

THE INSTITUTE OF PAPER CHEMISTRY

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EVALUATION OF THE IMPROVED LINERBOARD CRACKING
TESTER USING 42-POUND LINERS

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Report Four

A Preliminary Report

to

TECHNICAL COMMITTEE
FOURDRINIER KRAFT BOARD INSTITUTE, INC.

January 21, 1964

TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	2
MATERIALS	3
DOUBLE FACING, SCORING, AND FOLDING	4
DISCUSSION OF RESULTS	5

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TESTER USING 42-POUND LINERS

SUMMARY

Reports Two and Three discussed the correlation between combined board cracking and the liner cracking angle. The latter measurement was made on a tester developed at the Institute and involves folding the board over an anvil of known radius until cracking is observed. The past work utilized a number of lots of 69 and 90-pound liners and favorable correlations were obtained.

The above work has been extended to a number of 42-pound liner samples in this report with the following results:

1. Less favorable correlations were obtained with the 42-pound liner samples as compared to the previous work with 69 and 90-pound grades.
2. The over-all regression equation of the probability type for the 42-pound liners was slightly displaced from the lines previously obtained for 69 and 90-pound liners. Therefore, for best predictions the separate regression lines for each grade should be used.
3. A covariance analysis indicated that the slopes of the regression lines for the three grades were not significantly different. Using a common slope, the following regression equations were obtained for the three grades:

Grade	Equation
42	$\underline{Y} = 8.42 - 0.149\underline{x}$
69	$\underline{Y} = 7.54 - 0.149\underline{x}$
90	$\underline{Y} = 7.90 - 0.149\underline{x}$

where \underline{Y} = combined board cracking transformed to values of the normal deviate
 \underline{x} = liner cracking angle.

INTRODUCTION

Three previous reports have discussed the development of a tester for evaluating the score cracking potential of linerboard. Essentially, the test consists of folding the board over an anvil of known radius to induce tensile strains on the outside surface. The angle at which cracking is observed is measured.

In previous work, 90 and 69-pound liner samples were evaluated for their cracking angle and for their degree of cracking when used as the double-face liner of A-flute combined board. It was noted that:

- a. the linerboard cracking tests appeared to be reasonably well related to the degree of combined board cracking;
- b. useful relationships between the degree of combined board cracking and relative humidity were obtained; and
- c. slightly different relationships of the probability type were required for the 90 and 69-pound grades.

This report discusses data obtained using 42-pound liners. The combined boards were made up using a 90-pound single-face liner and a test series in progress will employ a 42-pound single-face liner. A greater incidence of cracking would be expected using a thinner, less stiff single-face liner and the greater degree of cracking may be helpful in evaluating the cracking relationships.

MATERIALS

The physical characteristics of the 42-pound liner samples used are tabulated in Table I.

TABLE I

PHYSICAL CHARACTERISTICS OF 42-POUND LINER SAMPLES

Sample No.	Basis Weight, lb./M sq. ft.	Caliper, pt.	Tensile, lb./in..		Stretch, %	
			In	Cross	In	Cross
2410	42.8	13.4	79.9	34.3	1.6	4.3
2418	44.9	12.0	95.5	36.8	1.6	3.9
2421	42.7	12.6	86.7	37.2	1.8	3.8
2424	44.0	10.4	84.2	42.2	2.0	4.6
2436	43.0	12.1	88.6	37.0	2.1	3.7
2476	42.8	12.8	85.9	41.4	1.8	3.0

The above samples were fabricated into double-faced board and evaluated for folding at 10, 20, and 30% R.H. Higher humidities were not used because of the little cracking obtained at 30% R.H.

In addition, portions of each sample were subjected to a 36-hour exposure at 125°C. prior to double facing. They were then conditioned at 50% R.H. and 73°F. prior to scoring.

