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The Effect of Pressdrying on Bogus Medium

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THE EFFECT OF PRESSDRYING ON BOGUS MEDIUM

by

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ABSTRACT

Pressdrying is simultaneous pressing and drying. It employs a steam heated roll in some type of extended nip.

This study was made to determine the effects of pressdrying on 100 % bogus medium. Pressure during pressdrying and nip residence time were constant. Freeness and solids content before drying were varied. Press-dried sheets were compared to sheets dried under no pressure but produced under otherwise similar conditions.

At any given freeness level, the pressdried sheets were higher in density and ring crush, and lower in tensile and caliper. Variance of solids content before drying showed no trend for tensile. Based on significance testing, caliper and ring crush may vary according to solids.

TABLE OF CONTENTS

	page
Introduction	1
Background	2
Basis of pressdrying	2
U.S. Forest Products Laboratory	3
Swedish Forest Products Research Laboratory	4
St. Anne's Board Mill	5
Summary	6
Experimental	7
Stock Preparation	7
Handsheet Formation	7
Control of Ingoing Solids	7
Drying	7
Conventional	7
Pressdrying	7
Heat Transfer Coefficient	8
Paper Testing	8
Results	9
Effect of Ingoing Solids	9
Effect of Pressdrying	9
Discussion	11
Conclusions	12
Recommendations	13

INTRODUCTION

Pressdrying is simultaneous pressing and drying of paper or paperboard. This study was made to see how pressdrying--"drying under Z-restraints"--affects the properties of 100 % bogus medium.

Pressdrying has been shown to improve strength properties of sheets made of high yield hardwood. If pressdrying improves the strength of recycled sheets, then more low grade fiber could be utilized. If the level of refining were reduced to the same strength specifications, refining energy reduction and paper machine speed increase could result.

Application of pressure during drying causes more surface area of the sheet to contact the heated dryer. Less air film resistance between the sheet and dryer improves heat transfer. Less energy cost and increased output for dryer limited machine provide great incentive to investigate pressdrying of bogus medium.

BACKGROUND

In conventional papermaking, the consolidated web is mechanically pressed and then passed through a series of steam heated dryer rolls. In 1975 Vance Setterholm and his coworkers at the U.S. Forest Products Laboratory found that these two dewatering stages--(a.) pressing and (b.) drying--can be combined by "drying under Z-restraints". (1) Simultaneous pressing and drying has since been called "pressdrying".

Basis of Pressdrying

The basis of pressdrying was first given in Setterholm's 1975 paper "Z-Direction Restraint, a New Approach to Papermaking":

> "Fiber flexibility is considered by many to be the key to paper strength because anything that promotes intimate contact between fibers promotes interfiber bonding during the web consolidation process. For example, although there are other benefits, a chief reason for beating a pulp is to improve conformability of the fibers. This idea is so much a cornerstone of papermaking that to consider making paper without first refining is 'unthinkable'.
>
> To meet rising costs, the pulp and paper industry has clearly moved toward higher pulp yields, which result in less flexible fiber. This effect is particularily true with Southern Pine. As a result, papermakers face an increasing challenge to maintain sufficient interfiber bonding is important for retention of adequate performance levels in corrugated containers.
>
> At present our best option is maintaining interfiber bonding is to use a moderate amount of refining, apply an increasing in the wet webs, and use whatever bonding aids are available. Even so, we are limited in pulp selection to yields below 55 % because of the aggrevated springback problems with the stiff course fibers.
>
> Therefore, this appears to be the appropriate time to consider what benefits are obtained from drying restraint imposed on the thickness (Z-direction) of paper. It is obvious that, if the

fibers connot spring back, they will have a better chance of bonding to one another. Restraint after pressing provides this opportunity." (1)

Three groups have directed efforts towards pressdrying of linerboard and container grades in general. They are:

A. U.S. Forest Products Laboratory, Madison, Wisconsin

B. Swedish Forest Product Research Laboratory, Stockholm

C. St. Anne's Board Mill Co. Ltd., Bristol, England

Weyerhauser had been said to be operating commercial pressdryers, and International Paper has a pilot pressdryer, but neither company has published a significant amount of literature on pressdrying. (2)

A. U.S. Forest Products Laboratory

In Setterholm's paper quoted earlier, unbeaten low to high yield Douglas Fir pulp was made into liner board handsheets and pressdried on a platen press. He experimented with on/off pressing at 230 psi and 300 ^{o}F. He applied a continuous pressure of 60 psi and 300 ^{o}F in another experiment. His control was conventional air-dried handsheets which he hot calendered to bring the density up to that of the pressdried sheets (.72 - .86 g/cc). The pressdried burst, ring crush, tensile, modulus of elasticity and edgewise compression were more than double the air-dried handsheets. (3) The pressdried tear was slightly less than the air-dried sheet. (1, 4, 5)

A 1977 paper by U.S. Forest Products is called "Variables in Press Drying Pulps From Sweetgum and Red Oak". High to low yield Red Oak and Sweetgum were beaten to freeness levels between 715 and 245 ml CSF. Pressdrying was done at 400 psi and 400 ^{o}F on a platen press. The same strength trends as before were observed. The strength of high yield Sweetgum was as good or better than high yield Douglas Fir when both were pressdried. Pressdried sheets of high yield hardwood pulps were far better in strength

than low yield conventionally dried handsheets of the same species. Softwood/hardwood blends were studied. A dynamic apparatus that applied 25 pli or 5 psi maximum normal pressure was experimented with. The same strength trends were evident. (4, 5, 6)

U. S. Forest Products Laboratory did a study on drying rates. U factor for pressdrying at 250 ^{o}F was 45 Btu/ft^{2}-hr-^{o}F while those for conventional are generally 20 to 35 Btu/ft^{2}-hr-^{o}F. Increased sheet to dryer surface area resulted in higher drying rates and contact coefficients, effects exaggerated at higher initial moisture contents. Pressdrying was done on a static platen press at 250 - 550 ^{o}F and 2 - 400 psi. Strength properties were not studied. (7, 4, 5)

