20% using C.D. tensile, tear and T.E.A. The percentage of prediction errors greater than ± 30% is about the same for all three equations — near 15%. Considering the variability inherent in butt drop tests, variations in crease strength and other fabrication factors, and the variability in the sack paper properties, the fact that nearly 80% of the predictions based on in- and cross-machine T.E.A. are within 20% of the observed value is encouraging.

Therefore, based on this analysis it appears that either of the following relationships gives some improvement over cross-direction T.E.A. alone.

$$B = 116.9\ WI + 155.0\ WC - 25.6$$

$$B = 189\ WC + 242\ TC + 0.47\ ET - 200.4$$

where

WI = M.D. T.E.A.

WC = C.D. T.E.A.

TC = C.D. tensile

ET = combined tear

Further improvements in prediction will require (a) the development of a mathematical model which will take into account both the strains imposed during impact and the potential strength of the sack paper including crease strength and (b) better methods for evaluating those sheet properties which actually determine butt drop performance.

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APPENDIX I

PROCEDURES

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

Report No.	Report Date
Twelve	February 8, 1960
Twenty-One	October 1, 1962
Twenty-Two	August 31, 1962
Twenty-Three	October 16, 1962
Twenty-Four	July 22, 1962
Twenty-Five	October 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, flat kraft sacks – $\underline{N} = 20$

(b) Study II, flat kraft sacks – $\underline{N} = 12$

(c) Study II, extensible kraft sacks – $\underline{N} = 14$

(d) Combined data – $\underline{N} = 46$

A list of the properties considered is shown in Table VI. It may be seen that some properties included in Study I were not included in Study II and vice versa. The properties in this category included the following:

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

As noted in Report Twenty-Nine, Van der Korput energy and the high-speed tensile, stretch and work tests correlated well with Instron tests at conventional test rates. Therefore, tests on the Instron should be an adequate substitute for the Van der Korput or high-speed tests. The remaining tests — namely, zero-span tensile, M.I.T. fold, Instron strain fatigue, and Instron energy fatigue are considered to be research tools and undesirable for control or specification purposes. Therefore, they are not considered further in the analyses.

All data were obtained at 50% R.H. As in the previous analysis, normally satisfactory conversion is assumed. High failure frequencies in creased areas, adhesive joints, etc., are only considered in the final phase of the analysis.

For this report, linear multiple factor relationships between butt drop and various combinations of sack paper properties were obtained. In evaluating the utility of the various relationships the following criteria were employed:

1. The regression coefficients for the properties used in a given relationship should be statistically significant at the 0.05% level.

TABLE VI

TEST PROPERTIES

	Test Properties	Flat Kraft Study I Av.	Flat Kraft Study I Range, %	Flat Kraft Study II Av.	Flat Kraft Study II Range, %	Extensible Kraft Study II Av.	Extensible Kraft Study II Range, %
A	Nondestructive						
	1. Weight, lb./M ft.^{2}	51.2	9	51.0	5	51.4	8
	2. Caliper, pt.	5.5	29	6.0	32	5.7	54
	3. Apparent density	9.4	33	8.5	29	9.1	40
	4. Porosity, sec./100 cc.	13	401	9	145	12	175
	5. Scattering coeff.	246	28	249	13	244	21
B	Tensile Type						
	6. Instron tensile, lb./in., in	33.6	26	33.4	31	21.2	40
	7. cross	19.2	53	19.0	28	16.4	38
	8. Instron stretch, %, in	1.6	44	1.5	33	9.2	69
	9. cross	3.8	89	3.3	58	4.6	41
	10. Instron T.E.A., in. lb./in.^{2}, in	0.354	63	0.328	48	1.245	50
	11. cross	0.530	73	0.466	54	0.576	50
	12. High-speed tensile, lb./in., in	28.1	24	--	--	--	--
	13. cross	18.2	45	--	--	--	--
	14. High-speed stretch, %, in	1.7	35	--	--	--	--
	15. cross	3.3	79	--	--	--	--
	16. High-speed T.E.A., %, in	0.36	53	--	--	--	--
	17. cross	0.50	68	--	--	--	--
	18. Van der Korput T.E.A., kg./cm., in	1.91	74	--	--	--	--
	20. cross	2.53	72	--	--	--	--
	21. Impulse, MNs, in	8	62	7.7	30	23.6	56
	22. cross	9	78	7.4	39	9.6	42
	23. Bursting strength, p.s.i.	39.4	36	38.5	30	45.2	36
	24. Zero-span tensile, lb./in., in	--	--	71.2	20	53.5	28
	25. cross	--	--	56.9	15	50.9	22
	26. Zero-span fiber stress, lb./in.	--	--	57	12	45.8	21
C	Tension Fatigue						
	27. T.A. impact fatigue falls	23	104	16	163	54	85
	28. Frag, kg./m. x 10^{-4}, in	403	79	379	87	698	51
	29. cross	596	103	484	69	450	57
	30. Instron strain fatigue, cycles, in	--	--	3.8	58	13.6	44
	31. cross	--	--	4.4	45	6.0	33
	32. Instron energy fatigue, cycles, in	--	--	5.6	73	10.9	38
	33. cross	--	--	5.4	56	6.1	52
	34. M.I.T. fold, in	--	--	432	92	679	82
	35. cross	--	--	421	86	406	86
D	Tearing Strength						
	36. Elmendorf tear, g., in	123	30	123	27	124	19
	37. cross	131	25	130	16	151	32
	38. combined	255	28	253	21	275	25
E	Sack Tests						
	39. Face drop, safe inch	414	106	325	88	846	100
	40. Butt drop, safe inch	62	95	53	83	84	102

2. The coefficient of multiple correlation should be as high as reasonably possible in keeping with (1) and should exhibit some improvement over the simple correlation coefficients for the individual properties being considered.

3. The paper properties involved should bear some logical relationship to butt drop performance.

4. The sign (positive or negative) of the regression coefficients for the properties used in a given relationship should be consistent with general experience.

The same numbering system is used for each data subdivision — e.g., Equation (3) involves the same properties for each set of data to simplify comparisons between data subdivisions.

APPENDIX II

DISCUSSION OF RESULTS

FLAT KRAFT SACKS AND SACK PAPER - STUDIES I AND II

The multiple linear regressions obtained for this report with the flat kraft sack data are tabulated in Tables VII and VIII. The following results were obtained:

1. Two-factor combinations involving tensile and tear [see Equations (1)-(3)] were not effective as the "F" ratio was not significant at the 5% level and neither factor achieved significance in any of the three regressions. Thus, these equations indicate that tensile and tear taken together are not well related to the butt drop performance of sacks made from the 50-lb. flat kraft papers used in this study.

