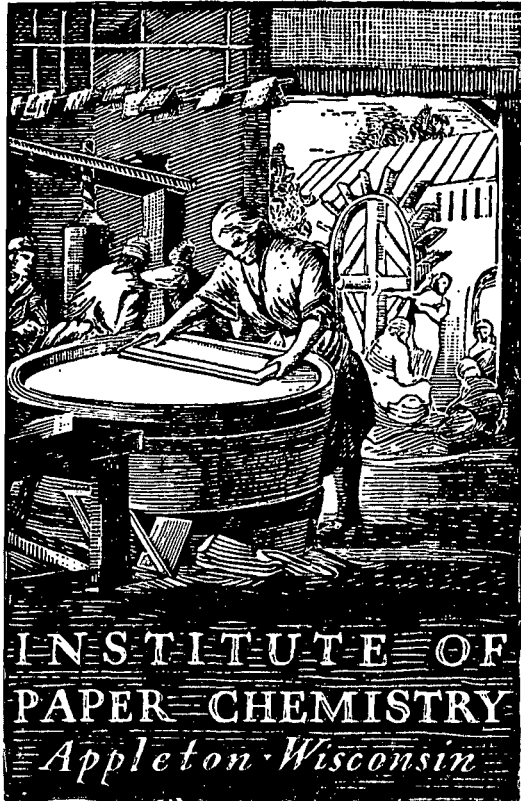


GENERAL



**INVESTIGATION OF METHODS FOR EVALUATING
THE SCUFFABILITY OF LINERBOARD**

Project 2694-14

**Report One
A Progress Report to the
FOURDRINIER KRAFT BOARD GROUP
of the
AMERICAN PAPER INSTITUTE**

July 6, 1978

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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INVESTIGATION OF METHODS FOR EVALUATING
THE SCUFFABILITY OF LINERBOARD

SUMMARY

In recent years a number of FKBG member companies have indicated that peeling and dusting problems were occurring in their box plants. The peeling occurs on the corrugator or in sheet feeding operations. Dusting on the flexo-folder-gluer makes it necessary to wash-up more frequently and causes poor print quality. Therefore, a limited study was carried out to investigate methods for evaluating the scuffability of linerboard.

The study was divided into two parts as follows:

1. Survey on scuffability.
2. Scuff testing and linerboard evaluation (note: this involved a very limited evaluation of commercial linerboards in terms of S & S scuff and other properties).

The following results were obtained:

1. Survey Findings

The survey findings based on 22 completed questionnaires from members of the Technical Committee of FKBG are briefly summarized below:

- a. Peeling and dusting during conversion operations are problems to most companies.
- b. Peeling and dusting are about equal in importance overall but their relative importance varies somewhat from company to company.

- c. The most common quality test for scuff is the S & S scuff tester.
Linerboards exhibiting low scuff results — below about 20-25 strokes — are believed to cause difficulties in the box plant.

2. Scuff Testing and Linerboard Evaluation

a. Scuff Tester

Based on the survey, an S & S scuff tester was obtained on loan from one of the FKBG members. Essentially the tester has means for repeatedly rubbing two board surfaces together until they dust and eventually peel. It may be noted that peeling problems in the box plant usually do not involve repeated rubbing of the same surfaces, therefore, the S & S tester action does not wholly simulate box plant conditions.

The tester is relatively crude and not well standardized. Various changes were required to obtain usable results with the tester obtained for this study.

b. Scuff Results on Commercial Linerboard

S & S scuff results on 23 sample lots of 69-lb linerboard varied over a wide range — from 7-497 strokes to peel in the M.D. and from 7-149 strokes to peel in the C.D. Five M.D. and 7 C.D. samples exhibited peel end-point averages of 20 or less. Based on the survey, such samples might be expected to cause problems on the corrugator or presses.

c. Scuff Relation to Other Properties

In general peeling and dusting would be expected to depend on the surface bonding strength of the board. Limited tests indicated that

the occurrence of peeling and dusting in the S & S test is related to IPC bonding strength using a rupture end-point. This is perhaps due to the surface ruptures produced in this type of bonding strength test. In contrast, ZDT bonding strength tests did not appear to be related to S & S scuff. This is not surprising since failure in the ZDT test is almost always in the interior of the sheet. Neither smoothness nor the friction coefficient were well related to S & S scuff.

INTRODUCTION

The term "scuff" is often used to refer to the characteristic peeling off and rubbing up of bundles of fibers from the surface of a sheet. Rubbing may also dislodge fibers and fiber fragments thereby producing dust. The term "scuffability" refers to either peeling or dusting as used in this report and specific consideration of peeling or dusting damage is noted in the text.

It appears that the occurrence of scuffing should depend on the bonding strength of the sheet, particularly in the surface layers. Scuffability could also depend to some extent on other surface characteristics such as friction. Moisture content is believed to be an important variable.

In recent years a number of FKBG member companies have indicated that their box plants were experiencing significant production losses due to peeling and dusting problems. The peeling occurs on the corrugator or in sheet feeding operations. Excessive dusting in the flexo-folder-gluer makes it necessary to stop the press and wash-up more frequently and causes poor print quality.

Because of the problems being encountered, a limited study was carried out having two parts as follows:

1. Survey on scuffability problems.
2. Scuff testing and linerboard evaluation (note: this involved a very limited evaluation of commercial linerboards in terms of S & S scuff and other properties).

A more comprehensive study would be required to determine the best ways to evaluate the peeling and dusting proclivity of linerboard in relation to end-use and to the basic properties of linerboard.

The results obtained are summarized in this report.

SCUFF SURVEY

SURVEY OBJECTIVES

The first phase involved a survey of the FKBG membership. The objective of the survey was to determine the following:

- A. Types of board problems to be considered as "scuff."
- B. Relative importance of the various types of scuff.
- C. Types of instruments and procedures used to evaluate board for the more important types of scuff.
- D. Factors affecting end use scuff performance and scuff tests.

The survey questionnaire was distributed to the members of the Technical Committee of FKBG. Twenty-two responses were received excluding one company making medium only.

ANALYSIS OF SURVEY RESPONSES

The responses to each question are briefly discussed below:

Question 1. Please identify the types of board performance which you normally include under the term scuffability.

In general, the respondents listed the following (see Table I):

- a. Peeling of liner on the corrugator
- b. Peeling of liner in box plant feeding operations.
- c. Dusting on presses in box plant
- d. Dusting in transit due to rubbing
- e. Weak glue tab strength
- f. Frictional drag on corrugator

TABLE I

TYPES OF PERFORMANCE INCLUDED UNDER SCUFF

Question 1: Please Identify the Types of Board Performances Which You Normally Include Under the Term Scuffability

Code	a	b	c	d
A	Dusting	Peeling	Frictional drag	--
B	Peeling on corr.	Peeling (roll wrapping)	--	--
C	Peeling (feeding operation)	Abrasion (transit)	--	--
D	Peeling (press & corr.)	Dusting (press)	--	--
E	Peeling (mfg.)	Dusting (transit)	--	--
F	Peeling	Ply separation	--	--
G	Cigaring (peeling)	Dusting	--	--
H	Dusting	Peeling	Weak mfg. joint	--
I	Peeling	Dusting	--	--
J	Chafe (rubbing)	Scuff (scrape)	Peel	--
K	Mild scuffing - peeling	Weak glue tab strength	Dusting	Surface peel
L	Peeling _a	Dusting	--	--
M	--	--	--	--
N	Peeling	Dusting	--	--
O	M.D. peeling	C.D. peeling	Linting	Abrasion (vibration)
P	Peeling	Delam. (scuffing)	Dusting	Loose surface fibers
Q	Peeling	Dusting	--	--
R	M.D. "cigaring"	Surface peel (C.D.)	Dusting	--
S	Peeling	Dusting	--	--
T	Dusting	Surface roughing	Spot peels	Large peels
U	Peeling on corr.	Dusting on flexo.	--	--
V	Peeling on corr.	--	--	--
W	No comment, mill makes medium only			

^aClassify peeling and dusting as separate problems, not under scuff.

Question 2. Please rank the types listed in order of importance, considering the frequency and cost.

The following were listed as being of first importance (see Table II, Column a):

Main Types	First Importance, no.
Peeling on corrugator or press	9
Dusting on presses	6
Peeling and dusting	2
Miscellaneous	4

Thus it appeared that peeling and dusting are about equal in importance overall.

Question 3. Which of the items in Question 2 are considered a serious problem from a production and cost standpoint?

The great majority of responses indicated that peeling on the corrugator or presses and dusting on the presses were serious problems (see Table III).

Question 4a. Does the damage originate during conversion or end use?

In most cases the problems occur during conversion on the corrugator and on the presses due to feeding difficulties or dusting (see Table IV).

Question 4b. Are certain grade weights more likely to exhibit damage?

Peeling problems appeared to be more common on the heavier grade weights and, in some cases, on mottled or bleached surface grades. Dusting is encountered

TABLE II

RELATIVE IMPORTANCE OF VARIOUS TYPES OF SCUFF

Question 2. Please Rank the Types Listed in Question 1 in Order of Importance Considering Frequency and Impact on Costs

Code	a	b	c	d
A	Frictional drag	Peeling	Dusting	
B	Peeling (roll wrapping)	Peeling on corr.	--	--
C	Peeling (feeding operation)	Abrasion (transit)	--	--
D	Peeling (press & corr.)	Dusting (press)	--	--
E	Peeling (mfg.)	Dusting (transit)	--	--
F	--	--	--	--
G	Dusting	Peeling	--	--
H	Weak mfg. joint	Peeling	Dusting	--
I	Dusting	Peeling	--	--
J	Chafe (rubbing in serv.)	Scuff	Peel	--
K	Peeling in conv.	Scuff in transit	Dusting	--
L	Peeling	Dusting	--	--
M	Dusting	Peeling	--	--
N	Peeling	Dusting	--	--
O	Linting (dusting)	M.D. & C.D. peeling	Abrasion	--
P	Delam. (scuffing)	Peeling	Dusting	Loose fiber
Q	Dusting	Peeling	--	--
R	All -- dusting & peeling			
S	Both peeling & dusting			
T	Dusting	Surface roughing	Spot peels	Large peels
U	Peeling on corr. ^a	Dusting	--	--
V	Peeling on corr.	--	--	--

^aEspecially clay white liners.

TABLE III

SCUFF TYPE CAUSING SERIOUS PROBLEM

Question 3. Which of the Items in Question 2 are Considered a Serious Problem from a Production and Cost Standpoint?