Byrd of U.S. Forest Products Laboratory, found that hemicellulose is responsible for increased bonding and strength of pressdried sheets. Lignin slows the flow of hemicellulose and does not contribute to bonding and strength by preserving hemicellulose bonds. Pressdrying was done on a platen press with 60 psi. (8, 9, 10, 4, 5)

Ince of U.S. Forest Products did an economic analysis of pressdrying. He found that a large savings in wood costs could be realized by pressdrying sheets of hardwood instead of softwood. (12)

B. Swedish Forest Products Research Laboratory

Back and Anderson, of Swedish Forest Products Research Laboratory, studied pressdrying of high yield softwood kraft liner board. They found that pressdried handsheets were higher in tensile and modulus than conventionally dried handsheets. Strength increase of pressdried handsheets over conventionally dried handsheets was greater at higher initial moisture content. When temperature was increased the same strength gain was obtainable at lower moisture content. (13) In later work, Back confirmed that the

same trends are apparent for multiplestage pressdrying when compared to multiplestage conventional drying. All of the Swedish work was done on platen presses. (14, 15)

C. St. Anne's Board Mill

Brian Attwood, of St. Anne's Board, claims that they began studying pressdrying in 1972 while working with their dry forming pilot plant. At first they did pressdrying on rewetted airlaid structures, then they used it to dry wet/drylaid laminated webs. Finally wet webs alone were pressdried. (17, 18, 19) St. Anne's laboratory handsheet pressdryer and their pilot machine, which also has a pressdryer, are shown in Figures 1 and 2.

Attwood said that pressdrying can be done at moisture contents between 80 % and 20 % indicating that a machine may have both cold and hot presses. Nip pressures of 5.5 - 670 pli and temperatures of 212 - 392 ^{O}F were quoted as being typical pressdrying conditions.

The following were listed as pressdrying's potentials; better products; the ability to produce smoother sheets without using a machine glaze cylindar; an improvement of apparent formation; simpler machine design; less energy cost and increased output for dryer capacity limited machines. Areas that need more development are: highspeed operation; design of fabrics that can take high pressure, hold the web in place and allow vapor to escape; design of dryers that provide for higher drying rates; keeping dryer cylindars clean and preventing the web from sticking. (17)

A paper that was presented at the 1979 TAPPI Annual Meeting was not done by any of the groups mentioned. Yang studied Red Oak for pressdrying. He Measured tensile and modulus of elasticity of handsheets pressdried at several pressure and moisture levels. His conclusions concured with other work reviewed. (20)

Background Summary

Pressdrying increased strength of handsheets made from various pulps. Dimensional stability, porosity and stretch were also improved, tear was slightly decreased.

All of the pressdrying data presented in the papers surveyed were based on pressdrying with a static platen press, though U.S. Forest Products Laboratory and St. Anne's Board Mill said that they have tried a dryer cylindar on either the laboratory or pilot plant scale. Temperatures ranged 200 - 400 ^{o}F while pressures ranged 60 - 500 psi and initial moistures ranged 25 - 75 %.

High drying rates were obtained with pressdrying.

Authors agree that pressdrying's greatest potential is in high yield pulps for container grades.

EXPERIMENTAL

Stock Preparation

Clean kraft clippings were slurried in a Mordan Slushmaker for 4 minutes at 1.8 % consisency. The pulp was refined in a Valley Beater according to TAPPI Standard 200. Initial freeness was approximately 600 ml CSF. It required 25 minutes to reach the 200 ml CSF range. A defoamer was used during refining.

Handsheet Formation

All handsheets were formed in a Noble and Wood handsheet mold.

Control of Ingoing Solids

The press nip on the Noble and Wood apparatus was used to control the solids level going into the dryers. It was found that using a blotter and roller did not produce a uniform sheet. The moisture profile was controllable between 34 % and 42 % solids with the press nip. The lower freeness pulps required more press loading. The forming wires were removed and the wet sheets weighed before drying.

Drying

Conventional Drying

The experimental control was dried under negligible pressure on the Noble and Wood dryer can. The temperature was 24o ^{o}F. Sheets were passed through the nip twice, wire side down, for a total of 1 minute drying time.

Pressdrying

The drying conditions for pressdrying were the same as the conventionally dried sheets, except the drying fabric was loaded. The 13" diameter

Noble and Wood dryer can was wrapped with a 30 mesh bronze wire. A 13 to 1 ratio lever arm was attached to a tension roll, and 34 lbs. was applied to the end of the arm. The loading is shown in Figure 3.

The elbow of the lever arm was the pivot point used to solve for the wire tension by summation of the moments (see Appendix 1). If the handsheets did not lift the wire from the dryer can, the load would have been carried across the 11" width contacting the dryer. If the handsheet did lift the wire, the tension wuld have been carried across the 8" sheet. Assuming a 20 % friction loss, the pressdrying pressure was a minimum of 17.8 pli and a maximum of 30.6 pli. Since the diameter of the dryer was constant, the psi $\propto$ pli. The nip psi could have been between 1.4 psi and 2.4 psi.

The uncertainty in how much tension was applied is high, but the tension was constant throughout the experiment. The wire stretched approximately 5 % during preliminary experiments. The pivot point and the position of the lever arm (θ on Figure 3) were not changed during the experiment.

Heat Transfer Coefficient

The heat transfer coefficient, U. for both drying methods was an estimated 16 - 20 Btu/ft^2-hr-^{o}F. Appendix 2 gives detailed calculation of U factor.