2. Combined T.E.A. in combination with combined tear [see Equation (4)] gave multiple correlation coefficients (0.61 and 0.85 for Studies I and II, respectively), which were essentially equal to the simple correlation coefficients obtained with combined T.E.A. (0.60 and 0.85 for Studies I and II, respectively). Also, while combined T.E.A. was a statistically significant property (1% level), combined tear did not reach significance at the 5% level. Thus, the results for both studies indicate that T.E.A. is more important than tearing strength to flat kraft butt drop performance though it may be of importance in other aspects of sack performance - e.g., nail tears, snags, etc.

3. Similar results were obtained using cross-machine T.E.A. in combination with M.D., C.D., and combined tear [see Equations (5)-(7)].

TABLE VII

MULTIPLE REGRESSIONS FOR FLAT KRAFT COMBINATIONS FROM STUDY I

(N = 20)

No.	Regression Coefficients[d] Prop. 1	Prop. 2	Prop. 3	Prop. 4	Constant	Regression Significance (F Test)	Significant Properties 5% Level	1% Level	Fraction Variance Removed (R^2)	Multiple Corr. Coeff. (R)	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction Diff., %[c]
1	-3.04 TI	-0.165 EI	--	--	185.2	1.18	None	None	0.12	0.35	-0.34	0.07	--	--	28.7
2	1.06 TC	-0.606 EC	--	--	121.8	1.67	None	None	0.16	0.41	0.25	-0.39	--	--	29.1
3	-0.604 TT	-0.251 ET	--	--	158.3	0.47	None	None	0.05	0.23	-0.07	-0.21	--	--	30.9
4	99.3 WT	0.141 ET	--	--	-61.3	5.01[a]	WT	WT	0.37	0.61	0.60	-0.21	--	--	24.2
5	143 WC	0.136 ET	--	--	-47.7	14.50[b]	WC	WC	0.63	0.79	0.79	-0.21	--	--	16.8
6	142 WC	0.436 EI	--	--	-66.1	16.65[b]	WC	WC	0.66	0.81	0.79	0.07	--	--	15.8
7	132 WC	-0.054 EC	--	--	-0.5	13.81[b]	WC	WC	0.62	0.79	0.79	-0.39	--	--	16.2
8	-27.3 WI	139 WC	0.095 ET	--	-25.8	9.43[b]	WC	WC	0.64	0.80	-0.17	0.79	-0.21	--	16.0
9	67.8 WC	5.42 IC	--	--	-22.5	17.54[b]	None	None	0.67	0.82	0.79	0.79	--	--	--
10	86.9 WC	0.055 FC	--	--	-16.3	17.31[b]	WC	None	0.67	0.82	0.79	0.75	--	--	--
11	136 WC	-0.008 FI	--	--	-6.3	13.85[b]	WC	WC	0.62	0.79	0.79	0.10	--	--	--
12	134 WC	0.109 TA	--	--	-10.8	13.85[b]	WC	WC	0.62	0.79	0.79	-0.23	--	--	--
13	48.7 WC	-0.074 FI	0.11 FC	--	0.7	14.89[b]	FC	None	0.74	0.86	0.79	0.10	0.75	--	--
14	49.7 WC	-0.093 FI	0.11 FC	0.33 TA	1.4	10.78[b]	FC	None	0.74	0.86	0.79	0.10	0.75	0.17	--
15	154 WC	0.20 BA	--	--	-68.3	16.11[b]	WC	WC	0.65	0.81	0.79	-0.23	--	--	--
16	135 WC	-0.036 FI	0.46 TA	--	-5.1	9.12[b]	WC	WC	0.63	0.79	0.79	0.10	0.17	--	--
17	142 WC	0.482 BG	--	--	-31.5	14.29[b]	WC	WC	0.63	0.79	0.79	-0.23	--	--	--
18	123 WC	0.345 PS	--	--	-7.4	15.94[b]	WC	WC	0.65	0.81	0.79	0.44	--	--	--
19	122 WC	0.129 TA	0.349 PS	--	-9.6	10.09[b]	WC	WC	0.65	0.81	0.79	0.17	0.44	--	--
20	153 WC	2.91 TC	0.236 ET	--	-134.7	16.22[b]	TC,WC	WC	0.75	0.87	0.79	0.25	-0.21	--	15.1
21	153 WC	3.08 TC	0.288 EC	--	-115.3	14.73[b]	TC,WC	WC	0.73	0.86	0.79	0.25	-0.39	--	14.7
22	153 WC	3.10 TC	0.288 EC	-0.006 PS	-115.7	10.35[b]	TC,WC	WC	0.73	0.86	0.79	0.25	-0.39	0.44	--
23	9.38 IC	1.58 TC	0.040 EC	--	-58.3	10.73[b]	IC	IC	0.67	0.82	0.79	0.25	-0.39	--	--
24	22.6 SC	7.50 TC	0.257 EC	--	-200.7	15.80[b]	TC,SC	TC,SC	0.75	0.86	0.52	0.25	-0.39	--	--
25	20.5 SC	6.78 TC	0.322 TA	--	-152.5	15.79[b]	TC,SC	TC,SC	0.75	0.86	0.52	0.25	0.17	--	--
26	136 WC	2.68 TC	0.258 TA	--	-67.2	14.15[b]	TC,WC	WC	0.73	0.85	0.79	0.25	0.17	--	--
27	145 WC	2.45 TC	0.391 EI	--	-109.2	16.24[b]	TC,WC	WC	0.75	0.87	0.79	0.25	0.07	--	14.7
28	139 WC	2.56 TC	--	--	-60.2	21.61[b]	TC,WC	WC	0.72	0.85	0.79	0.25	--	--	13.7
29	20.8 SC	6.69 TC	--	--	-144.9	23.48[b]	TC,SC	TC,SC	0.73	0.86	0.52	0.25	--	--	14.0
30	-34.8 WI	133.4 WC	--	--	4.1	14.69[b]	WC	WC	0.63	0.80	-0.17	0.79	--	--	--
31	-1.39 II	9.42 IC	--	--	-11.3	15.21[b]	IC	IC	0.64	0.80	-0.12	0.79	--	--	--
32	-0.096 FI	0.15 FC	--	--	10.3	20.96[b]	FI,FC	FI,FC	0.71	0.84	0.10	0.75	--	--	--
33	-2.69 TI	1.91 TC	--	--	116.2	1.77	None	None	0.17	0.42	-0.34	0.25	--	--	--
34	0.58 EI	-0.91 EC	--	--	110.1	2.32	EC	None	0.21	0.46	0.07	-0.39	--	--	--
35	-5.23 SI	10.85 SC	--	--	29.8	3.29	SC	None	0.28	0.53	-0.09	0.52	--	--	--
36	2.35 TC	0.59 TA	--	--	4.0	1.04	None	None	0.11	0.33	0.25	-0.23	--	--	--
37	2.46 TC	1.23 TA	-4.30 TI	--	131.8	2.65	TI	None	0.33	0.58	0.25	-0.23	-0.34	--	--

