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The Effects of Over Drying, Before the Size Press on Strength Properties

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THESIS PAPER #472

The Effects of Over Drying, Before the Size Press on Strength Properties.

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ABSTRACT

This thesis was designed to determine the effects of moisture variations before the size press, and its effects on strength properties. This experiment involved laboratory experimentation along with a paper program pilot plant two day trial.

The results from the laboratory data revealed that an increased moisture content into the size press resulted in an increase in overall strength content for tests including tear, burst, and fold. The pilot plant trial data showed a specific window effect, in that at very low/high moisture levels entering the size press, a significant decrease in strength could be seen.

It was also found that upon increased moisture content, an increased weight of starch was picked up by the web, however, this had little effect on overall strength properties. Finally, by completion of a mass and energy balance, it was determined that a consecutive increase in energy was needed to reach the lower moisture levels entering the size press; taking into account that moisture was held constant at the reel. This led to steam optimization which could be seen in ($/year).

INTRODUCTION

This experiment represents an in depth analysis of the relationship between moisture before the size press, and strength of the finished product at the reel. Laboratory experimentation was followed to determine a practical moisture range which could be used on the paper program pilot plant paper machine. Laboratory tests include moisture out of the dryer can, basis weight, burst, tear, tensile, MIT fold, and brightness.

Duplicate pilot plant trials were run on two consecutive days to serve as a check on the reproducibility of the tested data. These trials varied the moisture level of the web entering the size press, and adjust the after dryers in such a way as to arrive at a constant moisture level at the reel. Tests run included the above mentioned along with Hercules size test, and caliper determination. Finally, a mass and energy balance was performed to determine the amount of BTU's required to produce a given web with the above specifications. From these results, the cost to run each level of moisture into the size press in ($/year) was determined.

Background

Effects of Over Drying Before the Size Press on Strength Properties:

The effects of over drying the web before the size press can be dependent upon factors including size penetration and pick-up, web temperature entering the nip, starch percent solids and type used, and also when changing from an alkaline to an acid system. The following material has been chosen to set up a base line for this project from which the paper industry as a whole may benefit.

Surface sizing consists of applying a film-forming polymer to the webs surface at the size press. Traditionally, starch has been used, but there are many other materials which can be used to impart special properties into the fibrous matrix of paper. The original aim of surface sizing was to increase water resistance, coupled with resistance to feathering and improve the surface strength.(1)

The key paper property in the performance of surface sizing is basis weight, since the process involves coating combined with some penetration. If all other factors remained the same, the amounts of each will be essentially constant in going from one basis weight to another, so that the proportion of pickup will decrease as the basis weight increases above a certain limit. The smoothness of the paper in the nip will influence the amount of coating, while the resilience, internal sizing, and pore structure will influence how much surface size is absorbed.(2)

Viscosity of the surface sizing material has also been shown to be a major factor in the amount of size picked up by the moving web. The make up of the polymer chain length and concentration is directly dependent on the viscosity of the applied surface sizing agent. Finally, temperature is directly tied in with all these factors especially with solution of starches and gums. In these cases it is essential to have the size press equipped with a starch pan which has constant recirculation along with very tight temperature controls to keep the size viscosity within a small degree of variation.(3)

To further understand the mechanisms involved at the size press, the phenomena of surface penetration by cationic starches will be studied. Nissan (4), has determined the possible paths of surface penetration to be:

1. Liquid penetration through the pores by capillary flow.
2. Liquid movement through the pores by surface diffusion.
3. Liquid movement through fibers by various processes.
4. Vapor phase movement through the pores.

It can be pointed out that the actual mechanism is a combination of all four paths, with one path being the rate determining stage. To theoretically understand this concept, the Lucas - Washburn equation can be used to adequately describe the penetration of starch like sizing agents into paper:

$$L^2 = (r \text{ Cos } t)/2$$

where, L = depth of penetration
r = pore radius
t = time

By using this equation and following it up with intense experimentation, Brecht found that increasing the sheet moisture content increased the rate of penetration. This could be explained in terms of the increased moisture content increasing the pore size.(5) Olsson and Pihl followed this similar work and found that penetration time, viscosity, and sheet thickness were related as in the Lucas - Washburn equation.(6)

To further understand this concept, it is apparent that in initial penetration of a constant 9.7% solids starch solution into varying pore structure substrates, a very fast initial penetration rate is observed. (Fig. #1) This is followed by a slower linear penetration rate as the starch contact time is increased. (7) Also wetting times were observed to exist and found to be dependent on the roughness of the base sheet and the viscosity of the penetrating solution. (Fig. #2) Variables can be defined as:

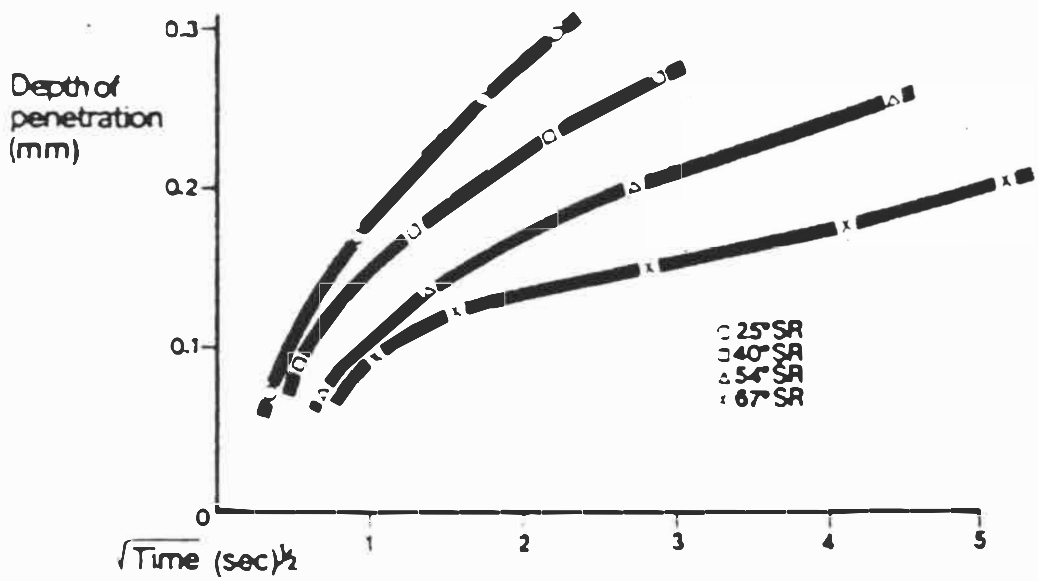
○ = 25 minutes beating of base substrate
□ = 40 minutes beating of base substrate
△ = 54 minutes beating of base substrate
X = 67 minutes beating of base substrate

Not only is liquid penetration into the surface of the web a function of final sheet properties, but, the incoming web's temperature and moisture content have been found to be of major concern.

Paper is extremely sensitive to moisture changes. The relationship between the moisture in air and that in paper is very difficult to define. It is not just a question of water vapor flowing from one to the other. There is always a change in the physical state of moisture during the process. The moisture in paper becomes highly condensed and occupies much less than a thousandth part of the volume that same amount of moisture would occupy in the surrounding air. (8) This helps to explain why changes in the moisture content and in most physical properties of paper are correlated with relative humidity rather than with absolute humidity.

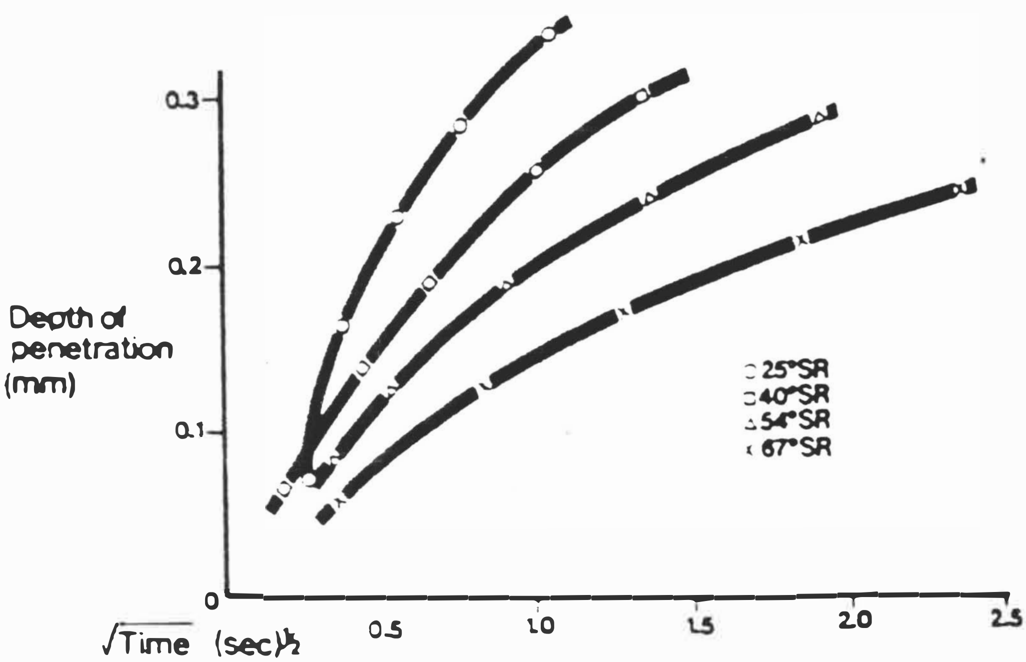
As the fibers of paper absorb increasing amounts of moisture, they increase in diameter and become pliable, losing in felted strength and bonding ability. The hydrogen bonding is reduced because the fiber proximity exceeds the minimal

FIGURE 1



Depth of penetration verses root time curves for a 9.7% solids starch solution

FIGURE 2

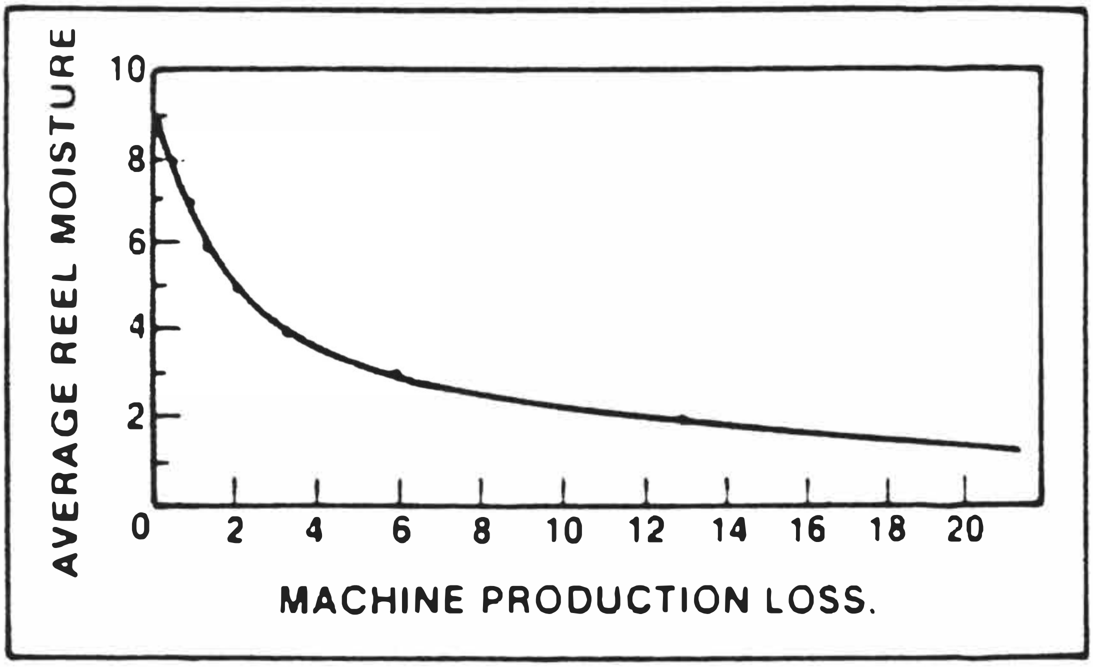


Depth of penetration verses root time curves for water requirement (approx. 5 angstroms) for H-bond development. Such alterations in the fibers effect the dimensions, the strength, the wettability, and other physical properties.(9)

It is apparent that moisture pick-up depends on the moisture content of the web before the size press. There is a minimum level at a moisture content of about 10%, above which between 30% - 60% it is almost constant. The impact of moisture content before the size press is less on starch pick-up than on moisture pick-up.(10) This is significant because it is again another factor which can lead to variability in the final physical sheet characteristics. Chilson's investigation showed that below a moisture level of 5%, the resistance to picking increased because of low penetration and starch being on the surface of the paper.(11) From the values of picking resistance, the conclusion can be drawn that below 5% and above 80% moisture, the starch will be located on the surface while for values within these limits, the whole cross section is penetrated with starch.

Other considerations exist in the area of over drying the web before the size press to obtain improved moisture profiles at the reel. Some paper makers attempt to reduce the entering size press web moisture level down to about 4% to bring the variations in the moisture profile into an acceptable range. Louden **states** that the sheet is typically over dried to minimize moisture variation because it is desirable and necessary to restrict cross directional moisture variation for uniform size on coating pick-up.(12) However, there are large costs associated with any deviation from optimum target drying levels.(Fig. #3) Proper

FIGURE #3 Average reel moisture vs. machine production loss. from Perrault (6).



use of steam showers will effectively hold a moisture profile level allowing average moisture levels to rise uniformly. The advantage of allowing average moisture levels to rise from 1% to 2% can save up to 10% on process steam requirements. Improved moisture within a certain range can also improve sizing uniformity and/or coat weight uniformity. Also, energy savings, improved moisture profiles, and improved coating all contribute to high returns on investment and increased profit margins.