Paper Testing

Paper testing was done in a temperature/humidity controlled room (73 ^{o}F, 50 % RH). Tests were performed on 250 separate handsheets: 1 basis weight determination, 4 caliper, 3 tensile, and 5 ring crush on each. Each sheet maintained its identity throughout the testing program.

To reduce the variability of the ring crush, gloves were worn during testing. Fitting strips into the ring was difficult because of caliper variation. A 12 mil ring was used for all strips tested.

RESULTS

Effect of Ingoing Solids

Three different press loadings for each freeness resulted in webs of 33 - 43 % solids. The bar graphs in Figure 4 show the solids levels produced. The ingoing solids were constant at each level which made statistical analysis difficult.

Significance testing (T Tests) showed that caliper and density were affected by ingoing solids level. Table I gives a breakdown of caliper and density by solids and freeness. Caliper increased only slightly with solids level.

When comparing the highest solids level to the lowest, results inconsistently show that ring crush factor* is affected by solids level. Ring crush may have increased with solids.

A breakdown of tensile by solids showed no significant effect of solids.

Effect of Pressdrying

To evaluate the effect of freeness, all the data were treated as if solids had no effect. By averaging the data, the standard deviation of most results was less than 6 %. The standard deviation of tensile factor was 10 %. Results are given in Figures 5 and 6, and Table II.

Significance testing was done assuming that there were no detectable differences in pulp at the following freeness pairs: 410 and 391, 297 and 312,

* strength factor = $\frac{\text{strength} \times \text{target basis weight}}{\text{actual basis weight}}$

and, 202 amd 217 ml CSF. T Tests showed that, on a confidence level better than 99.5 %, there was a difference between pressdrying and conventional drying at all freeness levels.

Caliper was decreased by pressdrying and freeness increase. Density was increased by pressdrying and freeness increase. Pressdrying improved ring crush factor by about 10 % for all freeness levels. Pressdrying caused a 30 % loss in tensile strength in the 400 - 300 ml CSF range. The tensile strength of the pressdried sheets was almost totally regained by refining to 200 ml CSF. A T Test of 200 ml CSF tensile factor results showed that the probability of the treatments being the same was 87 %.

DISCUSSION

Caliper and bulk of the pressdried sheets were lower. Application of pressure served to decrease void volume in the sheet.

Caliper and bulk decreased slightly with increased solids level. The sheets with more moisture may have expanded along the "Z" axis because of a fluffing effect of rapidly excaping steam.

Ring crush may have increased by pressdrying because of the increased sheet density. Significance testing did show that density and possibly ring crush increased with solids, supporting the hypothesis of density and ring crush interdependency.

Tensile strength is mostly determined by the number of bonds in the high freeness range and the strength of the individual fibers in the low freeness range. The mechanisms by which a sheet fails in tensile strength in the middle freeness range are complex. An explanation of tensile strength reduction by pressdrying of sheets of moderately refined pulp is beyond the scope of this report. Since significance testing showed that there was less probability that pressdried and conventionally dried sheets of 200 ml CSF pulp were different, it is hypothesized that whatever controlled the tensile strength in the middle freeness range had little effect at low freeness. It is probable that the 200 ml CSF sheets failed because of fiber breakage as opposed to fiber-fiber bond breakage.

CONCLUSIONS

Caliper and bulk decreased with pressdrying. Tensile factor was reduced by pressdrying sheets made of 400 - 300 ml CSF pulp. Tensile of conventional and pressdried sheets made of 200 ml CSF pulps did not differ significantly. Ring crush factor of bogus medium was increased by pressdrying.

The level of solids going into drying had an effect on caliper, density and possibly ring crush factor.

Conclusions were based largely on significance testing. T Tests were performed assuming that solids had no effect on results and that a 20 ml difference in freeness was not significant. The practice of correcting strength to constant basis weight was assumed acceptable.

RECOMMENDATIONS

Pressdrying of bogus medium would possibly result in increased ring crush. Reduction of refining and pressdrying to maintain constant ring crush is not recommended since loss of tensile strength may occur.

Further study could be done to discover why tensile stength of pressdried bogus medium is lost at moderate refining levels. A study of recycled/virgin fiber blends may be profitable.

TABLE I
EFFECT OF SOLIDS ON CALIPER AND DENSITY

Freeness - Method* CSF	584-P	518-C	410-P	391-C	297-P	312-C	202-P
Caliper - Density ,001" g/cc							
% Ingoing Solids							
33%	11.4 - .47	12.7 - .42					
34%							9.7 - .57
35%	11.4 - .47	12.7 - .42	10.6 - .51			10.8 - .50	9.6 - .58
36%	11.1 - .48	12.8 - .42	10.1 - .53			10.8. - .50	9.4 - .58
37%	10.8 - .47	12.1 - .45	9.7 - .55	11.2 - .48	9.9 - .54	10.9 - .50	9.4 - .59
38%	11.4 - .45	12.0 - .44	9.8 - .55	11.4 - .49	9.8 - .55	10.8 - .50	9.5 - .58
39%	11.0 - .49	11.8 - .44	10.1 - .53	10.8 - .47	9.3 - .56	10.7 - .50	9.2 - 5.9
40%	10.9 - .49	12.1 - .45	10.1 - .53	10.9 - .49	9.5 - .56	10.2 - .53	9.1 - .60
41%	11.0 - .49	12.1 - .45	9.7 - .55	10.8 - .50	9.3 - .58	10.2 - .52	9.2 - .61
42%	10.9 - .49	11.8 - .46	10.0 - .54	10.8 - .50	9.6 - .56		
43%		12.0 - .45		10.6 - .52			
44%							