[a] Significant at the 5% level.
[b] Significant at the 1% level.
[c] The average difference in percent between observed and computed values based on the given regression equation.
[d] Equation form: $Y = a + bx + cx_2 \ldots dx_n$

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Elmendorf tear	EI	EC	ET	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
Bursting strength	--	--	--	BG
T.A. fatigue	--	--	--	TA
Scattering coefficient	--	--	--	BA

TABLE VIII

MULTIPLE REGRESSIONS FOR FLAT KRAFT COMBINATIONS FROM STUDY II

(N = 12)

No.	Regression Coefficients[d] Prop. 1	Prop. 2	Prop. 3	Prop. 4	Constant	Regression Significance (F Test)	Significant Properties 5% Level	1% Level	Fraction Variance Removed (R^2)	Multiple Corr. Coeff. (R)	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction Diff., %[c]
1	0.066 TI	-0.270 EI	--	--	83.9	0.25	None	None	0.053	0.23	0.14	-0.23	--	--	22.4
2	5.60 TC	0.614 EC	--	--	-133.3	2.00	None	None	0.308	0.56	0.52	-0.30	--	--	17.2
3	1.13 TT	-0.0088 ET	--	--	-4.2	0.62	None	None	0.122	0.35	0.35	-0.27	--	--	22.3
4	104 WT	0.035 ET	--	--	-38.9	11.72[b]	WT	WT	0.723	0.85	0.85	-0.27	--	--	10.9
5	133 WC	0.0005 ET	--	--	-9.0	10.00[b]	WC	WC	0.690	0.83	0.83	-0.27	--	--	12.2
6	131 WC	-0.050 EI	--	--	-2.1	10.08[b]	WC	WC	0.691	0.83	0.83	-0.23	--	--	11.8
7	138 WC	0.151 EC	--	--	-31.2	10.24[b]	WC	WC	0.695	0.83	0.83	-0.30	--	--	11.8
8	66.0 WI	123 WC	0.035 ET	--	-34.8	7.91[b]	WC	WC	0.748	0.86	0.47	0.83	-0.27	--	10.5
9	124 WC	0.95 IC	--	--	-11.8	10.04[b]	None	None	0.690	0.83	0.83	0.76	--	--	--
10	74.9 WC	0.038 FC	--	--	0.9	14.38[b]	None	None	0.762	0.87	0.83	0.93	--	--	--
11	127 WC	0.032 FI	--	--	-18.4	12.66[b]	WC	WC	0.738	0.86	0.83	0.42	--	--	--
12	114 WC	0.632 TA	--	--	-10.3	18.10[b]	WC,TA	WC	0.801	0.90	0.83	0.59	--	--	--
13	84.0 WC	0.017 FI	0.030 FC	--	-6.3	9.04[b]	None	None	0.772	0.88	0.83	0.42	0.93	--	--
14	69.3 WC	-0.076 FI	0.024 FC	1.37 TA	16.9	11.03[b]	None	None	0.863	0.93	0.83	0.42	0.93	0.59	--
15	120 WC	-0.29 BA	--	--	68.4	12.67[b]	WC	WC	0.738	0.86	0.83	-0.49	--	--	--
16	103 WC	-0.069 FI	1.44 TA	--	8.3	14.01[b]	WC	WC	0.840	0.92	0.83	0.42	0.59	--	--
17	124 WC	0.95 BG	--	--	-41.4	13.76[b]	WC	WC	0.754	0.87	0.83	0.42	--	--	--
18	140 WC	-0.32 PS	--	--	-9.6	10.40[b]	WC	WC	0.698	0.84	0.83	0.31	--	--	--
19	120 WC	0.62 TA	-0.24 PS	--	-10.8	11.02[b]	WC	WC	0.805	0.90	0.83	0.59	0.31	--	--
20	116 WC	3.22 TC	0.25 ET	--	-126.7	7.92[b]	WC	WC	0.748	0.86	0.83	0.52	-0.27	--	10.0
21	126 WC	3.73 TC	0.89 EC	--	-192.6	9.79[b]	WC	WC	0.786	0.89	0.83	0.52	-0.30	--	9.8
22	135 WC	3.77 TC	0.91 EC	-0.36 PS	-196.2	6.83[a]	WC	WC	0.796	0.89	0.83	0.52	-0.30	0.31	--
23	10.7 IC	4.82 TC	0.91 EC	--	-236.5	7.32[a]	IC	IC	0.733	0.86	0.76	0.52	-0.30	--	--
24	17.1 SC	6.99 TC	0.87 EC	--	-249.7	9.03[b]	TC,SC	TC,SC	0.772	0.88	0.58	0.52	-0.30	--	--
26	105 WC	0.99 TC	0.61 TA	--	-24.3	11.78[b]	WC	WC	0.815	0.90	0.83	0.52	0.59	--	--
27	115 WC	2.43 TC	0.239 EI		-75.9	7.07[a]	WC	WC	0.726	0.85	0.83	0.52	-0.23	--	10.7
28	120 WC	1.21 TC	--	--	-26.0	11.11[b]	WC	WC	0.712	0.84	0.83	0.52	--	--	11.5
29	16.3 SC	4.37 TC	--	--	-84.2	10.55[b]	SC,TC	SC,TC	0.701	0.84	0.58	0.52	--	--	11.2
30	64.0 WI	121 WC	--	--	-24.4	13.23[b]	WC	WC	0.746	0.86	0.47	0.83	--	--	--
31	4.54 II	10.6 IC	--	--	-60.0	7.76[b]	IC	IC	0.633	0.80	0.44	0.76	--	--	--
32	-0.031 FI	0.15 FC	--	--	-10.4	42.46[b]	FC	FC	0.904	0.95	0.42	0.93	--	--	--
33	0.096 TI	3.73 TC	--	--	-21.1	1.68	None	None	0.272	0.52	0.14	0.52	--	--	--
34	0.17 EI	-0.83 EC	--	--	139.9	0.48	None	None	0.097	0.31	-0.23	-0.30	--	--	--
35	41.5 SI	11.5 SC	--	--	-47.9	5.57[a]	None	None	0.553	0.74	0.59	0.58	--	--	--
36	2.97 TC	0.89 TA	--	--	-17.5	4.58[a]	None	None	0.504	0.71	0.52	0.59	--	--	--
37	3.26 TC	1.39 TA	-1.94 TI	--	33.8	4.51[a]	TA	None	0.628	0.79	0.52	0.59	0.14	--	--

