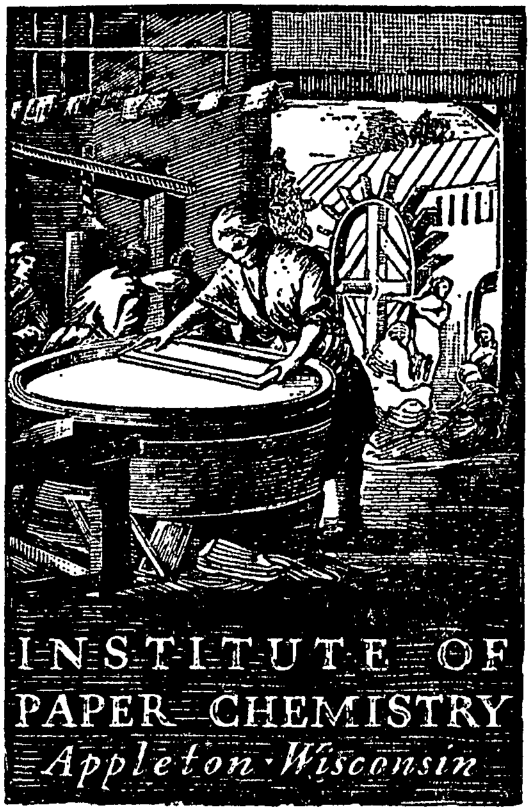

RELATIONSHIP BETWEEN SACK DROP AND SACK PAPER PROPERTIES

PART III. MULTIPLE LINEAR CORRELATIONS BETWEEN FACE DROP PERFORMANCE AND COMBINATIONS OF SACK PAPER PROPERTIES

Project 2033

Report Thirty-Four

A Progress Report

to

MULTIWALL SHIPPING SACK PAPER MANUFACTURERS

January 17, 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 improvements in sack paper manufacture and sack performance. Pursuant to this request, Reports Twenty-Nine and Thirty-One discussed the relationship between individual sack paper properties and face and butt drop performance, respectively.

In Report Twenty-Nine the best predictions of face drop performance for the 50-lb. flat and extensible papers used in past studies were obtained with the following properties:

Property	Corr. Coeff.	Av. Prediction Diff., %[c]
	Flat Kraft, Study I — N = 20	
T.E.A., combined[d]	0.53[b]	18.7
Stretch, combined	0.59[a]	19.0
Impulse, combined	0.49[b]	18.7
Frag, combined	0.48[b]	18.9
T.A. Impact fatigue	0.72[a]	16.7
	Flat Kraft, Study II — N = 12	
T.E.A., combined[d]	0.83[a]	12.3
Stretch, combined	0.85[a]	12.5
Impulse, combined	0.79[a]	13.0
Frag, combined	0.76[a]	12.6
T.A. Impact fatigue	0.69[b]	15.2

[a]Significant at the 1% level.
[b]Significant at the 5% level.
[c]Average difference in percent between observed and computed face drop based on the observed value as reference.
[d]Tensile energy absorption (T.E.A.).

Property	Corr. Coeff.	Av. Prediction Diff., %[c]
	Extensible Kraft, Study II — N = 14	
Scattering coeff.	-0.91[a]	9.7
Frag, in	0.83[a]	13.5
T.A. Impact fatigue	0.82[a]	15.1
Frag, combined	0.74[a]	17.6
T.E.A., cross[d]	0.66[b]	20.0
	Combined Data — N = 46	
T.A. Impact fatigue	0.93[a]	16.7
T.E.A., combined[d]	0.89[a]	18.4
Impulse, combined	0.87[a]	20.2
Stretch, combined	0.88[a]	20.3
Frag, in	0.87[a]	22.8

[a]Significant at the 1% level.
[b]Significant at the 5% level.
[c]Average difference in percent between observed and computed face drop based on the observed value as reference.
[d]Tensile energy absorption (T.E.A.).

Based on these results and on the difficulties in using fatigue-type tests in mill evaluation and control, the results indicated that combined T.E.A. is the best test for evaluating 50-lb. sack paper in terms of face drop. It was pointed out, however, that none of the properties mentioned will accurately predict the relative performance of all papers. The use of these tests, therefore, should be tempered by judgment and experience.

The present report focuses attention on the linear relationship between face drop performance and combinations of sack paper properties. To study this relationship, multiple linear regression equations were calculated for various combinations of sack paper properties. As in Report Twenty-Nine, the analysis was carried out separately for the flat kraft combinations of 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. except as specifically noted.

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

1. The regression coefficients for the individual properties should be statistically significant at the 0.05 level.

2. The coefficient of multiple correlation (R) should be as high as possible in keeping with (1) above. Also, it should exhibit improvement over the simple correlation coefficients for the individual properties as reported in Report Twenty-Nine.

3. The properties involved in the correlation should bear some logical relationship to face drop performance and the sign (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 included in current sack paper specifications. In addition, the multiple factor relationships are compared with the five properties exhibiting the greatest promise as single factors in Report Twenty-Nine.

The results for the flat kraft papers, extensible kraft papers, and combined data for flat and extensible kraft papers are summarized in the following sections.

FLAT KRAFT PAPERS (50% R.H.)

Single and multiple relationships selected as noted on the previous page are shown in Table I. The results indicate the following:

1. Excluding fatigue properties, no relationships were found which meet the criteria listed above for the data of both studies. Combinations meeting the criteria in one or the other study are listed below.

Regression No.	Study	Sack Paper Property 1	Sack Paper Property 2
35	I	Combined T.E.A.	Porosity
4	II	Combined tensile times stretch	Combined tear
5	II	Combined T.E.A.	Combined tear
27	II	T.E.A., M.D.	T.E.A., C.D.
32	II	Stretch, M.D.	Stretch, C.D.

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

2. For these 50-lb. flat kraft papers, the multiple relationships resulted in relatively small improvements in correlation for either study over the single factor relationships based on combined T.E.A. Thus, the tensile energy absorption characteristics of the sack paper appear to be best related to face drop performance.

3. Carlson (1) has suggested that a two-factor relationship using combined T.E.A. (or the tensile-strength product) and combined tearing strength should be used to predict face drop performance. This combination (Regressions 4 and 5) gave good results in Study II but failed to give much improvement in Study I. In both studies T.E.A. appeared to be the more important sack paper property. On the basis of these data, tearing strength does not seem to be of

TABLE I

COMPARISON OF SELECTED SINGLE AND MULTIPLE LINEAR REGRESSIONS FOR FLAT KRAFT

STUDY I

No.	Regression Equation	Significant Properties, 5% level	Mult. Corr. Coeff.	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[a]
	Simple Correlations[b]						
100	F = 442.0 WT + 22.7	WT	0.53				18.7
101	F = 67.43 ST + 49.1	ST	0.59				19.0
102	F = 25.19 IT - 22.1	IT	0.49				18.7
103	F = 0.2642 FT + 149.5	FT	0.48				18.9
104	F = 10.90 TA + 166.3	TA	0.72				16.7
	Multiple Linear Correlations Excluding Fatigue Properties						
3	F = -8.2 TT - 1.13 ET + 1134.9	None	0.28	-0.22	-0.14	--	24.9
4	F = 3.91 AT + 0.98 ET - 328.1	AT	0.55	0.53	-0.14	--	18.5
5	F = 511.0 WT + 1.03 ET - 301.6	WT	0.55	0.53	-0.14	--	18.3
34	F = 461.1 WT - 8.81 TT + 471.2	WT	0.60	0.53	-0.22	--	--
12	F = 140.2 WT + 52.4 ST + 6.6	None	0.60	0.53	0.59	--	--
35	F = 668.6 WT - 5.69 PS - 102.6	WT, PS	0.74	0.53	-0.21	--	--
41	F = 512.6 WT + 0.79 ET - 8.3 TT + 198.7	WT	0.61	0.53	-0.14	-0.22	--
27	F = 394 WI + 459 WC + 30.9	WC	0.53	0.22	0.47	--	18.9
32	F = 158.0 SI + 63.3 SC - 81.6	SC	0.62	0.30	0.53	--	--
	Multiple Linear Correlations Including Fatigue Properties						
19	F = 10.0 TA + 343.0 WC + 15.3	TA , WC	0.80	0.72	0.48	--	--
20	F = 9.7 TA + 46.7 SC + 17.5	TA , SC	0.82	0.72	0.53	--	--
46	F = 7.3 TA + 427 WT - 4.4 PS - 70.4	TA, WT, PS	0.84	0.72	0.53	-0.21	--
47	F = 9.8 TA + 471 WC - 3.78 PS - 8.3	TA, WC, PS	0.88	0.72	0.47	-0.21	--

STUDY II

No.	Regression Equation	Significant Properties, 5% level	Mult. Corr. Coeff.	Correlation Coeff. for Individual Tests[b] Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[a]
	Simple Correlations[b]						
100	F = 629.0 WT - 175.0	WT	0.83				12.3
101	F = 119.2 ST - 251.6	ST	0.85				12.5
102	F = 51.08 IT - 447.0	IT	0.79				13.0
103	F = 0.3742 FT + 1.9	FT	0.76				12.6
104	F = 7.781 TA + 201.5	TA	0.69				15.2
	Multiple Linear Correlations Excluding Fatigue Properties						
3	F = 14.82 TT + 2.98 ET - 1205.7	None	0.48	0.25	0.08	--	18.9
4	F = 5.83 AT + 2.54 ET - 979.2	AT, ET	0.95	--	0.08	--	7.3
5	F = 748 WT + 2.13 ET - 807.4	WT, ET	0.93	0.83	0.08	--	8.7
34	F = 724.1 WT - 5.08 TT + 15.2	WT	0.86	0.83	0.25	--	--
12	F = 319 WT + 72.2 ST - 278.2	ST	0.89	0.83	0.85	--	--
35	F = 756 WT - 5.37 PS - 228.4	WT	0.86	0.83	0.35	--	--
41	F = 709 WT + 2.71 ET + 3.85 TT - 1124.4	WT, ET	0.93	0.83	0.08	0.25	--
27	F = 781 WI + 555 WC - 190.8	WI, WC	0.84	0.65	0.70	--	12.1
32	F = 286 SI + 95.8 SC - 425.1	SI, SC	0.90	0.68	0.75	--	--
	Multiple Linear Correlations Including Fatigue Properties						
19	F = 5.8 TA + 529 WC - 14.6	TA , WC	0.86	0.69	0.70	--	--
20	F = 6.3 TA + 97.7 SC + 28.2	TA, SC	0.93	0.69	0.75	--	--
46	F = 2.21 TA + 618 WT - 3.46 PS - 170.3	WT	0.87	0.69	0.83	0.35	--

[a] Average difference between computed and observed face drop based on the observed value as reference.
[b] Taken from Report 29, Feb. 7, 1964.