* P= Pressdried

C= Conventional Drying

TABLE II
OVERALL RESULTS

FREENESS, ML CSF	584		518		410		391		297		312		202		217	
METHOD*	P		C		P		C		P		C		P		C	
	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.
SOLIDS %	38.2	2.4	39.0	2.9	37.9	2.2	39.9	2.1	40.6	1.6	38.9	1.8	38.3	2.7	39.0	2.1
BASIS WEIGHT G/M^2	135.2	4.5	136.5	2.4	137.2	1.5	137.2	2.6	135.9	2.2	136.6	1.6	139.6	2.6	137	2.4
CALIPER 1/1000 IN.	11.1	0.3	12.3	0.5	10.1	0.4	10.9	0.3	9.6	0.3	10.7	0.3	9.4	0.3	10.3	0.3
DENSITY G/CM^3	0.48	0.02	0.44	0.02	0.54	0.02	0.50	0.02	0.56	0.01	0.50	0.01	0.59	0.02	0.52	0.02
TENSILE FACTOR KG/IN.	10.3	1.5	14.6	1.3	12.8	1.3	15.8	1.5	12.5	1.2	16.4	1.9	21.9	2.3	22.5	2.0
RING CRUSH FACTOR LBS.	51.2	3.9	49.4	2.8	70.7	2.6	66.1	2.5	72.5	3.3	67.8	4.5	76.1	4.3	68.6	2.8
# HANDSHEETS	27		37		28		39		27		26		35		32	

* C = CONVENTIONALLY DRIED HANDSHEETS
P = PRESS DRIED HANDSHEETS

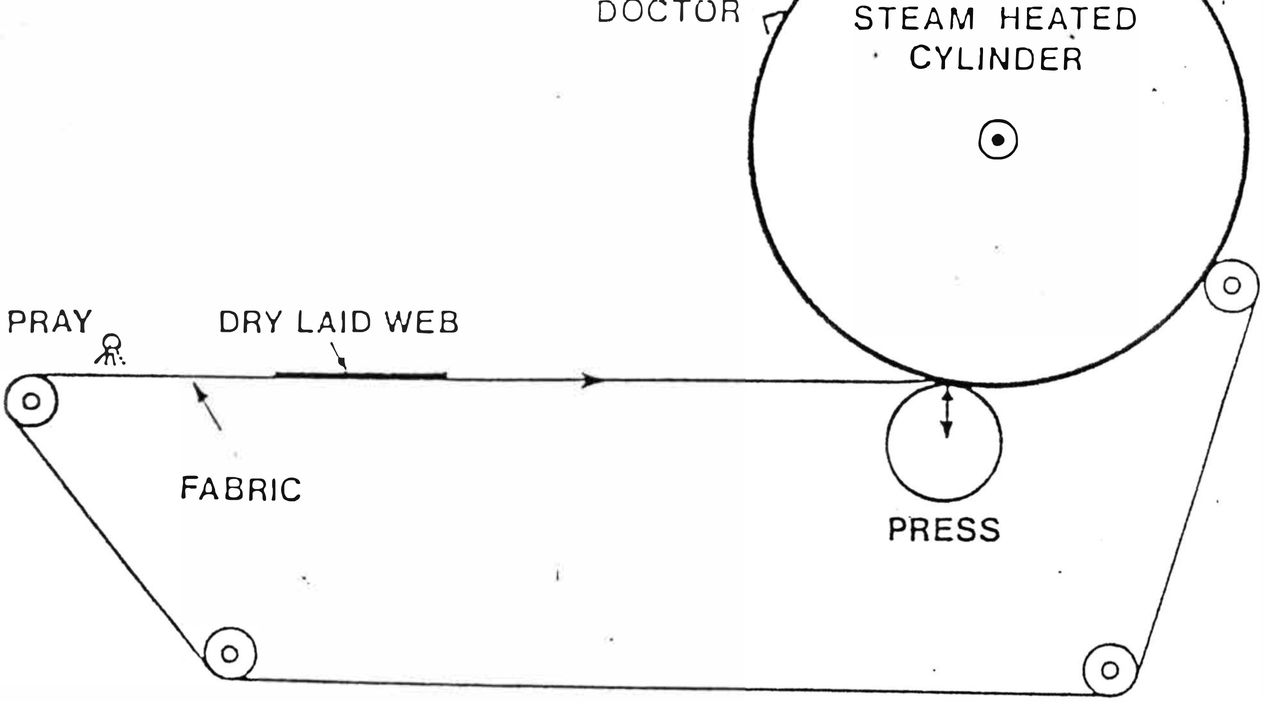


FIG. 1. LABORATORY EQUIPMENT FOR STUDYING PRESS DRYING.