Research by Cutshall suggests that drying paper to its lower level is undesirable because it increases the brittleness of the paper.(13) Moreover, finished moisture levels below 5% are generally regarded as being undesirable because of the possibility of over dried papers to cockle, wrinkle, and develop bagginess when the finished paper is subjected to relative humidity within anticipated ranges.(14)

Cationic Starch Size Press Application:

The use of cationic starches in the size press application has gained much popularity in the paper industry for its great versatility to various furnish types. Mill results show that cationic starches not only improve printing properties, but also sheet opacity and strength. The cationic property of the starch also helps reduce mill effluent BOD (biological oxygen demand), and can help increase drying rates.(15)

When the cationic starch is applied to the sheet,it is immediately retained by the surface fibers although, a portion of it flows into the sheet to varying depths. The starch is easily retained by the surface fibers because they are composed of a net anionic (-) negative charge, which is directly attracted by a net cationic (+) positive charge, creating a higher concentration of starch near the fiber surface.(16)

The cationic charge on the starch also increases fiber bonding and thus, produces a stronger sheet. The positively charged starch forms an electrochemical link from fiber to fiber, reinforcing the normal adhesive forces of hydrogen bonding.(17) With more starch near the surface and with greater adhesion between the starch and fiber components, sheet properties related to Tg (glass transition temperature) surface strength are enhanced. The fact that surface strength is improved with cationic surface sizing starch has been demonstrated in several offset printing tests on sheets giving lower wax picks. In these tests, the sheets surfaced - sized with cationic starch yielded consistently superior printing results in long press runs. Also, trial results show that there is a significant improvement in IGT pick strength and a modest improvement in burst, all though starch pick-up was reduced about 25%.(18) In general, it should be stated that the cationic starch has greater bonding power, and the higher affinity of cationic starch to cellulose fibers reduces the depth of penetration.(19)

Acid Vs. Alkaline Systems:

In todays paper producing markets, a drastic switch has taken place from the original acid systems to the alkaline systems used widely today. Acid systems at a pH of 4 - 5,

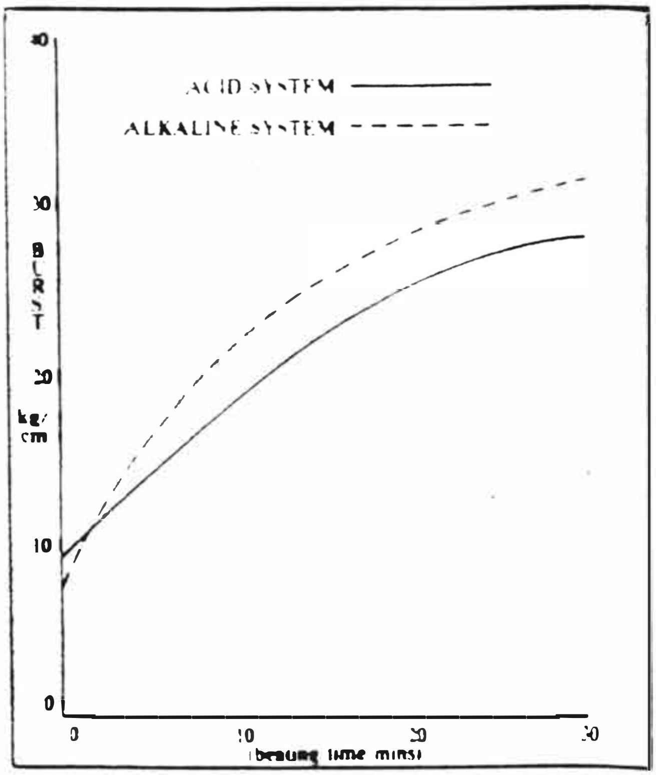


Fig. 4 Mullen burst v. time

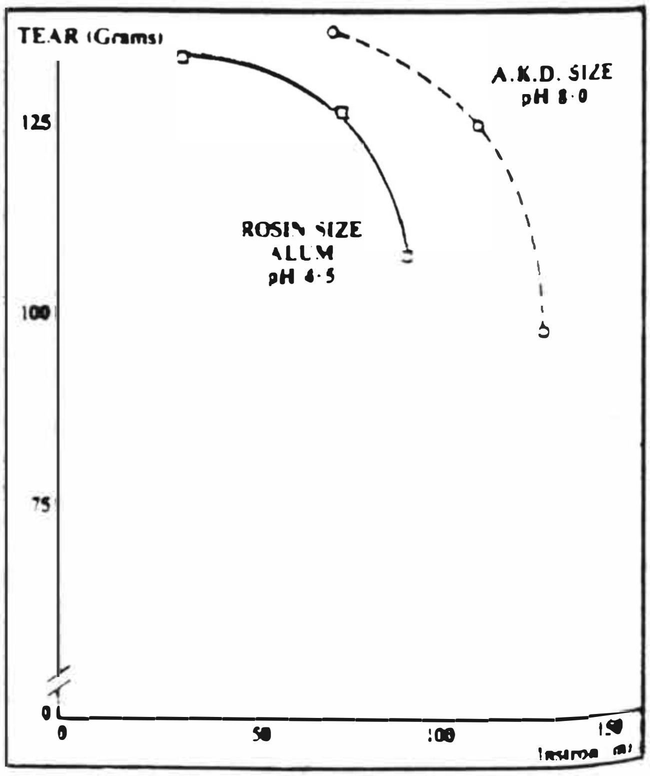


Fig. 5 A comparison of tear v. Instron tensile acid and alkaline making conditions

utilize alum in its formulation to serve as a linking agent between the fiber/rosin particles. Alum has also been found to be the prime cause of yellowing and embrittlement of the finished product. Alum hydrolyzes in water and, unless the acidity is monitored and controlled, the resulting increase in back water acidity can be extremely corrosive to all paper machine metal components.(20) Acid systems also have direct losses in strength properties namely, burst, tear, tensile, and MIT fold. The loss of folding endurance and the embrittlement of acid papers is considered to come from a change in the cellulose fiber itself.

Acid penetrates the open amorphous regions of the fiber and cuts the cellulose chains by hydrolytic action. It then simultaneously removes the portion of the fiber, plasticized by humidity and lowers the over-all degree of polymerization. The cut cellulose chains are free to rearrange; and as a result, the degree of crystallinity of the fiber increases.(21)

In alkaline systems the pH is normally between 7.5 - 8.5 with the adjusting chemical being a strong base. This type of system has recently taken a hold in the paper industry due to its outstanding advantages over the acid system including:

* Improved plybond, burst, and rigidity.
* Reduced slip during conversion.
* Reduced sizing cost.
* Improved system cleanliness, less foam, elimination of rosin wax plugging of felts.
* Elimination of sulphate deposits and filling of drilled couch and press rolls, reduced corrosion.
* Improved freeness, drainage.
* Reduced water usage, reduced fiber, filler, chemical and energy losses.
* Improved quality of final discharge to the recycling plant.

Physical strength properties including burst, tear, and tensile, are compared again showing the alkaline system to be superior. (Fig. #4,5) This fact opens the door for possible softwood level replacements with hardwood to maximize the savings on raw material costs. Possible incentives may also be present to move into more specialized grades, due to a more improved product.

Generally, the alkaline sized paper feels more slippery. In fact, it is measured at 30% lower coefficient of friction and 20% lower slip angle for paperboard manufactured with alkaline size as compared with rosin-alum size. (22) Arney reports that the use of alkaline size makes it possible to increase the moisture content 1.0 - 1.5% higher than in a clay filled sheet. (23) This could result in a smoother, denser and softer sheet.

A final advantage can be seen for the alkaline system in that the energy necessary to develop a certain strength level is lower by about 10%. This can benefit the manufacturer in two ways. The first way is through a direct power reduction to the refiners, and the second is a substitution of lower-cost fibers to reduce material costs overall.

As more and more paper mills change to alkaline sizing the uses to which these new products are placed will broaden our knowledge even more. Finally, as the paper industry strives to become more efficient, production orientated, and profitable, this type of system allows a mill the ability to venture into new markets and survive whereas before it was an impossibility.

Experimental Approach

Lab work was carried out to determine whether variations in drying conditions will have an effect on strength for alkaline or acid systems. The acid system included rosin-alum size at a pH of 4.5, being adjusted with H_2SO_4. The alkaline system will utilize a Hercon AKD sizing at a pH of 8.0. The base sheet was a 50 lb/ream (ream size 24 X 36 X 500) air dried sample. The furnish was made up of a 50/50 northern bleached HW/SW blend. The NBSW (northern bleached softwood) was refined in the Valley beater until a freeness level of 400 ml CSF (Canadian Standard Freeness) is reached, while the NBHW (northern bleached hardwood) was refined in a similar manner until 600 ml CSF is reached. This was then blended together to arrive at an overall freeness of 500 ml CSF for the furnish.

On the lab bench, rosin - alum/Hercon size was added to each particular furnish, along with adjusting the pH to the desired range. The proportioner was used to achieve uniform basis weight and mixing. Ten sheets for each moisture level was made on the Noble and Wood handsheet machine, then pressed with double weights.

The wet sheets were then placed in the drum dryer where by adjusting the variable drive mechanism, (bone dry, low, medium, high)% moisture levels were obtained. The procedure for determining moisture levels for each variable change involved sealing the wire and sample handsheet inside a Zip-Loc bag to determine the wet weights. Then two samples were bone dried to determine the overall basis weight for the set. These samples were all conditioned according to TAPPI standards and tested for burst, tear, tensile, MIT fold, elongation, TEA, and brightness. The test results were used to determine whether or not strength properties are affected directly by moisture variations in the drying process.

Further experimentation with the use of the pilot plant Fourdrinier paper machine held the furnish, basis weight, percent solids of starch, temperature of starch, and moisture at the reel, constant. Variables changed included using an alkaline (Hercon AKD size) system, along with varying the dryer can steam pressure prior to the size press to meet the desired percent moisture specifications at the reel.

Testing included moisture samples before and after the size press, moisture at the reel, burst, tear, tensile, MIT fold, elongation, and TEA. Testing also included percent brightness to determine the webs reaction to the excessively low moisture conditions. These test results were used to generate possible relationships between web moisture, size pick-up, and strength results. Finally, steam usages were looked at for each moisture level to determine possible economical savings based on steam consumption and machine speed efficiencies.

This experimental engineering project was initially designed to include both an acid and alkaline system. However, due to the forwarded opinion of the department faculty at the last thesis seminar before starting work, it was suggested that the scope of the project be reduced to the alkaline system alone. The rest of the project was performed as originally stated.

Results: Table #1
(Lab. Data)

Moisture Levels Before SP (%)	0.00	3.18	9.05	12.00
Moisture Level At Test (%)	5.70	8.23	7.21	5.46
Basis WT. (lb./ream)	46.65	48.24	48.54	48.21
Burst (psi)	35.9	37.9	41.3	43.0
Tear (gcm)	43	45	47	51
Tensile (kg/15mm strip)	63	61	60	58
MIT Fold (double folds)	30	36	41	48
Elongation (cm)	2.7	2.7	2.7	3.2
TEA (J/M^2)	60.4	57.1	57.6	66.7
Brightness (%)	75.0	74.0	72.7	72.4

Results: Table #2
(Pilot plant trial data day #1 and day #2 averaged)

Moisture Levels Before SP (%)	4.85	3.74	2.65	1.63	1.38
Moisture Reel (%)	4.31	3.78	5.33	4.30	4.70
Basis Wt. (lbs./ream)	44.68	49.84	52.34	50.17	47.86
Caliper (1/1000 inch)	5.0	4.9	4.6	4.7	4.9
Burst (psi)	32.2	40.3	39.1	37.4	35.9
Tear MD (gcm)	33	30	29	32	33
Tear CD (gcm)	36	33	33	34	34
MIT Fold MD (double folds)	21	58	76	40	41
Brightness (%)	87.9	87.6	87.5	87.1	87.1

DISCUSSION

Laboratory Results:

This part of the thesis study was necessary because it determined the moisture basis for the pilot plant trial. In this study, moisture levels were determined by averaging 10 samples per set, for the control as well as four other moisture levels. The moisture levels included 12% for control, 12,9,3,and bone dry. For preliminary investigation, % brightness was evaluated per set as can be seen in Figure #6. The results showed that a significant increase in brightness is present with a decrease in % moisture present. This can be explained that as the sheet looses irreplaceable water within its structure, more fiber-to-light interaction takes place, which increases brightness characteristics.

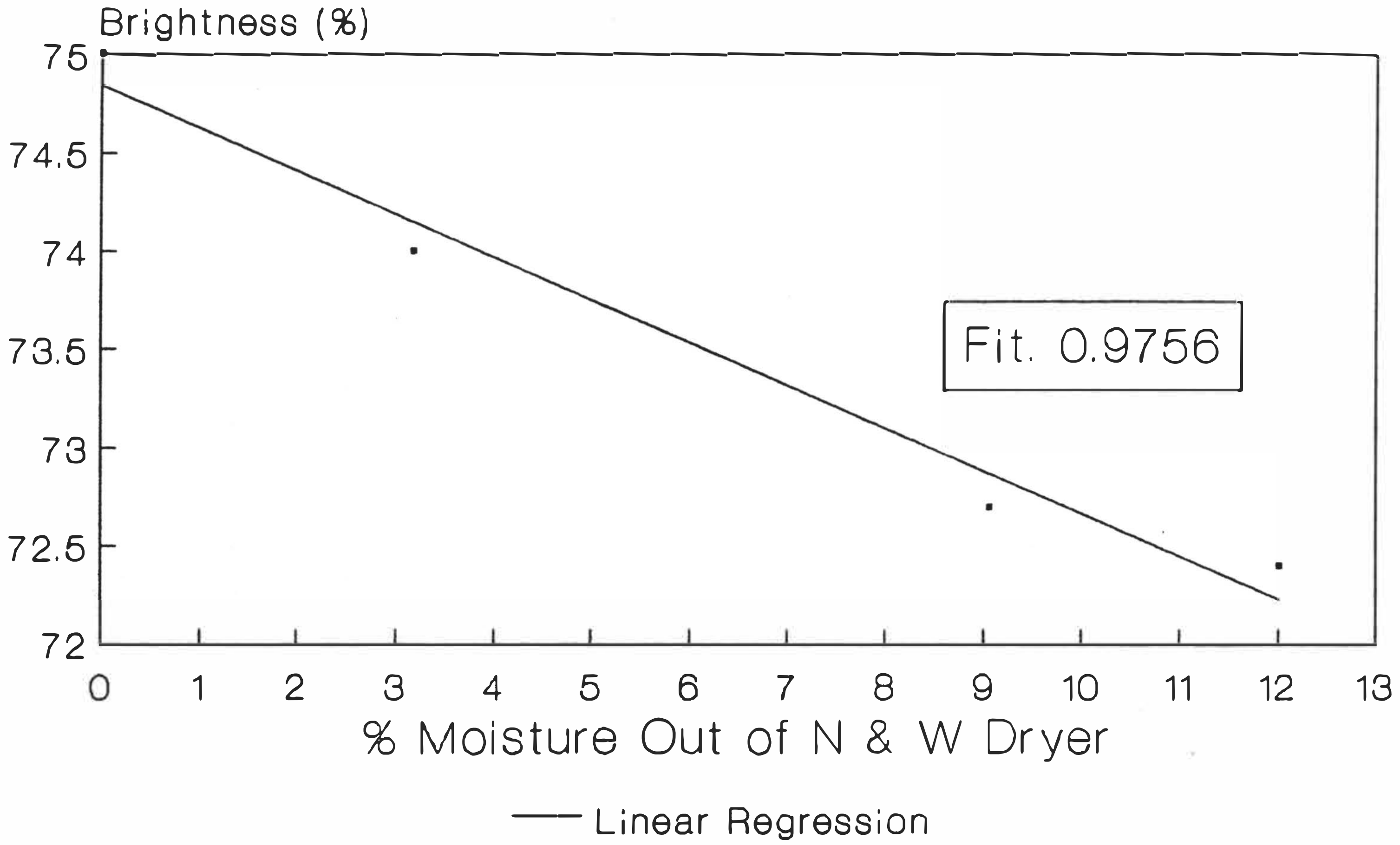
As can be seen by Figure #7, the burst increased almost linearly with increasing moisture content out of the Nobel and Wood dryer can. This can be explained by understanding that the fibers are becoming more brittle due to the amount of water present in the inner capillaries of the fiber's structure, which cannot be replenished by conditioning at TAPPI standards. This loss of capillary water caused the fibers to reduce their swelling ability which ultimately resulted in sheet rupture by the applied force.