[a]Significant at the 5% level.
[b]Significant at the 1% level.
[c]The average difference in percent between observed and computed values based on the given regression equation.
[d]Equation form: $\underline{Y} = \underline{a} + \underline{bx} + \underline{cx}_2 \ldots \underline{dx}_n$

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Elmendorf tear	EI	EC	ET	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
Bursting strength	--	--	--	BG
T.A. fatigue	--	--	--	TA
Scattering coefficient	--	--	--	BA

For the two-factor combinations involving cross-direction T.E.A. and a second factor [see Equations (5)-(7), (9)-(12), (15), (17), (18), (28), and (30)], the multiple correlation coefficients were in most cases only a little better than the simple correlation coefficient for cross-machine T.E.A. (0.79). The best relationship in this series involved cross-machine T.E.A. and tensile [Equation (28)] in which both factors were significant and the multiple correlation coefficient was modestly better than the cross-machine T.E.A. coefficient (0.85 to 0.79, respectively).

5. In Study II for the same two-factor combinations discussed in 4 above, modest improvements in correlation coefficient were obtained using the following second factors:

Equation No.	Second Property	Multiple Corr. Coeff.
10	Cross-machine frag	0.87
11	Machine-direction frag	0.86
12	T.A. impact fatigue	0.90
15	Scattering coefficient	0.86
17	Bursting strength	0.87
30	Machine-direction T.E.A.	0.86

In the above relationships cross-direction T.E.A. was the only statistically significant property except for Equation (12) where the T.A. impact fatigue test reached significance at the 5% level. The failure of these equations to yield improved results in Study I does not encourage much confidence in their general applicability. In addition, the fatigue properties and scattering coefficient would not easily lend themselves to specification or control.

6. For two-factor regressions involving the in-and cross-machine directions of various properties [see Equations (30)-(35)], no great improvements in correlation over the individual directional coefficients were obtained in both studies.

7. In a series of three and four-factor equations involving cross-direction T.E.A., cross-direction tensile and additional factors [Equations (20)-(22), (26), and (27)], no relationships were obtained for either study in which all three or four properties were significant. In Study I, cross-machine T.E.A. and tensile were significant factors in these three-factor equations; however, these limited efforts to find a significant third factor were not successful. Also, in Study I, the multiple correlation coefficients for these three-factor equations were not much better than was obtained with the two-factor equation involving cross-machine T.E.A. and tensile [see Equation (28)]. In Study II the multiple correlation coefficients were somewhat higher than the simple correlation coefficients in a few cases [see Equations (21), (22), and (26) in particular]; however, the factors other than C.D. T.E.A. were not statistically significant.

EXTENSIBLE KRAFT SACKS AND PAPERS

The multiple regressions studied are summarized in Table IX. The following relationships exhibited some improvement in correlation and all properties were significant at the 5% level:

Equation No.	Property 1	Property 2	Multiple Corr. Coeff.	Individual Correlation Coefficients	
				Prop. 1	Prop. 2
6	T.E.A., C.D.	Tear, M.D.	0.89	0.78	0.41
12	T.E.A., C.D.	T.A. impact fatigue	0.89	0.78	0.83
15	T.E.A., C.D.	Scattering coeff.	0.94	0.78	-0.87
29	Stretch, C.D.	Tensile, C.D.	0.77	0.43	0.60
34	Tear, M.D.	Tear, C.D.	0.71	0.41	-0.17
36	Tensile, C.D.	T.A. impact fatigue	0.95	0.60	0.83

Equations (12) and (36) utilized the T.A. impact fatigue test which would be difficult to use for control purposes. If scattering coefficient — a

TABLE IX

MULTIPLE REGRESSIONS FOR EXTENSIBLE KRAFT COMBINATIONS FROM STUDY II

(N = 14)