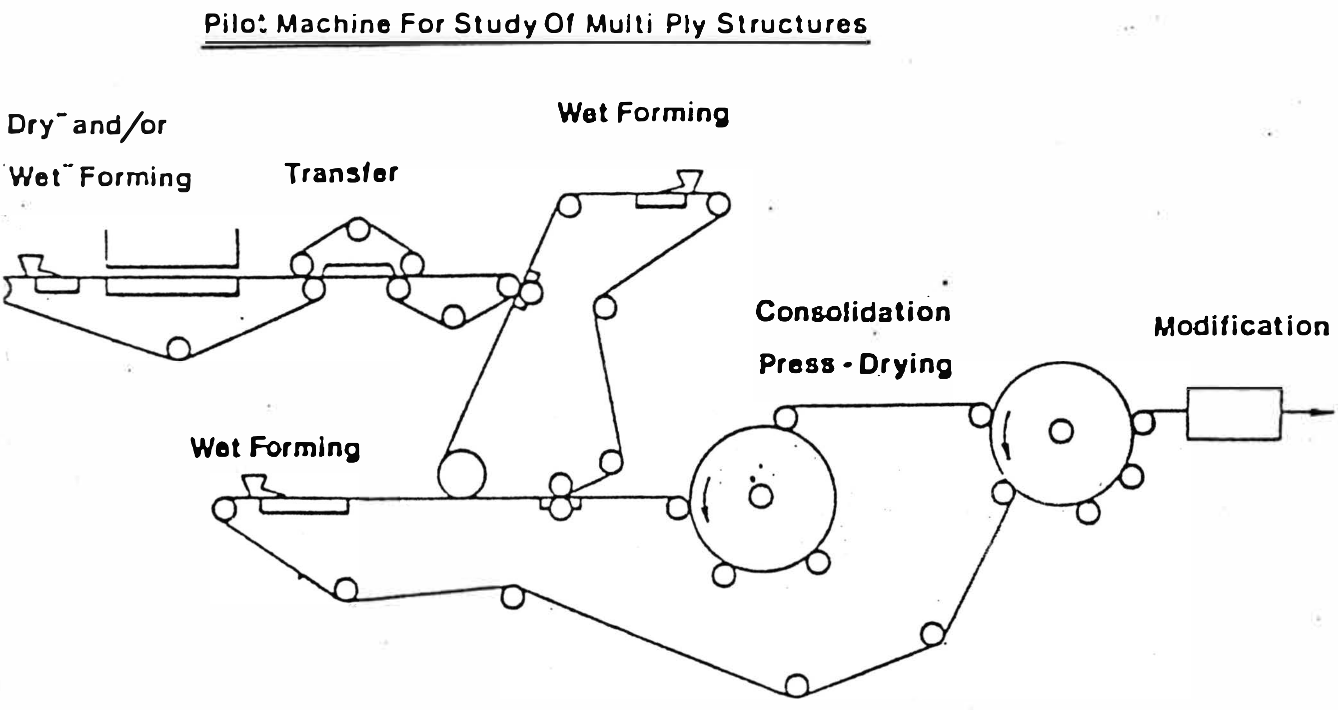


Fig. 2 St. Anne's pilot machine.