DOUBLE FACING, SCORING, AND FOLDING

Double-faced board was made by hand gluing sheets of the linerboard to a single-faced board corrugated on the Institute's experimental corrugator. With the exception that a 90-pound liner was used as the single-faced liner, the same conditions were used as specified in Report One.

Five sheets of board, with 3-11 inch long panel scores per sheet, were evaluated for cracking for each sample in each atmosphere. To increase crack visibility, a spray coating of flat black paint was used as described in the previous study.

Ten specimens of each linerboard sample were evaluated at each humidity level with the fold line at right angles to the machine direction. A spray coating of flat black paint was used to increase crack visibility and the rupture angle associated with the first appearances of a crack in the liner surface was measured.

DISCUSSION OF RESULTS

A tabulation of the combined board and linerboard cracking results obtained with 42-pound liners may be found in Table II. As in the previous studies the combined board and linerboard tests, in general, exhibit the expected trends with folding humidity and fabrication treatment.

In the previous reports, it was found that probability type equations appeared to have promise in the analysis of the relationship of combined board cracking to the liner cracking angle and relative humidity. With this in mind, the linerboard cracking was transformed to standard deviation units (\underline{Y}) as shown in Table I. A graph of the results in arithmetic probability co-ordinates is shown in Fig. 1 and the correlations are tabulated in Table III.

As may be noted, the correlations obtained were somewhat lower than were obtained with the 90 and 69-pound liner samples, possibly because of the difficulties in evaluating the lower degrees of cracking. Inspection of the data indicates that certain of the samples tended to exhibit consistent deviations from the other members of the group. For example, Sample No. 2424, a dense low caliper (10.4 pt.) sample, tended to exhibit considerably greater amounts of combined board cracking than would be expected from the liner cracking tests.

It may also be remarked that some difficulties were encountered in reproducing test results with the lighter weight liners. A check to determine if variations in the coating used for contrast are a possible cause for shifts in test readings is underway. In addition, a possible improvement in correlation through application of an initial strain to the liner cracking specimen is being investigated.

TABLE II
 COMBINED BOARD AND LINERBOARD CRACKING RESULTS

Sample No.	Combined Board Cracking, %		Combined Board Cracking Trans- formed to Normal Deviate Values		Linerboard Cracking Angle, °	
	10% R.H.	20% R.H.	10% R.H.	20% R.H.	10% R.H.	20% R.H.
Untreated						
2410	29.6	8.2	-0.54	-1.39	63.8	68.9
2418	20.0	0.0	-0.84	--	68.2	72.8
2421	14.5	1.0	-1.06	-2.33	63.1	66.6
2424	14.1	2.4	-1.08	-1.98	67.6	75.6
2436	33.2	2.5	-0.43	-1.96	64.8	68.8
2476	2.4	1.2	-1.97	-2.26	66.8	70.6
After drying at 125°C. for 36 hours						
2410	67.2	27.9	0.45	-0.59	58.8	63.5
2418	34.6	21.7	-0.40	-0.78	60.8	64.8
2421	20.0	5.5	-0.84	-1.60	58.2	63.0
2424	75.8	37.2	0.70	-0.33	60.8	66.2
2436	44.2	23.9	-0.15	-0.71	58.6	62.6
2476	30.5	15.7	-0.51	-1.01	58.7	62.6

Note: Linerboard cracking angle corresponding to initial observed crack.