Code

A	Frictional drag
B	Peeling on corr. and in roll wrapping operation
C	Peeling in feeding operations
D	Both (peeling on press and corr. and dusting on press)
E	Peeling in mfg.
F	--
G	Both (dusting and peeling)
H	All - peeling, dusting and mfg. joint failure
I	Dusting
J	Chafe (rubbing in service)
K	Dusting, scuff in conversion
L	Peeling
M	Both dusting and peeling, but dusting worse
N	Peeling
O	Linting (dusting)
P	Any surface problem that interferes
Q	Dusting (very serious)
R	All - dusting, M.D. and C.D. peeling
S	Both peeling and dusting
T	All
U	Peeling on corr.
V	Peeling on corr. and presses

TABLE IV

PLACE OF OCCURRENCE AND MOST TROUBLESOME GRADES

Code	4a		4b	
	Does the Damage Originate During Conversion or End-Use	In Conversion, What Type of Equipment	Are Certain Grade Wts. more Likely to Exhibit Damage	If Yes, Please List the More Critical Weights
A	Conversion	Corrugator	Yes	33 & 42 lb/MSF
B	Conversion and end-use	Corrugator	Yes	>45 lb/MSF
C	Conversion	Flexo-folder-gluer	No	--
D	Conversion	Corr. and press feeder	Yes	Primarily 69 lb/MSF
E	Conversion	Any under feeder, some feeder rolls	Yes	Cloudy white grades
F	--	--	Yes	Ply separation on heavy wts.
G	Conversion	Corr. and press feeder	Yes	Peeling (69 lb); dusting (26-38 lb)
H	Conversion	Corr. and press feeder	Yes	Peeling (69 & 90 lb liner)
I	Conversion	Presses	No	--
J	End-use	--	Yes	Bleached lined kraft
K	Conversion	Flexo under-stackers	No	--
L	Conversion	Flexo presses and corr.	Yes	42, 69, 90 lb
M	Conversion	Corr. and presses	Yes	Peeling on heavy wts. and bleached; dusting on dry finish
N	Conversion	Feeding equipment	Yes	42 lb dry finish
O	Conversion	Corr. and presses	Yes	Lighter weights
P	Both	Flexo presses	Yes	Heavy weights
Q	Conversion	Corr. and presses	Yes	Dusting all wts., peeling 69 lb
R	Both	Corr. and presses	Yes	Heavy grade wts.
S	Conversion	Flexo presses	Yes	Heavy grades peeling; light grades dusting
T	Conversion	Printing, slotting	Yes	42, 69, 90 lb
U	Conversion	--	Yes	Colored and 69 lb liner
V	Conversion	Corrugator mostly; press occasionally	Yes	33-42 lb clay coated board

on all grade weights but some respondents indicated it is more of a problem in the lighter weight grades (see Table IV).

Question 4c. Do environmental conditions affect the occurrence of the problem?

More than half of the respondents indicated that relative humidity or board moisture content affected peeling or dusting (see Table V). In general, peeling problems are believed to be more severe under high relative humidity or moisture content conditions. A few people noted that dusting is more severe at low board moisture contents as might be expected.

Question 4d. Is the damage more often associated with boxes for a given class of product?

Most responses indicated that scuff problems were not associated with boxes for specific products (see Table V).

Question 5. What test instruments and methods are used to evaluate linerboard quality for the most important type of scuff in Question 2?

The S & S scuff tester was the most frequently employed instrument by a considerable margin (see Table VI). Other tests used by some companies included Sutherland ink rub, various ply-bond tests, wax pick, Sheffield smoothness, friction and vibration types.

Question 6. Does the test (or tests) in Question 5 correlate satisfactorily with service scuff damage?

A variety of opinions were obtained (see Table VI). Of those companies using S & S testers, a majority indicated that the S & S results were fairly well

TABLE V

EFFECT OF RELATIVE HUMIDITY AND TYPE OF BOX ON OCCURRENCE

Code	4c	If "Yes", are Low or High RH Condi- tion More Detrimental	4d	If "Yes," Please Describe
	Do Environmental Conditions Affect the Occurrence of Problem		Is Damage More Often Associated With Boxes for Given Class of Product	
A	Unknown	Greater at high RH	No	--
B	Yes	Greater at high RH	--	275 lb series boxes or higher
C	Yes	Greater at high RH	No	Depends more on stack height and geometry
D	Yes (moisture content)	Greater at high RH (moisture)	--	--
E	Yes	Greater at high RH	No	--
F	--	--	--	--
G	Unknown	--	--	--
H	Yes	Dusting worse on dry board; peeling on wet board	--	--
I	No	--	No	--
J	Yes	Greater at high RH	Yes	Beer, applies, heavy load, long distances
K	No	--	No	--
L	Yes	Greater at high RH	No	Possibly larger boxes
M	--	--	--	--
N	Yes	Greater at high RH	No	--
O	Yes	Dusting -- worse at low RH	No	--
P	No	--	No	--
Q	--	--	Yes	For food boxes
R	Yes	High RH and wet board	No	--
S	Yes	Peel, high moisture; dusting low RH	--	--
T	Yes	High RH	No	--
U	Yes	Cold temperatures detrimental	No	--
V	No	--	No	--

TABLE VI

TESTS USED AND THEIR RELATION TO SCUFF

Code	5 What Test Instruments and Methods are Used to Evaluate Linerboard Quality for the Most Important Type of Scuff in Item 2	6 Does the Test (or Tests) in 5 Correlate Satisfactorily with Service Scuff Damage
A	S & S scuff, internal bond, friction	No
B	Home made	Usually, but test is not repeat- able
C	S & S scuff	Yes
D	Do not have acc. test, have tried bond and friction	Not always
E	Ply-bond for peel, Sutherland ink rub for dusting, vibration	Yes, generally
F	TAPPI ply-bond for ply separation	--
G	None	--
H	S & S scuff, wax pick, IGT tester, ply-bond not sat.	--
I	No test for dusting; use S & S or Scott bond for peel	Not for dusting; S & S or Scott bond satisfactory for peel
J	Kahn shaker	Yes - simulates rubbing in transit
K	S & S scuff, IGT, wax pick, Vanceometer	Yes - board with S & S below 20 gives trouble
L	Sutherland rub tester	Partly but difficult to detect marginal liner
M	--	--
N	ASTM D1029-59 (similar to S & S scuff)	Yes
O	S & S scuff, printing index, density	Low scuff will peel; low print index will dust
P	S & S scuff, Sheffield smoothness	Smoothness shows some corr. to scuff or print problems
Q	None	--
R	S & S scuff	Yes
S	S & S scuff	Yes
T	S & S scuff, Vanceometer	Yes
U	None	Not available
V	None	--

related to service (box plant) problems. However, some indicated that S & S test results were better related to peeling problems during conversion rather than dusting.

Based on the responses, it appears that the S & S scuff tester is the most common evaluation method for scuff type conversion problems. Low scuff results, below 20-25 strokes, frequently result in peeling problems and may also cause dusting on the flexo-presses.

Question 7. Is the test in Question 5 correlated with any other board quality test?

Only a few responses were received. S & S scuff results were reported to be related to such properties as smoothness, bonding strength, density, wax pick and top liner freeness (see Table VII).

Question 8. Is the test in Question 5 used for the following?

- a. Linerboard quality control: Ten affirmative responses were obtained (see Table VII).
- b. If "yes," what specification limits are employed? S & S scuff test minimums ranging from 7 to 25 strokes were reported. Other companies reported minimum specifications on Mullen ply bond, wax pick and Sutherland ink rub.

TABLE VII

RELATION OF SCUFF TEST TO OTHER PROPERTIES AND SPECIFICATIONS

Code	7		8: Is the Test on 5 Used for the Following		
	Is the Test in 5 Correlated with Any Other Board Quality Test	Linerboard Quality Control	Specification Limits	b	c
				Box Plant	R&D Tech. Service
A	--	Yes	Scott bond, 15 psi/min	--	Int. bond & friction
B	Freeness	Yes	Home made, 35-70 on 69 lb	--	--
C	Smoothness, bond str., freeness	Yes	S & S scuff, min = 7	--	--
D	--	--	--	--	Yes
E	Unknown	No	--	No	Yes
F	--	--	Ply bond, min = 80 psi	--	--
G	--	--	--	--	--
H	--	--	S & S scuff, min = 20; wax pick, min = 16	--	--
I	--	Yes	S & S scuff, min = 10; Scott, 75 ft/lb	--	--
J	Finish, friction coeff.	No	--	Yes	Yes
K	Wax pick	Yes	S & S scuff, min = 20	No	Yes
L	No	Yes	Ink rub, min = 15	--	--
M	--	--	--	--	--
N	Refining of top liner	--	Occasional use	--	--
O	Density and Mullen	Yes	Print index and density	--	Scuff (5-25)
P	No	Yes	Sheffield smoothness; max. = 360	Yes	--
Q	--	--	--	--	--
R	No	Yes	S & S scuff, min. = 25	--	--
S	Unknown	No	--	No	Yes
T	--	Yes	S & S scuff, min = 25; Vanceometer, 15-25	--	--
U	Not available	--	--	--	--
V	--	--	--	--	--

DESCRIPTION OF S & S SCUFF TESTER

Based on the survey, it was decided to study use of the S & S tester. Because the tester is no longer manufactured by the S & S Corrugated Machinery Co., an instrument was obtained on loan from one of the FKBG members (Fig. 1). It should be noted that while the tester is rather "old" in the industry, there is no TAPPI Standard Method (or Useful Method) covering its use. Thus, contacts with industry people indicate there are differences from company-to-company in the way the tester is set up and operated.

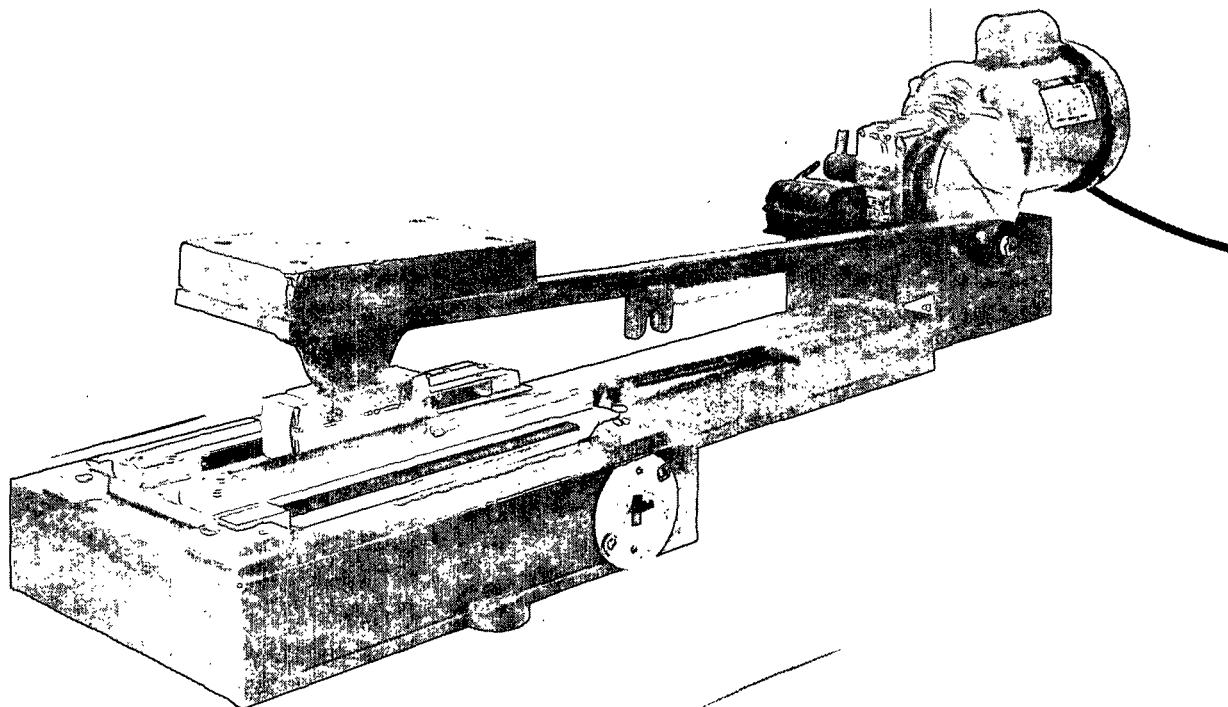


Figure 1. S & S Scuff Tester

Essentially, the tester has means for repeatedly rubbing two board surfaces together until they dust and eventually peel as shown schematically in Fig. 2. The lower specimen rests on a rubber covered plate although in some laboratories the rubber is omitted. The upper holder may be made of wood or aluminum with the edges rounded to various extents from tester-to-tester. A rubber strip may or may not be used on the bottom of the holder, depending on the test user.