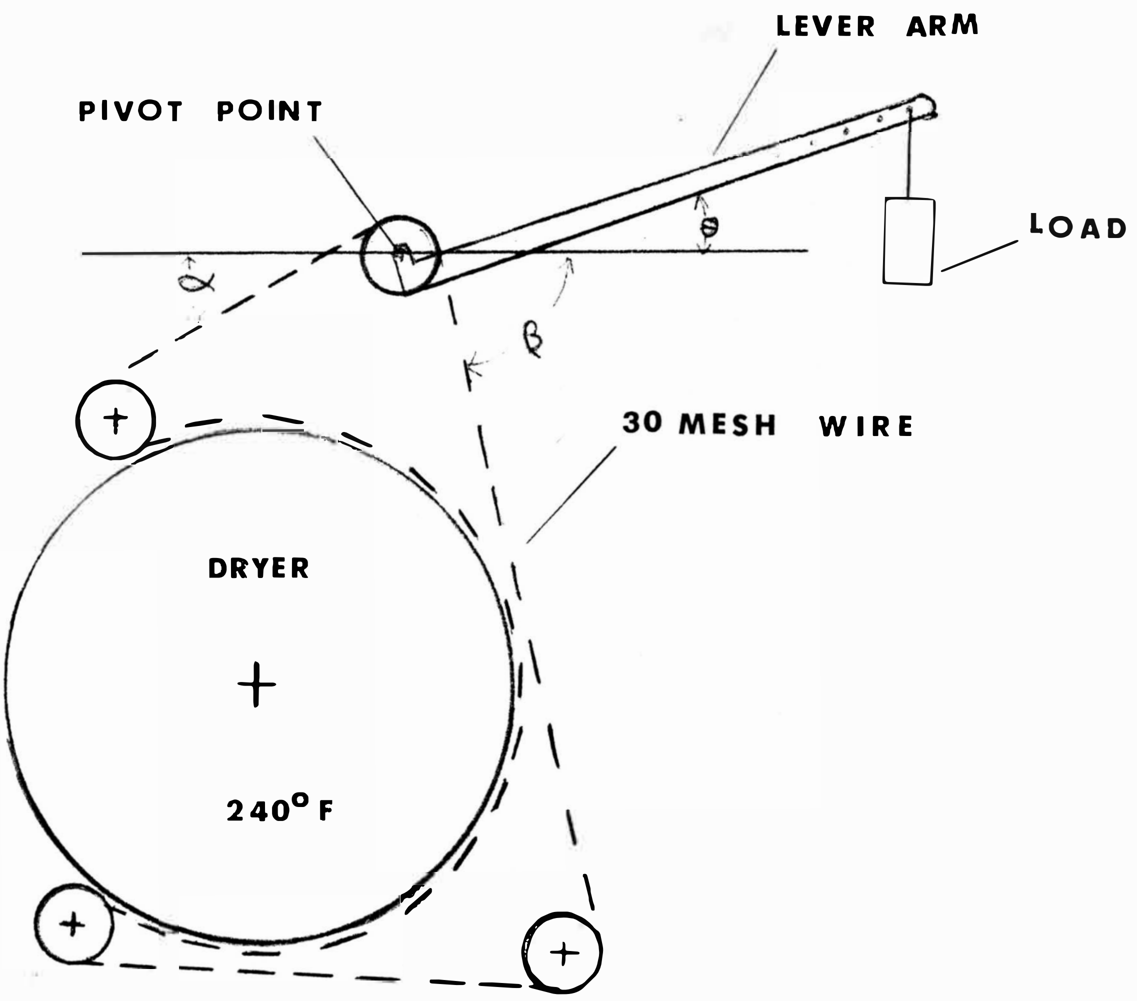


Figure 3. Noble and Wood Adaptation for Pressdrying

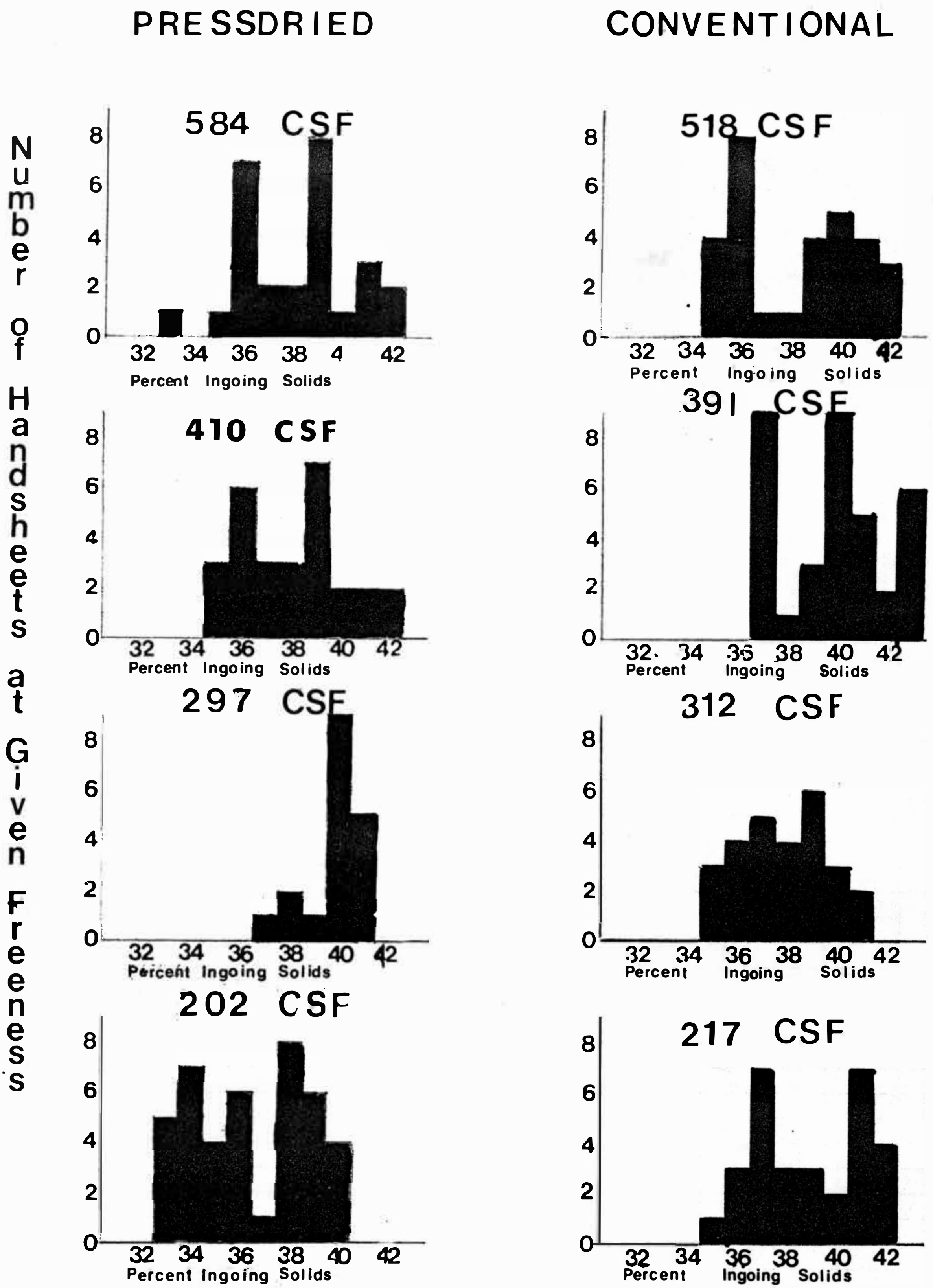
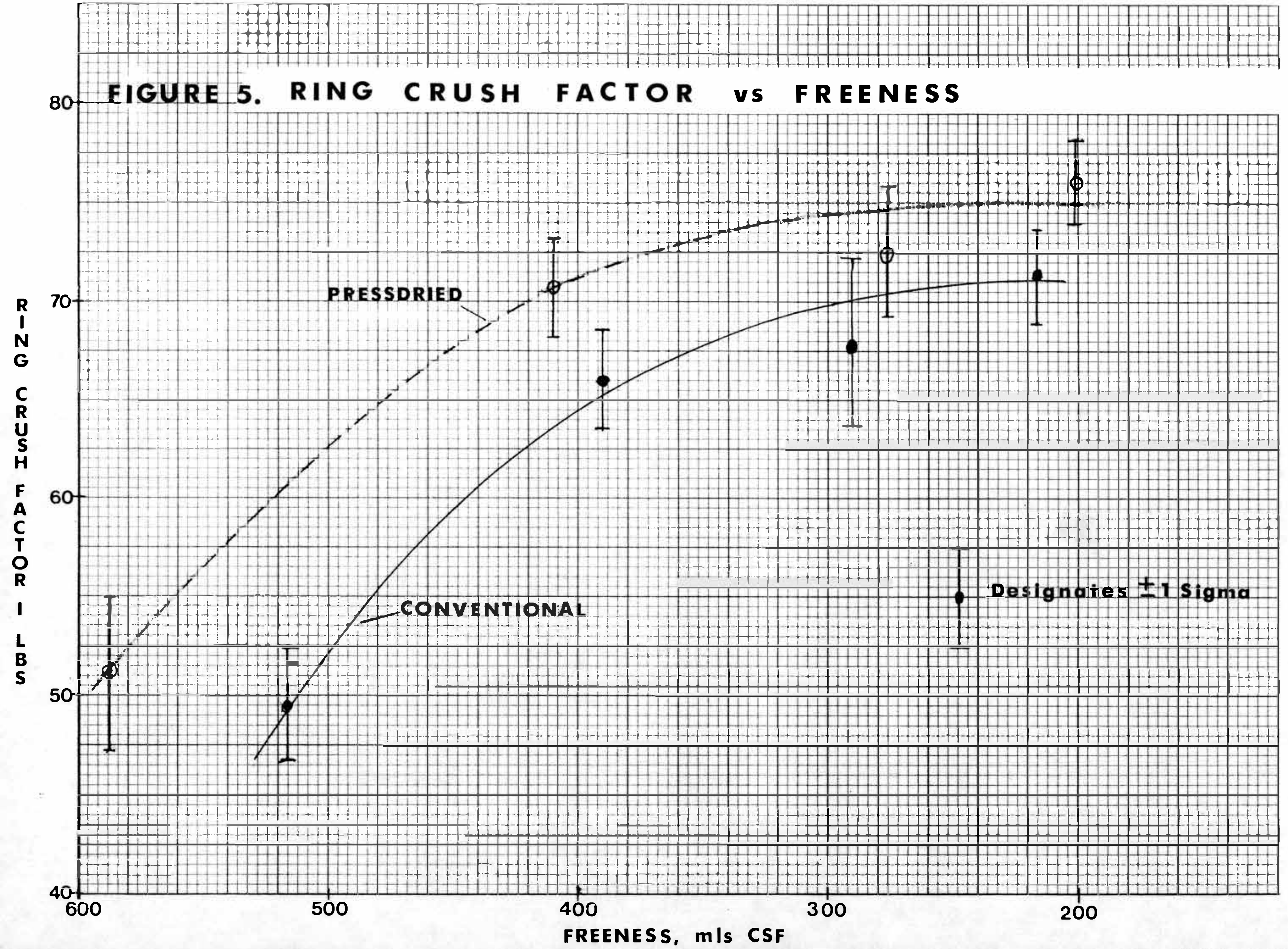