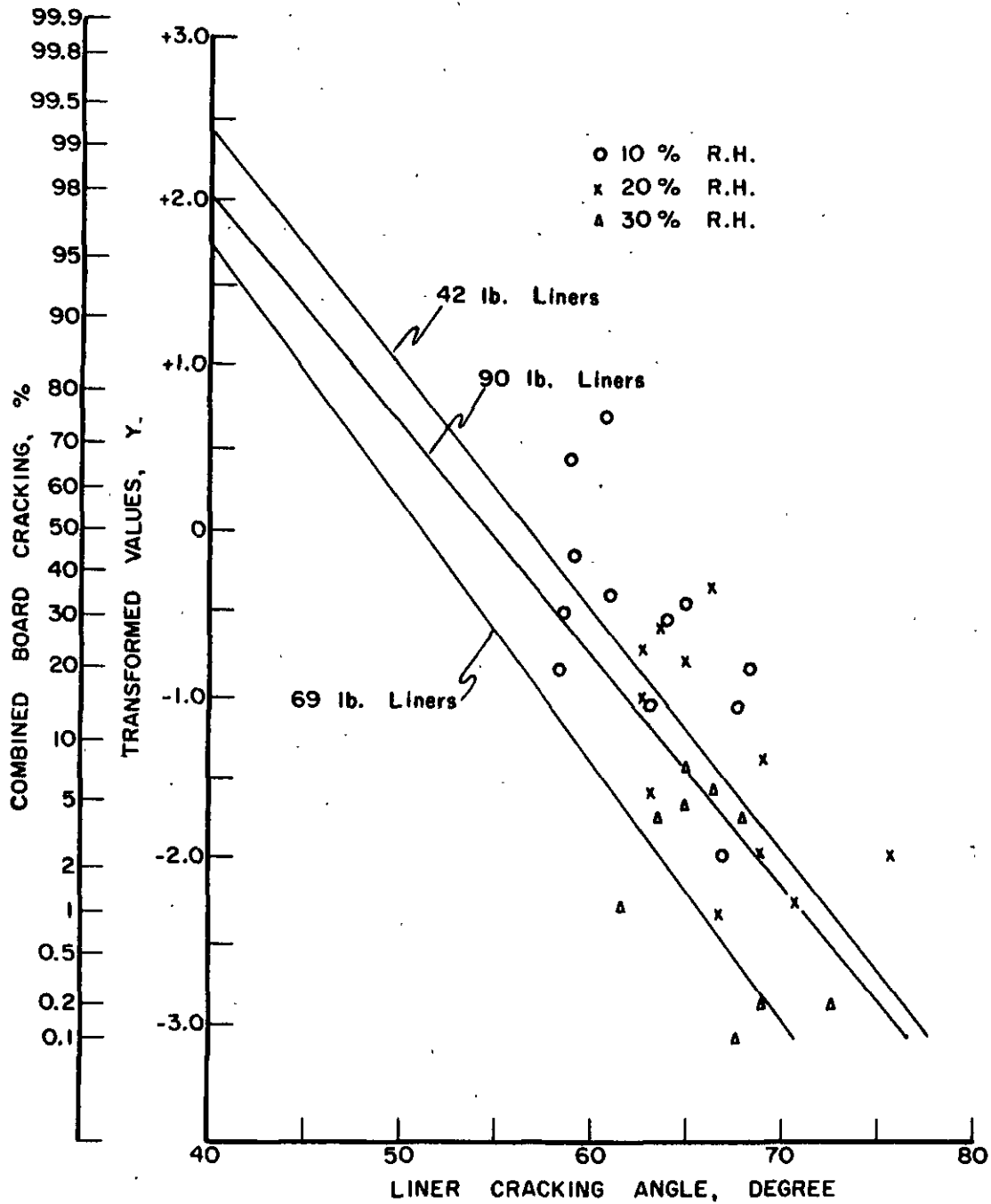


Figure 1. Relationship Between Combined Board Cracking and the Liner Cracking Angle for 42-Pound Liner Samples (Arithmetic Probability Co-ordinates)