Other strength tests evaluated included tear, tensile, and MIT fold. The tear test as seen in Figure #8, showed that as the moisture increased the tearing strength also increased. This also followed an almost linear path which can be seen by the r-squared fit of 0.9251. This result can be explained because as

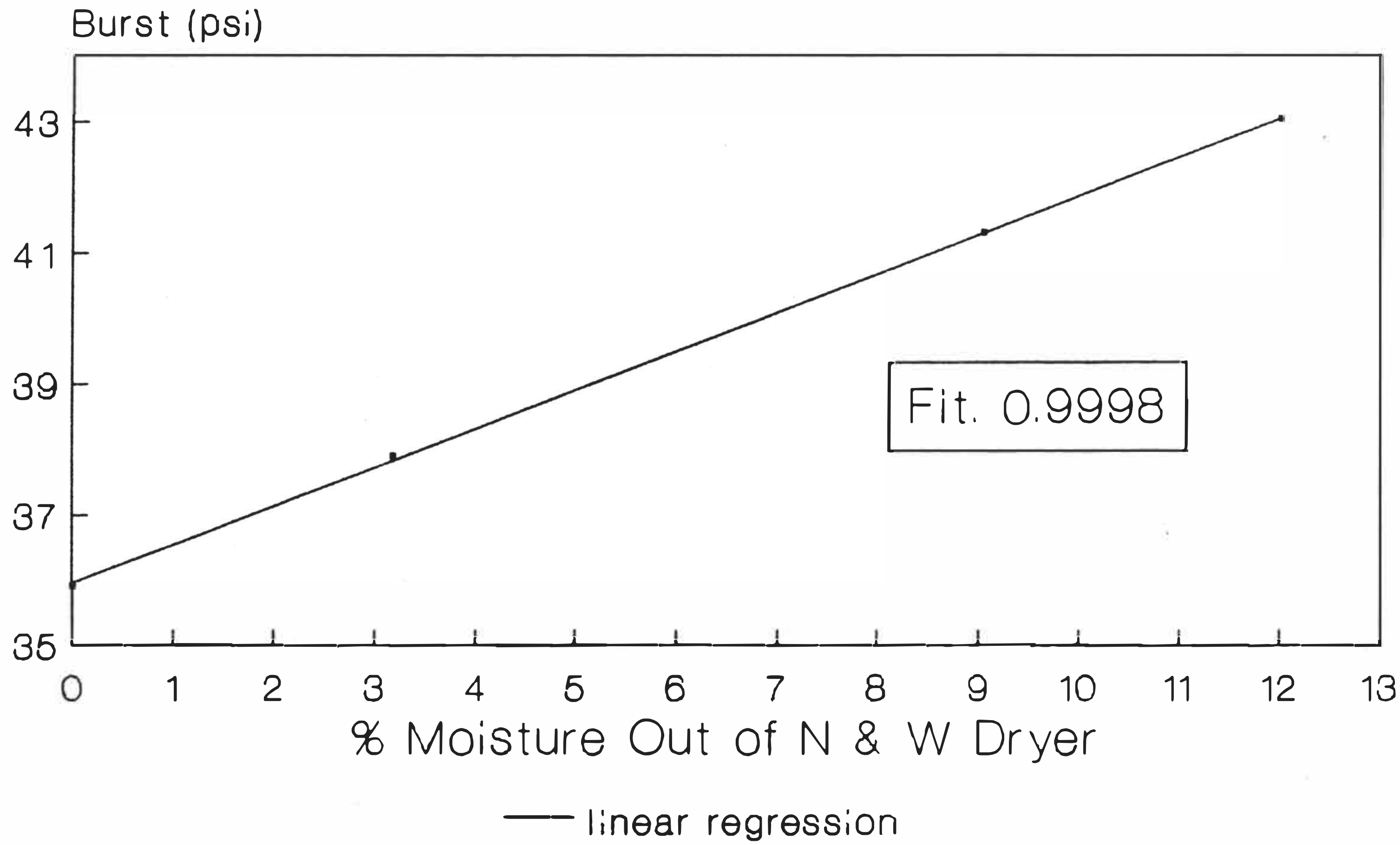
% Brightness vs. % Moisture

Laboratory Data

Figure #6



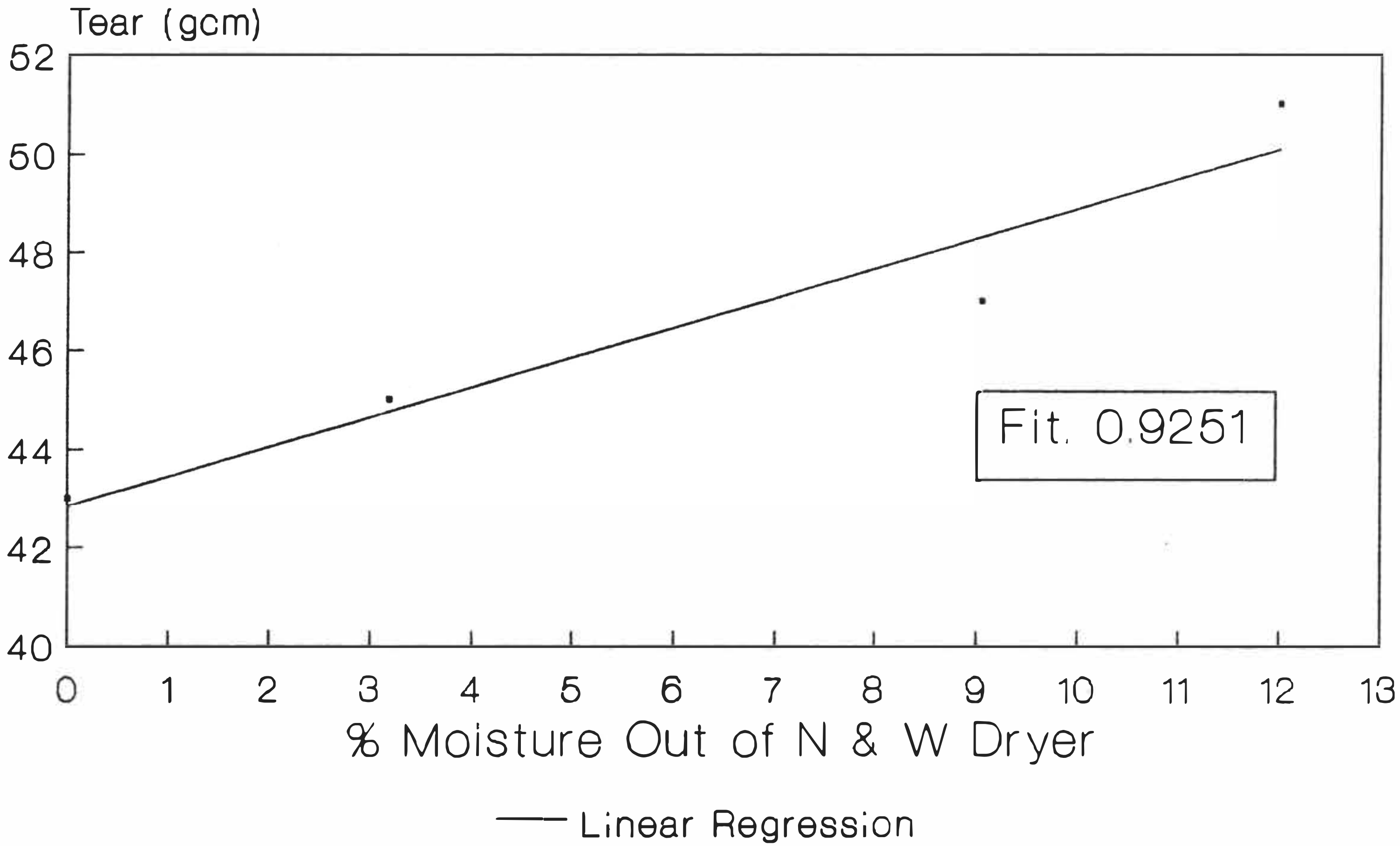
Burst vs. % Moisture
Laboratory Data
Figure #7



Tear vs. % Moisture

Laboratory Data

Figure #8



the % moisture increases, the fiber is more flexible and agile which gives it much greater tearing resistance. If the fiber's moisture content is decreased, the sheet upon testing will tear with much less force because the fibers are more rigid.

The tensile results as seen in Figure #9, provides contrary conclusions because this is opposite to the burst results. Normally it has been seen that for a given sample of uniform basis weight, the tensile test data will follow similar trends as the burst data. A Possible reason for this error includes, variations in basis weight among samples tested due to the assumption that the last and the first sheet made is representative of the entire set.

The MIT fold results as can be seen in Figure #10, depicts similar results as previously seen by the burst results. Again, the fit of the curve is very good and near linear. The folding test is dependent upon fibers that are flexible and have the ability to create fiber-to-fiber bonds. Upon increasing moisture content, the fiber begins to swell in the alkali system and as a result, more bonding surface area is present which allows for increased folding strength.

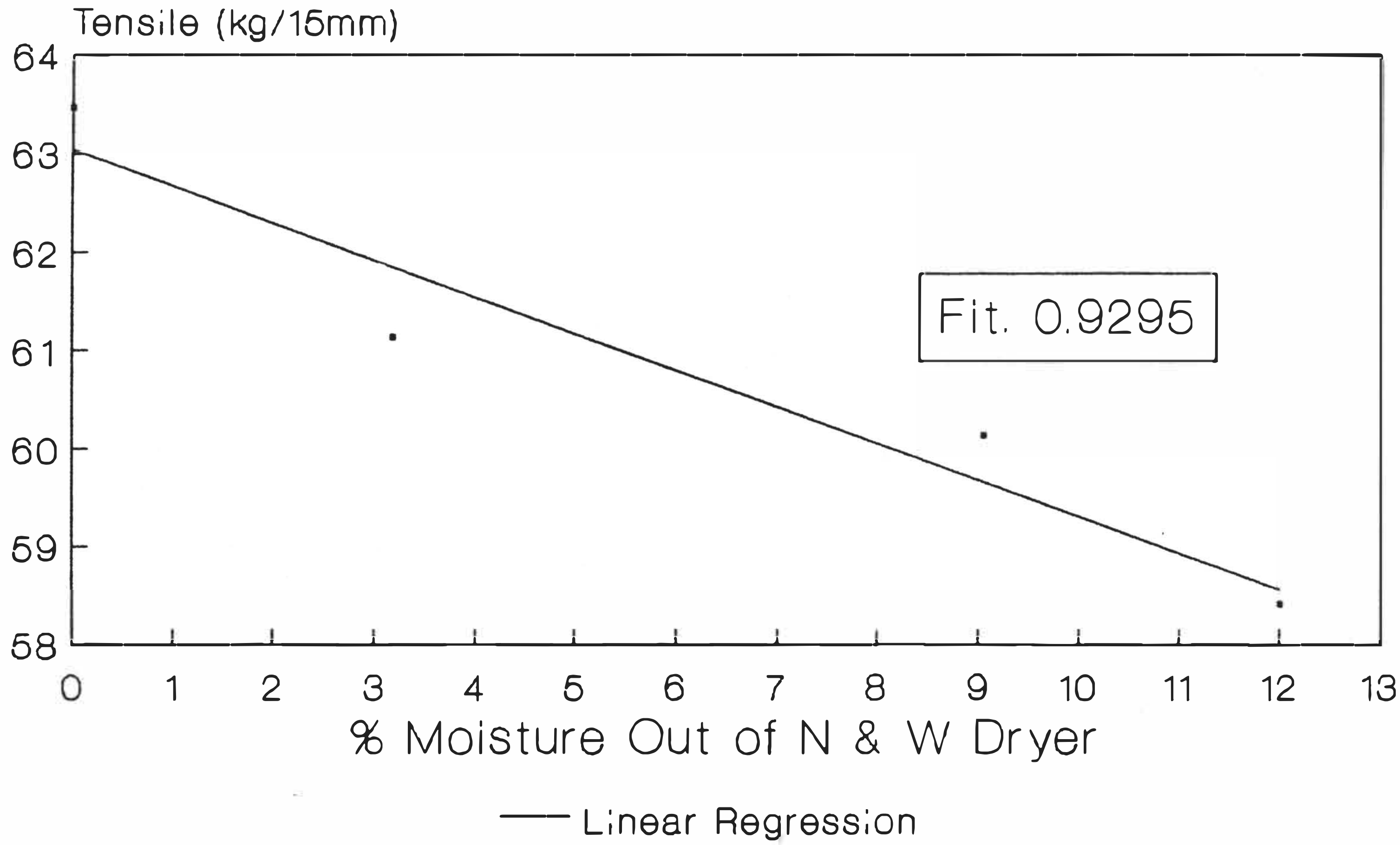
Pilot Plant Trials Day#1 and Day#2:

This trial was designed for two days to be able to determine the reproducibility of the system variable changes as well as the validity of the tested data. The results which can be seen in Results Table #2 show that the moisture levels before the size press were not exactly the desired 6,4,2,0%, but rather for a two