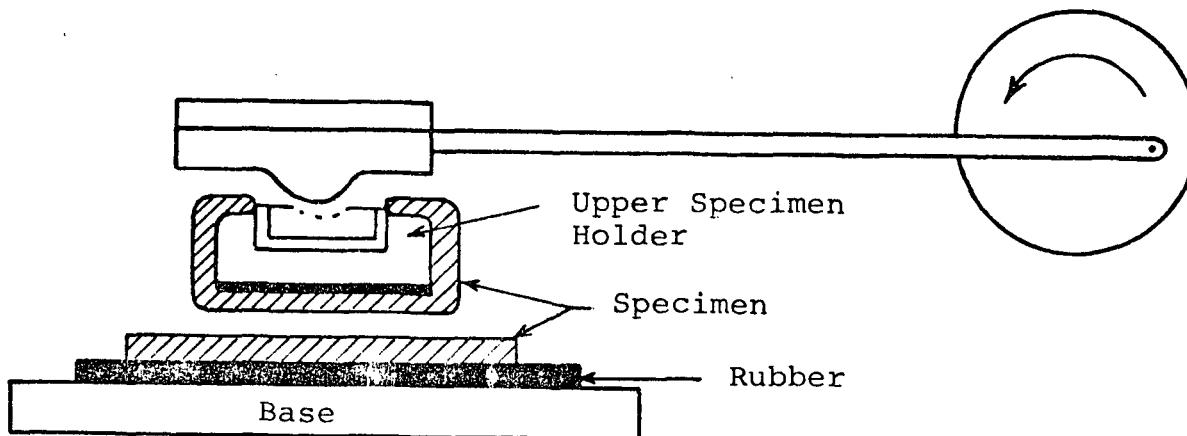


Figure 2. Schematic Drawing of S & S Tester

The upper holder is moved back and forth by the reciprocating arm. Unfortunately, the design is such that the upper holder tends to rock back and forth on each cycle. It is not known how this would affect the test readings.

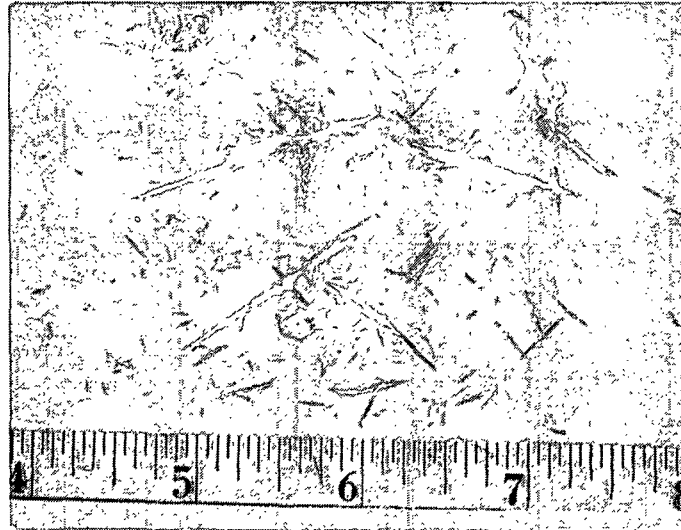
Preliminary tests on the machine received by the Institute showed that the tester was not operating properly as received. For many of the commercial samples, such severe vibrations were encountered from the start as to prevent testing. After a phone canvass of various users, a number of changes were made as follows:

1. Weight on arm: This was reduced from over 40 lb to 25 lb for the arm plus upper specimen holder. The 25-lb weight level was approximately the same as used by a number of the companies contacted.
2. The gear drive was repositioned and other mechanical changes were made on the eccentric wheel in order to improve alignment and motion of the reciprocating arm and hence upper specimen block.
3. New 60 durometer rubber strips were installed on the holders.
(Note: A few tests were made comparing operation with and without rubber backing and aluminum vs. wood holders; however, the results were inconclusive considering the test variability.)

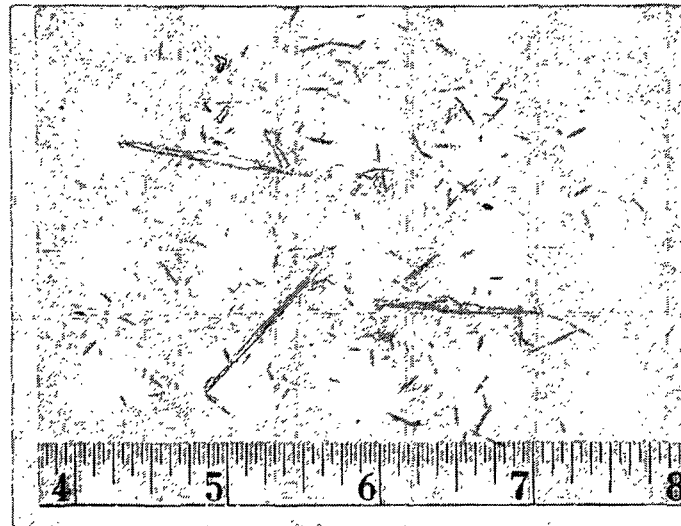
After the above changes, the tester operated more smoothly. However, further improvements would be desirable to reduce rocking of the upper holder and to secure the specimen more tightly on the upper holder.

A limited comparison was made of results obtained on the tester at the Institute with results obtained by one of the companies on their tester. The Institute results were slightly lower in magnitude but the differences did not appear to be significant considering the test variability.

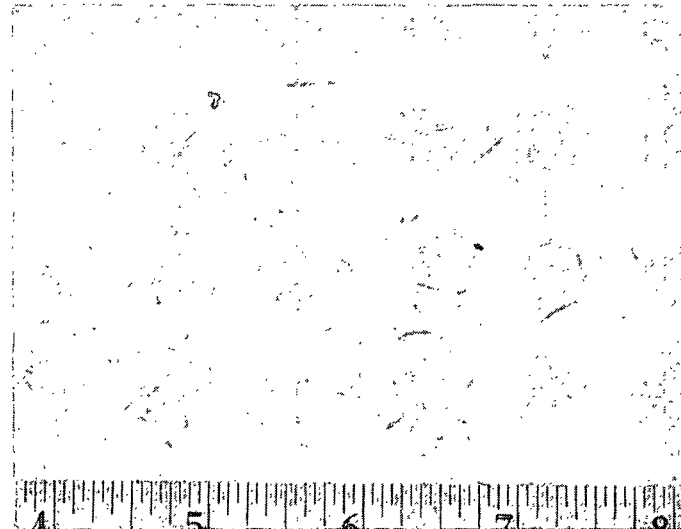
The progression of damage in the S & S scuff tester on linerboards exhibiting "poor" and "average" printing quality is illustrated in Fig. 3 and 4, respectively. These photographs were submitted by a FKBG member company. A noticeable amount of dust was produced on the "poor" quality liner after 6 cycles and large cigar-shaped bundles of fibers were present after 10 cycles (Fig. 3).



30 Cycles

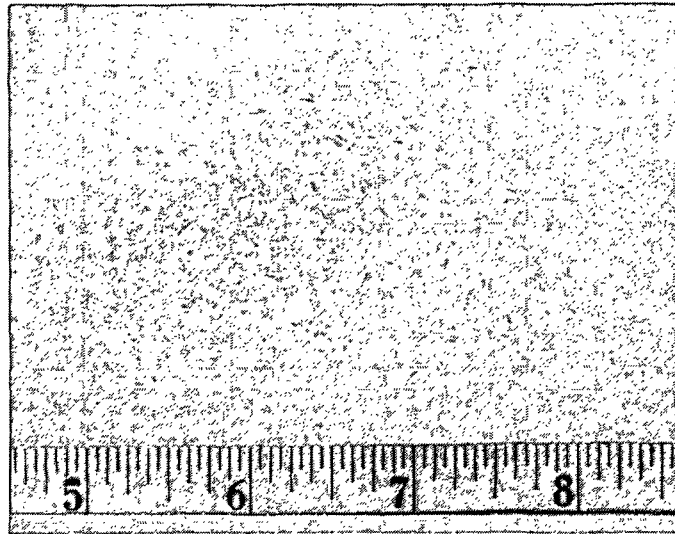


10 Cycles

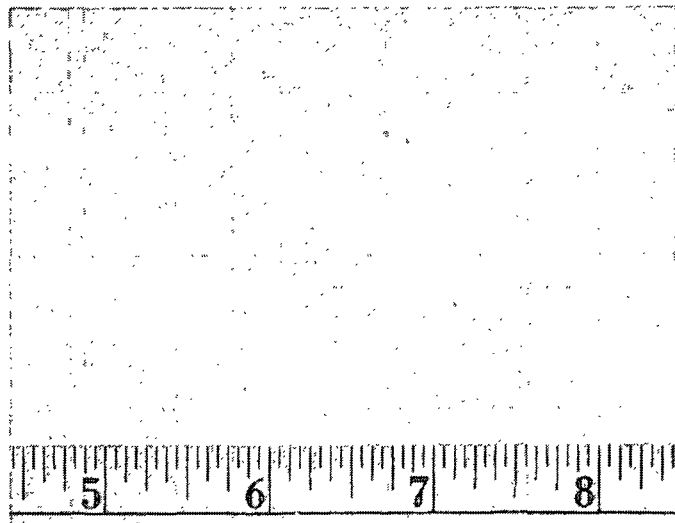


6 Cycles

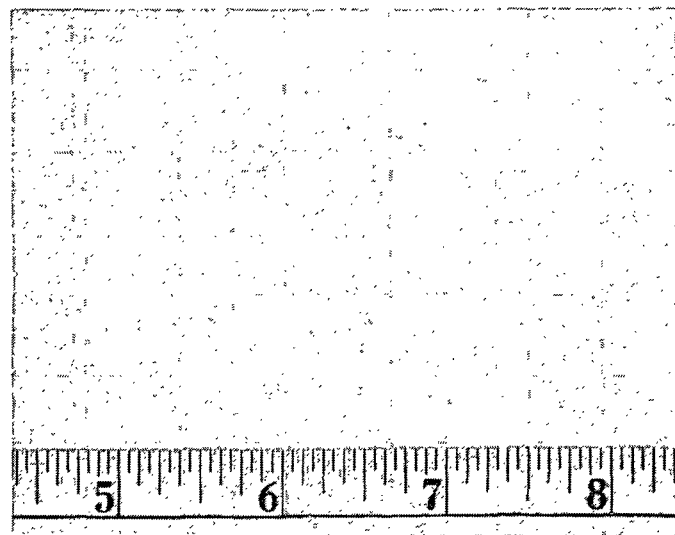
Figure 3. Appearance of Linerboard Exhibiting "Poor" Printing Quality
After Indicated Number of Scuff Cycles



30 Cycles



20 Cycles



10 Cycles

Figure 4. Appearance of Linerboard Exhibiting "Average" Printing Quality
After Indicated Number of Scuff Cycles

Many bundles of fibers were present after 30 scuff cycles. The company reported a scuff average of 17 cycles for this sample.