Note: Test Properties Coded as Follows:

	Directional Properties In	Cross	Combined
Tensile	TI	TC	TT
Stretch	SI	SC	ST
T.E.A.	WI	WC	WT
Impulse	II	IC	IT
Frag	FI	FC	FT
Elmendorf tear	EI	EC	ET

Nondirectional Properties	
T.A. impact fatigue	TA
Porosity	PS

major importance to the face drop performance of flat kraft although it may be important in other aspects of sack performance — e.g., snagging, nail tears, etc.

4. Because these studies were restricted to one grade weight, the importance of stretch is probably overemphasized. This conclusion is based on the observation that stretch is independent of basis weight and hence will not predict changes in sack performance associated with changes in basis weight. Except in special cases, such as within a given grade weight level, T.E.A. should be the better property.

5. Treating machine- and cross-machine T.E.A. as separate sack paper properties gives no marked advantage over combined T.E.A. — in which the two directions are given equal weight.

6. While it can be argued that face drop performance should be related to porosity, the porosity differences encountered in the papers used in these studies apparently are not sufficient to establish its importance.

7. The dominant paper property in Regressions 4 and 5 appears to be T.E.A. or its analog, the product of tensile x stretch.

8. Considering fatigue properties, the T.A. impact fatigue test in combination with either (1) C. D. stretch or (2) cross-machine T.E.A. exhibits relatively good correlations using the data of either study.

9. Combined tensile and combined tear do not give a favorable relationship for either study. In the main body of this report, the same conclusion was obtained using either the M.D. or C.D. orientations. It is concluded, therefore, that tensile and tear taken separately or together are not well related to the face drop performance of pasted sacks made from 50-lb. flat kraft.

EXTENSIBLE KRAFT PAPERS (50% R.H.)

Simple and multiple relationships selected as mentioned previously are shown in Table II. The results indicate the following:

1. Excluding fatigue properties, the only multiple relationships which were superior to scattering coefficient alone, utilized combined T.E.A. or impulse with the scattering coefficient. Both factors were significant in each regression equation.

2. If scattering coefficient is also excluded as being unsuitable for control or specification, none of the remaining relationships exhibit much improvement over single factor relationships. For these data, however, the combination of machine- and cross-machine T.E.A. exhibits a modest improvement in correlation coefficient over combined T.E.A. alone.

3. As in the case of the flat kraft, combined tensile and tear exhibit no significant relationship to the face drop performance of the 50-lb. extensible kraft samples of this study.

4. In the regressions involving combined tear with combined T.E.A. or the tensile-stretch product, tear is not a significant property. Also, the multiple correlation coefficient is little better than the simple correlation coefficient for combined T.E.A. alone.

COMBINED 50% R.H. DATA FOR FLAT AND EXTENSIBLE KRAFT PAPERS

A comparison of relationships selected as described previously is shown in Table III. The following results were obtained:

TABLE II

COMPARISON OF SELECTED SINGLE AND MULTIPLE LINEAR REGRESSIONS FOR EXTENSIBLE KRAFT

($\underline{N}$ = 14)

No.	Regression Equation	Significant Properties, 5% level	Mult. Corr. Coeff.	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[a]
	Simple Correlations[b]						
105	F = -12.73 BA + 3956.7	BA	-0.91				9.7
106	F = 1.77 FI - 388.5	FI	0.83				13.5
107	F = 14.60 TA + 50.7	TA	0.82				15.1
108	F = 1.08 FT - 394.6	FT	0.74				17.6
109	F = 1893 WC - 244.6	WC	0.66				20.0
110	F = 656 WT - 348.8	WT	0.63				21.6
	Multiple Linear Correlations Excluding Fatigue Properties						
3	F = 11.0 TT + 1.29 ET + 75.6	None	0.14	0.11	0.07	--	26.4
4	F = 4.17 AT - 3.61 ET + 718.8	AT	0.60	--	0.07	--	21.3
5	F = 740 WT - 2.79 ET + 265.1	WT	0.66	0.63	0.07	--	19.4
34	F = 653 WT + 7.28 TT - 616.6	WT	0.63	0.63	0.11	--	--
12	F = 814 WT - 19.0 ST - 374.0	None	0.63	0.63	0.55	--	--
35	F = 703 WT - 3.06 PS - 396.0	WT	0.63	0.63	0.33	--	--
41	F = 735 WT - 2.64 ET + 3.13 TT + 117.9	WT	0.66	0.63	0.07	0.11	--
27	F = 385 WI + 1676 WC - 599.4	WC	0.73	0.46	0.66	--	17.9
32	F = 51.8 SI + 186.4 SC - 495.8	None	0.60	0.48	0.43	--	--
9	F = 262 WT - 11.1 BA + 3073.4	WT, BA	0.94	0.63	-0.91	--	--
15	F = 11.1 IT - 11.6 BA + 3315.6	WT, BA	0.94	0.52	-0.91	--	--
	Multiple Linear Correlations Including Fatigue Properties						
46	F = 11.9 TA + 669.1 WC - 188.1	TA	0.84	0.82	0.66	--	--
21	F = -10.6 BA + 0.34 FT + 3031.5	BA	0.93	-0.91	0.74	--	--
22A	F = -9.1 BA + 0.76 FI + 45	BA, FI	0.94	-0.91	0.89	--	--
19A	F = -8.0 BA + 0.69 FI + 25.8 NT + 40.8	NT, BA, FI	0.96	-0.91	0.83	0.62	--

[a]Average difference between computed and observed face drop based on observed values as reference.
[b]Taken from Report 29, Feb. 7, 1964.

Note: Test Properties Coded as Follows:

	Directional Tests In	Cross	Combined
Tensile	TI	TC	TT
Stretch	SI	SC	ST
T.E.A.	WI	WC	WT
Impulse	II	IC	IT
Frag	FI	FC	FT
Elmendorf tear	EI	EC	ET
Instron strain fatigue	NI	NC	NT

Nondirectional Tests	
T.A. impact fatigue	TA
Scattering coeff.	BA
Porosity	PS

TABLE III

COMPARISON OF SELECTED SINGLE AND MULTIPLE LINEAR REGRESSIONS FOR THE COMBINED DATA

($\underline{N}$ = 46)

No.	Regression Equation	Significant Properties, 5% level	Mult. Corr. Coeff.	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[a]
		Simple Correlations[b]					
111	$\underline{F}$ = 13.31 TA + 115.2	TA	0.93				16.7
112	$\underline{F}$ = 495.3 WT - 45.6	WT	0.89				18.4
113	$\underline{F}$ = 27.5 IT - 70.4	IT	0.87				20.2
114	$\underline{F}$ = 55.4 ST + 88.6	ST	0.88				20.3
115	$\underline{F}$ = 1.344 FI - 131.9	FI	0.87				22.8
	Multiple Linear Regressions Excluding Fatigue Properties						
3	$\underline{F}$ = -25.20 TT - 0.26 ET + 1800.3	TT	0.72	-0.72	0.41	--	33.0
4	$\underline{F}$ = 3.24 AT - 0.20 ET + 35.6	AT	0.88	0.88	0.41	--	19.6
5	$\underline{F}$ = 493 WT + 0.13 ET - 76.2	WT	0.89	0.89	0.41	--	18.4
34	$\underline{F}$ = 509 WT + 1.05 TT - 112.4	WT	0.89	0.89	-0.72	--	--
12	$\underline{F}$ = 454 WT + 4.70 ST - 35.6	WT	0.89	0.89	0.88	--	--
35	$\underline{F}$ = 506 WT - 3.08 PS - 22.0	WT	0.89	0.89	0.09	--	--
41	$\underline{F}$ = 510 WT + 0.29 ET + 1.53 TT - 211.0	WT	0.89	0.89	0.41	-0.72	--
27	$\underline{F}$ = 460 WI + 771 WC - 169.1	WI, WC	0.89	0.85	0.55	--	19.0
32	$\underline{F}$ = 50.1 SI + 88.1 SC - 19.1	SI, SC	0.88	0.85	0.66	--	--
28	$\underline{F}$ = 26.2 II + 38.5 IC - 169.1	II, IC	0.87	0.85	0.54	--	--
9	$\underline{F}$ = 472 WT - 2.68 BA + 642.1	WT, BA	0.90	0.89	-0.37	--	--
	Multiple Linear Regressions Including Fatigue Properties						
46	$\underline{F}$ = 12.3 TA + 395 WC - 61.8	TA, WC	0.94	0.93	0.55	--	--
23B	$\underline{F}$ = 10.4 TA + 14.2 ST + 152.4	TA, ST	0.94	0.93	0.88	--	--
10	$\underline{F}$ = 311 WT + 0.58 FI - 115.8	WT, FI	0.90	0.89	0.87	--	--

[a]Average difference between computed and observed face drop based on observed values as reference.

[b]Taken from Report 29, Feb. 7, 1964.

Note: Test Properties Coded as Follows:

	Directional Tests In	Cross	Combined
Tensile	TI	TC	TT
Stretch	SI	SC	ST
T.E.A.	WI	WC	WT
Impulse	II	IC	IT
Frag	FI	FC	FT
Elmendorf tear	EI	EC	ET

Nondirectional Tests	
T.A. impact fatigue	TA
Porosity	PS
Scattering coeff.	BA

1. Excluding the relationships involving fatigue properties, none of the multiple regressions involving conventional properties exhibit any marked improvement over the single-factor relationships with regard to correlation coefficient.

2. In the regressions involving combined T.E.A. and a second property, the multiple correlation coefficients exhibit little or no improvement over the simple correlation coefficient for combined T.E.A. alone (0.89). In most cases, combined T.E.A. is the only factor which exhibits significance at the 5% level.