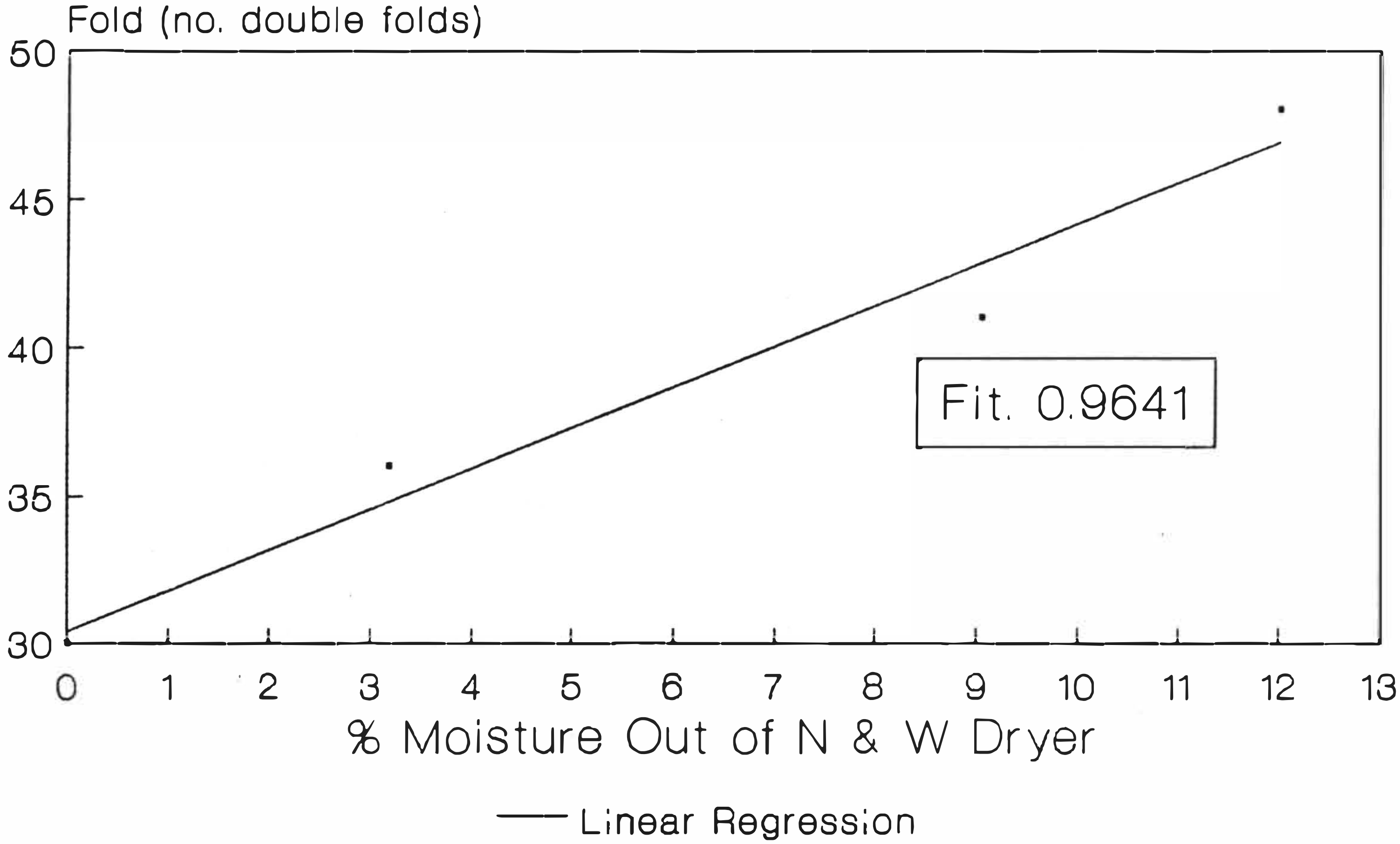
Tensile vs. % Moisture

Laboratory Data

Figure #9



Fold vs. % Moisture
Laboratory Data
Figure #10



day average 4.85 for control,(3.74,2.65,1.63,1.38)%.

These moisture levels resulted in the brightness of the web slightly increasing for both days with an increase in moisture level into the size press as can be seen in Figure #11. This could have been the result of variable amounts of starch being picked up by the web. If a greater amount of starch is present at the surface of the moving web, then light reflection can be altered to reduce the overall % brightness being measured.

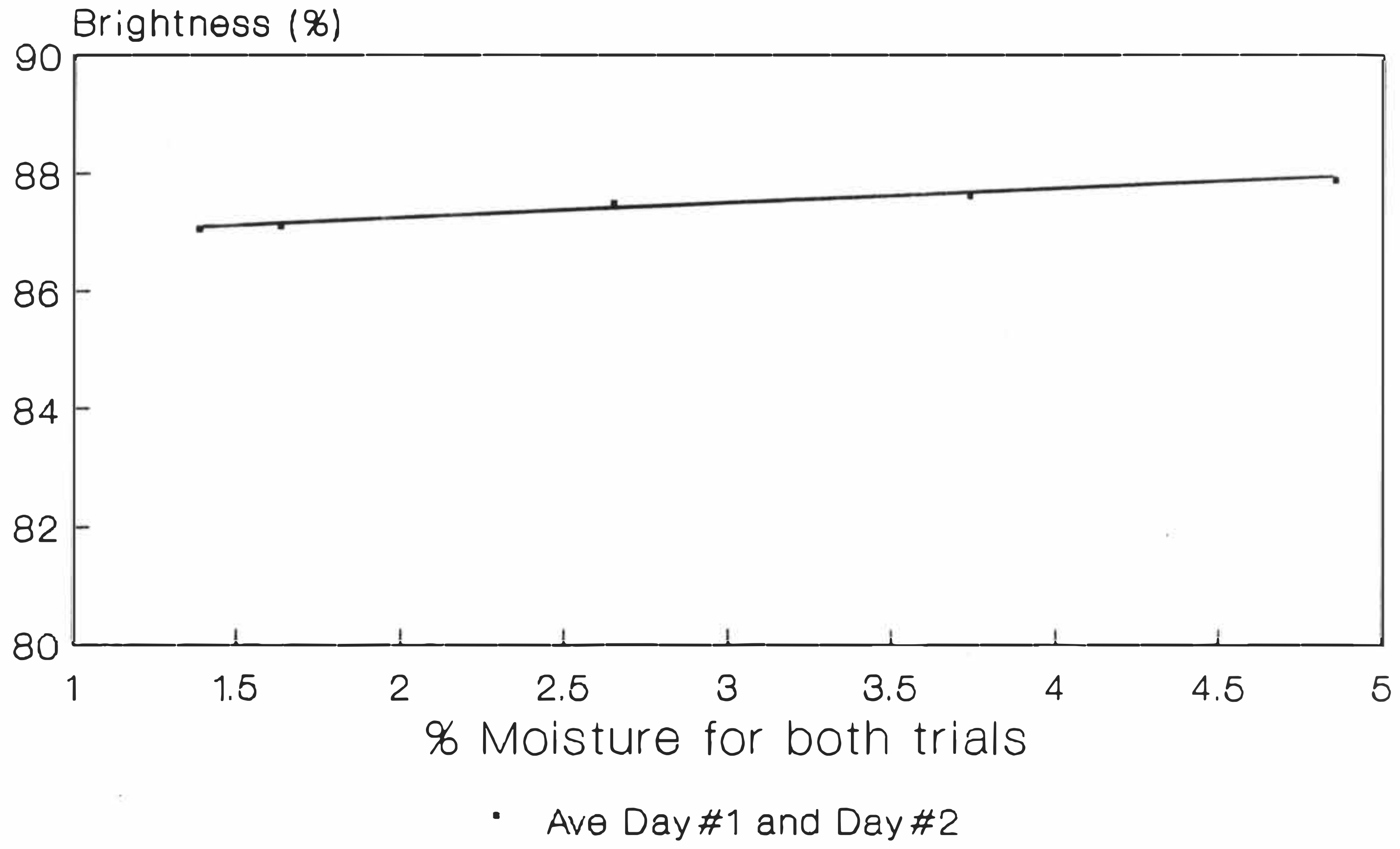
When evaluating the strength results, which are plotted as an average of both trials, it can be seen that a window effect is present, where at the high and low moisture ends the strength is reduced. This data, unlike the laboratory data, involves a much more specific range which could account for this effect not occurring in the laboratory results.

The burst results in Figure #12, show that the highest strength is at 3.74 % moisture, where an increase in moisture would cause a significant decrease in strength. Since all these pilot plant trial values have been corrected for basis weight, the only other variable which could have caused error, is the varying amounts of starch picked up by each set. In the literature sighted, it is known that starch adds strength to the sheet. Therefore, it is possible that these trends may be the direct result of increased starch content on the web's surface. In other sighted literature, it is stated that in theory this result is true, but in reality starch size will not add as significant an amount of strength as is depicted by these strength results.

% Brightness vs. % Moisture

Pilot Plant Trials #1 and #2

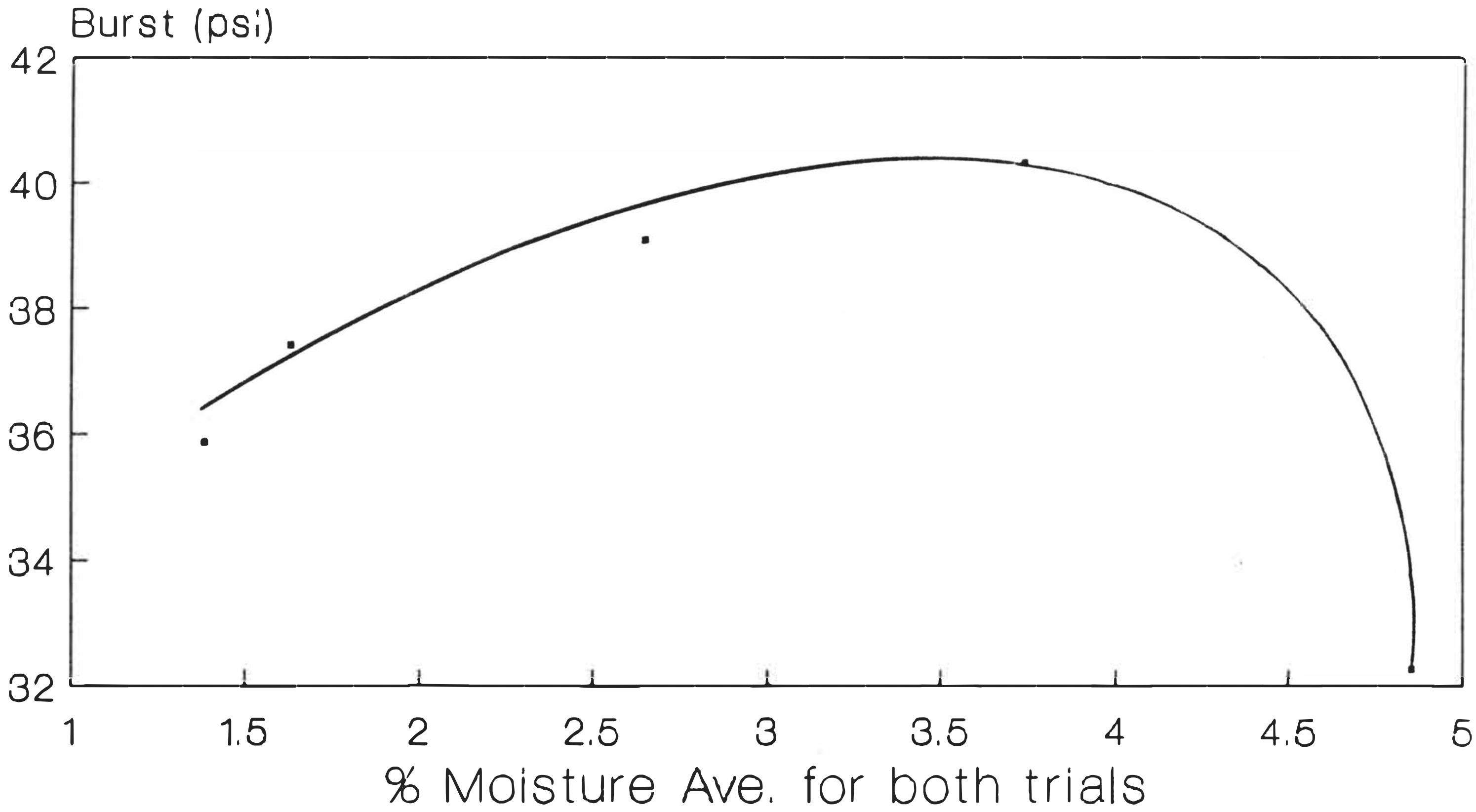
Figure #11



Burst vs. % Moisture

Pilot Plant Trials #1 and #2

Figure #12



The tearing results which can be seen in Figure #13, showed a definite window effect in the 2-4% moisture range, for both the MD and CD samples tested. The CD is obviously higher than the MD data, due to the CD samples being tested across the grain of the fibers which increases the resistance of the sample.

The MIT fold test data directly follows the burst data in that a window effect is present on both ends of the curve as can be seen in Figure #14. This suggests that an increase in moisture above a particular point causes fibers to become far enough apart that the fiber-to-fiber bonding is decreased. With a decrease in moisture, the fibers must become partially brittle which leads to a decrease in fold testing.

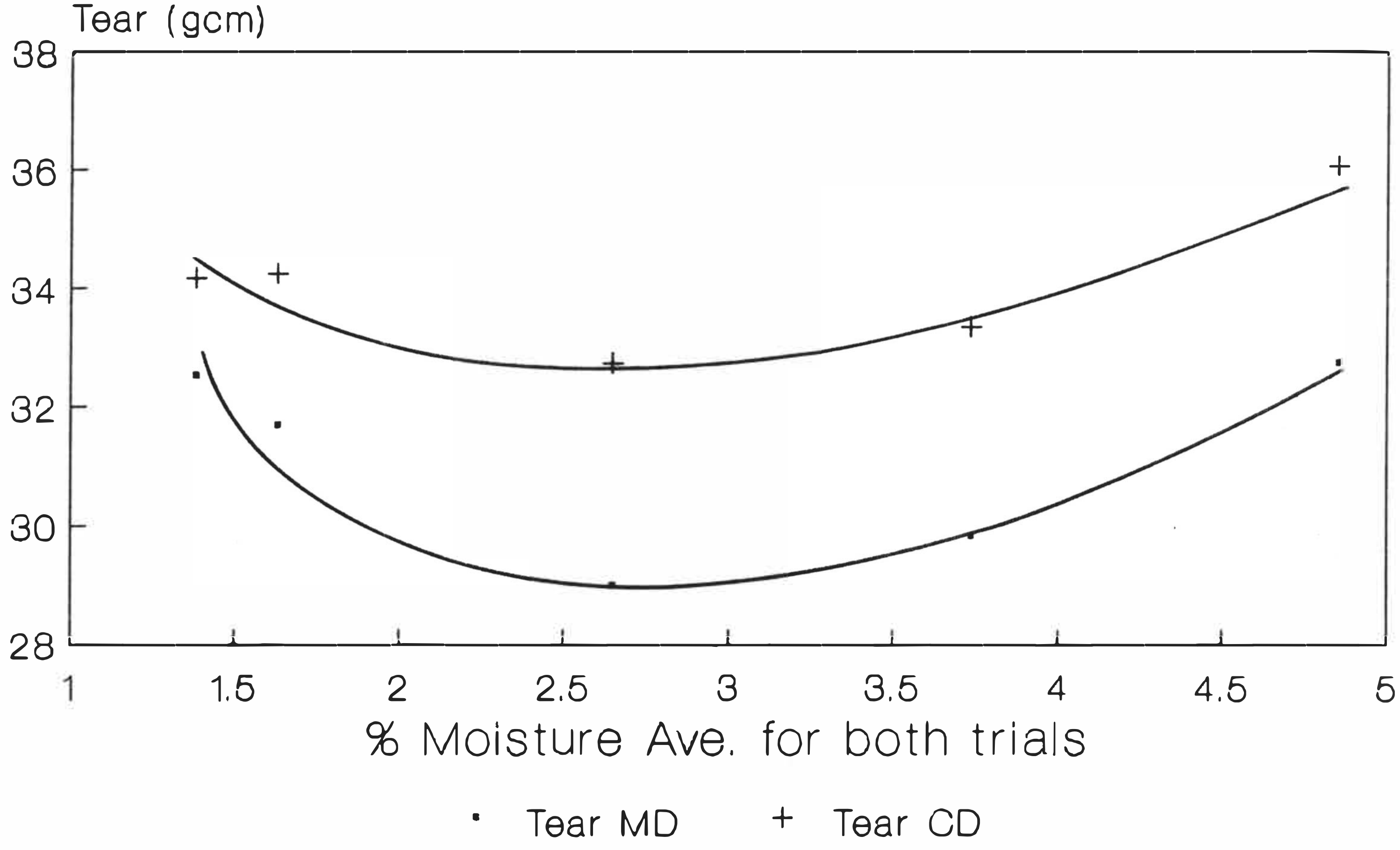
In order to understand the physical construction of the fibrous samples, caliper was run for all moisture variables and can be seen in Figure #15. The results showed that for all samples, the caliper was basically the same, therefore, this is not a factor causing deviations in the data.