No.	Regression Coefficients[d] Prop. 1	Prop. 2	Prop. 3	Prop. 4	Constant	Regression Significance (F Test)	Significant Properties 5% Level	1% Level	Fraction Variance Removed (R^2)	Multiple Corr. Coeff. (R)	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction Diff., %[c]
1	-0.564 TI	1.60 EI	--	--	-102.9	1.11	None	None	0.169	0.41	-0.10	0.41	--	--	27.6
2	9.81 TC	0.367 EC	--	--	-131.8	3.43	TC	None	0.384	0.62	0.60	-0.17	--	--	22.0
3	3.26 TT	0.167 ET	--	--	-84.5	0.70	None	None	0.113	0.34	0.32	0.03	--	--	29.0
4	85.7 WT	-0.379 ET	--	--	32.3	4.56[a]	WT	None	0.453	0.67	0.63	0.03	--	--	20.8
5	288 WC	0.503 ET	--	--	-220.4	13.78[b]	WC	WC	0.715	0.84	0.78	0.03	--	--	15.0
6	254 WC	1.68 EI	--	--	-270.4	20.98[b]	WC,EI	WC	0.792	0.89	0.78	0.41	--	--	13.3
7	289 WC	0.525 EC	--	--	-161.9	10.86[b]	WC	WC	0.664	0.82	0.78	-0.17	--	--	17.7
8	-4.70 WI	294 WC	0.54 ET	--	-228.6	8.37[b]	WC	WC	0.715	0.85	0.41	0.78	0.03	--	15.0
8A	-15.8 WI	263 WC	1.97 EI	--	-292.9	13.25[b]	WC,EI	WC	0.799	0.89	0.41	0.78	0.41	--	--
9	231 WC	1.89 IC	--	--	-67.1	8.90[b]	WC	None	0.618	0.79	0.78	0.66	--	--	--
10	247 WC	0.0096 FC	--	--	-62.4	8.83[b]	WC	None	0.616	0.78	0.78	0.49	--	--	--
11	65.9 WC	0.18 FI	--	--	-79.6	30.34[b]	FI	FI	0.847	0.92	0.78	0.91	--	--	--
12	137 WC	1.12 TA	--	--	-55.6	21.82[b]	WC,TA	TA	0.798	0.89	0.78	0.83	--	--	--
13	74.4 WC	0.182 FI	-0.021 FC	--	-76.8	18.66[b]	FI	FI	0.848	0.92	0.78	0.91	0.49	--	--
14	82.2 WC	0.127 FI	-0.046 FC	0.61 TA	-64.4	15.89[b]	None	None	0.876	0.94	0.78	0.91	0.49	0.83	--
15	140 WC	-0.99 BA	--	--	245.7	45.75[b]	WC,BA	WC,BA	0.892	0.94	0.78	-0.87	--	--	--
16	63.6 WC	0.132 FI	0.51 TA	--	-72.2	21.83[b]	FI	one	0.867	0.93	0.78	0.91	0.83	--	--
17	279 WC	-0.96 BG	--	--	-33.0	9.40[b]	WC	WC	0.631	0.79	0.78	0.34	--	--	--
18	247 WC	1.27 PS	--	--	-73.9	12.35[b]	WC	WC	0.692	0.83	0.78	0.32	--	--	--
19	147 WC	1.00 TA	0.43 PS	--	-60.6	13.79[b]	WC,TA	None	0.805	0.90	0.78	0.83	0.32	--	--
20	247 WC	2.88 TC	0.54 ET	--	-253.0	9.35[b]	WC	WC	0.737	0.86	0.78	0.60	0.03	--	14.7
21	245 WC	3.53 TC	0.65 EC	--	-213.9	7.60[b]	WC	WC	0.695	0.83	0.78	0.60	-0.17	--	16.0
22	222 WC	3.12 TC	0.29 EC	0.96 PS	-150.8	5.71[a]	WC	None	0.717	0.85	0.78	0.60	-0.17	0.32	--
23	11.1 IC	5.48 TC	0.034 EC	--	-117.4	3.96[a]	None	None	0.544	0.74	0.66	0.60	-0.17	--	--
24	31.3 SC	11.4 TC	0.68 EC	--	-350.9	6.57[b]	TC,SC	TC	0.663	0.82	0.43	0.60	-0.17	--	--
25	1.40 SC	6.82 TC	1.48 TA	--	-114.5	34.30[b]	TC,TA	TC,TA	0.912	0.96	0.43	0.60	0.83	--	--
26	-17.9 WC	7.21 TC	1.57 TA	--	-109.1	34.50[b]	TC,TA	TC,TA	0.912	0.96	0.78	0.60	0.83	--	--
27	241 WC	0.862 TC	1.65 EI	--	-273.7	12.86[b]	EI,WC	WC	0.794	0.89	0.78	0.60	0.41	--	13.5
28	222 WC	2.01 TC	--	--	-76.4	9.24[b]	WC	None	0.627	0.79	0.78	0.60	--	--	19.4
29	27.6 SC	9.11 TC	--	--	-193.2	7.96[b]	SC,TC	TC	0.592	0.77	0.43	0.60	--	--	20.0
30	31.9 WI	233.4 WC	--	--	-90.4	10.94[b]	WC	WC	0.665	0.82	0.41	0.78	--	--	17.8
31	0.45 II	14.2 IC	--	--	-62.9	4.28[a]	None	None	0.438	0.66	0.46	0.66	--	--	--
32	0.22 FI	0.0033 FC	--	--	-68.8	26.75[b]	FI	FI	0.829	0.91	0.91	0.49	--	--	--
33	-0.48 TI	8.50 TC	--	--	-44.8	3.14	TC	TC	0.363	0.60	-0.10	0.60			
34	3.68 EI	-1.65 EC	--	--	-123.2	5.78	EI,EC	EI	0.512	0.71	0.41	-0.17	--	--	--
35	4.70 SI	21.81 SC	--	--	-60.4	2.36	None	None	0.300	0.55	0.40	0.43	--	--	--
36	6.76 TC	1.51 TA	--	--	-108.6	56.34[b]	TC,TA	TC,TA	0.911	0.95	0.60	0.83	--	--	--
37	6.50 TC	1.55 TA	-1.67 TI	--	-71.1	45.13[b]	TC,TA	TC,TA	0.931	0.96	0.60	0.83	-0.10	--	--

[a]Significant at the 5% level.
[b]Significant at the 1% level.
[c]The average difference in percent between observed and computed values based on the given regression equation.
[d]Equation form: $\underline{Y} = \underline{a} + \underline{bx} + \underline{cx}_2 \ldots \underline{dx}_n$

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Elmendorf tear	EI	EC	ET	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
Bursting strength	--	--	--	BG
T.A. fatigue	--	--	--	TA
Scattering coefficient	--	--	--	BA

measure of the unbonded area — is considered unsuitable for control purposes, then Equation (15) would not be useful. The multiple correlation coefficients for Equations (29) and (34) are lower than the simple correlation coefficient for cross-direction T.E.A. Also, in Equation (29), cross-direction stretch and tensile are two of the factors entering into cross-direction T.E.A. Thus Equations (29) and (34) appear to have less promise than cross-direction T.E.A. by itself.

In view of the above considerations, Equation (6) involving cross-direction T.E.A. and machine-direction tear is the only relationship which offers much hope of improvement over cross-direction T.E.A. alone for the 50-lb. extensible sack papers used in this study.

COMBINED DATA

The multiple regressions obtained using the combined data for both flat and extensible kraft are shown in Table X. As in the case of the flat and extensible kraft sack data, tensile and tear taken together in two-factor equations did not give useful regressions [see Equations (1)-(3)]. Their multiple correlation coefficients were lower than many of the more favorable simple correlation coefficients. Thus, these two-factor multiple regressions indicate that tensile and tear taken together fail to be well related to the butt drop performance of the 50-lb. flat and extensible kraft sacks of this study.

Excluding fatigue properties, small improvements in correlation coefficients relative to the simple correlation coefficients with all factors significant were obtained in the cases shown in Table XI.

Regressions 20, 21, 24, and 30 gave multiple correlation coefficients (0.84-0.86) which were modestly better than the coefficient (0.79) obtained with

TABLE X

MULTIPLE LINEAR REGRESSIONS FOR FLAT AND EXTENSIBLE KRAFT PAPERS FROM STUDIES I AND II

($\underline{N}$ = 46)