3. Combined T.E.A. and combined tear exhibit a multiple correlation coefficient of 0.89 which is equal to that exhibited by combined T.E.A. alone. Also, combined tear was not a significant statistical factor in the relationship while combined T.E.A. was highly significant. It appears, therefore, that combined tear is not an important factor in the face drop performance at 50% R.H. of pasted sacks made from 50-lb. flat or extensible kraft.

4. The relationships involving combined tensile and tear are considerably inferior to relationships based on combined T.E.A.

5. While the multiple correlation coefficient for the combination of machine- and cross-machine T.E.A. is higher than the simple correlation coefficient for either direction separately, it is nevertheless only equal to the simple correlation coefficient for combined T.E.A. Thus, giving the two directions equal weight in the combined value used in obtaining the simple correlation coefficient seems about as efficient as using the two directions in the two-factor relationship. It has been felt that this conclusion would not hold for all sack designs and shapes. For this reason, the two-factor type of equation has been favored in past work.

6. As mentioned previously, the favorable results obtained with stretch are probably due, in part, to the fact that these data were obtained on sacks made from one grade weight.

7. It is a curious feature of the results that combined T.E.A. and the combined tensile-stretch product appear to be about equally well related to face drop performance. Since T.E.A. is dependent on the shape of the load-elongation curve, it can be argued that it should be a better predictor of face drop performance than the tensile-stretch product which is solely dependent on maximum stretch and tensile. This is not the case for these data, however. Perhaps curve shape differences for papers within a given grade weight level are not large enough to seriously affect the relationships.

COMBINED 10, 25, AND 50% R.H. DATA FOR FLAT AND EXTENSIBLE KRAFT PAPERS

A limited number of relationships were investigated for the combined data – i.e., the 50% R.H. data from Studies I and II and the 10 and 25% R.H. data from Study II. A disadvantage of using the combined data for three relative humidity levels is that the effects of relative humidity on both commodity and paper are intertwined and consequently changes in paper properties may be called upon to explain changes in sack performance which are partly attributable to changes in the flow characteristics of the commodity. With this reservation, the following results were obtained:

1. An improvement in correlation coefficient and prediction accuracy can be achieved using combined tear with either combined T.E.A. or the combined tensile-stretch product. The improvement in prediction accuracy is especially noticeable for the 10 and 25% R.H. data.

2. For the regressions studied, the highest correlations were obtained using either C.D. T.E.A. or combined tear with T.A. impact fatigue test.

CONCLUSIONS

Considering the results as a whole, one general conclusion is that linear multiple property relationships using conventional sack paper properties offer no real advantage over linear single-factor regressions based on combined T.E.A. or some of the other paper properties. Both the single and multiple property relationships fail to accurately predict the relative performance of <u>all</u> papers. There is little indication that curvilinear regressions would materially improve predictions.

In Report Twenty-Nine, for the combined data the five best tests in order of decreasing predictive ability were:

1. T.A. impact fatigue
2. T.E.A., combined
3. Impulse, combined
4. Stretch, combined
5. Frag, combined

Taking test cost, calibration, etc., into account, it was concluded in Report Twenty-Nine that at the present time combined T.E.A. is the best test for evaluating sack paper in terms of face drop performance for flat and extensible papers. Despite the limitations of T.E.A., the present analysis indicates there is no simple combination of conventional sack paper properties which will yield excitingly better results.

There are at least two probable reasons for the occasional large discrepancies between predicted and observed face drop performance. First, it appears that none of the conventional properties accurately measure those characteristics of the sack paper which actually determine face drop sack performance. Second, in some instances fabrication quality in the form of crease quality, nesting, etc. may cause reductions in face drop performance which cannot be predicted by any paper test.

For the first problem it appears desirable to investigate new ways of evaluating sack paper. Various avenues of approach were suggested at the last Technical Committee meeting. These included the following:

(a) High rate tensile tests
(b) Examination of load-deformation curve parameter such as elastic and plastic moduli
(c) Biaxial tension effects
(d) Shear

Work is in progress in these areas.

The second problem requires a better understanding of those fabrication factors which may be responsible for premature failures in the face sack drop test. This would permit the proper weighting or rejection of such results in studies where the primary aim is to relate paper quality to sack drop performance.

In Appendix I a description is given of the procedure followed in carrying out this study. In Appendix II the results are presented and described in detail.

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1. Carlson, W. E. Measurement of the strain properties of shipping sack kraft. Tappi 47, no. 5:310-12(May, 1964).

2. Report Twelve, Project 2033, Feb. 8, 1960.

3. Report Twenty-One, Project 2033, Oct. 1, 1962.

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Research Associate

R. C. McKee, Chairman
Container Section

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 discussion.

The analysis was restricted to the data obtained at 50% R.H. because the sack drop test results at other humidities included both commodity and paper effects. It appeared desirable as a matter of thoroughness, however, to include data obtained at 10, 25, and 50% R.H. when examining multiple relationships involving T.E.A. and Elmendorf tearing strength.

As in the previous analysis, normally satisfactory conversion is assumed. High failure frequencies in creased areas, adhesive joints, etc., are not considered in the analysis.

For this report linear multiple factor relationships between progressive height face 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 5% level.

2. The coefficient of multiple correlation ($\underline{R}$) should be as high as reasonably possible 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 face 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.

APPENDIX II

DISCUSSION OF RESULTS

FLAT KRAFT PAPERS - STUDIES I AND II (50% R.H.)

The multiple linear regressions obtained for this report with the flat kraft sack data are tabulated in Tables V and VI and indicate the following:

1. Two factor combinations involving tensile and tear (see Regressions 1 through 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 results indicate that tensile and tear are not useful as predictors of the face drop performance of sacks fabricated from 50-lb. flat kraft paper.

2. Combined T.E.A. or the combined tensile-stretch product in combination with combined tear (see Regressions 4 and 5) gave good multiple regressions in Study II and both the work and tear properties entered significantly into the regressions. In Study I, however, the multiple correlation coefficients were not markedly higher than the simple correlation coefficient for combined T.E.A. and only the work properties exhibited significance. Thus, contradictory results were obtained from the two studies even though tearing strength varied over about the same range in the two studies (see Table IV). It may be recalled that Carlson (1) reported a high correlation for a relationship of this type using the combined tensile-stretch product with combined tear. He also noted that combined T.E.A. could probably be substituted for the tensile-stretch product. The data of these studies confirm that the two quantities (T.E.A. and tensile-stretch product) give about equal efficiencies in these regression equations for flat kraft. Since T.E.A. is dependent on the shape of the load-deformation curve as well as on the magnitudes of tensile and stretch, this result suggests that differences in curve

TABLE V

FLAT KRAFT MULTIPLE LINEAR CORRELATIONS FOR STUDY I AT 50% R.H.

($\underline{N}$ = 20)