The tensile and elongation data seen in Figures #16 and #17, show basically identical trends. The tensile data for MD is obviously higher then the CD data because the MD is in the direction of the fibers which can withstand much more tensile forces. The CD data is much lower because of the tensile forces which are directed across the grain of the web, causing less force to be withstood. The elongation data is opposite in that, the CD data is larger than the MD data. This is because the CD data has a much greater stretch potential.

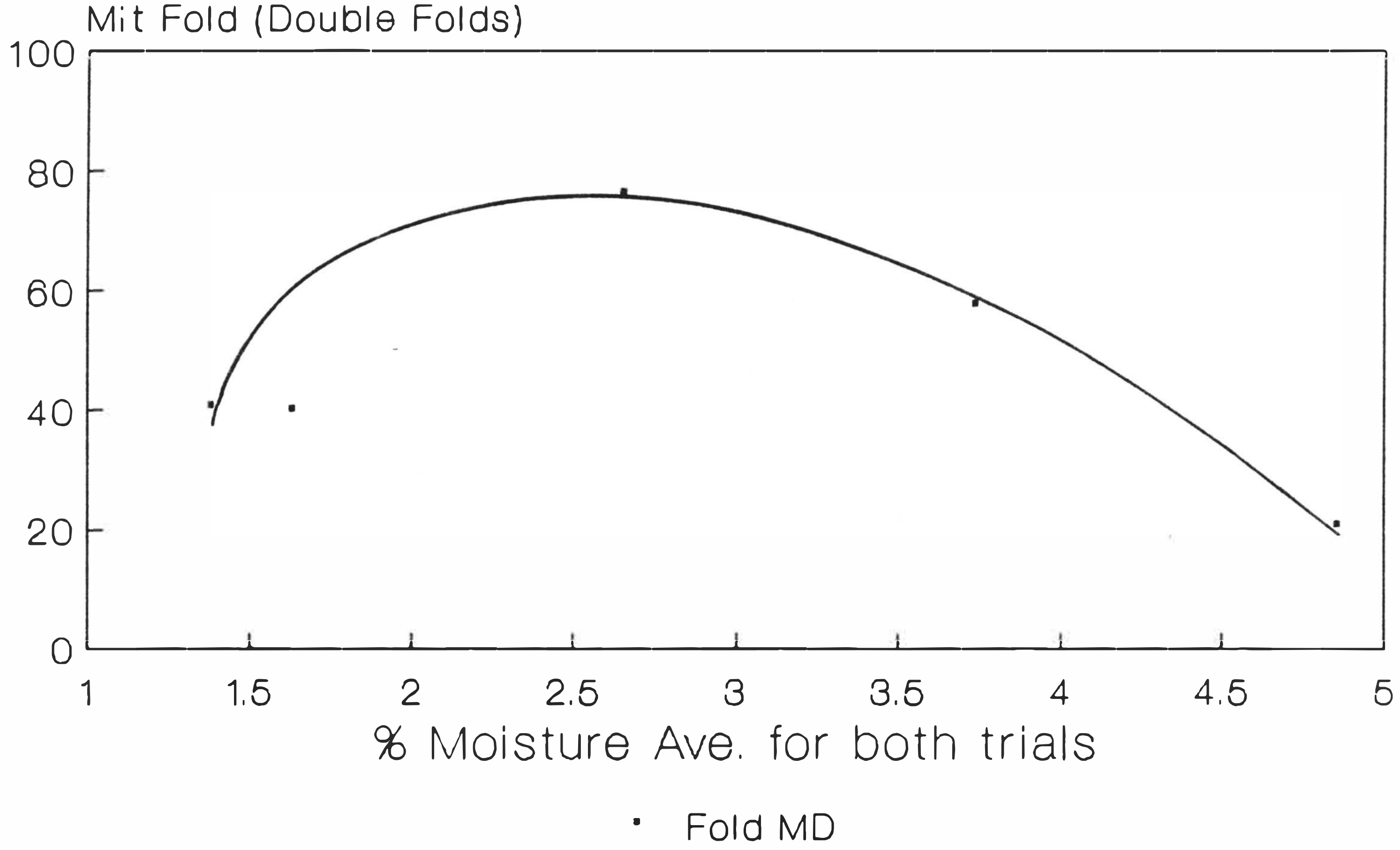
Tear vs. % Moisture

Pilot Plant Trials #1 and #2

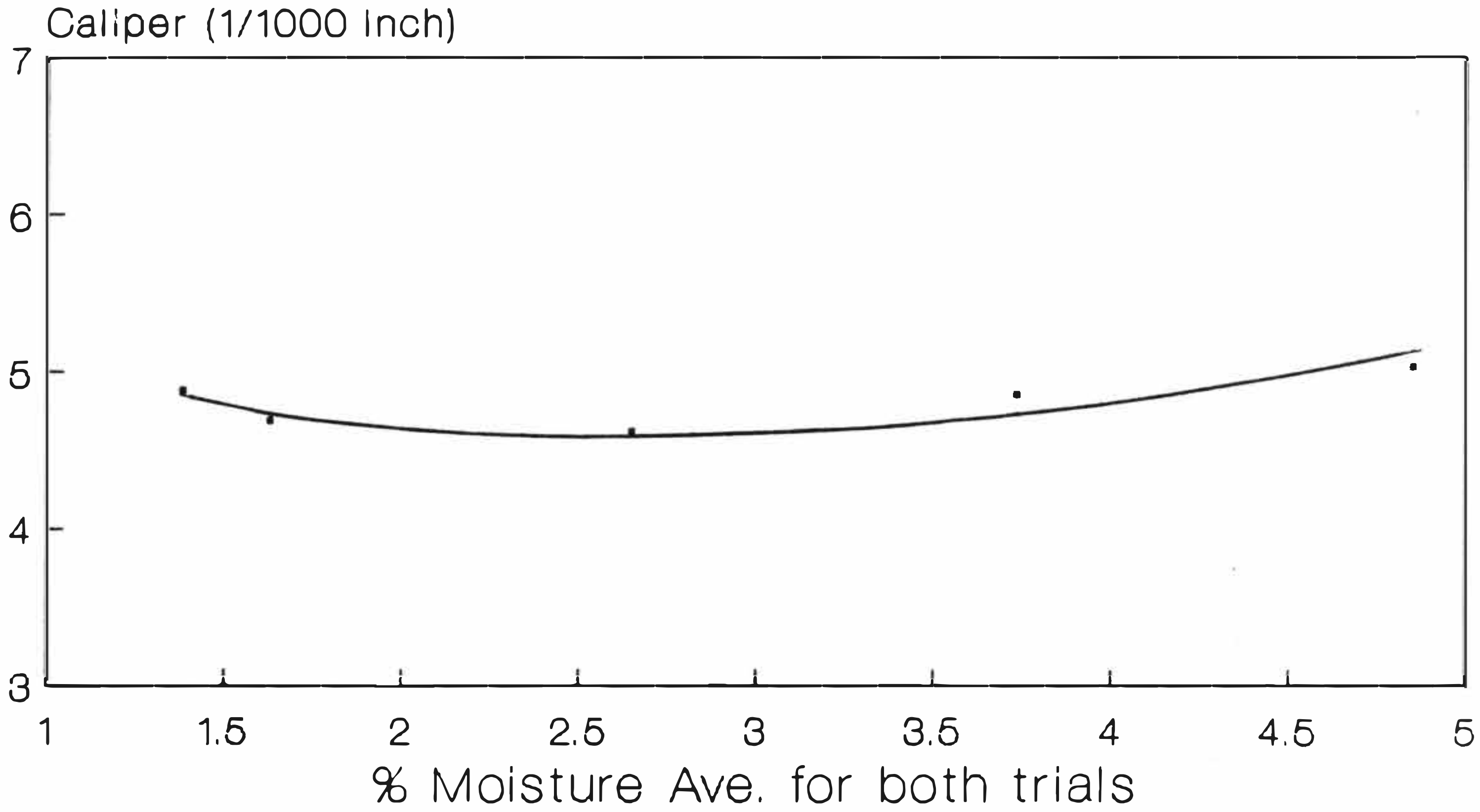
Figure #13



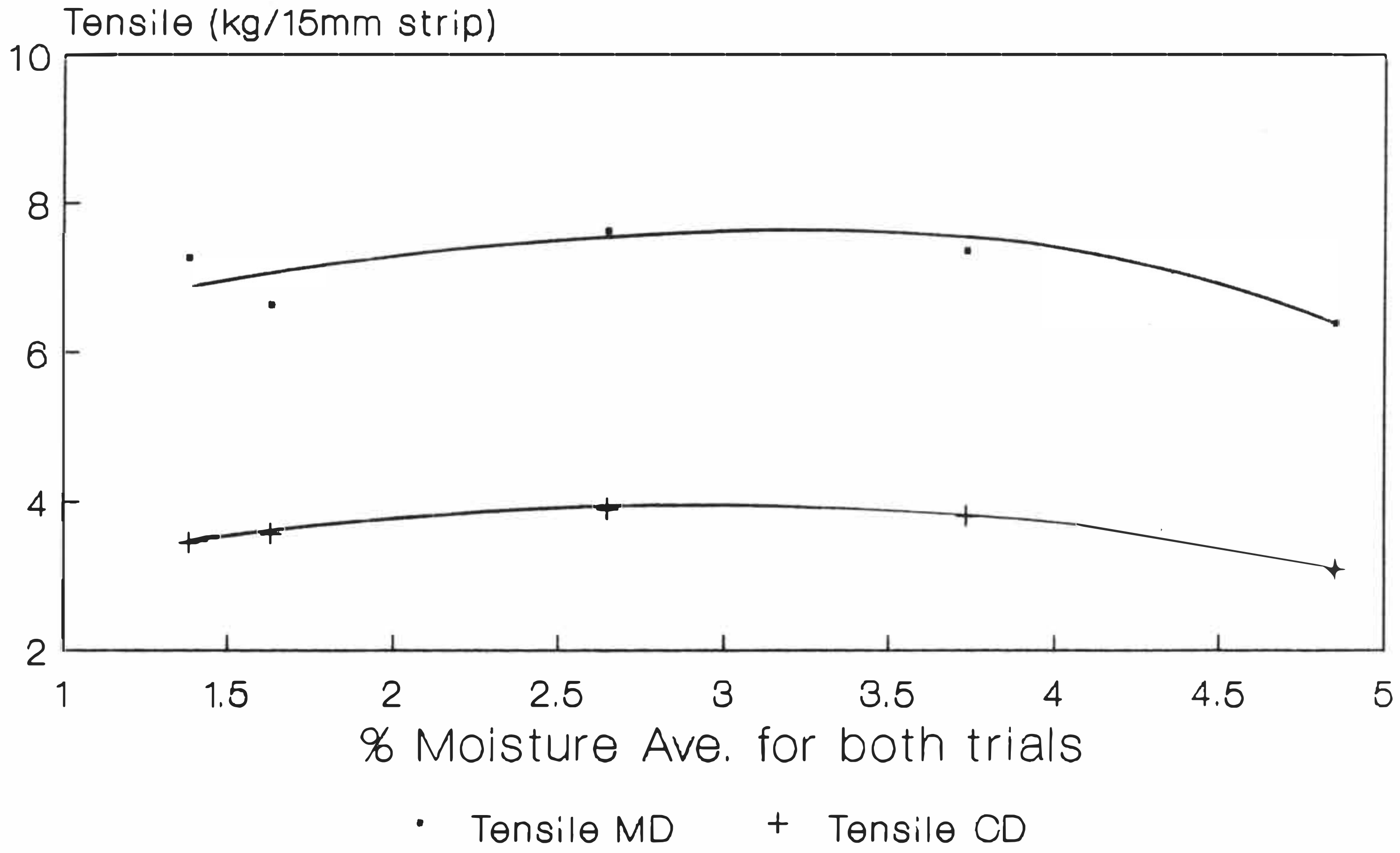
MIT Fold vs. % Moisture
Pilot Plant Trials #1 and #2
Figure #14