Figure 4. Ingoing Solids

FIGURE 5. RING CRUSH FACTOR vs FREENESS



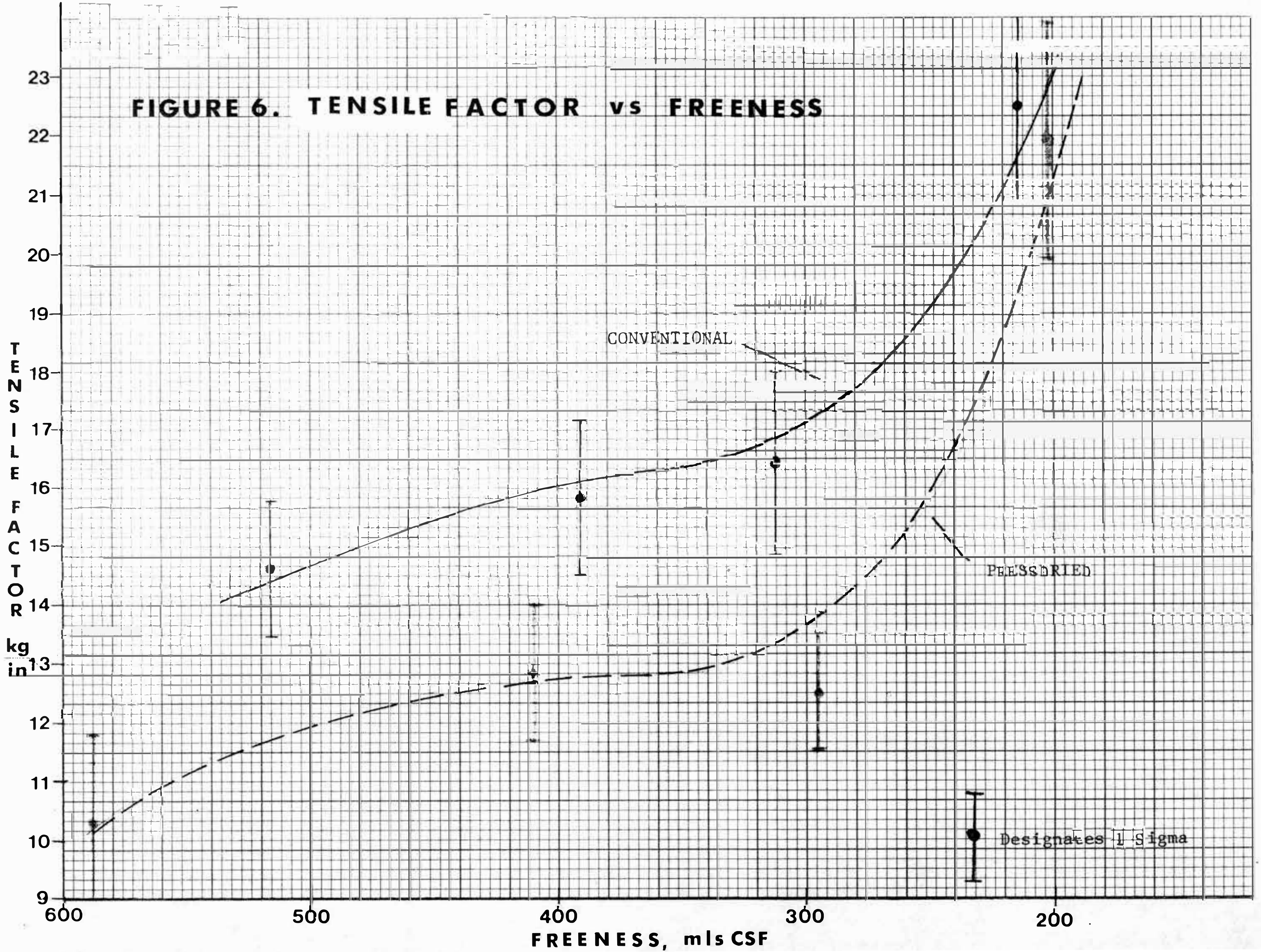


FIGURE 6. TENSILE FACTOR vs FREENESS
TENSILE FACTOR kg/in
FREENESS, mls CSF
CONVENTIONAL
PRESSDRIED
Designates 1 Sigma
600
500
400
300
200
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