No.	Regression Coefficients[a] Property 1	Property 2	Property 3	Property 4	Constant	Regression Significance (F-Test)	Significant Properties 5% Level	1% Level	Fraction Variance Removed (R^2)	Multiple Correlation Coeff. (R)	Correlation Coeff. for Individual Tests[d] Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction Diff., %
A	Highest single factor correlation – T.A. impact fatigue									0.72	0.72	--	--	--	16.7
1	-1.4 TI	-2.08 EI	--	--	716.0	0.26	None	None	0.03	0.17	0.04	-0.17	--	--	24.1
2	-18.4 TC	-2.04 EC	--	--	1035.5	1.51	None	None	0.15	0.39	-0.34	-0.06	--	--	23.1
3	-8.2 TT	-1.13 ET	--	--	1134.9	0.75	None	None	0.08	0.28	-0.22	-0.14	--	--	24.9
4	3.91 AT	0.98 ET	--	--	-328.1	3.6	AT	None	0.30	0.55	--	-0.14	--	--	18.5
5	511.0 WT	1.03 ET	--	--	-301.6	3.7[b]	WT	None	0.30	0.55	0.53	-0.14	--	--	18.3
6	321.4 WT	9.05 IT	--	--	-27.1	3.51	None	None	0.29	0.54	0.53	0.49	--	--	
7	356.3 WT	0.070 FT	--	--	28.5	3.42	None	None	0.29	0.54	0.53	0.48	--	--	18.2
8	200.5 WT	9.13 TA	--	--	28.9	10.83[c]	TA	TA	0.56	0.75	0.53	0.72	--	--	13.5
9	419.4 WT	-0.25 BA	--	--	103.7	3.36	None	None	0.28	0.53	0.53	-0.33	--	--	
10	420.3 WT	0.051 FI	--	--	21.2	3.36	None	None	0.28	0.53	0.53	0.34	--	--	
11	356.1 WT	0.107 FC	--	--	34.7	3.45	None	None	0.29	0.54	0.53	0.47	--	--	
12	140.2 WT	52.4 ST	--	--	6.6	4.83[b]	None	None	0.36	0.60	0.53	0.59	--	--	
13	16.0 IT	0.14 FT	--	--	-3.0	3.21	None	None	0.27	0.52	0.49	0.48	--	--	
14	7.25 IT	9.71 TA	--	--	67.6	9.58[c]	TA	TA	0.53	0.73	0.49	0.72	--	--	15.1
15	22.0 IT	-0.86 BA	--	--	244.2	3.11	None	None	0.27	0.52	0.49	-0.33	--	--	
16	22.9 IT	0.087 FI	--	--	-17.6	2.78	None	None	0.25	0.50	0.49	0.34	--	--	
17	16.3 IT	0.224 FC	--	--	-3.1	3.37[b]	None	None	0.28	0.53	0.49	0.47	--	--	
18	11.2 TA	-0.014 FT	--	--	174.3	9.07[c]	TA	TA	0.52	0.72	0.72	0.48	--	--	16.9
19	10.0 TA	343.0 WC	--	--	15.3		TA,WC	TA, WC	0.64	0.80	0.72	0.47	--	--	
20	9.7 TA	46.7 SC	--	--	17.5		TA,SC	TA, SC	0.67	0.82	0.72	0.53	--	--	
21	0.25 FT	-0.27 BA	--	--	234.6	2.51	None	None	0.23	0.48	0.48	-0.33	--	--	
22	15.6 TA	-0.34 FT	16.1 WC	--	16.8		TA,FT,WC	TA,FT,WC	0.76	0.87	0.72	0.48	0.47	--	
23	16.9 TA	-0.94 FT	392 WI	0.95 FC	13.0		TA,FT,WI,FC	TA,WI,FC	0.78	0.88	0.72	0.48	0.22	0.47	
24	16.9 TA	395 WT	-0.95 FI	--	61.5	18.42[c]	TA,FI,WT	TA,FI,WT	0.78	0.88	0.72	0.53	0.34	--	
25	12.4 TA	509 WT	-0.32 FT	--	4.3	9.35[c]	WT, TA	TA	0.64	0.80	0.72	0.53	0.48	--	
26	9.2 TA	214 WT	-0.02 FC	--	26.9	6.80[c]	TA	TA	0.56	0.75	0.72	0.53	0.47	--	
27	394 WI	459 WC	--	--	30.9	3.36	WC	None	0.28	0.53	0.22	0.47	--	--	18.9
28	27.0 II	23.9 IC	--	--	-25.5	2.74	None	None	0.24	0.49	0.34	0.35	--	--	
29	0.14 FI	0.34 FC	--	--	151.1	2.61	None	None	0.24	0.48	0.34	0.47	--	--	
30	1.08 TI	-15.0 TC	--	--	665.7	1.09	None	None	0.11	0.34	0.04	-0.34	--	--	
31	-2.03 EI	0.18 EC	--	--	639.9	0.26	None	None	0.03	0.17	-0.17	-0.06	--	--	
32	158.0 SI	63.3 SC	--	--	-81.6	5.42[b]	SC	SC	0.39	0.62	0.30	0.53	--	--	
33	441.6 WT	0.115 BG	--	--	18.5	3.34	WT	None	0.28	0.53	0.53	0.06	--	--	
34	461.1 WT	-8.81 TT	--	--	471.2	4.65[b]	WT	None	0.35	0.60	0.53	-0.22	--	--	
35	668.6 WT	-5.69 PS	--	--	-102.6	10.23[c]	WT, PS	WT, PS	0.55	0.74	0.53	-0.21	--	--	
36	510.0 WT	1.04 ET	0.31 BG	--	-314.5	2.31	WT	None	0.30	0.55	0.53	-0.14	0.06	--	
37	396.2 WT	1.00 ET	8.41 IT	--	-336.7	2.41	None	None	0.31	0.56	0.53	-0.14	0.49	--	
38	661.8 WT	-0.14 ET	-5.75 PS	--	-59.2	6.42[c]	WT, PS	WT, PS	0.55	0.74	0.53	-0.14	-0.21	--	
39	468.7 WT	1.37 ET	-0.71 BA	--	-176.3	2.44	WT	None	0.31	0.56	0.53	-0.14	-0.33	--	
40	199.7 WT	0.60 ET	48.9 ST	--	-178.8	3.12	None	None	0.37	0.61	0.53	-0.14	0.59	--	
41	512.6 WT	0.79 ET	-8.3 TT	--	198.7	3.07	WT	None	0.37	0.61	0.53	-0.14	-0.22	--	
42	667.8 WT	-0.16 ET	1.20 TT	-6.0 PS	-121.5	4.53[b]	WT, PS	WT	0.55	0.74	0.53	-0.14	-0.22	-0.21	
43	727.5 WT	-0.13 ET	-8.99 ST	-6.1 PS	-68.1	4.54	PS	None	0.55	0.74	0.53	-0.14	0.59	-0.21	
44	474.5 WI	522 WC	1.02 ET		-291.4	2.32	WC	None	0.30	0.55	0.22	0.47	-0.14	--	
45	719.4 WI	382 WC	12.5 TT		616.9	3.23	None	None	0.38	0.61	0.22	0.47	-0.22	--	
46	7.28 TA	427 WT	-4.45 PS		-70.4	13.07[c]	TA, WT, PS	TA	0.71	0.84	0.72	0.53	-0.21	--	
47	9.79 TA	471 WC	-3.78 PS		-8.3	18.42[c]	TA, WC, PS	TA, WC, PS	0.78	0.88	0.72	0.47	-0.21	--	
48	701.5 WI	659 WC	-5.72 PS		-108.7	6.45[c]	WI, WC, PS	WI, WC, PS	0.55	0.74	0.22	0.47	-0.21	--	

[a] Regression Equation $\underline{Y} = \underline{a} + \underline{bx}_1 + \underline{cx}_2 \cdots \underline{dx}_n$.
[b] Significant at 5% level.
[c] Significant at 1% level.
[d] Taken from Report 29, Feb. 7, 1964.

Test Properties Coded as Follows:

	Directional Tests In	Cross	Combined
Tensile x stretch	AI	AC	AT
Tensile	TI	TC	TT
Elmendorf tear	EI	EC	ET
Stretch	SI	SC	ST
T.E.A.	WI	WC	WT
Impulse	II	IC	IT
Frag	FI	FC	FT

Nondirectional Tests	
T.A. impact fatigue	TA
Scattering coeff.	BA
Bursting strength	BG
Porosity	PS

TABLE VI

FLAT KRAFT MULTIPLE LINEAR CORRELATIONS FOR STUDY II AT 50% R.H.

(N = 12)

No.	Regression Coefficients[a] Property 1	Property 2	Property 3	Property 4	Constant	Regression Significance (F-Test)	Significant Properties 5% Level	Significant Properties 1% Level	Fraction Variance Removed (R^2)	Multiple Correlation Coeff. (R)	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction Diff., %
A	Highest single factor correlation – stretch, combined									0.85			--	--	12.5
1	13.4 TI	3.03 EI	--	--	716.0	1.07	None	None	0.19	0.44	0.29	0.11	--	--	20.0
2	8.67 TC	2.14 EC	--	--	-118.5	0.06	None	None	0.01	0.12	0.05	0.29	--	--	21.3
3	14.82 TT	2.98 ET	--	--	-1205.7	1.34	None	None	0.23	0.48	0.25	0.08	--	--	18.9
4	5.83 AT	2.54 ET	--	--	-979.2	38.5^c	AT, ET	AT, ET	0.90	0.95	--	0.08	--	--	7.3
5	748.0 WT	2.13 ET	--	--	-807.4	27.7^c	WT, ET	WT, ET	0.86	0.93	0.83	0.08	--	--	8.7
6	575 WT	4.90 IT	--	--	-206.3	10.19^c	None	None	0.69	0.83	0.83	0.79	--	--	
7	516 WT	0.088 FT	--	--	-160.7	10.59^c	None	None	0.70	0.84	0.83	0.76	--	--	
8	495 WT	3.17 TA	--	--	-118.7	12.91^c	WT	WT	0.74	0.86	0.83	0.69	--	--	10.8
9	670 WT	1.18 BA	--	--	-501.1	11.21^c	WT	WT	0.71	0.84	0.83	-0.16	--	--	
10	578 WT	0.101 FI	--	--	-172.8	10.61^c	WT	WT	0.70	0.84	0.83	0.56	--	--	
11	565 WT	0.082 FC	--	--	-163.4	10.20^c	None	None	0.69	0.83	0.83	0.80	--	--	
12	319 WT	.72.2 ST	--	--	-278.2	17.08^c	ST	None	0.79	0.89	0.83	0.85	--	--	
13	41.3 IT	0.081 FT	--	--	-368.9	7.61^b	None	None	0.63	0.79	0.79	0.76	--	--	
14	40.0 IT	2.57 TA	--	--	-319.6	8.27^c	IT	None	0.65	0.80	0.79	0.69	--	--	
15	57.1 IT	1.68 BA	--	--	-956.3	8.88^c	IT	IT	0.66	0.82	0.79	-0.16	--	--	
16	53.9 IT	-0.050 FI	--	--	-470.0	7.54^b	IT	None	0.63	0.79	0.79	0.56	--	--	
17	23.8 IT	0.418 FC	--	--	-236.4	8.63^c	None	None	0.66	0.81	0.79	0.80	--	--	
18	1.19 TA	0.33 FT	--	--	23.5	6.03^b	None	None	0.57	0.76	0.69	0.76	--	--	
19	5.8 TA	529 WC	--	--	-14.6	12.2^c	TA, WC	TA, WC	0.73	0.86	0.69	0.70	--	--	
20	6.3 TA	97.7 SC	--	--	28.2	28.2^c	TA, SC	TA, SC	0.86	0.93	0.69	0.75	--	--	
20A	4.9 TA	96.5 ST	--	--	36.5	--	TA, ST	TA, ST	0.89	0.94	0.69	0.85	--	--	
21	0.50 FT	3.40 BA	--	--	-953.6	10.33^c	FT	FT	0.70	0.84	0.76	-0.16	--	--	
22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
23	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
24	7.10 TA	501 WT	-0.340 FI	--	-56.5	8.96^c	WT	WT	0.77	0.88	0.69	0.83	0.56	--	
25	7.90 TA	753 WT	-0.354 FT	--	-92.7	9.35^c	WT	None	0.78	0.88	0.69	0.83	0.76	--	10.1
26	3.46 TA	610 WT	-0.162 FC	--	-136.4	7.77^b	None	None	0.74	0.86	0.69	0.83	0.80	--	
27	781 WI	555 WC	--	--	-190.8	10.66^c	WI, WC	WC	0.70	0.84	0.65	0.70	--	--	12.1
28	43.9 II	56.8 IC	--	--	-433.4	7.67^b	IC	None	0.63	0.79	0.55	0.70	--	--	
29	0.11 FI	0.66 FC	--	--	-34.2	8.23^c	FC	FC	0.65	0.80	0.56	0.80	--	--	
30	7.68 TI	-0.66 TC	--	--	80.8	0.41	None	None	0.08	0.29	0.29	0.05	--	--	
31	2.97 EI	-3.83 EC	--	--	459.4	0.17	None	None	0.04	0.19	0.11	0.02	--	--	
32	286 SI	95.8 SC	--	--	-425.1	20.27^c	SI, SC	SC	0.82	0.90	0.68	0.75	--	--	
33	--	--	--	--	--	--	--	--	--	--	--	--			
34	724.1 WT	5.08 TT	--	--	15.2	12.6^c	WT	WT	0.74	0.86	0.83	0.25	--	--	
35	756.0 WT	-5.37 PS	--	--	-228.4	12.7^c	WT	WT	0.74	0.86	0.83	0.35	--	--	
36	673.8 WT	2.40 ET	4.71 BG	--	-1000.0	20.5^c	WT, ET	WT, ET	0.89	0.94	0.83	0.08	0.50	--	
37	647.1 WT	2.14 ET	9.32 IT	--	-871.4	16.8^c	ET	ET	0.86	0.93	0.83	0.08	0.79	--	
38	874.0 WT	2.12 ET	-5.32 PS	--	-858.9	25.2^c	WT, ET	WT, ET	0.90	0.95	0.83	0.08	0.35	--	
39	727.2 WT	3.03 ET	2.10 BA	--	-496.8	22.7^c	WT, ET	WT, ET	0.90	0.95	0.83	0.08	-0.16	--	
40	769.6 WT	2.07 ET	0.06 ST	--	-811.5	16.7^c	WT, ET	WT	0.86	0.93	0.83	0.08	0.85	--	
41	708.9 WT	2.71 ET	3.85 TT	--	-1124.4	18.3^c	WT, ET	WT	0.87	0.93	0.83	0.08	0.25	--	
42	834.8 WT	2.66 ET	3.57 TT	-5.22 PS	-1151.8	18.9^c	WT, ET	WT	0.92	0.96	0.83	0.08	0.25	0.35	
44	902.0 WI	675 WC	2.13 ET	--	-823.6	18.0^c	WI, WC, ET	WI, WC	0.87	0.93	0.65	0.70	0.08	--	
45	1200 WI	587 WC	-8.41 TT	--	97.4	10.2^c	WI, WC	WI, WC	0.89	0.89	0.65	0.70	0.25	--	
46	2.21 TA	617.5 WT	-3.46 PS	--	-170.3	8.24^c	WT	WT	0.76	0.87	0.69	0.83	0.35	--	
47A	685.3 WC	0.61 PS	--	--	-0.1	4.31^b	WC	WC	0.49	0.70	0.70	0.35	--	--	
48	1020 WI	662 WC	-6.39 PS	--	-264.1	8.57	WI, WC	WC	0.76	0.87	0.65	0.70	0.35	--	