Caliper vs. % Moisture
Pilot Plant Trials #1 and #2
Figure #15



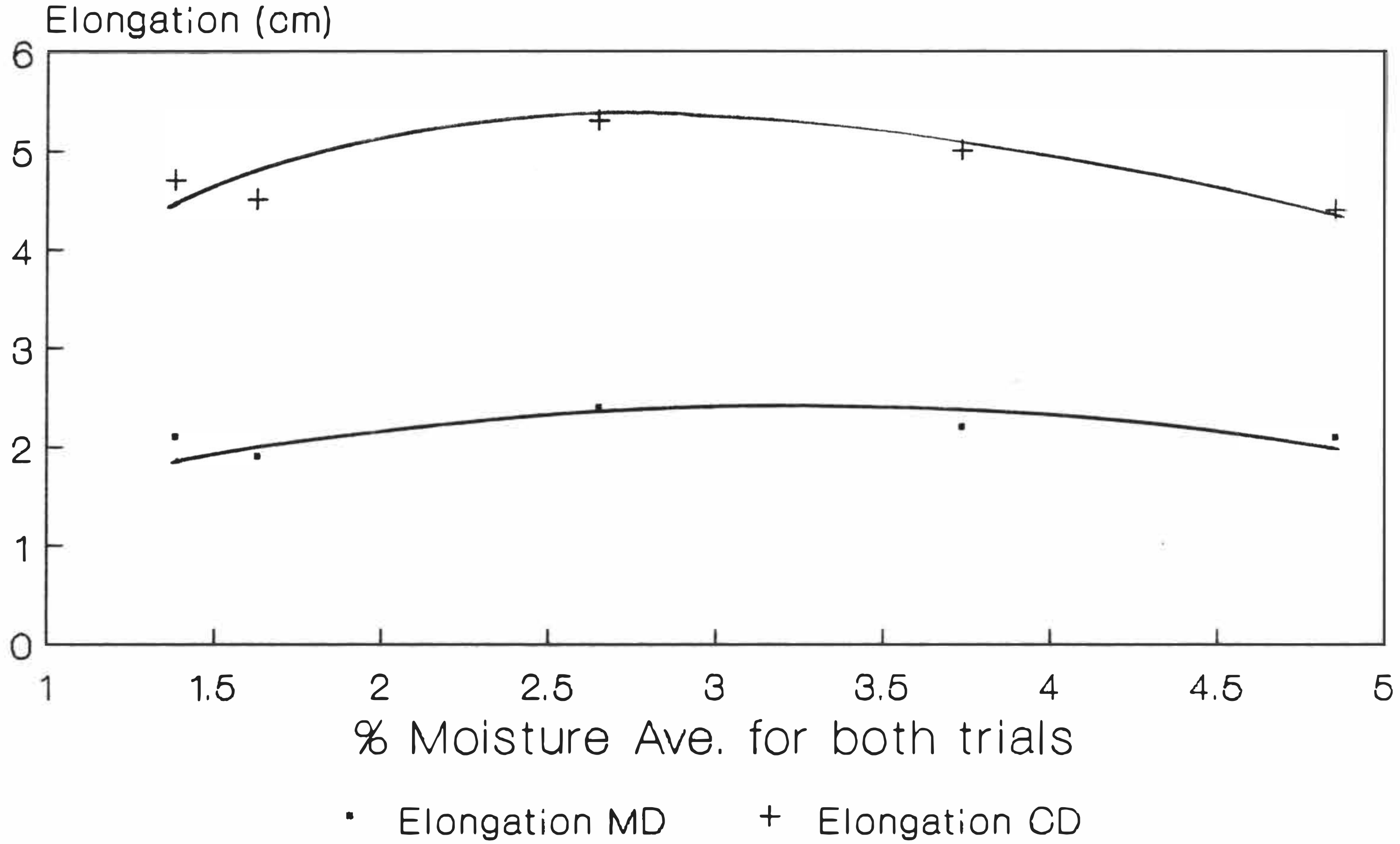
Tensile vs. % Moisture
Pilot Plant Trials #1 and #2
Figure #16



Elongation vs. % Moisture

Pilot Plant Trials #1 and #2

Figure #17



Economic Analysis:

In evaluating the financial benefits found from the implementation of an optimal steam specification, a mass and energy balance had to be undertaken. This balance was not a complete energy balance because the entering steam from the main headers did not come equipped with a volumetric gage, and therefore, the amount of steam supplied to the dryer cans could not be determined.

In order to compensate for this lack of information, knowing the basis weights, dryer can temperatures, web temperatures at the major points of the system, and information available from the steam tables (Latent heats of evaporation, and enthalpy values), the heat required to produce the web could be determined. The results as can be seen in Figure #18, show the actual energy costs in ($/year). This information is based on the fact that the only variable changed in this experiment was the incoming web moisture before the size press, and the after dryers were adjusted to arrive at a constant 5 percent moisture at the reel.

The results show an incremental savings at the higher moisture levels entering the size press. The actual dollars saved are perceived as being smaller than originally predicted. However, the magnitude of savings would be considerably increased taking into account an industrial paper machine running at much higher speeds and producing ten times the trim size.

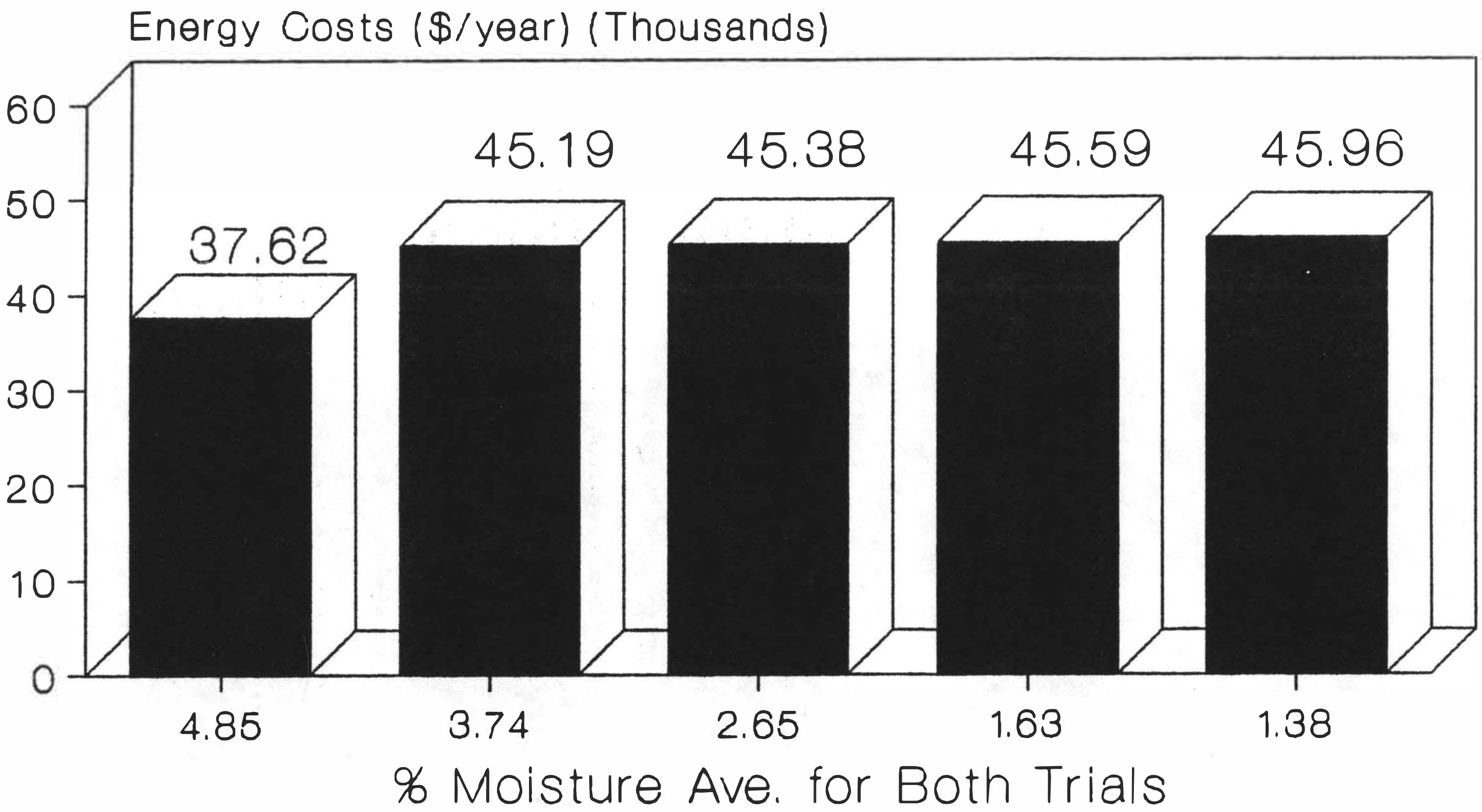
Starch Pickup at the Size Press:

By looking at Figure #19, it can be seen that the amount of

Energy Costs vs. % Moisture

Pilot Plant Trials #1 and #2

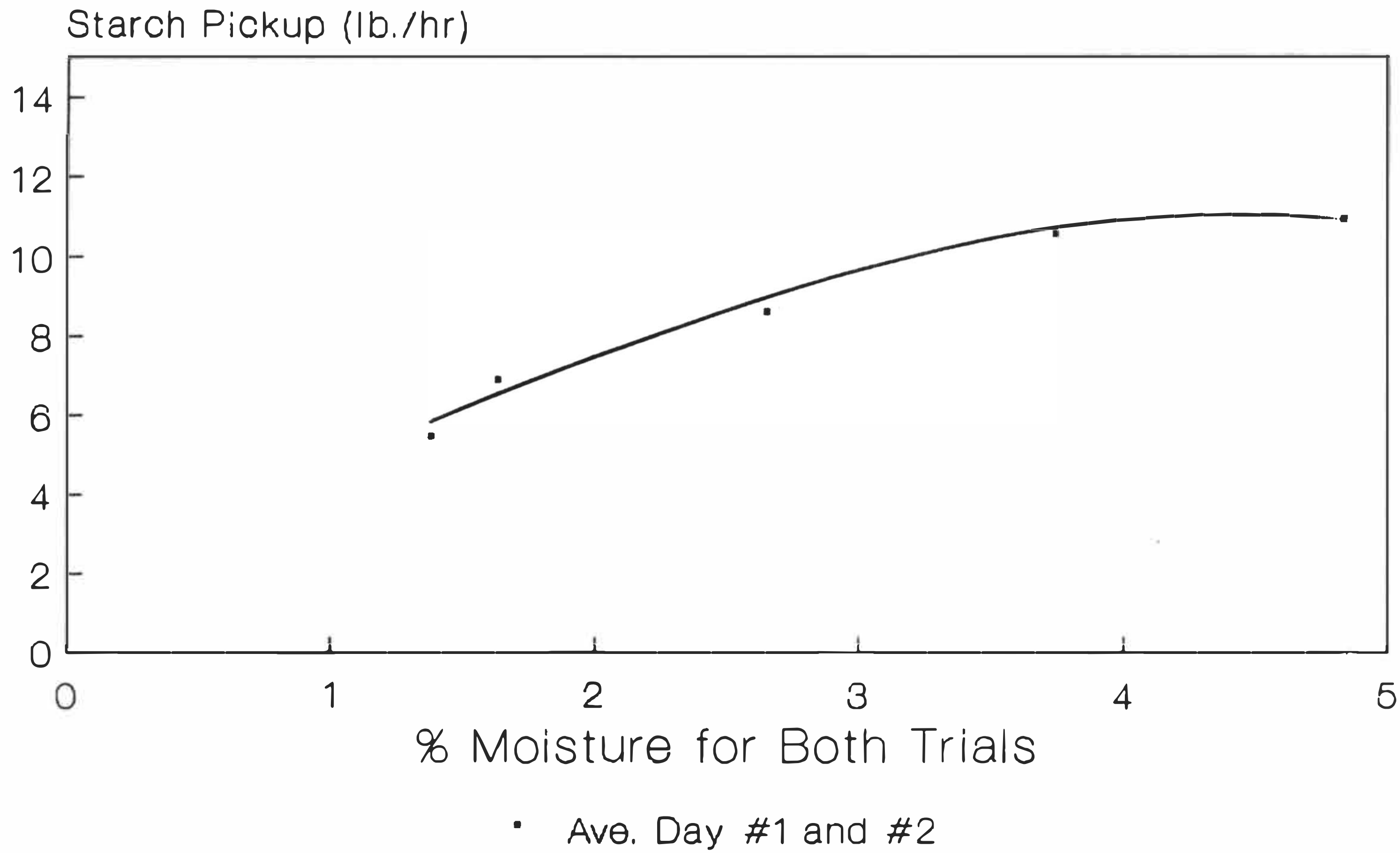
Figure #18



Starch Pickup vs. % Moisture

Pilot Plant Trials #1 and #2

Figure #19



starch pickup by weight increased with an increase in web moisture content entering the size press nip. The scenario which was stated in the literature was that a sponge will pick up more water when it is initially wetted, as opposed to when it is bone dry. Other literary information states that external starch sizing applied at the size press, significantly increases the strength parameters of the web. However, it has been shown in previous strength results that upon an increase in starch pickup, the strength continues to decrease at its upper end points.

RECOMMENDATIONS

Further investigation into the area of steam optimization in paper manufacturing, to arrive at a product with appreciable strength properties, should follow these parameters:

* Be able to utilize more instrumentation, including sensors as well as process control equipment to obtain more accurate data.

* Utilize a more precise method of moisture sampling, that will greatly reduce variability.

* Replace the starch size application with a constant temperature deionized water application, to reduce the chance of starch adding strength to the sheet, which is difficult to interpret.

* Determine a complete mass and energy balance, taking into account the actual volumetric steam flow rate and temperature of the incoming header steam supply. This would be possible by the installation of a flow and temperature sensor at the inlet header positions.

Finally, by being able to maintain an optimal web moisture at strategic points on the paper machine, a mill can benefit financially, as well as produce a product of greater quality for which the industry has come to demand.

CONCLUSION

In conclusion, one should keep in mind that, the paper industry is the third largest consumer of steam and, as a result, can benefit greatly from its optimization. This experimental project was designed to determine an optimum level of web moisture at a particular point in the paper making process. By understanding the parameters involved, not only the steam usage can be optimized, but also, the highest strength levels can be obtained.

This report has shown significant data to conclude that an optimal moisture level does exist before the size press, that a mill can put into production for each particular grade, and arrive at a superior product with optimum steam savings. It is in the paper industry's best interest to take into account all methods of energy savings to remain a leader in an ever competitive market.