For the "average" printing quality liner, only small amounts of dust are observed after 10 and 20 scuff cycles. It is only after 30 cycles that the dusting becomes very evident. The company reported a scuff average of 70 cycles for this sample.

These photographic sequences illustrate the marked differences in scuffability which can occur in commercial linerboards.

MATERIALS AND TEST PROCEDURES

For scuff evaluation, sample lots of 69-lb linerboard were obtained from the FKBG member companies. The selection of the 69-lb grade weight was based on the survey comments which indicate that peeling problems were more frequently encountered on the heavier grade weights while dusting tended to occur on all grade weights. Twenty-three samples were received. All were unbleached kraft linerboards except one sample (Sample No. 16 in the data tables) which had a mottled white surface.

All samples were preconditioned at less than 35% RH and 73°F and then conditioned for at least 48 hours at 50% RH and 73°F prior to test.

The number of tests performed per sample is shown in Table VIII.

TABLE VIII

LIST OF TESTS

Test	No. of Tests Per Sample
S & S Scuff Test	
M.D.	5
C.D.	5
Bendtsen Smoothness	5
Kinetic Coefficient of Friction (top liner <u>vs.</u> top liner)	
M.D.	3
C.D.	3
ZDT Test	5
IPC Bonding Strength	
M.D., blister end point	4
M.D., rupture end point	6
C.D., rupture end point	6

The S & S scuff tests were carried out using the conditions noted in the previous section. Two end-points were employed as follows:

1. Dusting: Number of strokes to the first observable dust.
2. Peeling: Number of strokes to a peel type failure.

The friction tests were carried out in the Instron tester using a normal force of 0.44 lb on a 3 square inch area (0.15 psi). The speed was 3.4 inches/minute. Smoothness of the top liner surface was measured with a Bendtsen instrument using a pressure difference of 150 mm of water.

The IPC bonding strength tests were carried out using the apparatus described by Wink, et al. (1,2). The instrument consists essentially of a pair of steel wheels. The specimen is attached to the lower wheel and a film of a Newtonian oil having a known thickness and viscosity is applied to the upper wheel. The upper wheel rolls over the test specimen under a known load with constant acceleration. The speed at the appropriate end point is recorded. Various end-points may be employed. One of these is the point at which the paper blisters due to the onset of internal failure. As the paper is subjected to higher and higher normal forces complete rupture will occur. This is another end-point which may be used. Both the blister and rupture end-points were used in this study. It has been found that the product of the velocity of the wheels and the viscosity of the oil is a constant for samples of the same paper. Therefore the results are reported in kilopoise cm/sec at the end-points of blister and rupture.

DISCUSSION OF RESULTS

SCUFF TESTS ON COMMERCIAL LINERBOARDS

In order to compare relationships between S & S scuff test results and other sheet properties, the FKBG members were requested to supply samples of 69-lb linerboard. Machine and cross-direction S & S scuff tests were carried out on these samples as shown in Table IX and X, respectively. The number of strokes required to produce (a) noticeable dusting and (b) peeling rupture was recorded.

The machine and cross-direction scuff results are arrayed in ascending order of peel in Fig. 5 and 6, respectively. Substantial differences were obtained between samples for both peeling and dusting. The maximum and minimum sample averages are shown below.

	Number of Strokes ^a		
	Maximum	Minimum	Average
Peeling			
M.D.	497(7)	7(16)	91
C.D.	149(1)	7(16)	45
Dusting			
M.D.	26(8)	2(12)	12
C.D.	35(4)	1(3,12,22)	18

^aSample number is in parentheses.

Five M.D. samples (No. 9, 10, 12, 16 and 18) and 7 C.D. samples (No. 10, 12, 15, 16, 18, 21 and 22) exhibited peel end-point averages of 20 or less. Based on comments in the survey, such samples might be expected to cause problems on the corrugator or presses.

In general, at low peel values the same samples were low in both directions. However, Fig. 7 shows that there was no relationship between M.D.

TABLE IX
MACHINE DIRECTION S & S SCUFF TEST

Sample Number	Type of Finish	Top Liner Freeness, cc	Machine Direction S & S Test, no. of Strokes					
			Dusting End-point			Peeling End-point		
			Max.	Min.	Av.	Max.	Min.	Av.
1	Starch	471	18	8	13	38	10	26
2	Starch	440	13	4	7	115	41	65
3	Water	400	6	3	4	26	17	21
4	Starch	424	16	10	14	116	37	78
5	Water, starch	550	14	8	11	485	62	268
6	Water, starch	550	13	10	11	555	232	368
7	Water, starch	550	19	10	14	820	58	497
8	Wet, starch	580	33	20	26	63	35	44
9	Dry	455	7	5	6	38	11	20
10	Starch	470	13	7	9	20	11	14
11	Water, starch	390	19	12	15	49	30	43
12	Dry	--	3	2	2	22	7	13
13	Starch	--	28	20	24	94	60	72
14	Starch	500	14	8	11	126	44	94
15	Water	500	22	12	17	32	18	24
16	Starch	450	5	3	4	9	5	7
17	Dry	-- ^a	11	4	6	56	16	37
18	Water	520	13	5	10	15	7	12
19	Starch	395	24	12	18	66	25	37
20	Water, starch	--	22	7	14	319	111	212
21	Water, starch	320	22	13	18	51	29	41
22	Dry finish	325	7	4	5	38	14	24
23	Water	250	30	13	19	143	20	70
Average					12			91

^a190-215 Williams freeness.

TABLE X

CROSS-DIRECTION S & S SCUFF TEST RESULTS

Sample Number	Type of Finish	Top Liner Freeness, cc	Cross-Direction S & S Test no. of strokes					
			Dusting End-point			Peeling End-point		
			Max.	Min.	Av.	Max.	Min.	Av.
1	Starch	471	16	10	14	208	100	149
2	Starch	440	15	10	13	46	25	36
3	Water	400	1	1	1	70	3	26
4	Starch	424	58	23	35	85	28	48
5	Water, starch	550	20	13	17	98	28	44
6	Water, starch	550	18	16	17	75	21	36
7	Water, starch	550	18	8	12	37	15	31
8	Wet, starch	580	9	7	8	72	43	58
9	Dry	455	13	4	7	41	23	33
10	Starch	470	4	3	3	15	11	13
11	Water, starch	390	15	4	10	54	15	32
12	Dry	--	1	1	1	33	2	12
13	Starch	--	28	19	24	105	69	88
14	Starch	500	30	7	19	41	30	36
15	Water	500	20	11	15	25	13	19
16	Starch	450	5	3	4	9	5	7
17	Dry	-- ^a	48	12	24	81	60	69
18	Water	520	12	4	7	17	7	11
19	Starch	395	23	11	16	56	34	40
20	Water, starch	--	37	18	25	174	54	122
21	Water, starch	320	13	6	10	25	11	17
22	Dry finish	325	1	1	1	31	6	17
23	Water	250	16	6	10	115	49	76
Average					18			45

^a190-215 Williams freeness.