[a]Regression Equation: $Y = a + bx_1 + cx_2 \dots dx_n$.

[b]Significant at 5% level.

[c]Significant at 1% level.

Test Properties Coded as Follows:

	Directional Tests In	Cross	Combined
Tensile x stretch	AI	AC	AT
Tensile	TI	TC	TT
Elmendorf tear	EI	EC	ET
Stretch	SI	SC	ST
T.E.A.	WI	WC	WT
Impulse	II	IC	IT
Frag	FI	FC	FT

Nondirectional Tests	
T.A. impact fatigue	TA
Scattering coeff.	BA
Bursting strength	BG
Porosity	PS

shape among flat kraft samples are not great enough to affect correlations with face drop. Also, the results for both studies indicate that T.E.A. is more important than tearing strength to flat kraft face drop performance. In general, it appears that tearing strength is not a strong factor in face drop performance though it may be of importance in other aspects of sack performance — e.g., snagging, nail tears, etc.

3. Of the two factor combinations involving combined T.E.A. and a second factor (see Regressions 6-12, 33-35), the multiple correlation coefficients were in most cases only a little better than the highest simple correlation coefficients exhibited by the properties in question. A relationship of possible interest in terms of relevance to theory was exhibited by the combination of combined T.E.A. and porosity in Study I. Both factors were significant at the 1% level and the signs of their coefficients were in the proper sense. However, in Study II porosity was not a significant factor. The difference in results between the two studies apparently arises from the fact that the porosity of the sheets in the second study did not vary over as wide a range as in the first study (see Table IV) — thus masking its possible importance in the second study. It can be argued that porosity should be a significant factor since a very low permeability could lead to higher pressures on the sack walls. The results of this analysis are not sufficient, however, to establish its degree of importance.

4. For the series of two factor regressions involving combined impulse and a second factor (see Numbers 13-17), no favorable relationships were found in which both factors were significant and/or the multiple correlation coefficients exhibited any great improvement over the related simple correlation coefficients.

5. For two factor regressions involving the in and cross-machine directions of various properties (see Numbers 27-32) no great improvements in correlation over the individual directional correlations were obtained for Study I. For Study II, Regressions 27 and 32 involving T.E.A. and stretch, respectively, exhibited improved relationships with both directions entering significantly at the 5% level. While it seems reasonable to expect that both machine and cross-machine T.E.A. would be involved in face drop performance, the failure of machine direction T.E.A. to show significance in both studies is disappointing.

6. In a series of three and four factor equations involving combined T.E.A., combined tear, and a third factor (see Regressions 36-42), no relationships were obtained for either study in which all three or four factors were significant. For Study I the best multiple correlation coefficients for Regressions 36-42 were obtained in Regressions 38 and 42; however, combined tear was not a significant factor and its coefficient exhibited a negative sign. For these equations it is evident that the improvement in correlation is due to combined T.E.A. and porosity. For Study II, the highest multiple correlations in Regressions 36-42 were obtained with porosity or scattering coefficient or combined tensile and porosity as the third and fourth factors. However, the additional factors were not significant.

7. A number of improved correlations were obtained in equations involving the T.A. impact fatigue test and other factors. In Regressions 19 and 20, C.D. stretch, combined stretch, or C.D. work were significant factors for both studies along with T.A. impact fatigue. Regression 24 involving the T.A. impact fatigue test, combined work and M.D. frag exhibited a high correlation for Study I; however, the coefficient for M.D. frag was negative.

8. For both studies, the 50-lb. flat kraft results may be summarized as follows:

(a) Excluding fatigue properties, regression equations were obtained in which the following properties were significant either for Study I or Study II:

	Paper Property 1	Paper Property 2	Study
1.	Combined tensile x stretch	Combined tear	II
2.	Combined T.E.A.	Combined tear	II
3.	M.D. T.E.A.	C.D. T.E.A.	II
4.	M.D. Stretch	C.D. Stretch	II
5.	Combined T.E.A.	Porosity	I

(b) The failure of any of the above equations to be equally effective for both studies casts doubt on their general applicability. Because of this fact, predictions based on any of the relationships may not be superior to predictions based on combined T.E.A. alone. This suggests that additional ways of evaluating sack paper are needed.

EXTENSIBLE KRAFT PAPERS – STUDY II (50% R.H.)

The multiple linear regressions studied are summarized in Table VII. The highest multiple correlation coefficients were obtained using the scattering coefficient (simple correlation coefficient = 0.91) in combination with other properties as follows:

TABLE VII

EXTENSIBLE KRAFT MULTIPLE LINEAR CORRELATIONS FOR STUDY II AT 50% R.H.

(N = 14)