TABLE III
 CORRELATION OF COMBINED BOARD CRACKING AND
 THE LINERBOARD CRACKING TEST

Equation No.	Data Subdivision	N	Regression Equation ^a	Correlation Coefficient
42-lb. Liners				
1	10% R. H.	12	$\underline{Y} = 6.45 - 0.112\underline{x}$	0.59
2	20% R. H.	11	$\underline{Y} = 5.73 - 0.106\underline{x}$	0.61
3	30% R. H.	9	$\underline{Y} = 4.98 - 0.107\underline{x}$	0.54
4	Overall	32	$\underline{Y} = 8.31 - 0.147\underline{x}$	0.65
69-lb. Liners				
5	Overall	102	$\underline{Y} = 8.15 - 0.160\underline{x}$	0.93
90-lb. Liners				
6	Overall	70	$\underline{Y} = 7.68 - 0.141\underline{x}$	0.94
Combined Grades				
7	Overall	204	$\underline{Y} = 7.31 - 0.139\underline{x}$	0.88

^a \underline{Y} = combined board cracking transformed to standard deviation units.

\underline{x} = liner cracking angle, °.

With the above in mind, it may be noted that the over-all regression line for the 42-pound liner data was slightly displaced from the 90 and 69-pound regression lines. At this time it is not known whether the differences in regression line are due to experimental difficulties or to factors unaccounted for in the correlations.

An analysis of covariance using I.B.M. program 6.0.032 was used to determine if the slopes of the over-all regression lines for the three grades were significantly different. The slopes were not statistically different—implying that regression lines of common slope could be used for the three liner grades. The covariance analysis gave the regression lines shown in Table IV.

TABLE IV
COVARIANCE REGRESSION LINES

Equation No.	Liner Grade, lb.	Regression Equation
8	42	$\underline{Y} = 8.42 - 0.149\underline{x}$
9	69	$\underline{Y} = 7.54 - 0.149\underline{x}$
10	90	$\underline{Y} = 8.18 - 0.149\underline{x}$
11	Combined	$\underline{Y} = 7.90 - 0.149\underline{x}$

These equations may be preferred over Equations (4), (5), and (6) because of the convenience of using a common slope. As may be noted in Fig. 2, the differences between the equations for the individual grades and the covariance equations of equal slope are relatively minor except near the data extremes.