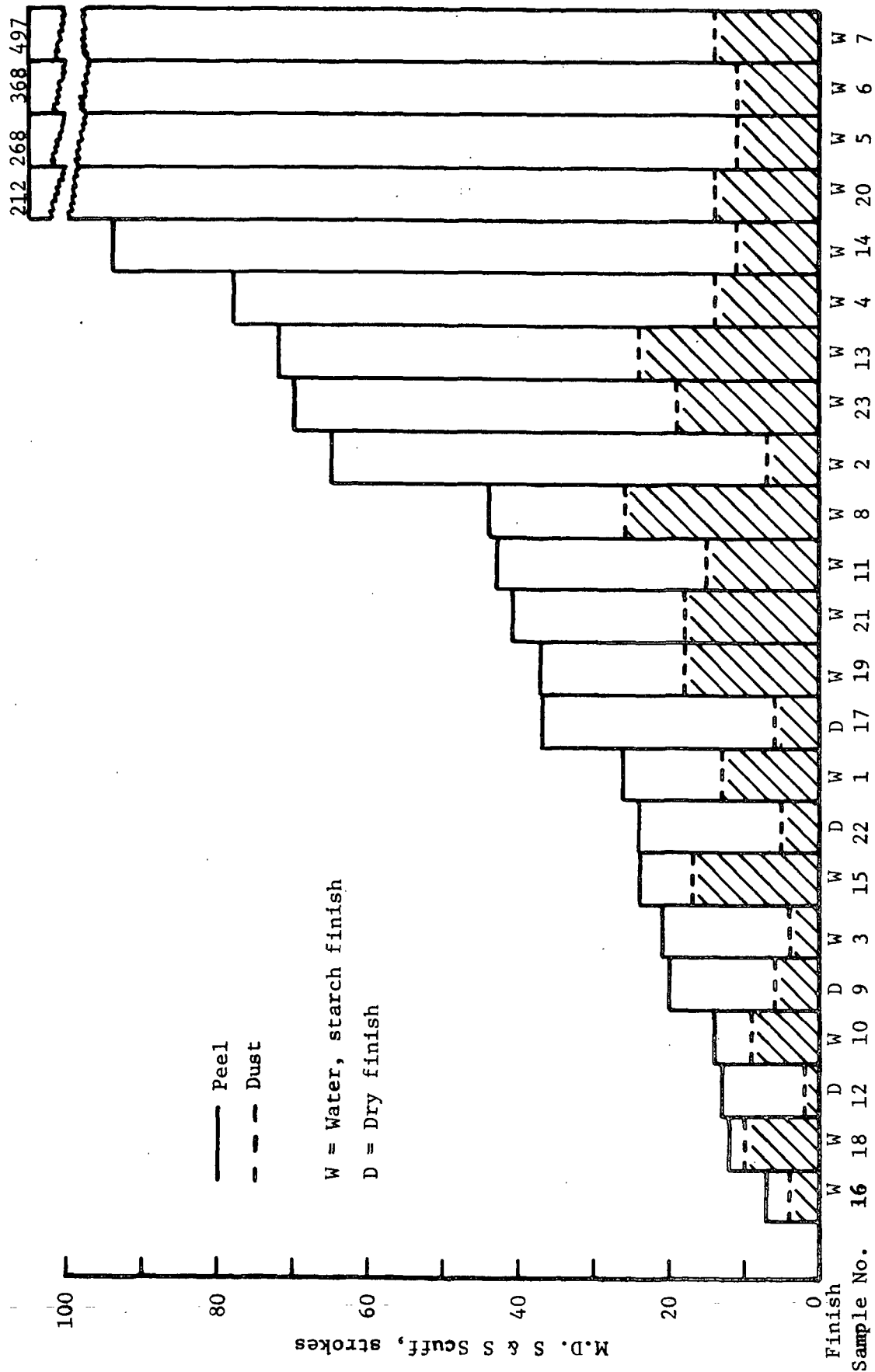


Figure 5. Machine Direction S and S Scuff Results

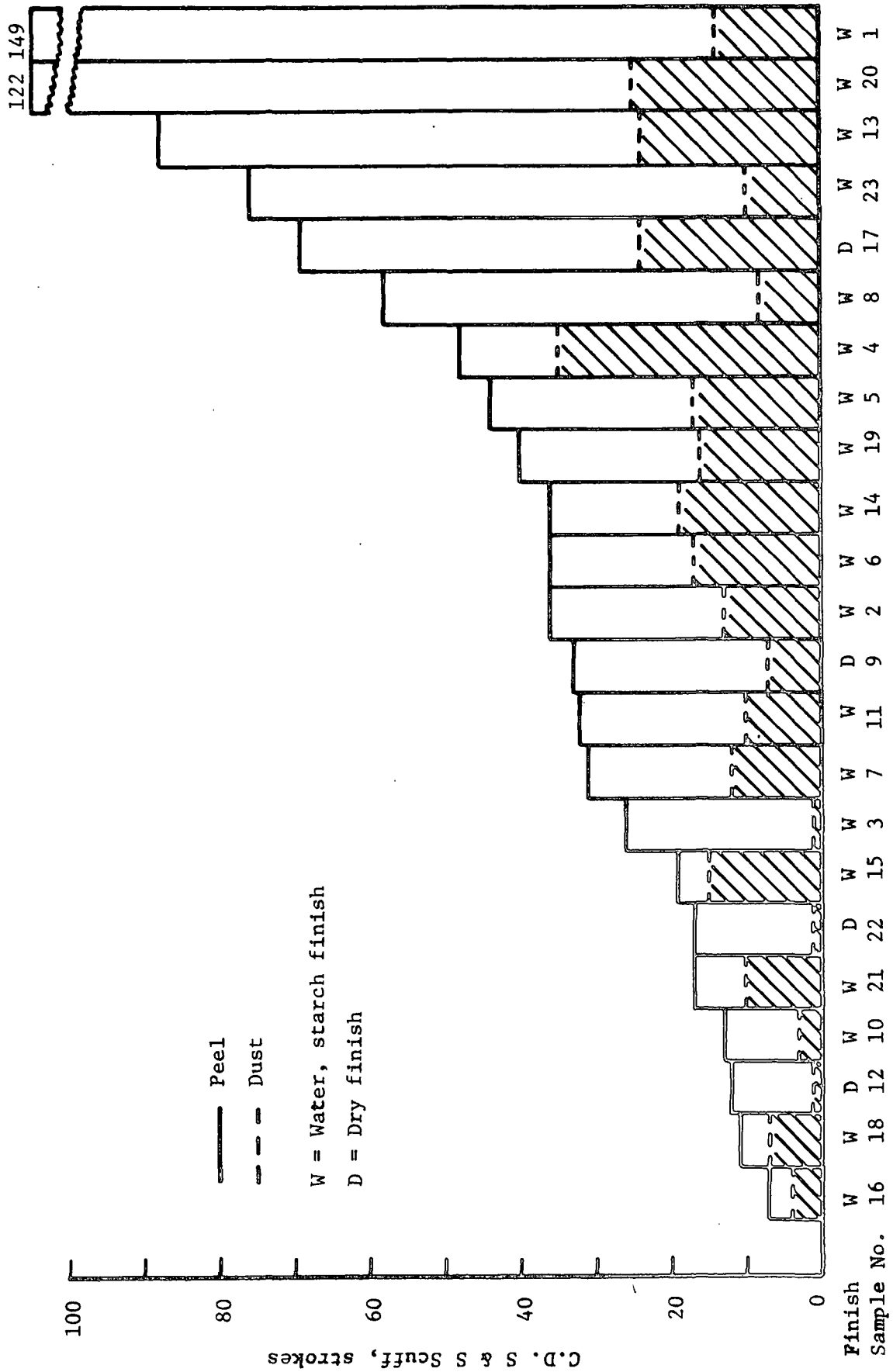


Figure 6. Cross-Machine Direction S and S Scuff Results

and C.D. tests when all samples were considered. Peeling failures in the test are the end result of the repeated stressing of surfaces in a rather complex way as debris builds up. Thus, the lack of general relationship between M.D. and C.D. results may be due to such factors as fiber orientation and degree of shingling of the surface fibers.

Figure 8 shows that there is little relation between peeling and dusting. While samples which dust readily often show low peel, there is considerable scatter.

In the S & S test, the first visual evidence of surface damage involves the loosening of fibers on the surface either in whole or part. The loosened fibers then tend to collect together, usually in the form of rolled up cigar-shaped bundles. Finally, it appears that cigar-shaped bundles as they roll back and forth become entangled with fibers which are still partially bonded. The rolling action then causes peeling. In the M.D. tests, it appeared that the development of the first cigar generally resulted in peeling whereas in C.D. several or many cigars might form before peeling occurred. The cigars formed in the M.D. tests were also usually smaller than the C.D. cigars.

Based on the test observations, it appears that the onset of dusting is delayed if the surface fibers are well bonded. Then the number of strokes required to produce peeling depends on such factors as the interior sheet bonding, "shingling" and the rate of generation of fibrous debris to form cigars. At the other extreme, if the surface fibers are weakly bonded, dusting occurs almost immediately in the test. In this case, peeling also will often occur at a low number of strokes but may be delayed depending on other sheet characteristics.

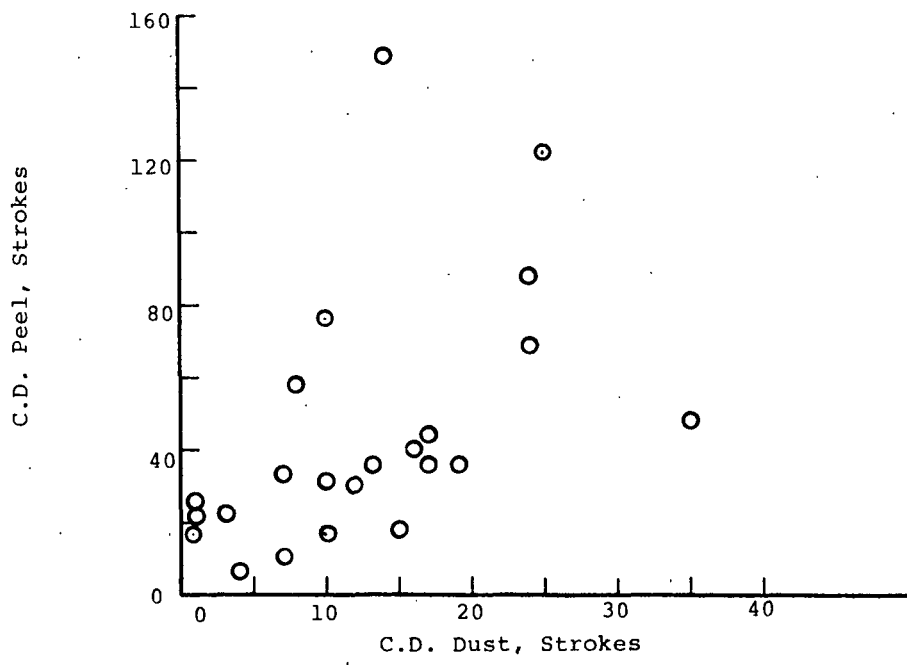
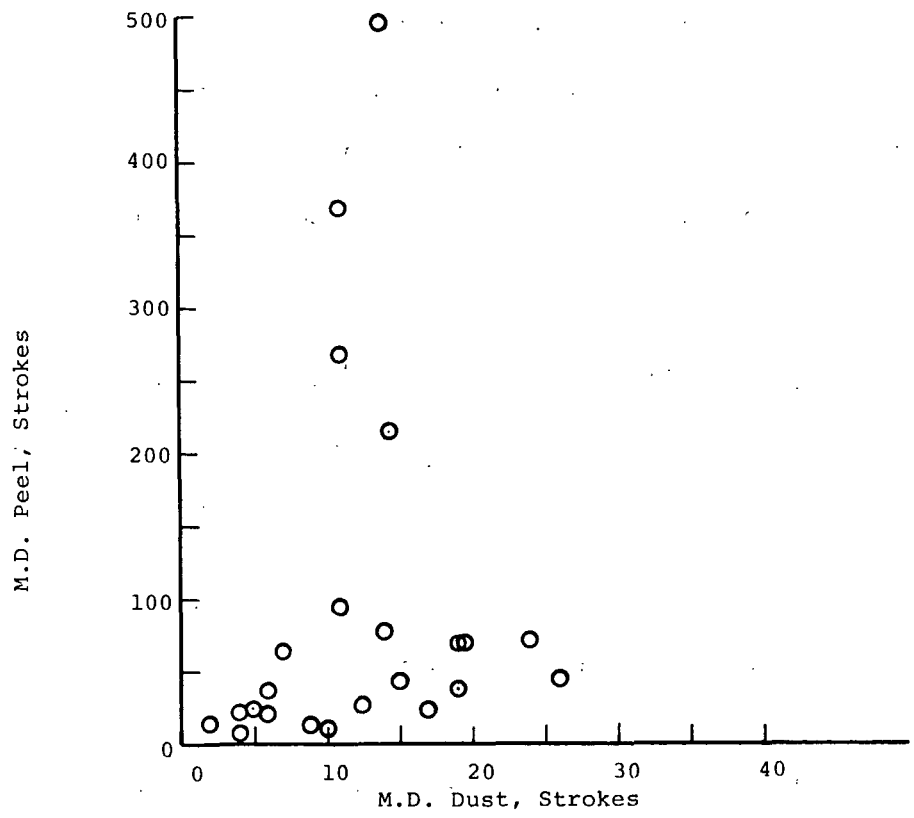


Figure 8. Relation Between Peeling and Dusting

BONDING STRENGTH AND SURFACE CHARACTERISTICS

The relation of dusting and peeling to other sheet characteristics was studied in a limited way due to budgetary considerations. As an initial step, five samples were selected, two of which exhibited low, one intermediate and two high cross-direction S & S peel. ZDT and IPC bonding strength tests were then carried out on the five selected samples (see Table XI).