No.	Regression Coefficients[a] Property 1	Property 2	Property 3	Property 4	Constant	Regression Significance (F-Test)	Significant Property 5% Level	1% Level	Fraction Variance Removed (R^2)	Multiple Correlation Coeff. (R)	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction Diff., %
A	Highest single factor correlation – scattering coefficient									-0.91					9.7
1	-21.1 TI	14.0 EI	--	--	-450.5	1.55	None	None	0.22	0.47	-0.26	0.42	--	--	23.7
2	69.7 TC	2.75 EC	--	--	708.9	1.77	None	None	0.24	0.49	0.48	-0.13	--	--	21.1
3	11.0 TT	1.29 ET	--	--	75.6	0.12	None	None	0.02	0.14	0.11	0.07	--	--	26.4
4	4.17 AT	-3.61 ET	--	--	718.8	3.1	AT	None	0.36	0.60	--	0.07	--	--	21.3
5	740 WT	-2.79 ET	--	--	265.1	4.2[b]	WT	None	0.43	0.66	0.63	0.07	--	--	19.4
6	1230 WT	-25.7 IT	--	--	-541.8	4.25[b]	WT	None	0.44	0.66	0.63	0.52	--	--	15.3
7	378.8 WT	0.83 FT	--	--	-769.9	9.89[c]	FT	FT	0.64	0.80	0.63	0.74	--	--	15.1
8	54.6 WT	13.9 TA	--	--	-11.2	11.22[c]	TA	TA	0.67	0.82	0.63	0.82	--	--	
9	261.5 WT	-11.1 BA	--	--	3073.4	40.05[c]	WT, BA	BA	0.88	0.94	0.63	-0.91	--	--	
10	183.7 WT	1.53 FI	--	--	-559.1	13.40[c]	FI	FI	0.71	0.84	0.63	0.83	--	--	
11	629.0 WT	1.05 FC	--	--	-770.3	5.34[b]	WT	WT	0.49	0.70	0.63	0.36	--	--	
12	814.1 WT	-19.0 ST	--	--	-374.0	3.65	None	None	0.40	0.63	0.63	0.55	--	--	
13	10.9 IT	0.92 FT	--	--	-578.3	7.96[c]	FT	FT	0.67	0.82	0.52	0.74	--	--	14.6
14	-4.3 IT	15.8 TA	--	--	127.1	11.40[c]	TA	TA	0.67	0.82	0.52	0.82	--	--	
15	11.1 IT	-11.6 BA	--	--	3315.6	43.64[c]	IT, BA	BA	0.89	0.94	0.52	-0.91	--	--	
16	1.58 IT	1.72 FI	--	--	-409.1	12.31[c]	FI	FI	0.69	0.83	0.52	0.83	--	--	
17	22.2 IT	1.16 FC	--	--	-408.7	3.49	IT	None	0.39	0.62	0.52	0.36	--	--	
18	11.8 TA	0.28 FT	--	--	-117.4	11.76[c]	TA	None	0.68	0.82	0.82	0.74	--	--	
19A	-8.0 BA	0.69 FI	25.8 NT	--	40.8	--	NT, BA, FI	BA, FI	0.92	0.96	-0.91	0.83	0.62	--	
20A	1.47 FI	41.1 NT	--	--	1.94	--	NT, FI	FI	0.78	0.88	0.83	0.62	--	--	
21	0.34 FT	-10.6 BA	--	--	3031.5	34.28[c]	BA	BA	0.86	0.93	0.74	-0.91	--	--	
22A	0.76 FI	-9.1 BA	--	--	45.5	--	BA, FI	BA	0.89	0.94	0.83	-0.91	--	--	
23A	0.73 XC	7.83 TA	-18.9 ZI	--	23.3	--	TA, XC, ZI	TA, ZI	0.87	0.93	0.74	0.82	-0.47	--	
24	29.8 TA	7.1 WT	1.03 FI	--	-317.9	9.90[c]	None	None	0.75	0.86	0.82	0.63	0.83	--	15.1
25	9.36 TA	132 WT	0.36 FT	--	-315.3	7.34[b]	None	None	0.69	0.83	0.82	0.63	0.74	--	
26	18.8 TA	-135 WT	-0.79 FC	--	423.9	7.53[b]	TA	TA	0.69	0.83	0.82	0.63	0.36	--	
27	385 WI	1676 WC	--	--	-599.4	6.25[b]	WC	WC	0.53	0.73	0.46	0.66	--	--	17.9
28	8.50 II	98.8 IC	--	--	-301.3	3.00	None	None	0.35	0.59	0.46	0.58	--	--	
29	1.90 FI	-0.38 FC	--	--	-309.1	12.80[c]	FI	FI	0.70	0.84	0.83	0.36	--	--	
30	-21.7 TI	57.7 TC	--	--	363.7	2.05	None	None	0.27	0.52	-0.26	0.48	--	--	
31	31.9 EI	-13.6 EC	--	--	-1059.5	5.00[b]	EI, EC	EI	0.48	0.69	0.42	-0.13	--	--	
32	51.8 SI	186.4 SC	--	--	-495.8	3.09	None	None	0.36	0.60	0.48	0.43	--	--	
33	669.2 WT	12.0 BG	--	--	-913.1	4.27[b]	WT	None	0.44	0.66	0.63	0.17	--	--	
34	652.9 WT	7.28 TT	--	--	-616.6	3.69	WT	None	0.40	0.63	0.63	0.11	--	--	
35	702.8 WT	-3.06 PS	--	--	-396.0	3.63	WT	None	0.40	0.63	0.63	0.33	--	--	
36	729.5 WT	-2.08 ET	9.52 BG	--	-339.0	2.79	WT	None	0.46	0.68	0.63	0.07	0.17	--	
37	1086 WT	-1.16 ET	-17.7 IT	--	-224.5	2.60	None	None	0.44	0.66	0.63	0.07	0.52	--	
38	713.1 WT	-3.15 ET	2.50 PS	--	382.8	2.54	WT	None	0.43	0.66	0.63	0.07	0.33	--	
39	250.0 WT	0.28 ET	-11.2 BA	--	3040.7	24.35[c]	BA	BA	0.88	0.94	0.63	0.07	-0.91	--	
40	738.9 WT	-2.79 ET	0.18 ST	--	266.1	2.53	None	None	0.43	0.66	0.63	0.07	0.55	--	
41	734.6 WT	-2.64 ET	3.13 TT	--	117.9	2.54	WT	None	0.43	0.66	0.63	0.07	0.11	--	
42	704.6 WT	-3.01 ET	3.46 TT	2.69 PS	229.0	1.73	None	None	0.43	0.66	0.63	0.07	0.11	0.33	
43	715.5 WT	-3.14 ET	-0.32 ST	2.50 PS	381.2	1.73	None	None	0.43	0.66	0.63	0.07	0.55	0.33	
44	206.0 WI	1970 WC	2.66 ET	--	-1276.8	4.02[b]	WC	None	0.55	0.74	0.46	0.66	0.07	--	
45	284.7 WI	2098 WC	-20.2 TT	--	42.8	4.36[b]	WC	None	0.57	0.75	0.46	0.66	0.11		
46	669.1 WC	11.9 TA	--	--	-188.1	12.96[c]	TA	TA	0.70	0.84	0.66	0.82	--	--	
47	728.6 WC	11.2 TA	2.46 PS	--	-216.3	7.96[c]	TA	TA	0.70	0.84	0.66	0.82	0.33	--	

[a]Regression Equation: $\underline{Y} = a + b\underline{x}_1 + c\underline{x}_2 \ldots d\underline{x}_n$.

[b]Significant at 5% level.

[c]Significant at 1% level.

Test Properties Coded as Follows:

	Directional Tests In	Cross	Combined
Tensile x stretch	AI	AC	AT
Tensile	TI	TC	TT
Elmendorf tear	EI	EC	ET
Stretch	SI	SC	ST
T.E.A.	WI	WC	WT
Impulse	II	IC	IT
Frag	FI	FC	FT
Strain fatigue	NI	NC	NT
Zero-span tensile	ZI	ZC	ZT
M.I.T. fold	XI	XC	XT

Nondirectional Tests

T.A. impact fatigue	TA
Scattering coeff.	BA
Bursting strength	BG
Porosity	PS

No.	Regression Equation	Multiple Corr. Coeff.
9	$F = 261.5\ WT - 11.1\ BA + 3073.4$	0.94
15	$F = 11.1\ IT - 11.6\ BA + 3315.6$	0.94
22A	$F = 0.76\ FI - 9.1\ BA + 45.5$	0.94
19A	$F = -8.0\ BA + 0.69\ FI + 25.8\ NT + 40.8$	0.96
39	$F = -11.2\ BA + 250\ WT + 0.28\ ET + 3040.7$	0.94

where F = face drop, safe inch

BA = scattering coeff., mμ

WT = combined T.E.A., in. lb./in.^{2}

IT = combined impulse, mNs

FI = M.D. frag, kg. m. x 10^{-4}

NT = combined Instron strain fatigue, cycles

ET = combined Elmendorf tear, g./sheet

In the relationships above, each property was significant at the 5% level and, in some cases, at the 1% level. Equations 19A and 22A utilized fatigue properties and would not be considered suitable for control purposes. If scattering coefficient — a measure of the unbonded area — is considered unsuitable for specification purposes, then the remaining equations would also not be useful.

Excluding the regressions involving the scattering coefficient or fatigue properties, none of the relationships involving combinations of conventional properties appeared promising. In general, one or more of the properties in each equation failed to exhibit significance at even the 5% level. Also, where high multiple correlation coefficients were obtained, inspection indicated very little improvement over the highest simple correlation coefficient for the particular properties. For the regressions studied, this indicates there is little to be gained from the use of conventional properties in multiple regressions for these data.

In regressions involving tensile and tear (see Regression Equations 1-3) low multiple correlation coefficients were obtained and neither factor was statistically significant. In regressions involving combined T.E.A. and combined tear, the multiple correlation coefficient was only slightly higher than that obtained for T.E.A. alone and tear was not a significant factor. Therefore, these data do not indicate that combinations of tensile and tear or T.E.A. and tear are particularly useful for predictions of the face drop performance of 50-lb. extensible kraft sack paper.

COMBINED DATA (50% R.H.)

The multiple regressions obtained using the combined data for both flat and extensible kraft are shown in Table VIII. As in the case of the flat and extensible kraft data, tensile and tear did not give useful regressions (see Regression Equations 1-3). Their multiple correlation coefficients were lower than many of the more favorable simple correlation coefficients. The tensile regression coefficients were negative in all three Equations because of the generally lower tensile strengths exhibited by the extensible kraft samples. Negative regression coefficients were also associated with M.D. and combined tear in Regression Equations 1 and 3. Therefore, the two-factor multiple linear regressions indicate that tensile and tear taken together fail to be well related to face drop performance of the 50-lb. regular and extensible kraft sacks of this study.

TABLE VIII

MULTIPLE LINEAR CORRELATIONS FOR FLAT AND EXTENSIBLE KRAFT AT 50% R.H.

(N = 46)