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Appendix IA

Bag Verification Day #1 and Day #2

Bag Number	Indentification
1 - 10	6% - BSP(Before the Size Press)
11- 20	6% - ASP(After the Size Press)
21- 30	6% - Reel(At the Reel)
31- 40	4% - BSP
41- 50	4% - ASP
51- 60	4% - Reel
61- 70	2% - BSP
71- 80	2% - ASP
81- 90	2% - Reel
91- 100	Dry- BSP
101-110	Dry- ASP
111-120	Dry- Reel
121-130	6% - BSP
131-140	6% - Reel

Actual % variable identification (Before the Size Press)

Assumed Moisture (%)	Trial Day #1 (%)	Trial Day #2 (%)	Two Day Ave. (%)
Control	4.60	5.10	4.85
6.0	3.91	3.56	3.74
4.0	2.57	2.73	2.65
2.0	1.14	2.12	1.63
Bone Dry	0.94	1.82	1.38

Day #1 Appendix #1B (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
1	6.87	11.67	4.80		
2	6.87	11.57	4.70		
3	6.87	11.46	4.59		
4	6.93	12.71	5.78		
5	6.89	12.61	5.72		
6	6.86	13.29	6.43		
7	6.98	12.65	5.67		
8	6.93	11.57	4.64		
9	6.90	12.15	5.25		
10	6.96	10.57	3.61		
Avg.			51.19	49.19	3.91
11	6.88	18.30	11.42		
12	6.89	20.83	13.94		
13	6.88	19.49	12.61		
14	6.91	17.20	10.29		
15	6.93	16.65	9.72		
16	6.93	16.60	9.67		
17	6.89	18.68	11.79		
18	6.86	18.42	11.56		
19	6.82	17.44	10.62		
20	6.86	17.39	10.53		
Avg.			112.15	80.83	27.93
21	6.94	12.40	5.46		
22	6.93	13.38	6.45		
23	6.94	13.30	6.36		
24	6.88	13.89	7.01		
25	6.94	13.93	6.99		
26	6.93	10.87	3.94		
27	6.91	13.02	6.11		
28	6.95	12.14	5.19		
29	6.95	11.91	4.96		
30	6.86	11.69	4.83		
Avg.			57.30	54.84	4.29
31	6.87	11.52	4.65		
32	6.93	11.45	4.52		
33	6.91	11.52	4.61		
34	6.85	12.15	5.30		
35	6.92	11.98	5.06		
36	6.98	11.53	4.55		
37	6.93	12.29	5.36		
38	6.89	12.81	5.92		
39	6.91	12.53	5.62		
40	6.84	11.87	5.03		
Avg.			50.62	49.32	2.57
41	6.93	17.46	10.53		
42	6.94	17.08	10.14		
43	6.92	20.02	13.10		
44	6.95	17.27	10.32		

Note: All weights in Grams

Day #1 Appendix #2 (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
45	6.97	16.70	9.73		
46	6.89	17.91	11.02		
47	6.92	17.57	10.65		
48	6.95	16.49	9.54		
49	6.91	18.07	11.16		
50	6.95	15.74	8.79		
Avg.			104.98	77.38	26.29
51	6.87	13.05	6.18		
52	6.89	11.03	4.14		
53	7.01	13.33	6.32		
54	6.97	13.53	6.56		
55	6.93	12.31	5.38		
56	6.93	11.84	4.91		
57	6.89	12.60	5.71		
58	6.91	12.54	5.63		
59	6.95	11.64	4.69		
60	6.86	12.63	5.77		
Avg.			55.29	51.61	6.66
91	6.96	11.54	4.58		
92	6.99	13.07	6.08		
93	6.92	11.80	4.88		
94	6.93	11.64	4.71		
95	6.93	12.19	5.26		
96	6.88	11.44	4.56		
97	6.88	11.83	4.95		
98	6.96	9.00	2.04		
99	6.93	13.04	6.11		
100	6.90	13.00	6.10		
Avg.			49.27	48.71	1.14
71	6.92	13.63	6.71		
72	6.95	14.93	7.98		
73	6.96	15.98	9.02		
74	6.99	17.35	10.36		
75	6.96	14.97	8.01		
76	6.95	18.74	11.79		
77	6.96	15.09	8.13		
78	6.98	14.21	7.23		
79	6.93	16.07	9.14		
80	6.89	15.62	8.73		
Avg.			87.10	65.12	25.24
81	6.95	11.01	4.06		
82	6.88	10.57	3.69		
83	6.87	11.07	4.20		
84	6.90	10.88	3.98		
85	6.99	11.66	4.67		
86	6.91	11.17	4.26		
87	6.88	11.26	4.38		
88	6.84	11.72	4.88		
89	6.92	11.24	4.32		

Day #1 Appendix #3 (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
90	6.88	12.34	5.46		
Avg.			43.90	41.81	4.76
61	6.91	12.67	5.76		
62	6.92	11.95	5.03		
63	6.92	12.18	5.26		
64	6.93	11.85	4.92		
65	6.90	13.62	6.72		
66	6.96	11.30	4.34		
67	7.05	11.33	4.28		
68	6.93	10.77	3.84		
69	6.95	14.21	7.26		
70	6.95	11.74	4.79		
Avg.			52.20	51.71	0.94
101	6.84	17.56	10.72		
102	6.92	19.87	12.95		
103	6.95	18.15	11.20		
104	6.97	16.32	9.35		
105	6.86	15.40	8.54		
106	6.87	18.30	11.43		
107	6.88	18.80	11.92		
108	6.89	16.60	9.71		
109	6.91	18.77	11.86		
110	6.91	14.15	7.24		
Avg.			104.92	79.96	23.79
111	7.02	12.75	5.73		
112	6.91	10.96	4.05		
113	6.91	13.50	6.59		
114	6.97	9.42	2.45		
115	6.91	11.76	4.85		
116	7.02	12.53	5.51		
117	6.96	12.58	5.62		
118	6.90	12.69	5.79		
119	6.93	11.26	4.33		
120	6.93	12.23	5.30		
			50.22	47.83	4.76
121	7.04	13.73	6.69		
122	6.74	14.29	7.55		
123	6.81	12.73	5.92		
124	6.80	12.16	5.36		
125	6.78	11.68	4.90		
126	6.73	11.89	5.16		
127	6.73	13.10	6.37		
128	6.79	11.81	5.02		
129	6.80	12.03	5.23		
130	6.84	12.93	6.09		
Avg.			58.29	55.61	4.60
131	6.79	13.15	6.36		
132	6.80	13.44	6.64		

Day #1 Appendix #4 (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
133	6.79	14.52	7.73		
134	6.84	13.98	7.14		
135	6.79	12.01	5.22		
136	6.85	11.76	4.91		
137	6.84	12.92	6.08		
138	6.80	12.25	5.45		
139	6.80	12.61	5.81		
140	6.83	13.58	6.75		
Avg.			62.09	59.48	4.20

Day #2 Appendix #5 (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
1	6.87	11.16	4.29		
2	6.87	11.14	4.27		
3	6.87	12.16	5.29		
4	6.93	12.52	5.59		
5	6.89	12.28	5.39		
6	6.86	11.70	4.84		
7	6.98	12.35	5.37		
8	6.93	12.36	5.43		
9	6.90	12.37	5.47		
10	6.96	12.08	5.12		
Avg.			51.06	49.24	3.56
11	6.88	22.67	15.79		
12	6.89	16.76	9.87		
13	6.88	16.14	9.26		
14	6.91	16.93	10.02		
15	6.93	17.26	10.33		
16	6.93	19.22	12.29		
17	6.89	17.10	10.21		
18	6.86	18.96	12.10		
19	6.82	16.36	9.54		
20	6.86	18.36	11.50		
Avg.			110.91	79.28	28.52
21	6.94	11.43	4.49		
22	6.93	11.99	5.06		
23	6.94	13.47	6.53		
24	6.88	12.37	5.49		
25	6.94	11.61	4.67		
26	6.93	12.37	5.44		
27	6.91	12.86	5.95		
28	6.95	11.72	4.77		
29	6.95	12.52	5.57		
30	6.86	12.85	5.99		
Avg.			53.96	52.20	3.26
31	6.96	12.36	5.40		
32	6.99	11.35	4.36		
33	6.92	11.75	4.83		
34	6.93	12.90	5.97		
35	6.93	11.32	4.39		
36	6.88	11.26	4.38		
37	6.88	10.29	3.41		
38	6.96	12.13	5.17		
39	6.93	11.10	4.17		
40	6.90	12.18	5.28		
Avg.			47.36	46.07	2.73
41	6.93	17.25	10.32		
42	6.94	18.66	11.72		
43	6.92	16.52	9.60		
44	6.95	15.16	8.21		

Note: All Weights in Grams

Day #2 Appendix #6 (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
45	6.97	17.48	10.51		
46	6.89	18.91	12.02		
47	6.92	19.11	12.19		
48	6.95	18.12	11.17		
49	6.91	18.05	11.14		
50	6.95	16.87	9.92		
Avg.			106.80	79.26	25.79
51	6.87	11.16	4.29		
52	6.89	12.47	5.58		
53	7.01	13.09	6.08		
54	6.97	12.20	5.23		
55	6.93	12.49	5.56		
56	6.93	12.26	5.33		
57	6.89	12.17	5.28		
58	6.91	11.81	4.90		
59	6.95	11.55	4.60		
60	6.86	13.35	6.49		
Avg.			53.34	51.21	3.99
61	6.91	11.69	4.78		
62	6.92	12.31	5.39		
63	6.92	11.87	4.95		
64	6.93	12.51	5.58		
65	6.90	12.75	5.85		
66	6.96	11.30	4.34		
67	7.05	12.09	5.04		
68	6.93	12.93	6.00		
69	6.95	10.32	3.37		
70	6.95	11.54	4.59		
Avg.			49.89	48.83	2.12
71	6.92	15.50	8.58		
72	6.95	16.77	9.82		
73	6.96	15.98	9.02		
74	6.99	15.84	8.85		
75	6.96	18.65	11.69		
76	6.95	19.10	12.15		
77	6.96	16.06	9.10		
78	6.98	16.93	9.95		
79	6.93	17.00	10.07		
80	6.89	17.54	10.65		
Avg.			99.88	74.86	25.05
81	6.95	12.33	5.38		
82	6.88	11.22	4.34		
83	6.87	11.56	4.69		
84	6.90	11.70	4.80		
85	6.99	11.82	4.83		
86	6.91	12.05	5.14		
87	6.88	12.19	5.31		
88	6.84	12.00	5.16		

Day #2 Appendix #7 (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
89	6.92	12.04	5.12		
90	6.88	12.31	5.43		
Avg.			50.20	48.27	3.84
91	6.87	11.85	4.98		
92	6.93	13.11	6.18		
93	6.91	13.12	6.21		
94	6.85	12.34	5.49		
95	6.92	12.74	5.82		
96	6.98	12.39	5.41		
97	6.93	12.71	5.78		
98	6.89	14.77	7.88		
99	6.91	13.32	6.41		
100	6.84	12.43	5.59		
Avg.			59.75	58.66	1.82
101	6.84	15.59	8.75		
102	6.92	18.36	11.44		
103	6.95	15.97	9.02		
104	6.97	16.27	9.30		
105	6.86	16.91	10.05		
106	6.87	15.61	8.74		
107	6.88	16.87	9.99		
108	6.89	14.76	7.87		
109	6.91	17.29	10.38		
110	6.91	18.63	11.72		
Avg.			97.26	72.76	25.19
111	7.02	11.83	4.81		
112	6.91	11.98	5.07		
113	6.91	11.38	4.47		
114	6.97	12.35	5.38		
115	6.91	11.93	5.02		
116	7.02	11.48	4.46		
117	6.96	12.36	5.40		
118	6.90	12.08	5.18		
119	6.93	11.28	4.35		
120	6.93	11.13	4.20		
Avg.			48.34	46.10	4.63
121	7.04	12.49	5.45		
122	6.74	11.09	4.35		
123	6.81	11.38	4.57		
124	6.80	12.37	5.57		
125	6.78	12.30	5.52		
126	6.73	10.78	4.05		
127	6.73	11.44	4.71		
128	6.79	12.14	5.35		
129	6.80	12.00	5.20		
130	6.84	10.56	3.72		
Avg.			48.49	46.02	5.10

Day #2 Appendix #8 (Moisture)

Bag #	Bag Wt.	Bag & Wet Wt.	Sample Wet Wt.	Dry Wt.	% Moisture
131	6.79	11.34	4.55		
132	6.80	11.54	4.74		
133	6.79	11.75	4.96		
134	6.84	11.78	4.94		
135	6.79	11.24	4.45		
136	6.85	11.54	4.69		
137	6.84	11.88	5.04		
138	6.80	12.18	5.38		
139	6.80	11.49	4.69		
140	6.83	11.53	4.70		
Avg.			48.14	46.01	4.42

Appendix #9(Laboratory Data)

% Moisture after Dryer	% Moisture Before Test	Burst (psi)	Brightness (%)	Tear (gcm)	Tensile (kg/15mm)
12.00	5.46	43.0	72.4	51	58
9.05	7.21	41.3	72.7	47	60
3.18	8.23	37.9	74.0	45	61
0.00	5.70	35.9	75.0	43	63

Elongation (cm)	TEA (J/m^2)	Fold Test (# Folds)	Sheet Weight (grams)	Area (inches^	Basis Weight (lbs./ream)
3.2	66.7	48	3.240	64.0	48.21
2.7	57.6	41	3.262	64.0	48.54
2.7	57.1	36	3.242	64.0	48.24
2.7	60.4	30	3.135	64.0	46.65

Appendix #10 (Dryer Can Temperatures)

Day #1 Dryer Number		Control (F)	6% (F)	4% (F)	2% (F)	BD (F)
Main Section Dryers	1	164	145	163	126	254
		172	152	163	127	261
		184	166	163	142	260
	2	207	210	221	255	270
		208	211	221	262	268
		210	213	221	262	266
	3	206	214	232	263	271
		203	215	232	265	268
		206	217	232	266	265
	4	210	205	222	237	270
		212	211	222	245	261
		210	209	222	250	260
	5	213	213	229	267	279
		212	216	229	265	279
		216	218	229	267	278
	6	213	214	226	268	279
		214	215	226	272	280
		213	216	226	273	278
	7	207	217	237	272	280
		206	218	237	275	281
		211	221	237	275	280
	8	213	214	233	273	275
		216	218	233	274	280
		215	221	233	274	278
	Avg.	206	207	220	248	272

After Dryer Section	1	108	183	179	163	163
		108	186	179	165	160
		106	190	179	168	159
	2	133	207	204	203	206
		130	208	204	204	205
		126	210	204	205	202
	3	133	203	200	197	203
		133	204	200	200	200
		134	208	200	201	204
	4	107	210	205	208	208
		107	211	205	208	203
		105	211	205	208	207
	5	110	153	145	153	150
		109	148	145	155	151
		108	137	145	152	154
	Avg.	117	191	187	186	185

Appendix #11(Dryer Can Temperatures)