TABLE XI
 SCUFF AND BONDING STRENGTH TEST RESULTS

Sample Number	S & S Scuff, no. of strokes		ZDT Strength, psi	IPC Bonding Strength, kp cm/sec			
	M.D.	C.D.		M.D.		C.D.	
				Blister End-point	Rupture End-point	Blister End-point	Rupture End-point
1	26	149	45	148	384	--	474
13	72	88	39	104	474	--	524
14	94	36	47	143	453	--	484
16	7	7	46	88	186	--	196
18	12	11	42	83	282	--	314

The ZDT results show no obvious relationship to S & S peel results (Fig. 9). This is not surprising since failure in the ZDT test is almost always in the interior of the sheet. Thus, the resulting ZDT test value does not provide a measure of the bonding on the surface.

Machine and cross-direction peel results on the same five samples are compared to IPC bonding strength values, using a rupture end-point, in Fig. 10 and 11, respectively. The results suggest that S & S peel may be fairly well related to IPC rupture end-point bond strength although more data would be required to substantiate this. The failure in the IPC tests can occur due to

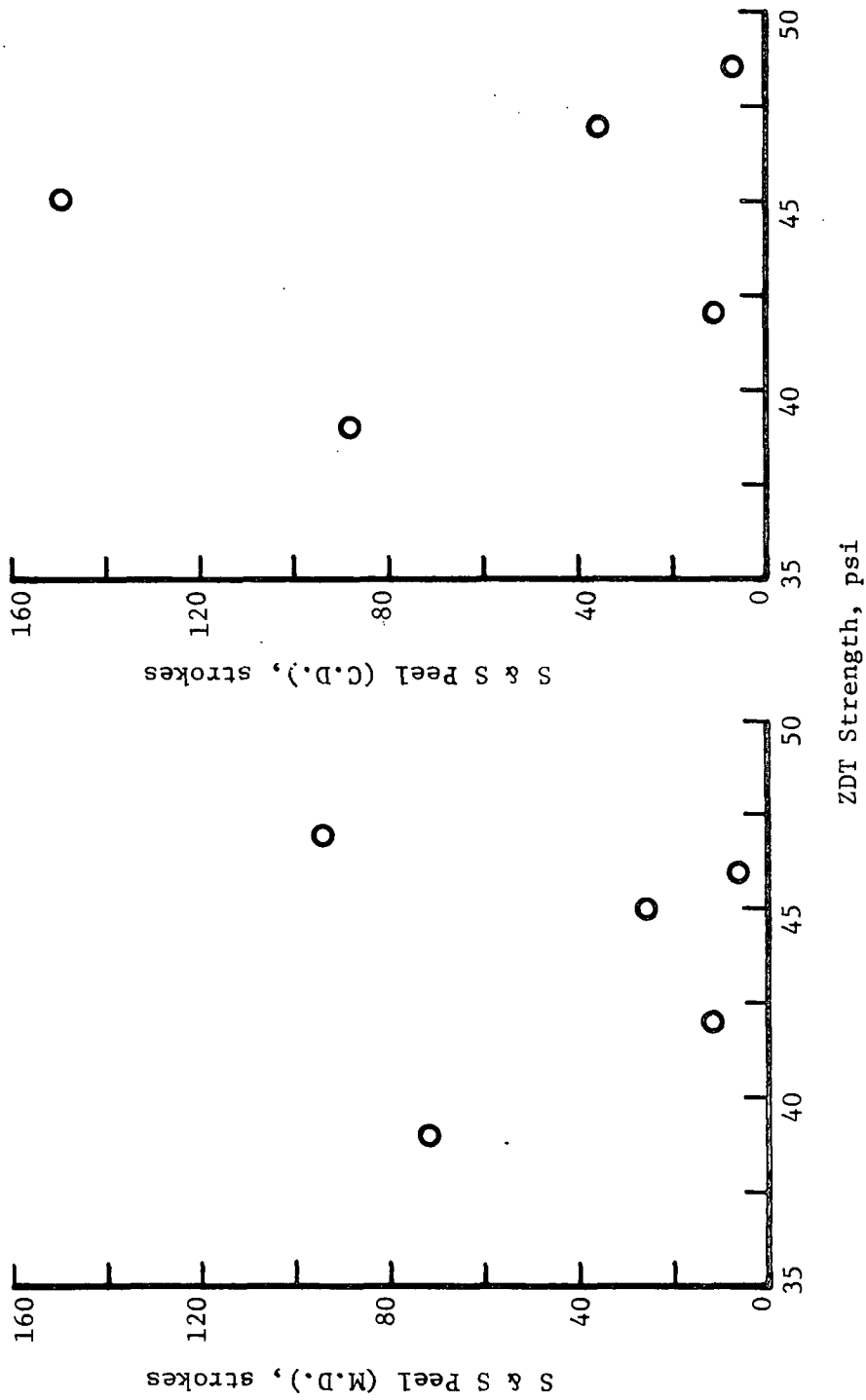


Figure 9. Relation Between S & S Peel and ZDT Strength

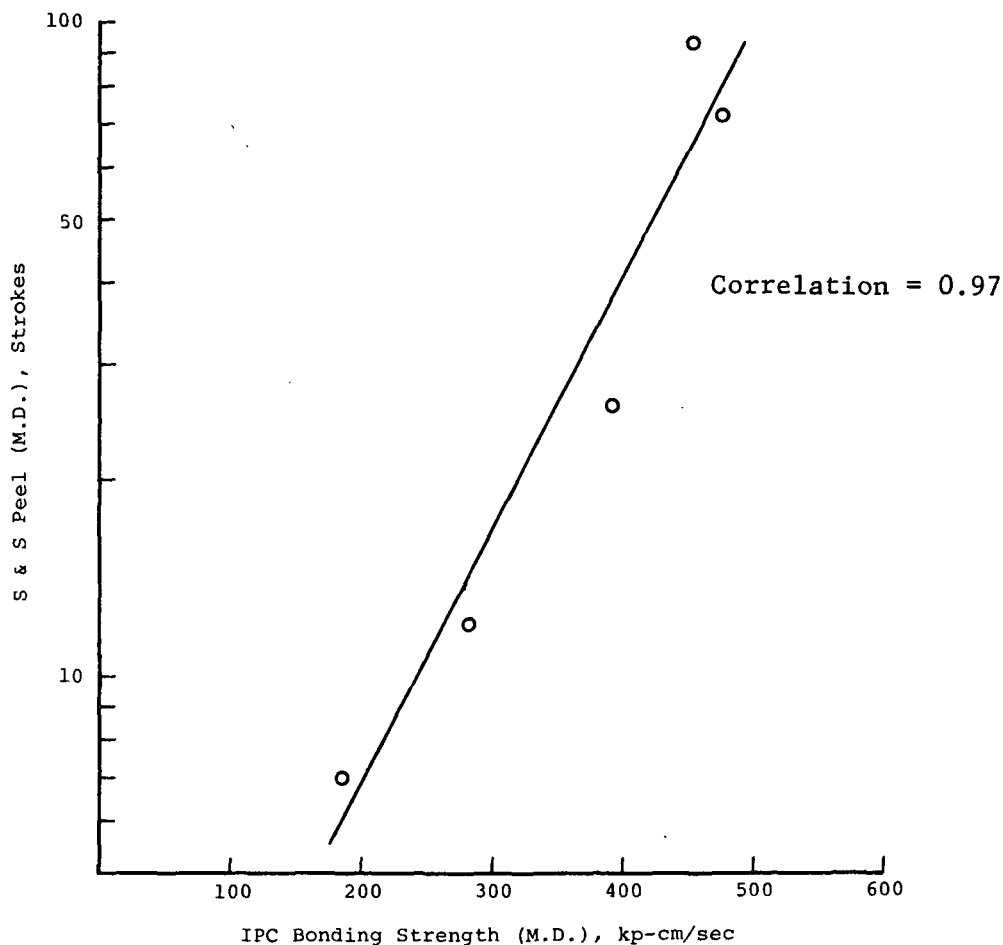


Figure 10. Relation Between M.D. Peel and M.D. Rupture
End-point IPC Bonding Strength

zones of bonding weakness near or on the surface of the sheet and this may account for its relation to peel.

Figure 12 compares the appearance of rupture failure in the IPC bonding strength tests. The direction of stressing is from left to right in the photograph. The low peel strength samples (No. 16 and 18) developed surface ruptures near the left end at low bonding strength values. In contrast, the higher peel strength samples (No. 13 and 14) show surface ruptures near the right end where the wheel velocities and resulting bonding strength values are high.

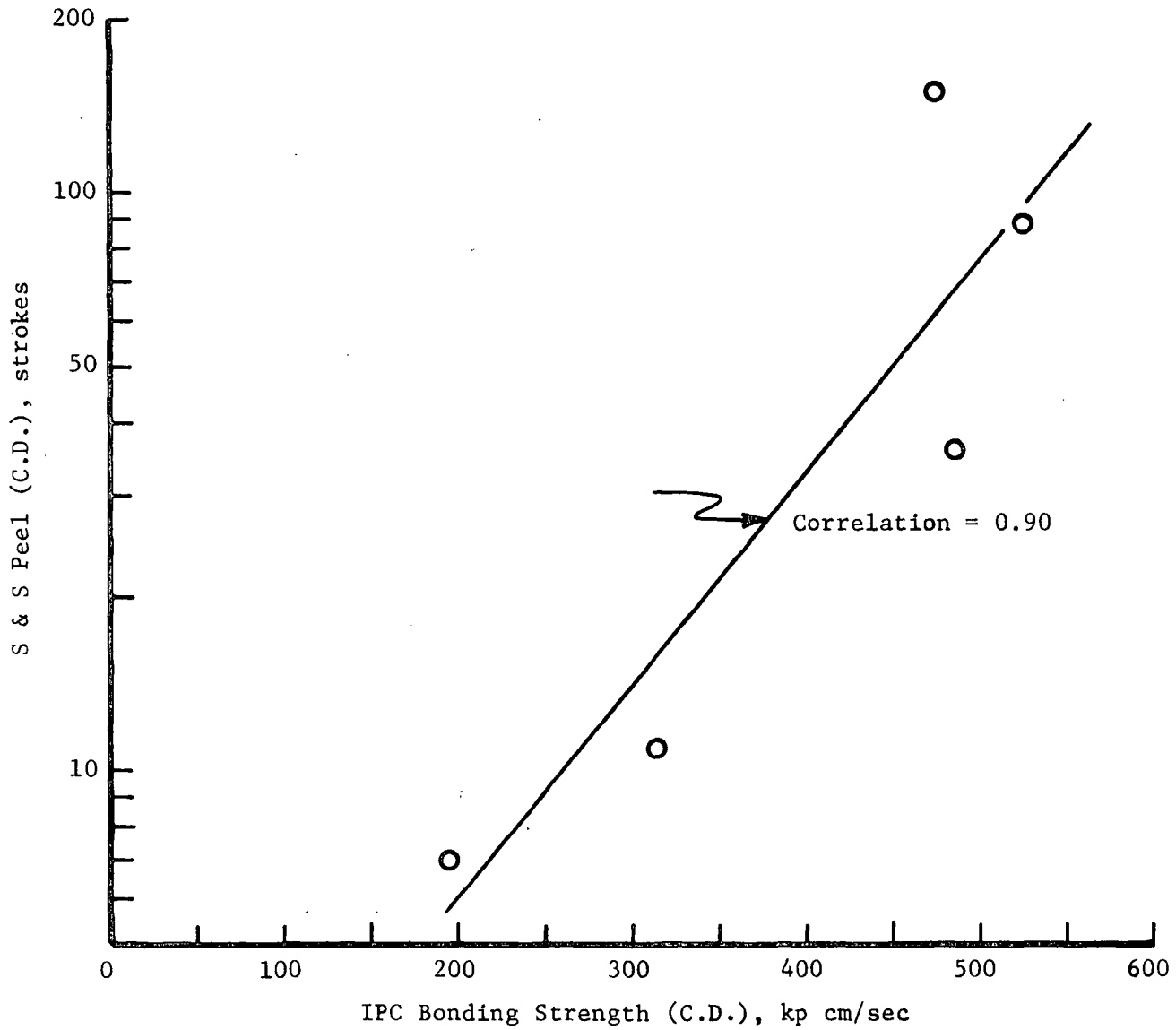


Figure 11. Relation Between C.D. Peel and C.D. Rupture End-point
IPC Bonding Strength