No.	Regression Coefficients[a] Property 1	Property 2	Property 3	Property 4	Constant	Regression Significance (F-Test)[b]	Significant Properties 5% Level	1% Level	Fraction Variance Removed (R^2)	Multiple Correlation Coeff. (R)	Correlation Coeff. for Individual Tests Prop. 1	Prop. 2	Prop. 3	Prop. 4	Av. Prediction, Diff., %
A	Highest single-factor – T.A. impact fatigue									0.93					16.7
1	-32.2 TI	-1.52 EI	--	--	1670.1	27.1	TI	TI	0.56	0.75	-0.74	0.11	--	--	32.6
2	-9.60 TC	8.46 EC	--	--	-461.9	7.49	EC	EC	0.26	0.51	-0.37	0.50	--	--	40.1
3	-25.20 TT	-0.26 ET	--	--	1800.3	23.3	TT	TT	0.52	0.72	-0.72	0.41	--	--	33.0
4	3.24 AT	-0.20 ET	--	--	35.6	72.2	AT	AT	0.77	0.88	--	0.41	--	--	19.6
5	493 WT	0.13 ET	--	--	-76.2	79.9	WT	WT	0.79	0.89	0.89	0.41	--	--	18.4
6	529 WT	-1.95 IT	--	--	-42.4	79.94	WT	WT	0.79	0.89	0.89	0.87	--	--	
7	426 WT	0.26 FT	--	--	-225.5	93.07	WT, FT	WT	0.81	0.90	0.89	0.67	--	--	
8	113 WT	10.6 TA	--	--	67.3	147.0	TA	TA	0.87	0.93	0.89	0.93	--	--	14.9
9	472 WT	-2.68 BA	--	--	642.1	96.8	WT, BA	WT, BA	0.82	0.90	0.89	-0.37	--	--	
10	311 WT	0.58 FI	--	--	-115.8	96.6	WT, FI	WT, FI	0.82	0.90	0.89	0.87	--	--	
11	506 WT	0.21 FC	--	--	-167.6	84.4	WT	WT	0.80	0.89	0.89	-0.08	--	--	
12	454 WT	4.70 ST	--	--	-35.6	80.0	WT	None	0.79	0.89	0.89	0.88	--	--	
13	23.0 IT	0.30 FT	--	--	-281.3	82.5	IT, FT	IT, FT	0.79	0.89	0.85	0.67	--	--	
14	2.72 IT	12.2 TA	--	--	91.3	140.5	TA	TA	0.87	0.93	0.85	0.93	--	--	
15	26.2 IT	-3.24 BA	--	--	755.9	87.2	IT, BA	IT, BA	0.80	0.90	0.85	-0.37	--	--	16.3
16	15.1 IT	0.70 FI	--	--	-141.0	88.0	IT, FI	IT, FI	0.80	0.90	0.85	0.87	--	--	
17	28.3 IT	0.25 FC	--	--	-218.1	72.0	IT	IT	0.77	0.88	0.85	-0.08	--	--	
18	13.5 TA	-0.024 FT	--	--	133.9	139.4	TA	TA	0.87	0.93	0.93	0.67	--	--	
19B	15.7 TA	-1146 WI	125 SI	--	140.5	--	TA, WI, SI	TA, WI, SI	0.91	0.95	0.93	0.85	0.85	--	
20B	13.8 TA	-1369 WI	115 SI	350 WT	123.8	--	TA,WI,SI,WT	TA,WI,SI,WT	0.92	0.96	0.93	0.85	0.85	0.89	
21	0.88 FT	0.23 BA	--	--	-421.2	17.88	FT	FT	0.45	0.67	0.67	-0.37	--	--	
22B	12.4 TA	60.4 ST	-539 WI	--	135.5	--	TA , ST,WI	TA, ST,WI	0.91	0.95	0.93	0.88	0.85	--	
23B	10.4 TA	14.2 ST	--	--	152.4	--	TA , ST	TA	0.88	0.94	0.93	0.88	--	--	
24	11.5 TA	120 WT	-0.12 FI	--	91.6	96.4	TA	TA	0.87	0.93	0.93	0.89	0.87	--	
25	10.6 TA	114 WT	0.0063 FT	--	62.2	95.7	TA	TA	0.87	0.93	0.93	0.89	0.67	--	14.9
26	10.5 TA	121 WT	0.041 FC	--	41.8	96.0	TA	TA	0.87	0.93	0.93	0.89	-0.08	--	
27	460 WI	771 WC	--	--	-169.1	85.5	WI, WC	WI, WC	0.80	0.89	0.85	0.55	--	--	19.0
28	26.2 II	38.5 IC	--	--	-150.7	68.5	II, IC	II, IC	0.76	0.87	0.85	0.54	--	--	
29	1.34 FI	-0.085 FC	--	--	-86.5	65.4	FI	FI	0.75	0.87	0.87	-0.08	--	--	
30	-31.3 TI	-2.5 TC	--	--	1498.6	26.8	TI	TI	0.56	0.75	-0.74	-0.37	--	--	
31	-4.1 EI	10.7 EC	--	--	-442.5	7.92	EC	EC	0.27	0.52	0.11	0.50	--	--	
32	50.1 SI	88.1 SC	--	--	-19.1	74.9	SI, SC	SI, SC	0.78	0.88	0.85	0.66	--	--	
33	476 WT	3.29 BG	--	--	-157.8	81.0	WT	WT	0.79	0.89	0.89	0.55	--	--	
34	509 WT	1.05 TT	--	--	-112.4	80.0	WT	WT	0.79	0.89	0.89	-0.72	--	--	
35	506 WT	-3.08 PS	--	--	-22.0	84.4	WT	WT	0.80	0.89	0.89	0.09	--	--	
36	469 WT	0.28 ET	3.52 BG	--	-232.2	52.9	WT	WT	0.79	0.89	0.89	0.41	0.55	--	
37	547 WT	0.25 ET	-3.24 IT	--	-101.1	52.1	WT	None	0.80	0.89	0.89	0.41	0.87	--	
38	511 WT	-0.23 ET	-3.20 PS	--	34.1	55.0	WT	WT	0.80	0.89	0.89	0.41	0.09	--	
39	429 WT	1.88 ET	-3.64 BA	--	437.0	68.4	WT, BA	WT, BA	0.83	0.91	0.89	0.41	-0.37	--	
40	491 WT	0.17 ET	-0.096 ST	--	-85.5	52.1	WT	WT	0.79	0.89	0.89	0.41	0.88	--	
41	510 WT	0.29 ET	1.53 TT	--	-211.0	52.2	WT	WT	0.79	0.89	0.89	0.41	-0.72	--	
42	581 WT	0.20 ET	5.51 TT	-4.44 PS	-408.0	41.7	WT	WT	0.80	0.90	0.89	0.41	-0.72	-0.37	
43	509 WT	-0.16 ET	-0.15 ST	-3.26 PS	21.4	40.4	WT	WT	0.80	0.89	0.89	0.41	0.88	-0.37	
44	427 WI	840 WC	1.10 ET	--	-473.3	57.2	WI, WC	WI, WC	0.80	0.90	0.85	0.55	0.41	--	
45	436 WI	776 WC	-1.55 TT	--	-81.9	55.9	WI, WC	WI, WC	0.80	0.89	0.85	0.55	-0.72	--	
46	12.3 TA	395 WC	--	--	-61.8	166.2	TA, WC	TA, WC	0.89	0.94	0.93	0.55	--	--	
47	12.3 TA	471 WC	-2.80 PS	--	-67.9	116.1	TA, WC	TA, WC	0.89	0.94	0.93	0.55	0.09	--	
48	463 WI	880 WC	-4.30 PS	--	-177.8	61.9	WI, WC	WI, WC	0.82	0.90	0.85	0.55	0.09	--	

[a]Regression Equation: $\underline{Y} = \underline{a} + \underline{bx}_1 + \underline{cx}_2 \ldots \underline{dx}_n$.

[b]Significant at 1% level.

Test Properties Coded as Follows:

	Directional Tests In	Cross	Combined
Tensile x stretch	AI	AC	AT
Tensile	TI	TC	TT
Elmendorf tear	EI	EC	ET
Stretch	SI	SC	ST
T.E.A.	WI	WC	WT
Impulse	II	IC	IT
Frag	FI	FC	FT

Nondirectional Tests	
T.A. impact fatigue	TA
Scattering coeff.	BA
Bursting strength	BG
Porosity	PS

When combined T.E.A. or the combined tensile-stretch product was used with combined tear (see Regression Equations 4 and 5) the multiple correlation coefficient of 0.89 was equal to the simple correlation coefficient obtained with combined T.E.A. alone. Combined tear was not a significant factor in either regression. Thus, these data indicate that two-factor multiple regressions based on combined T.E.A. and combined tear offer no advantage over a simple regression based on combined T.E.A. alone.

Excluding fatigue properties, small improvements in correlation coefficients with all factors significant were obtained in the following cases:

Regression No.	Properties	Mult. Corr. Coeff.
9	Combined T.E.A. (0.89) and scatt. coeff. (-0.37)	0.90
27	M.D. T.E.A. (0.85) and C.D. T.E.A. (0.55)	0.89
28	M.D. impulse (0.85) and C.D. impulse (0.54)	0.87
32	M.D. stretch (0.85) and C.D. stretch (0.66)	0.88

Note: Figures in parentheses are simple correlation coefficients from Report Twenty-Nine.

None of the multiple regressions noted above appear to offer any major improvement over the best simple regressions obtained for individual properties such as combined T.E.A.

It may be remarked that properties such as tensile, tear, stretch, T.E.A., and impulse fail to predict the relatively poor performance of a number of flat and extensible paper combinations. To illustrate this, Regression Equation 5 was used to estimate the 50% R.H. face drop performance of all runs. The results are shown in Table IX. Differences greater than 25% were recorded for flat kraft runs C, G, N, P, T, EE, KK, and LL. For the extensible kraft

TABLE IX

COMPARISON OF OBSERVED AND PREDICTED VALUES OF 50% R.H.
FACE DROP SACK PERFORMANCE

($\underline{N}$ = 46)

Run	Face Drop, safe inch — Observed	Face Drop, safe inch — Predicted	Difference, %
	Flat Kraft – Study I		
A	411	397	-3.5
B	295	294	-0.3
C	608	431	-29.1
D	494	454	-8.1
E	465	451	-2.9
F	476	391	-17.8
G	326	495	52.0
H	374	421	12.7
I	258	304	17.8
J	330	375	13.8
K	489	423	-13.5
L	358	376	5.1
M	434	404	-7.0
N	192	335	74.7
O	303	315	3.9
P	536	390	-27.1
Q	481	498	3.5
R	417	358	-14.3
S	425	359	-15.7
T	600	389	-35.2
	Flat Kraft – Study II		
AA	401	408	1.8
BB	370	356	-3.8
CC	435	360	-17.3
DD	288	335	16.3
EE	201	297	47.9
FF	222	256	15.5
GG	316	369	16.9
HH	296	303	2.6
II	338	370	9.5
JJ	487	445	-8.7
KK	262	345	31.8
LL	281	390	38.7
	Extensible Kraft – Study II		
MM	855	760	-11.1
NN	987	849	-14.0
OO	1144	1003	-12.3
PP	781	698	-10.6
QQ	1023	871	-15.0
RR	1288	1055	-18.1
SS	438	657	50.0
TT	565	856	51.6
UU	585	994	70.0
VV	1038	986	-5.0
WW	807	673	-16.7
XX	650	865	33.1
YY	727	819	12.6
ZZ	951	829	-12.8
Grand average			19.6

Note: Predicted values calculated from the following equation:

$$F = 493\ WT + 0.13\ ET - 76.2$$

where $\underline{F}$ = face drop, safe inch
$\underline{WT}$ = combined T.E.A., in. lb./in.^{2}
$\underline{ET}$ = combined Elmendorf tear, g./sheet

runs, differences greater than 25% were obtained for Runs SS, TT, UU, and XX. Certain of these differences may be explainable in terms of crease strength – e.g., Run N exhibited the largest loss in cross-machine T.E.A. in the side crease in Study I (2). In most cases, however, the reasons for the discrepancies are unknown. While T.E.A. explains the face drop performance of many sack papers, the foregoing observations suggest that additional methods of measurement are required. For this reason, work is going forward in this area.

The multiple correlation coefficient of 0.89 for the two-factor regression involving in and cross-machine T.E.A. was slightly better than the simple correlation for machine-direction T.E.A. and much better than that for cross-direction T.E.A. It was, however, no more than equal to that exhibited by the simple correlation for combined T.E.A. alone. Thus, for these data, giving equal weight to the T.E.A. in the two directions in the combined value was just as efficient as the separate weighting involved in the two-factor multiple regressions.