No.	Regression Coefficients[d] Prop. 1	Prop. 2	Prop. 3	Prop. 4	Constant	Regression Significance ($\underline{F}$ Test)	Significant Properties 5% Level	1% Level	Fraction Variance Removed (R^2)	Multiple Corr. Coeff. (R)	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction Diff., %[c]
1	-1.86 TI	0.028 EI	--	--	118.6	6.83[b]	TI	TI	0.241	0.49	-0.49	0.12	--	--	29.6
2	2.34 TC	0.518 EC	--	--	-47.2	1.31	None	None	0.058	0.24	0.05	0.15	--	--	33.1
3	-1.34 TT	-0.109 ET	--	--	159.7	3.85[a]	TT	None	0.152	0.39	-0.38	0.16	--	--	31.3
4	36.4 WT	-0.199 ET	--	--	76.7	17.62[b]	WT	WT	0.450	0.67	0.65	0.16	--	--	25.0
5	185 WC	0.315 ET	--	--	-113.1	46.78[b]	WC,ET	WC,ET	0.685	0.83	0.79	0.16	--	--	18.2
6	184 WC	0.565 EI	--	--	-99.9	42.33[b]	WC,EI	WC	0.663	0.81	0.79	0.12	--	--	18.5
7	183 WC	0.388 EC	--	--	-82.9	43.51[b]	WC,EC	WC	0.669	0.82	0.79	0.15	--	--	18.4
8	12.1 WI	165 WC	0.163 ET	--	-70.5	34.69[b]	WC,WI	WC	0.713	0.84	0.53	0.79	0.16	--	16.9
9	127 WC	3.93 IC	--	--	-35.1	37.39[b]	WC	WC	0.635	0.80	0.79	0.74	--	--	--
10	196 WC	-0.023 FC	--	--	-24.9	36.52[b]	WC	WC	0.629	0.79	0.79	0.34	--	--	--
11	140 WC	0.053 FI	--	--	-33.1	58.51[b]	WC,FI	WC,FI	0.731	0.86	0.79	0.65	--	--	--
12	134 WC	0.534 TA	--	--	-20.7	66.24[b]	WC,TA	WC,TA	0.755	0.87	0.79	0.69	--	--	--
13	138 WC	0.053 FI	0.021 FC	--	-33.4	38.12[b]	WC,FI	WC,FI	0.731	0.86	0.79	0.65	0.34	--	--
14	127 WC	-0.004 FI	0.008 FC	0.59 TA	-20.4	31.80[b]	WC,TA	WC	0.756	0.87	0.79	0.65	0.34	0.69	--
15	166 WC	-0.14 BA	--	--	13.9	35.98[b]	WC	WC	0.626	0.79	0.79	-0.46	--	--	--
16	135 WC	-0.004 FI	0.57 TA	--	-19.9	43.15[b]	WC,TA	WC	0.755	0.87	0.79	0.65	0.69	--	--
17	168 WC	1.14 BG	--	--	-68.6	43.54[b]	WC,BG	WC	0.669	0.82	0.79	0.37	--	--	--
18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	126 WC	0.537 TA	0.325 PS	--	-20.0	45.99[b]	WC,TA	WC,TA	0.767	0.88	0.79	0.69	0.35	--	--
20	189 WC	2.42 TC	0.47 ET	--	-200.4	37.90[b]	TC,WC,ET	WC,ET	0.730	0.86	0.79	0.05	0.16	--	17.3
21	187 WC	3.14 TC	0.74 EC	--	-190.9	38.04[b]	WC,TC,EC	WC,TC,EC	0.731	0.86	0.79	0.05	0.15	--	17.3
22	187 WC	3.13 TC	0.74 EC	0.008 PS	-190.5	27.85[b]	WC,TC,EC	WC,TC,EC	0.731	0.86	0.79	0.05	0.35	--	--
23	11.1 IC	2.00 TC	0.40 EC	--	-121.1	19.96[b]	IC	IC	0.588	0.77	0.74	0.05	0.15	--	--
24	26.4 SC	8.35 TC	0.72 EC	--	-288.8	34.19[b]	SC,TC,EC	SC,TC,EC	0.709	0.84	0.62	0.05	0.15	--	--
25	16.8 SC	6.16 TC	0.75 TA	--	-134.8	61.83[b]	SC,TA,TC	SC,TA,TC	0.815	0.90	0.62	0.05	0.69	--	--
26	118 WC	2.76 TC	0.73 TA	--	-68.7	62.86[b]	WC,TA,TC	WC,TA,TC	0.818	0.90	0.79	0.05	0.69	--	--
27	183 WC	0.77 TC	0.60 EI	--	-118.3	28.34[b]	EI,WC	WC	0.669	0.82	0.79	0.05	0.12	--	18.1
28	178 WC	0.43 TC	--	--	-35.1	34.99[b]	WC	WC	0.619	0.79	0.79	0.05	--	--	17.9
29	25.2 SC	5.47 TC	--	--	-132.4	32.69[b]	SC,TC	SC,TC	0.603	0.78	0.62	0.05	--	--	18.0
30	16.9 WI	155.0 WC	--	--	-25.6	50.40[b]	WI,WC	WI,WC	0.701	0.84	0.53	0.79	--	--	16.5
31	0.92 II	9.43 IC	--	--	-27.9	35.77[b]	II,IC	II,IC	0.625	0.79	0.55	0.74	--	--	--
32	0.093 FI	0.071 FC	--	--	-16.0	27.67[b]	FI,FC	FI,FC	0.563	0.75	0.65	0.34	--	--	--
33	-2.54 TI	3.54 TC	--	--	77.5	11.25[b]	TI,TC	TI	0.344	0.59	-0.49	0.05	--	--	--
34	0.16 EI	0.21 EC	--	--	17.6	0.58	None	None	0.026	0.16	0.12	0.15	--	--	--
35	1.91 SI	12.5 SC	--	--	9.9	17.27[b]	SI,SC	SC	0.446	0.67	0.54	0.62	--	--	--

[a] Significant at the 5% level.
[b] Significant at the 1% level.
[c] The average difference in percent between observed and computed values based on the given regression equation.
[d] Equation form: $\underline{Y} = \underline{a} + \underline{bx} + \underline{cx}_2 \cdots \underline{dx}_n$

Note: Test Properties Coded as Follows:

	M.D.	C.D.	Combined	Nondirectional
Tensile	TI	TC	TT	--
Stretch	SI	SC	ST	--
T.E.A.	WI	WC	WT	--
Elmendorf tear	EI	EC	ET	--
Impulse	II	IC	IT	--
Frag	FI	FC	FT	--
Bursting strength	--	--	--	BG
T.A. fatigue	--	--	--	TA
Scattering coefficient	--	--	--	BA