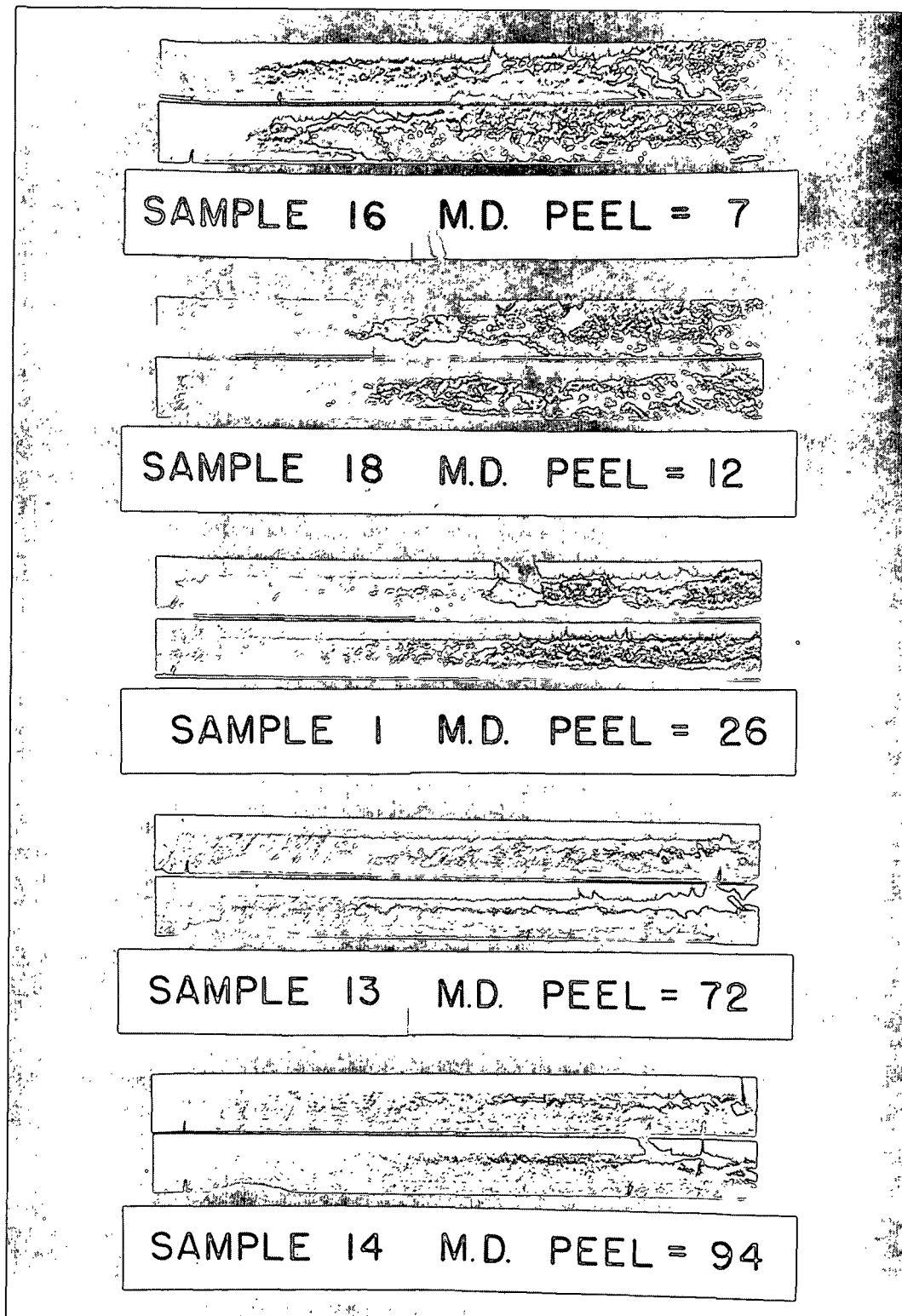


Figure 12. Appearance of M.D. IPC Bonding Strength Specimens from Samples Exhibiting Different S & S Peel Strengths

While the above results were obtained using the IPC bonding strength tester, it is believed that the IGT tester, used with a Newtonian fluid, would yield similar correlations.

IPC bonding strength tests were also carried out on the same five samples using a "blister" end-point (Fig. 13). As may be noted, the peel results were not well related to the blister end-point tests. This is not surprising because no rupture of the surface is involved as blisters form.

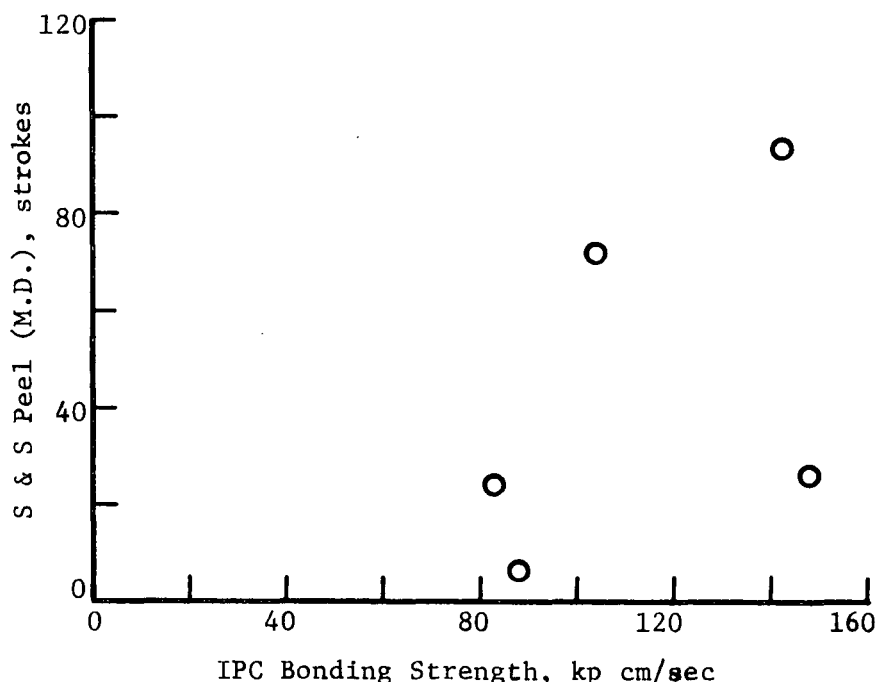


Figure 13. Relation Between M.D. S & S Peel and Blister End-point IPC Bonding Strength

Figures 14 and 15 for the M.D. and C.D. directions, respectively, indicate that the IPC bonding strength results may also correlate with the onset of dusting in the S & S scuff test. This was particularly true for the cross-direction results in Fig. 15. The fibrous dust generated in the S & S test is

not removed and appears to trigger formation of the cigar-shaped bundles which are associated with peeling ruptures. This may be the reason that the IPC rupture-bonding strength measurements appear to correlate with both peeling and dusting.

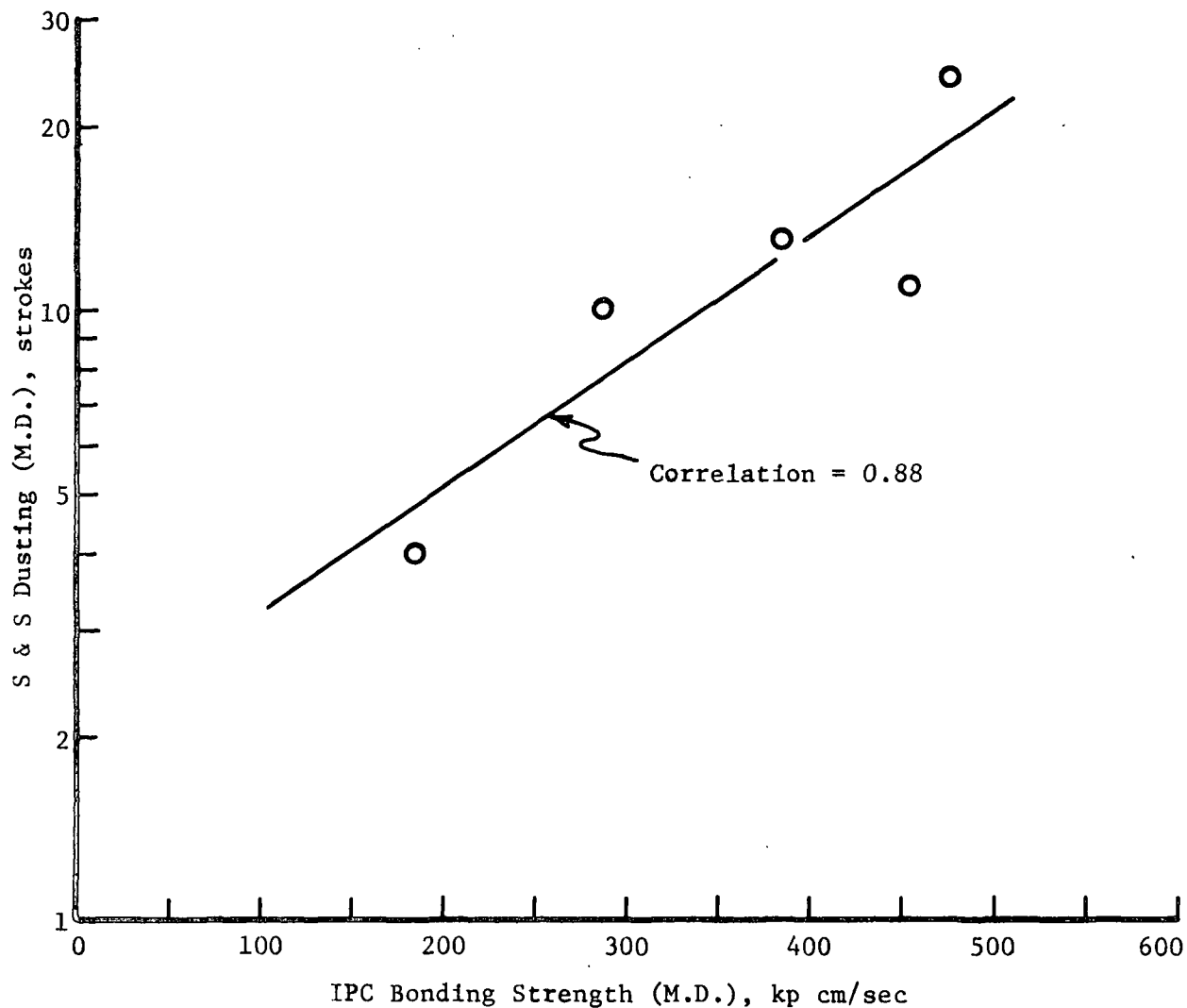


Figure 14. Relation Between M.D. Dusting and IPC Bonding Strength (rupture end-point)