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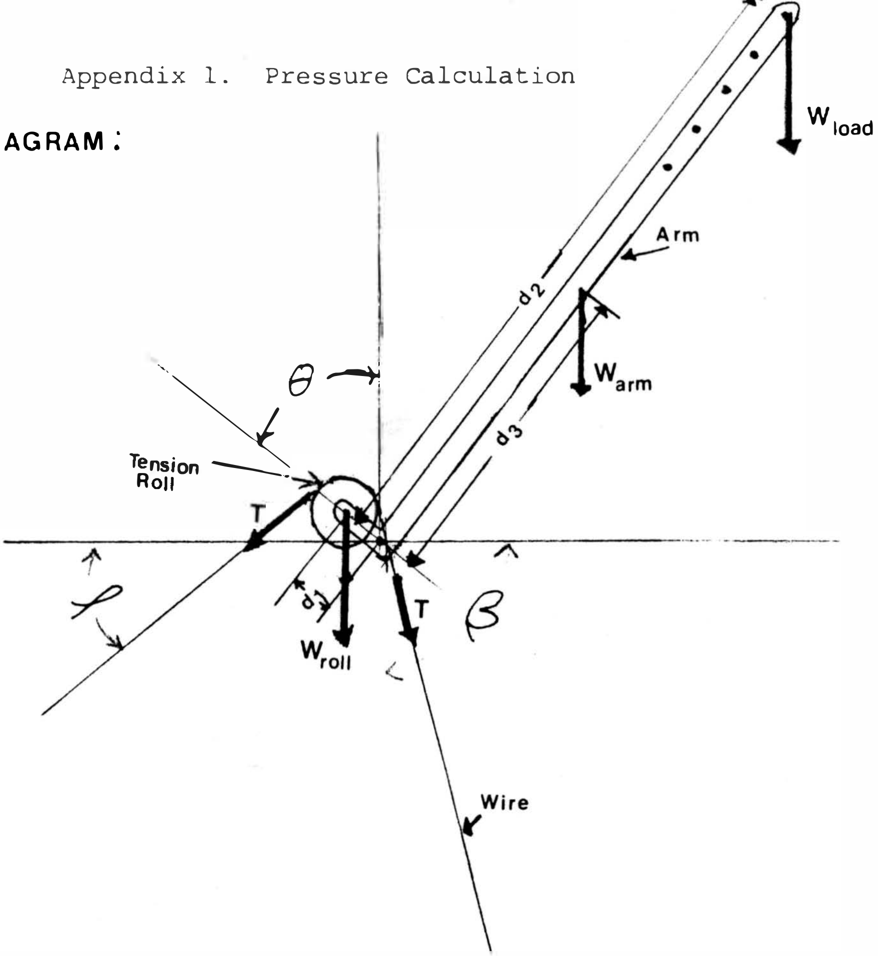
Appendix 1. Pressure Calculation

FREE BODY DIAGRAM:



$W_{load} = 34$ lbs

$W_{arm} = 3$ lbs

$W_{roll} = 2$ lbs

$d_1 = 1.5$ in.

$d_2 = 20$ in.

$d_3 = 9.4$ in. = distance to centroid from pivot point

$\theta = 38^\circ$

$\alpha = 27^\circ$

$\beta = 84^\circ$

$$M_{elbow} = 0 = -d_2 W_{load} \cos\theta - d_3 W_{arm} \cos\theta + d_1 \sin\theta\, T \sin\alpha + d_1 \cos\alpha\, T \cos\theta + d_1 \sin\theta\, T \sin\beta - d_1 \cos\beta\, T \cos\alpha$$

Solving for T & inserting values:

$$T = \frac{-W_{load} \cos\theta - W_{arm} d_3 \cos\theta + W_{roll} \sin\theta}{(\sin\alpha \sin\theta - \cos\beta \cos\alpha + \sin\theta \sin\beta + \cos\alpha \cos\theta) d_1}$$

$T = 245$ lbs

PRESSURE IN PLI: assuming no lift of wire, $pli_{min} = \frac{245 lbs}{11 in} = 22.3$ pli

assuming sheet takes entire load, $pli_{max} = \frac{245 lbs}{8 in}$

PRESSURE IN PSI: pressure in psi is proportional to pli and dryer diameter since the diameter is constant.

$psi_{min} = 22.3 lbs/13 in = 1.7$ psi $\quad psi_{max} = 30.6 lbs/13 in = 2.4$ psi

Appendix 2. U Factor Calculation

drying time = 45 - 60 seconds

temperature during drying = 240 ^{o}F

ambient temperature = 65 - 70^{o}F

estimated sheet temperature exiting = 180 ^{o}F

mass of fiber = 5.25 grams = .01157 #

mass of water evaporated = 7.88 grams = .01736 #

area of sheet = 64 in^2

heat capacity of cellulose = .32 Btu/#-^{o}F

enthalpy of saturated vapor @ 240 ^{o}F = 1112.5 Btu/#

$$Q = mC_p(\Delta T) = UA\Delta T = m\lambda$$

$$U = \frac{(.01157\ \#\ \text{fiber})(.32\ \text{Btu/\#-}^{o}F)(180 - 70)^{o}F + (.01736\#\ H_2O)(112.5\ \text{Btu/\#})}{(64in^2/144)(240-70)^{o}F \times (60\ \text{sec}/3600)}$$

U_{min} = 15.7 Btu/ft^2-hr-^{o}F

U_{max} = 20.3 Btu/ft^2-hr-^{o}F (similar calculation using 65^{o}F ambient and 45 sec drying time)