TABLE XI

MOST FAVORABLE MULTIPLE FACTOR RELATIONSHIPS EXCLUDING FATIGUE PROPERTIES

Regression No.	Property 1	Property 2	Property 3	Mult. Corr. Coeff.	Individual Correlation Coefficients			Av. Prediction Diff., %
					Prop. 1	Prop. 2	Prop. 3	
5	T.E.A., C.D.	Tear, combined	--	0.83	0.79	0.16	--	18.2
6	T.E.A., C.D.	Tear, M.D.	--	0.81	0.79	0.12	--	-18.5
7	T.E.A., C.D.	Tear, C.D.	--	0.82	0.79	0.15	--	-18.4
17	T.E.A., C.D.	Bursting strength	--	0.82	0.79	0.37	--	--
20	T.E.A., C.D.	Tensile, C.D.	Tear, comb.	0.86	0.79	0.05	0.16	17.3
21	T.E.A., C.D.	Tensile, C.D.	Tear, C.D.	0.86	0.79	0.05	0.15	17.3
27	T.E.A., C.D.	Tensile, C.D.	Tear, M.D.	0.82	0.79	0.05	0.12	18.1
24	Stretch, C.D.	Tensile, C.D.	Tear, C.D.	0.84	0.62	0.05	0.15	--
30	T.E.A., C.D.	T.E.A., M.D.	--	0.84	0.79	0.53	--	16.5
31	Impulse, C.D.	Impulse, M.D.	--	0.79	0.74	0.55	--	--
33	Tensile, C.D.	Tensile, M.D	--	0.59	-0.49	0.05	--	--
35	Stretch, C.D.	Stretch, M.D.	--	0.67	0.62	0.54	--	--

C.D. T.E.A. alone. The average prediction differences ranged from 16.5 to 17.3 and were slightly better than the average prediction difference obtained using C.D. T.E.A. (18.1%). These regression equations involved combinations of the following properties:

1. C.D. T.E.A.
2. C.D. tensile
3. Combined tear or C.D. tear
4. C.D. stretch

As discussed previously, the fact that cross-direction tensile, T.E.A., or stretch give better correlations is a result of the fact that cross-direction stresses must be so directly involved in butt drop. It is not obvious why the inclusion of combined tear or cross-direction tear gave slightly higher multiple correlations as compared to M.D. tear (compare Regressions 20, 21, and 27).

Predictions obtained using Equations (21) and (30) are compared in Table XII with those obtained using cross-direction T.E.A. alone. The predicting equations are shown below:

Regression 21:

$$BD = 187\ WC + 3.14\ TC + 0.74\ EC - 190.9$$

Regression 30:

$$BD = 16.9\ WI + 155.0\ WC - 25.6$$

Regression 230:

$$BD = 177.8\ WC - 27.2$$

TABLE XII

COMPARISON OF OBSERVED AND PREDICTED BUTT DROP PERFORMANCE

	Butt Drop, safe inch								
Run	Observed	Predicted[a] (Based on C.D. Tensile, Tear, T.E.A.)	Diff., %[d]	Predicted[b] (Based on M.D. & C.D. T.E.A.)	Diff., %[d]	Predicted[c] (Based on C.D. T.E.A.)	Diff., %[d]	Crease Failure Frequency, %	Pasted Seam Failure Frequency, %
				Study I — Flat Kraft					
A	70.0	79.4	13.4	79.8	14.0	88.7	26.8	40	3
B	32.0	30.6	-4.2	25.7	-19.7	24.7	-22.8	53	3
C	76.0	72.1	-5.1	72.3	-4.8	77.7	2.2	33	17
D	46.0	69.0	50.0	70.3	52.8	73.6	60.0	53	10
E	42.0	59.0	40.6	59.2	41.0	60.8	44.8	73	10
F	64.0	54.1	-15.5	56.3	-12.0	59.6	-6.9	23	17
G	97.0	92.9	-4.2	86.8	-10.5	93.5	-3.6	30	17
H	85.0	78.0	-8.2	80.1	-5.7	88.0	3.5	30	10
I	51.0	51.4	0.7	41.4	-18.9	44.6	-12.5	20	17
J	76.0	82.5	8.6	69.8	-8.1	77.3	1.8	43	10
K	77.0	93.4	21.4	71.7	-6.9	76.8	-0.2	30	0
L	61.0	69.4	13.7	72.5	18.9	80.2	31.5	40	17
M	90.0	83.0	-7.8	63.6	-29.3	67.7	-24.7	43	3
N	31.0	51.7	66.7	45.5	46.9	47.7	53.7	77	7
O	33.0	23.7	-28.1	28.0	-15.2	26.9	-18.6	43	7
P	76.0	60.5	-20.4	62.9	-17.3	67.7	-10.9	17	13
Q	65.0	80.7	24.1	86.9	33.7	93.3	43.6	23	23
R	44.0	51.9	18.1	44.4	0.8	45.7	3.9	30	7
S	56.0	51.1	-8.7	55.8	-0.3	59.7	6.7	30	0
T	77.0	77.2	0.2	77.1	0.2	85.7	11.3	13	3
				Study II — Flat Kraft					
AA	70.0	66.3	-5.3	61.6	-12.0	64.7	-7.5	30	10
BB	43.0	52.8	22.9	52.8	22.9	55.8	29.8	20	3
CC	61.0	64.3	5.5	63.4	3.9	69.0	13.1	17	7
DD	39.0	31.5	-19.3	40.1	2.7	41.3	5.8	47	13
EE	34.0	29.6	-13.0	32.9	-3.1	33.8	-0.6	30	13
FF	31.0	20.0	-35.5	28.6	-7.9	29.9	-3.6	27	10
GG	54.0	66.0	22.2	62.3	15.3	68.1	26.1	40	17
HH	57.0	48.7	-14.6	43.3	-24.0	46.4	-18.6	50	7
II	58.0	49.4	-14.8	47.3	-18.4	49.4	-14.8	40	7
JJ	75.0	69.9	-6.8	70.2	-6.4	74.7	-0.4	10	7
KK	58.0	62.1	7.1	59.6	2.8	65.4	12.8	23	27
LL	56.0	65.7	17.3	64.2	14.6	69.5	24.1	20	13
				Study II — Extensible Kraft					
MM	108.0	101.1	-6.4	101.2	-6.3	99.7	-7.6	40	17
NN	91.0	85.5	-6.0	93.4	2.6	86.4	-5.0	57	13
OO	122.0	107.6	-11.8	99.8	-18.2	89.4	-26.7	57	13
PP	73.0	70.3	-3.6	75.7	3.7	69.2	-5.2	30	3
QQ	97.0	75.8	-21.8	85.4	-12.0	74.7	-23.0	17	3
RR	127.0	105.0	-17.3	105.2	-17.2	92.3	-27.3	13	0
SS	41.0	49.6	21.0	62.4	52.2	54.9	34.0	43	3
TT	51.0	72.3	41.9	84.0	64.8	74.5	46.1	40	30
UU	59.0	83.9	42.2	88.3	49.6	74.1	25.7	40	23
VV	112.0	93.6	-16.4	98.7	-11.8	89.4	-20.1	40	0
WW	66.0	55.8	-15.4	65.4	-0.9	57.1	-13.5	27	17
XX	65.0	71.3	9.7	63.1	-2.9	48.9	-24.8	30	13
YY	70.0	78.8	12.5	80.4	14.9	71.1	1.6	30	7
ZZ	95.0	68.6	-27.7	82.5	-13.1	70.6	-25.7	27	0
Av.			17.3		16.5		18.1		