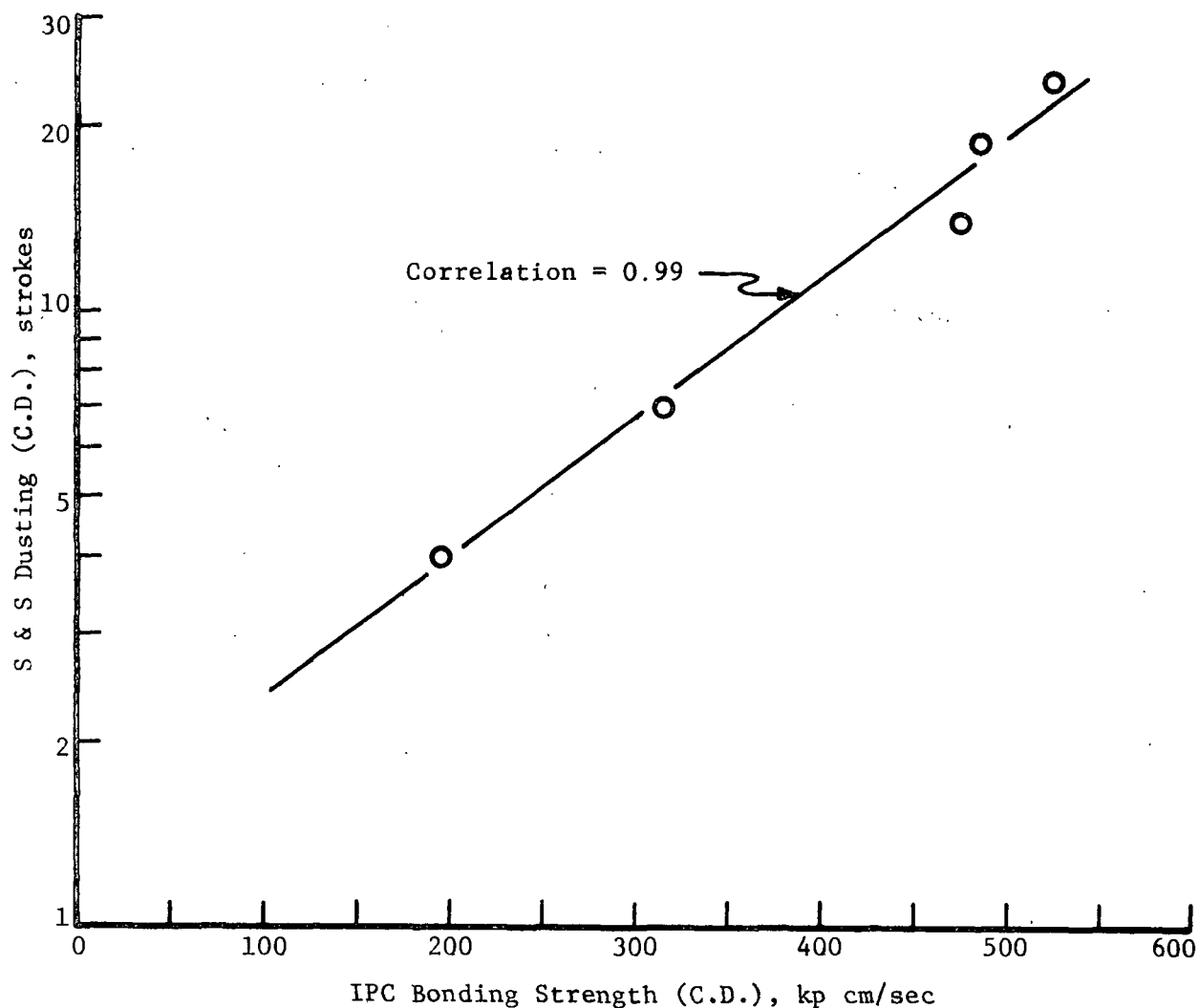


Figure 15. Relation Between C.D. Dusting and IPC Bonding Strength (rupture end-point)

The above results are very limited and more scatter would be expected if more samples were evaluated. One reason for this is the variable nature of the S & S test and the subjectivity involved in the determination of end-points. However, bonding strength measurements of the IPC type should provide a better way of evaluating the scuff characteristics of board than the S & S tester which appears to be a relatively crude instrument.

Some survey respondents suggested that smoothness and friction may be related to scuff. Table XII and Fig. 16 show that neither Bendtsen smoothness nor the kinetic friction coefficient were well related in a simple way to scuff.

TABLE XII
SMOOTHNESS AND FRICTION RESULTS

Sample Number	S & S Scuff, no. of strokes		Bendtsen Smoothness, mL/min	Kinetic Coeff. of Friction	
	M.D.	C.D.		M.D.	C.D.
1	26	149	1120	0.27	0.23
2	65	36	1740	0.22	0.25
3	21	26	1690	0.44	0.54
4	78	48	1990	0.37	0.29
5	268	44	1150	0.35	0.33
6	368	36	1150	0.32	0.31
7	497	31	1270	0.30	0.36
8	44	58	1440	0.35	0.29
9	20	33	2000	0.50	0.40
10	14	13	1710	0.38	0.34
11	43	32	1510	0.32	0.42
12	13	12	2390	0.38	0.27
13	72	88	1800	0.24	0.22
14	94	36	1150	0.39	0.30
15	24	19	2330	0.34	0.33
16	7	7	1350	0.31	0.34
17	37	69	1650	0.43	0.43
18	12	11	1880	0.33	0.27

Note: Smoothness and friction tests were not performed on Samples 19-23 because they arrived too late for inclusion.

In general, it appears that controlled experimentation would be required to help understand the factors influencing dusting and peeling. This might involve handsheet studies to vary the surface and interior bonding, surface friction, smoothness, etc.

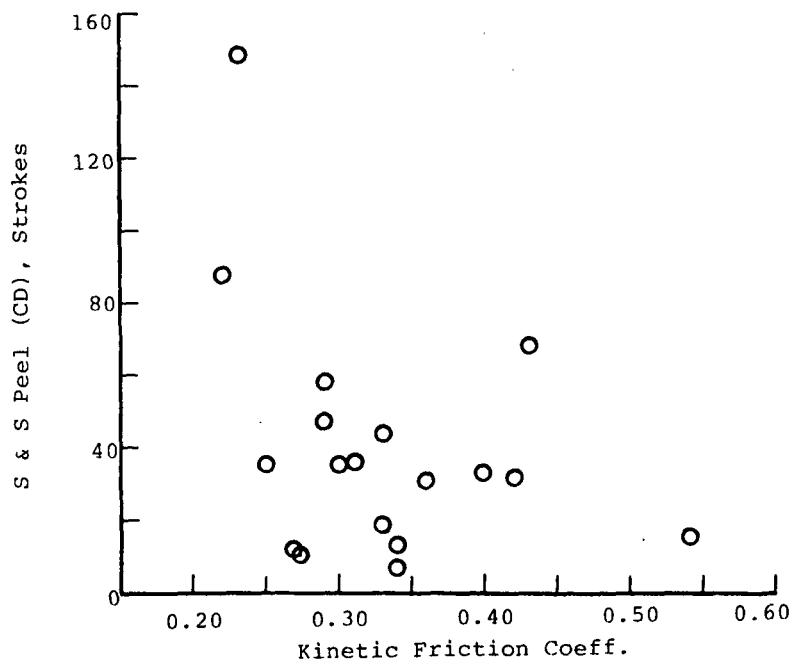
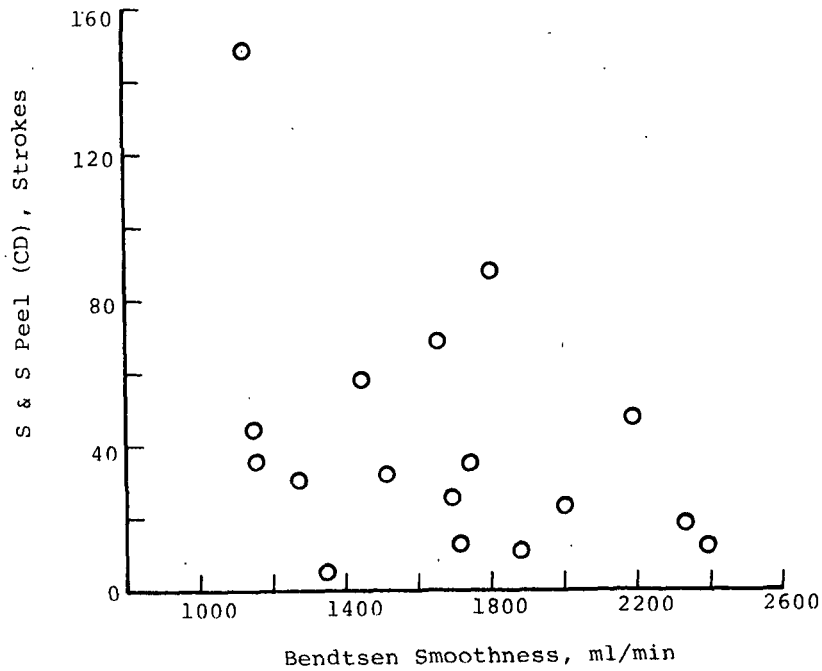


Figure 16. Relation of Peel to Smoothness and Friction

In addition, peeling on the press involves a single stressing of the board surface rather than a repeated abrasion as occurs in the S & S scuff test. This suggests that a better measure of peeling tendencies would be obtained with a test involving a single stress application to the surface of the sheet.

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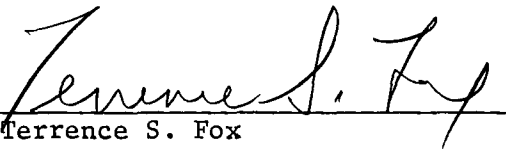


William J. Whitsitt
Research Associate
Engineering Division



W. A. Wink
Research Associate
Engineering Division

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