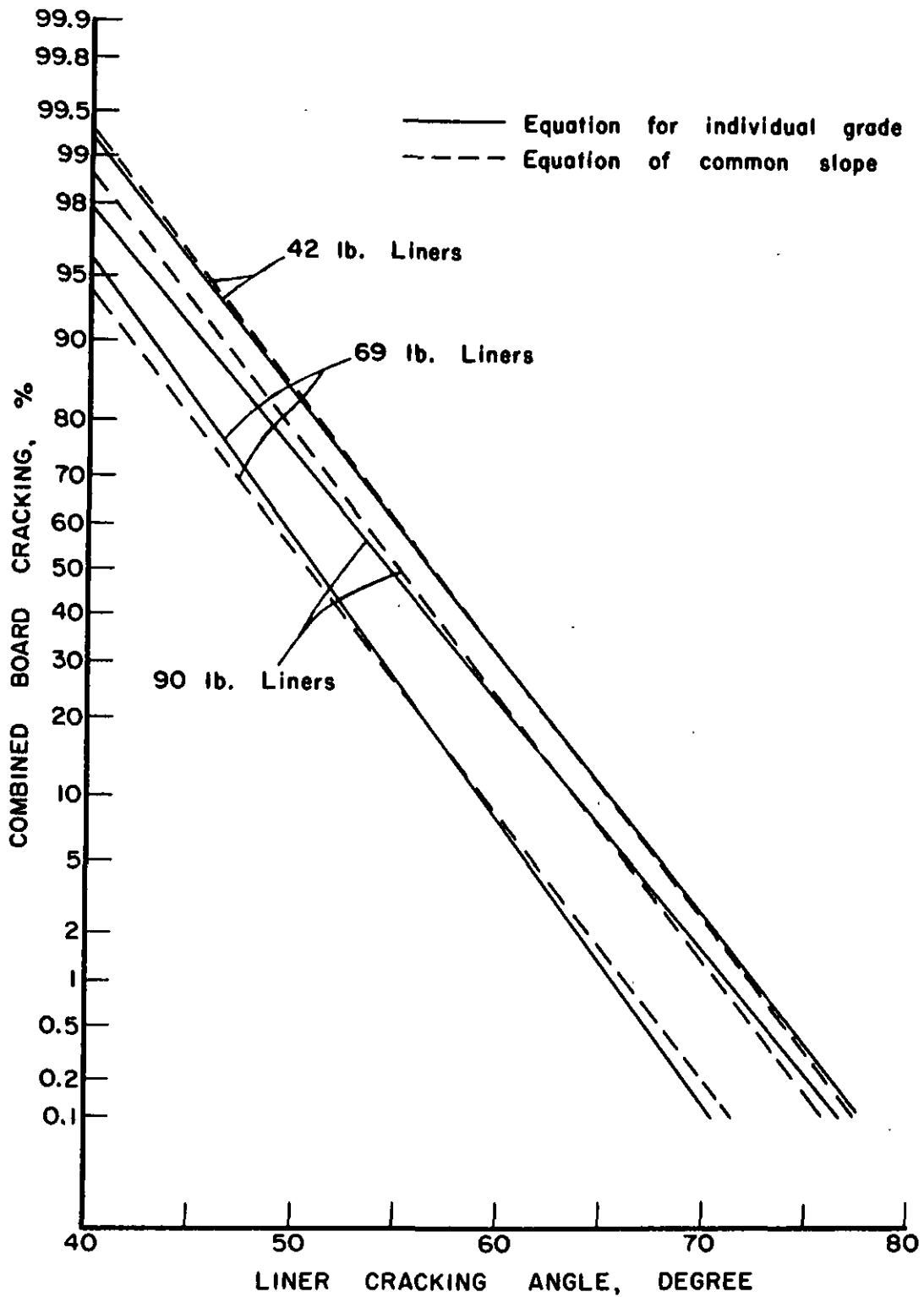


Figure 2. Comparison of Equal Slope Regression Lines with Regression Equation for Each Grade

The above equations indicate that an increase of one unit in the cracking angle will decrease \bar{Y} by 0.149 units. To illustrate, the improvement in combined board cracking associated with a 0.15 unit decrease in \bar{Y} , values are tabulated in Table V for various initial levels of \bar{Y} . For example, if \bar{Y} is changed from 0.0 to -0.15 the expected degree of combined board cracking will decrease from 50 to 44%, a change of 6%. Similarly, changing \bar{Y} from -2.0 to -2.15 would change the percentage cracking from 2.28% to 1.50%. Thus, the absolute effectiveness of a one unit change in liner cracking angle is more apparent at higher levels of cracking.

TABLE V
EFFECT OF A ONE UNIT CHANGE IN THE LINER CRACKING
ANGLE ON COMBINED BOARD CRACKING

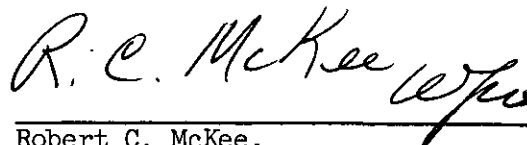
Normal Deviate (\bar{Y})		Combined Board Cracking, %		Change
Original Level	New Level	Original Level	New Level	
0.0	-0.15	50.0	44.0	6.0
-1.0	-1.15	15.9	12.5	3.4
-1.5	-1.65	6.7	5.0	1.7
-2.0	-2.15	2.28	1.58	0.73
-2.5	-2.65	0.62	0.40	0.22

Because the evaluations were only possible at the three lower humidities, a detailed analysis of the relationship between combined board cracking and relative humidity could not be carried out for each sample. An over-all regression equation was obtained, however, with a slope equal to -0.0795. This value was about the same as that obtained with 69-pound liners, -0.0804, and it is assumed that the regression equation for the pooled 69-pound liner data in Table VII of Report Three would be suitable for 42-pound liners.

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