[a] BD = 187 WC + 3.14 TC + 0.74 EC - 190.9 where BD = butt drop, WC = T.E.A., C.D., TC = Tensile, C.D., EC = Tear, C.D.
[b] BD = 16.9 WI + 155.0 WC - 25.6 where BD = butt drop, WC = T.E.A., C.D., WI = T.E.A., M.D.
[c] BD = 177.8 WC - 27.2 where BD = butt drop, WC = T.E.A., C.D.
[d] Based on observed value as reference.

where BD = butt drop, safe inch
$\bar{W}\bar{C}$ = C.D. T.E.A.
$\bar{T}\bar{C}$ = C.D. tensile
$\bar{E}\bar{C}$ = C.D. tear
$\bar{W}\bar{I}$ = M.D. T.E.A.

As noted in Table XII, the differences in average predictive ability between regression equations are not great. It also may be noted that the three regression equations generally give poor predictions for the same samples. For example, samples having predictive errors of 20% or more are listed in Table XIII.

TABLE XIII

COMPARISON OF SAMPLES EXHIBITING LARGE PREDICTIVE ERRORS

		Samples Exhibiting Prediction Differences Greater Than + 20% (Prediction Overestimates Performance)		
Regression Equation	Regression Variables	Study I Flat Kraft	Study II Flat Kraft	Study II Extensible Kraft
21	WC,TC,EC	D,E,K,N,O,Q	BB,GG	SS,TT,UU
30	WI,WC	D,E,N,Q	BB	SS,TT,UU
230	WC	A,D,E,L,N,Q	BB,GG,LL	SS,TT,UU
		Samples Exhibiting Prediction Differences Greater Than - 20% (Prediction Underestimates Performance)		
21	WC,TC,EC	P	FF	QQ,ZZ
30	WI,WC	M	HH	--
230	WC	B,M	--	OO,QQ,RR,VV,XX,ZZ

In Study I, the predictions from the three equations all overestimate the performance of Runs D, E, N, and Q. Relatively high crease failure frequencies in the butt drop tests were obtained with Runs D, E, and N. Also, tensile tests of the side creases showed a large reduction in T.E.A. for Run N. Thus, the poor predictions for Runs D, E, and N are probably caused by poor crease strength.

Run Q exhibited a low incidence of crease failures but did exhibit a higher incidence of pasted seam failures. This may cause the prediction overestimate for this run.

In the flat kraft sacks from Study II, the greatest prediction overestimates were obtained for Runs BB, GG, and LL. The reported crease failure frequencies in Table XI do not indicate abnormal behavior for Runs BB and LL. However, Run GG exhibits one of the higher crease failure frequencies and gave the highest loss in creased T.E.A., Report Twenty-One. At least, for this run, poor crease performance may have a bearing on the poor prediction.

For the extensible sacks prediction, overestimates are obtained with Runs SS, TT, and UU with all three equations. The crease failure frequencies for these runs were high — but no higher than a number of the other runs. Runs TT and UU also exhibited the highest pasted seam failure frequencies and TT exhibited the highest loss in creased T.E.A. There is considerable question, however, as to whether the poor predictions for Run SS, TT, and UU are associated with poor crease or pasted seam performance.

Taken as a whole, the data suggest that the serious prediction overestimates for a number of the flat kraft runs may result from higher than normal crease or pasted seam failures.

The above is illustrated in another way in Table XIV. In the table multiple correlation coefficients are shown for a number of equations where T.E.A. measured in the side crease area is substituted for T.E.A. cut from the uncreased areas. In general, use of creased T.E.A. increased the correlation coefficients for the flat kraft runs. There was no improvement with the extensible papers.

TABLE XIV

USE OF T.E.A. MEASURED ON SIDE CREASES TO PREDICT BUTT DROP PERFORMANCE

No.	Property 1	Property 2	Property 3	Multiple Correlation Coefficient: Regular Kraft Study I	Regular Kraft Study II	Extensible Kraft	Combined
500	T.E.A., C.D.	--	--	0.786	0.831	0.785	0.786
501	Creased T.E.A., C.D.	--	--	0.821	0.862	0.785	0.802
502	T.E.A., C.D.	T.E.A., M.D.	--	0.80	0.86	0.82	0.84
503	Creased T.E.A., C.D.	T.E.A., M.D.	--	0.837	0.875	0.808	0.842
504	T.E.A., C.D.	Tear, M.D.	--	0.81	0.83	0.89	0.81
505	Creased T.E.A., C.D.	Tear, M.D.	--	0.866	0.878	0.851	0.826
506	T.E.A., C.D.	Tear, C.D.	--	0.79	0.83	0.82	0.82
507	Creased T.E.A., C.D.	Tear, C.D.	--	0.821	0.866	0.785	0.826
508	T.E.A., C.D.	Tensile, C.D.	--	0.85	0.84	0.79	0.79
509	Creased T.E.A., C.D.	Tensile, C.D.	--	0.880	0.916	0.819	0.810
510	T.E.A., C.D.	Tensile, C.D.	Tear, M.D.	0.868	0.852	0.891	0.818
511	Creased T.E.A., C.D.	Tensile, C.D.	Tear, M.D.	0.916	0.924	0.878	0.838
512	T.E.A., C.D.	Tensile, C.D.	Tear, C.D.	0.86	0.89	0.83	0.86
513	Creased T.E.A., C.D.	Tensile, C.D.	Tear, C.D.	0.916	0.949	0.831	0.862
514	T.E.A., C.D.	Tensile, C.D.	T.E.A., M.D.	--	--	--	--
515	Creased T.E.A., C.D.	Tensile, C.D.	T.E.A., M.D.	0.896	0.924	0.854	0.885
516	T.E.A., C.D.	T.E.A., M.D.	Tear, M.D.	--	--	--	--
517	Creased T.E.A., C.D.	T.E.A., M.D.	Tear, M.D.	0.867	0.885	0.851	0.859
518	T.E.A., C.D.	T.E.A., M.D.	Tear, C.D.	--	--	--	--
519	Creased T.E.A., C.D.	T.E.A., M.D.	Tear, C.D.	0.837	0.879	0.819	0.844

As a result the coefficients utilizing creased T.E.A. had little or no effect for the combined data — i.e. the apparent effect on flat kraft papers is obscured in the combined data.