Since stretch is not influenced by basis weight to any great extent, its importance is probably overemphasized in these data since they are restricted to one grade weight.

When fatigue properties are considered, it may be concluded that the combination of T.A. impact fatigue strength and cross-machine work was slightly better than T.A. impact fatigue alone. This same combination of properties gave generally favorable results with both flat and extensible papers.

The single and two-factor regression equations involving tensile and tear are summarized in Table X. For the 50% R.H. data it may be concluded that tensile and tear taken together or separately do not correlate well with the face drop performance of sacks made from 50-lb. sack kraft papers.

TABLE X

CORRELATION OF TENSILE AND TEARING STRENGTH WITH PROGRESSIVE HEIGHT FACE DROP IN SAFE INCHES

No.	Regression Equation[a]	Significant Variables (5% Level)	Correlation Coefficient	Av. Predicted Diff., %[b]
	Flat Kraft – Study I (N = 20) – 50% R.H.			
1	PD = 350.8 + 1.9 TI	None	0.04	24.5
2	PD = 652.6 - 1.94 EI	None	-0.17	24.0
3	PD = 716.0 - 1.4 TI - 2.08 EI	None	0.17	24.1
4	PD = 703.2 - 15.10 TC	None	-0.34	22.6
5	PD = 489.0 - 0.57 EC	None	-0.06	25.0
6	PD = 1035.5 - 18.44 TC - 2.04 EC	None	0.39	23.1
7	PD = 797.5 - 7.265 TT	None	-0.22	25.0
8	PD = 639.7 - 0.88 ET	None	-0.14	24.7
9	PD = 1134.9 - 8.19 TT - 1.13 ET	None	0.28	24.9
	Flat Kraft – Study II (N = 12) – 50% R.H.			
10	PD = 71.0 + 7.6 TI	None	0.29	20.9
11	PD = 217.7 + 0.87 EI	None	0.11	21.7
12	PD = -494.1 + 13.4 TI + 3.03 EI	None	0.44	20.0
13	PD = 281.3 + 2.29 TC	None	0.05	22.2
14	PD = 288.7 + 0.28 EC	None	0.02	22.1
15	PD = -118.5 + 8.67 TC + 2.14 EC	None	0.12	21.3
16	PD = 50.4 + 5.24 TT	None	0.25	21.3
17	PD = 225.0 + 0.39 ET	None	0.08	21.8
18	PD = -1205.7 + 14.82 TT + 2.98 ET	None	0.48	18.9
	Extensible Kraft – Study II (N = 14) – 50% R.H.			
19	PD = 1407.6 - 26.5 TI	None	-0.26	25.6
20	PD = -1017.1 + 15.0 EI	None	0.42	23.5
21	PD = -450.5 - 21.1 TI + 14.0 EI	None	0.47	23.7
22	PD = -141.6 + 60.38 TC	None	0.48	20.9
23	PD = 1220.7 - 2.48 EC	None	-0.13	25.3
24	PD = 708.9 + 69.70 TC + 2.75 EC	None	0.49	21.1
25	PD = 502.8 + 9.126 TT	None	0.11	26.1
26	PD = 603.9 + 0.878 ET	None	0.07	26.8
27	PD = 75.6 + 11.03 TT + 1.29 ET	None	0.14	26.4
	Combined Data (N = 46) – 50% R.H.			
28	PD = 1467.5 - 31.7 TI	TI	-0.74	33.1
29	PD = 110.2 - 3.34 EI	None	0.11	46.5
30	PD = 1670.1 - 32.2 TI - 1.52 EI	TI	0.75	32.6
31	PD = 1262.4 - 40.53 TC	TC	-0.37	39.7
32	PD = -783.9 + 9.53 EC	EC	0.50	40.9
33	PD = -461.9 - 9.60 TC + 8.46 EC	EC	0.51	40.1
34	PD = 1715.4 - 24.82 TT	TT	-0.72	33.1
35	PD = -897.4 + 5.45 ET	ET	0.41	43.1
36	PD = 1800.3 - 25.20 TT - 0.26 ET	TT	0.72	33.0
	Combined Data (N = 76) – 10, 25, and 50% R.H.			
37	PD = 1241.4 - 17.5 TT	TT	0.56	--
38	PD = -599.4 + 4.31 ET	ET	0.66	--
39	PD = 203.9 - 13.7 TT + 3.70 ET	TT,ET	0.79	--

[a]Test Code: PD = Progressive height face drop.
TI, TC, TT = Tensile, in, cross, combined.
EI, EC, ET = Elmendorf Tear, in, cross, combined.

[b]Average percentage difference between computed and observed drop test values.

When the data obtained at 10, 25, and 50% R.H. are combined, a statistically significant regression equation is obtained. However, the negative sign obtained for combined tensile implies that the lower the tensile the better the sack performance — not a very reasonable conclusion.

COMBINED DATA (10, 25, AND 50% R.H.)

Carlson (1) has noted that success was achieved in screening new materials for multiwall sack applications using the instantaneous reversible elongation (I.R.E.) in combination with machine-direction tear. Tear was included in the regression equation because I.R.E. did not properly account for humidity effects. He also found that the tensile-stretch product (M.D. and C.D.) could be substituted for I.R.E. His work was based on 4-ply sewn cement sacks made from natural kraft (two weight constructions), four creped samples (four weight constructions), and a microcreped sack paper in two weight constructions.

The preceding analyses of the 50% R.H. data of these studies have suggested that only minor improvements in correlation are obtained by utilizing tear and T.E.A. (or tensile and stretch) in two-factor linear regressions. However, to test the idea further, the analysis was extended to include the 10 and 25% R.H. data from Study II. A limited number of relationships were investigated for the combined data (N = 76). A disadvantage of using the combined data is that the effects of R.H. on both commodity and paper are intertwined. Therefore, changes in paper properties may be called upon to explain changes in sack performance which are partly attributable to changes in the flow characteristics of the commodity.

With this reservation, the results shown in Tables XI and XII indicate the following:

TABLE XI

SINGLE AND MULTIPLE FACTOR RELATIONSHIPS FOR FLAT AND EXTENSIBLE KRAFT AT 10, 25 AND 50% R.H.

(N = 76)

No.	Regression Coefficients: Property 1	Regression Coefficients: Property 2	Regression Coefficients: Property 3	Constant	Regression Significance (F-Test)[a]	Significant Properties: 5% Level	Significant Properties: 1% Level	Fraction Variance Removed (R^2)	Multiple Correlation Coeff. (R)	Correlation Coeff. for Individual Variables: Prop. 1	Prop. 2	Prop. 3	Av. Prediction Diff., %[b]: 50% R.H.	10-25% R.H.
						Single-Factor Relationships								
1	496 WT	--	--	-135.5	150.1	WT	WT	0.670	--	0.82	--	--	24.7	105.0
2	3.48 AT	--	--	-139.5	172.0	AT	AT	0.699	--	0.84	--	--	25.2	112.6
3	13.7 TA	--	--	43.4	307.9	TA	TA	0.806	--	0.90	--	--	18.7	70.8
4	0.92 FT	--	--	-466.5	89.6	FT	FT	0.548	--	0.74	--	--	24.5	83.9
						Multiple Linear Relationships								
6	404 WT	2.77 ET	--	-677.6	175.6	WT, ET	WT, ET	0.828	0.910	0.82	0.66	--	20.5	43.7
7	2.84 AT	2.55 ET	--	-630.4	176.9	AT, ET	AT, ET	0.828	0.910	0.84	0.66	--	20.4	31.2
8	-13.7 TT	3.70 ET	--	203.9	60.3	TT, ET	TT, ET	0.623	0.789	-0.56	0.66	--	--	--
9	4.92 TT	2.69 ET	483 WT	-980.7	123.3	TT, ET, WT	TT, ET, WT	0.837	0.915	-0.56	0.66	0.82	19.3	34.9
10	365 WI	1293 WC		418.1	151.6	WI, WC	WI, WC	0.806	0.898	--	--	--	--	--
11	-9.60 WI	721 WC	11.0 TA	-211.5	184.2	WC, TA	WC, TA	0.885	0.941	--	--	0.90	--	--
12	731 WC	10.8 TA	--	-216.1	280.0	WC, TA	WC, TA	0.885	0.941	--	--	0.90	--	--
13	-14.7 WT	14.0 TA	--	50.5	152.0	TA	TA	0.806	0.898	0.82	0.90	--	18.7	70.9
14	38.7 SI	158.2 SC	--	-279.2	155.8	SI, SC	SI, SC	0.810	0.900	--	--	--	--	--
15	1.20 FI	0.38 FC	--	-346.8	59.0	FI, FC	FI, FC	0.618	0.786	--	--	--	--	--
16	1.94 ET	11.5 TA	--	-348.5	254.0	ET, TA	ET, TA	0.874	0.935	0.66	0.90	--	17.5	31.6

[a] Significant at the 0.01 level.

[b] Average percentage difference between observed and predicted values of face drop based on the observed value as reference.

TABLE XII

SIMPLE CORRELATION COEFFICIENTS FOR COMBINED FLAT AND EXTENSIBLE KRAFT DATA AT 10, 25, AND 50% R.H.

	Combined T.E.A.	Combined Tensile x Stretch	Combined Impulse	Combined Stretch	Combined Frag	Combined Tensile	Combined T.A. Fatigue	Face Drop
Combined tear	0.35	0.40	0.41	0.39	0.39	-0.21	0.48	0.66
Combined T.E.A.		0.99	0.98	0.98	0.68	-0.79	0.92	0.82
Combined tensile x stretch			0.99	0.98	0.67	-0.74	0.92	0.84
Combined impulse				0.97	0.68	-0.74	0.92	0.83
Combined stretch					0.59	-0.84	0.89	0.83
Combined frag						-0.28	0.79	0.74
Combined tensile							-0.65	-0.56
T.A. fatigue								0.90

1. An improvement in correlation coefficient and prediction accuracy can be achieved using combined tear with either combined T.E.A. or the combined tensile-stretch product. The improvement in prediction accuracy is especially noticeable for the 10 and 25% R.H. data.

2. For the regressions studied, the highest correlations were obtained using either C.D. T,E.A. or combined tear with the T.A. impact fatigue test.