Day #2

	Dryer Number	Control (F)	6% (F)	4% (F)	2% (F)	BD (F)
Main Section Dryers	1	197	195	208	239	254
		195	194	218	240	260
		193	193	221	239	257
	2	220	214	233	242	270
		215	215	235	250	269
		215	215	234	248	268
	3	217	211	225	240	266
		211	212	224	241	263
		212	214	227	239	262
	4	212	209	233	251	265
		216	209	235	250	267
		213	207	236	251	267
	5	215	213	236	248	275
		214	214	232	250	272
		213	215	236	252	273
	6	220	210	236	254	271
		218	215	237	256	276
		217	215	238	257	278
	7	218	214	240	257	278
		220	216	234	260	278
		218	211	239	261	278
	8	219	211	239	256	274
		220	216	242	258	279
		219	218	243	257	279
	Avg.	214	211	233	250	270
After Dryer Section	1	119	112	115	116	116
		118	113	116	117	117
		119	114	117	116	116
	2	132	216	209	195	201
		128	217	209	199	204
		129	220	209	203	206
	3	127	224	209	207	209
		127	219	214	209	207
		128	220	212	209	208
	4	164	214	205	203	200
		165	216	208	202	202
		165	220	210	202	202
	5	132	156	157	147	152
		132	166	161	156	157
		132	163	157	153	154
	Avg.	134	186	181	176	177

Appendix #12(Basis Wt., Steam Usage)

Day #1

Dryer Number	Control	6%	4%	2%	BD
Reel BW	47.10	52.10	53.90	51.30	52.20
	49.50	50.60	52.10	51.30	51.90
	49.50	50.70	52.50	51.30	52.20
Avg.	48.70	51.13	52.83	51.30	52.10
Size Section	2.51	1.67	0.92	1.12	1.42
	2.47	1.79	0.91	1.12	1.42
	2.46	1.83	0.97	1.12	1.42
Avg.	2.48	1.76	0.93	1.12	1.42
Main Section	9.5	10.2	16.5	37.4	41.2
	9.5	10.2	16.7	37.4	41.2
	9.5	10.1	16.6	37.4	41.2
Avg.	9.5	10.1	16.6	37.4	41.2

Day #2

Dryer Number	Control	6%	4%	2%	BD
Reel BW	51.40	51.40	52.40	53.10	50.60
	51.50	51.70	52.10	52.20	49.20
	51.40	49.40	52.10	52.70	49.10
Avg.	51.43	50.83	52.20	52.67	49.63
Size Section	2.78	5.13	2.31	1.78	1.86
	2.76	5.71	3.08	1.84	1.86
	2.77	5.55	2.85	1.82	1.81
Avg.	2.77	5.46	2.75	1.81	1.84
Main Section	10.8	10.0	17.4	27.6	40.2
	10.8	9.9	18.5	27.6	41.3
	10.8	9.9	18.4	27.7	40.5
Avg.	10.8	9.9	18.1	27.6	40.7

Note: Basis Wt. expressed in #/24 X 36 X 500

Pressure expressed in $\#/in^2$

Appendix #13 (Caliper)

Caliper Day #1	Control	6%	4%	2%	BD
	4.4	4.9	4.7	4.5	4.7
	4.2	5.0	4.8	4.5	4.7
	4.0	4.9	4.8	4.5	4.7
	4.1	4.8	4.8	4.6	4.6
	4.2	4.9	4.7	4.7	4.6
	4.3	5.0	4.7	4.6	4.7
	4.4	4.9	4.9	4.6	4.5
	4.4	4.9	4.8	4.6	4.5
	4.4	5.0	4.7	4.5	4.6
	4.2	5.0	4.8	4.5	4.5
Avg.	4.3	4.9	4.8	4.6	4.6
Std*2	0.3	0.1	0.1	0.1	0.2
Corr. Ave./Bw	5.0	4.7	4.7	4.6	4.9

Day #2	Control	6%	4%	2%	BD
Dryer Number	4.7	4.8	5.0	5.0	4.5
	4.7	4.8	5.0	4.9	4.5
	4.7	4.7	4.7	4.9	4.6
	4.7	4.7	4.8	4.8	4.8
	4.7	4.8	5.0	4.7	4.8
	4.8	4.7	5.1	4.8	4.9
	4.7	4.8	4.9	4.8	4.8
	4.8	4.8	5.0	4.8	4.7
	4.8	4.7	4.8	5.0	4.8
	4.8	4.6	4.7	4.8	4.9
Avg.	4.7	4.7	4.9	4.9	4.7
Std*2	0.1	0.1	0.3	0.2	0.3
Corr. Ave./Bw	5.0	5.0	4.6	4.8	4.9
Total Corr Ave.	5.0	4.9	4.6	4.7	4.9

Note: Caliper Readings expressed as 1/1000 inch

Appendix #14 (Moisture/Basis Wt. Ave.)

Trial Day#1	Control	6%	4%	2%	Dry
Moisture BSP	4.60	3.91	2.57	1.14	0.94
Moisture ASP	–	27.93	26.29	25.24	23.79
Moisture Reel	4.20	4.29	6.66	4.76	4.76

Trial Day#2	Control	6%	4%	2%	Dry
Moisture BSP	5.10	3.56	2.73	2.12	1.82
Moisture ASP	–	28.52	25.79	25.05	25.19
Moisture Reel	4.42	3.26	3.99	3.84	4.63

Total Set Ave.	Control	6%	4%	2%	Dry
Moisture BSP	4.85	3.74	2.65	1.63	1.38
Moisture ASP	–	28.23	26.04	25.15	24.49
Moisture Reel	4.31	3.78	5.33	4.30	4.70

Basis weight Trial Day#1	Control	6%	4%	2%	Dry
Set Wt.	118.67	145.71	143.40	139.16	132.35
Area	267.0	267.0	267.0	267.0	267.0
Basis Wt. (lbs/ream)	42.33	51.97	51.15	49.64	47.21

Basis weight Trial Day#2	Control	6%	4%	2%	Dry
Set Wt.	133.08	132.23	148.36	140.57	135.25
Area	269.5	264.0	264.0	264.0	265.5
Basis Wt. (lbs/ream)	47.03	47.70	53.52	50.71	48.52

Total Set Ave.	Control	6%	4%	2%	Dry
Basis Wt. (lbs/ream)	44.68	49.84	52.34	50.17	47.86

Note: Basis Weight Ream Size (24 X 36 X 500)

Appendix #15 (% Brightness)

Brightness Trial Day#1	Control	6%	4%	2%	Dry
	88.1	88.0	87.8	87.0	87.1
	88.2	87.8	87.2	87.1	87.1
	88.4	88.0	87.6	87.0	87.4
	88.0	87.8	87.8	86.8	87.1
	88.2	87.9	87.2	86.8	87.1
	88.7	87.7	87.4	86.7	87.2
	88.3	88.0	87.8	87.2	87.3
	88.0	87.6	88.0	87.0	87.5
	88.7	87.7	87.9	86.2	87.2
	88.2	87.8	87.5	87.3	87.3
Avg.	88.3	87.8	87.6	86.9	87.2
STD*2	0.5	0.3	0.5	0.6	0.3
Total Set Ave.	87.9	87.6	87.5	87.1	87.1

Brightness Trial Day#2	Control	6%	4%	2%	Dry
	87.4	87.5	87.7	87.1	87.2
	87.6	87.5	87.6	87.1	87.2
	87.3	87.0	87.2	87.4	87.5
	86.9	87.7	87.5	87.4	86.7
	87.2	87.5	87.1	87.4	86.7
	88.2	87.3	87.4	87.1	86.7
	87.5	87.4	87.1	87.4	86.8
	87.2	87.2	87.3	87.5	86.7
	87.8	87.5	87.2	87.6	86.7
	87.7	87.4	87.2	87.1	86.6
Avg.	87.5	87.4	87.3	87.3	86.9
STD*2	0.7	0.4	0.4	0.4	0.6

Appendix #16 (Burst)

Burst Trial Day#1	Control	6%	4%	2%	Dry
	24.0	39.5	47.0	38.0	42.5
	21.0	44.5	45.0	43.0	39.0
	20.0	46.0	45.0	39.5	42.5
	23.5	42.0	42.0	42.0	39.5
	19.5	41.5	43.0	40.5	38.0
	20.0	42.0	36.0	40.0	37.0
	22.0	46.5	41.5	40.0	36.0
	23.0	44.0	45.0	39.5	36.0
	21.5	44.0	47.5		35.5
	20.5				37.0
Avg.	21.5	43.3	43.6	40.3	38.3
Std*2	3.0	4.3	6.6	2.9	4.9
Corr. Ave/BW	25.4	41.7	42.6	40.6	40.6
Burst Trial Day#2	Control	6%	4%	2%	Dry
	42.0	37.0	38.0	32.0	32.0
	35.0	39.0	38.5	35.0	30.0
	36.0	32.5	42.0	31.0	27.0
	39.0	39.5	39.0	38.0	32.0
	32.0	37.0	36.5	39.0	28.0
	32.0	41.0	38.5	34.0	31.5
	43.5	39.5	36.0	38.0	29.0
	36.5	30.0	39.5	36.0	34.0
	35.0	37.0	35.0	32.0	29.0
	37.0	39.5		32.0	30.0
Avg.	36.8	37.2	38.1	34.7	30.3
Std*2	7.2	6.6	3.9	5.6	4.0
Corr. Ave/BW	39.1	38.9	35.6	34.2	31.2

Note: Burst expressed in psi.

Appendix #17 (Tear Test)

Tear Test Trial Day#1 (5 samples per set) MD samples	Control	6%	4%	2%	Dry
	30	29	29	29	29
	29	33	30	29	30
	29	30	30	31	28
	30	32	30	32	28
	30	30	28	29	27
	31	34	30	28	28
	28	31	28	29	30
	28	29	28	29	31
	27	31	30	29	29
		31	28	30	28
Avg.	29	31	29	29	29
Std*2	2.4	3.1	1.9	2.2	2.3
Corr. Ave/BW	34	30	29	30	31

Tear Test Trial Day#2 (5 samples per set) MD samples	Control	6%	4%	2%	Dry
	30	28	32	32	34
	30	28	31	34	33
	29	28	31	35	35
	30	28	33	34	32
	28	28	32	36	32
	28	28	32	33	34
	30	30	31	34	34
	28	30	30	34	32
	31	28	32	36	35
	29	29	31	34	
Avg.	29	29	32	34	33
Std*2	2.0	1.6	1.6	2.3	2.3
Corr. Ave/BW	31	30	29	34	34
Total Corr Ave.	33	30	29	32	33

Note: Tear Readings expressed in (gcm)

Appendix #18 (Tear Test)

Tear Test (5 samples per set) CD samples					
Trial Day#1	Control	6%	4%	2%	Dry
	32	33	34	35	33
	30	34	33	33	31
	36	32	32	33	30
	33	36	38	34	29
	32	38	39	35	32
	31	39	39	34	31
	33	39	32	34	30
	35	32	31	35	31
	35	31	31	34	30
	35	31	36		29
Avg.	33	35	35	34	31
Std*2	3.8	6.1	6.1	1.5	2.4
Corr. Ave/BW	39	33	34	34	32

Tear Test (5 samples per set) CD samples					
Trial Day#2	Control	6%	4%	2%	Dry
	32	32	35	37	35
	32	32	36	35	35
	29	32	34	34	34
	30	32	33	33	34
	32	32	35	35	35
	31	32	35	34	34
	31	32	35	35	38
	32		35	36	34
	32		33	35	34
			32	35	36
Avg.	31	32	34	35	35
Std*2	2.1	0.0	2.4	2.1	2.4
Corr. Ave/BW	33	34	32	34	36
Total Corr Ave.	36	33	33	34	34

Note: Tear Readings expressed in (gcm)

Appendix #19 (MIT Fold Tester)

MIT Fold test Trial Day#1	MD Control	6%	4%	2%	Dry
	12	41	75	42	43
	17	14	98	33	29
	24	98	72	40	45
	18	72	69	34	34
	17	76	77	51	42
Avg.	18	60	78	40	39
Std*2	8	59	21	13	12

MIT Fold test Trial Day#2	MD Control	6%	4%	2%	Dry
	30	23	20	20	24
	29	21	27	38	19
	29	23	21	28	18
	30	34	28	22	27
		24	37	30	17
Avg.	30	25	27	28	21
Std*2	1	9	12	13	8
Corr. Ave./BW	31	26	25	27	22

Note: MIT Fold readings expressed in number of double folds.

Appendix #20 (Tensile, Elongation, TEA)

Tensile Test	CD														
Trial Day#1	Control			6%			4%			2%			Dry		
	Tensile	Elong.	TEA	Tensile	Elong.	TEA	Tensile	Elong.	TEA	Tensile	Elong.	TEA	Tensile	Elong.	TEA
	2.05	3.2	82	3.40	4.2	207	3.85	5.2	299	3.83	4.3	252	3.31	4.4	219
	1.80	3.0	77	3.50	4.2	216	3.57	5.1	270	3.60	4.9	280	3.40	4.9	249
	2.07	4.3	92	3.35	4.1	198	3.85	5.8	317	3.23	4.6	242	3.35	4.7	231
	1.90	3.6	98	3.55	4.2	214	4.05	6.5	380	4.03	4.1	196	3.30	5.2	253
	2.25	4.6	127	4.32	5.8	349	3.30	6.6	390	3.65	5.6	326	3.65	5.6	318
	2.30	4.1	100	4.01	5.9	333	4.00	5.4	310	4.13	4.5	240	3.33	5.2	261
	1.95	3.6	118	4.00	5.7	325	4.09	6.0	356	3.72	5.4	317	3.37	5.4	278
	2.07	3.9	110	3.75	5.2	278	3.90	5.0	278	3.43	5.2	297	3.44	4.8	252
	1.92	4.0	124	3.75	5.0	276	4.20	5.8	351	3.44	4.4	207	3.35	4.9	250
	2.18	4.0		4.30	5.5	337	4.38	5.9	378		4.3	221			
Avg.	2.05	3.8	103	3.79	5.0	273	3.92	5.7	333	3.67	4.7	258	3.39	5.0	257
Std*2	0.30	0.9	34	0.67	1.4	115	0.59	1.1	83	0.55	1.0	86	0.20	0.7	54
Corr. Ave/BW	2.42	3.8	110	3.65	5.0	273	3.83	5.7	333	3.70	4.7	258	3.59	5.0	257

	MD														
Trial Day#1	Control			6%			4%			2%			Dry		
	Tensile	Elong.	TEA	Tensile	Elong.	TEA	Tensile	Elong.	TEA	Tensile	Elong.	TEA	Tensile	Elong.	TEA
	4.40	1.8	89	8.18	2.5	261	8.65	2.4	277	6.12	1.6	110	6.15	1.6	125
	4.48	1.9	105	8.95	2.7	300	8.72	2.6	271	6.42	1.6	123	6.30	1.5	109
	4.95	2.1	121	8.35	2.6	274	8.32	2.4	256	7.13	1.9	158	6.90	2.2	176
	4.20	1.6	80	8.20	2.5	249	8.20	2.3	245	7.03	1.9	147	6.62	1.8	140
	4.70	1.9	105	8.85	2.5	275	8.05	2.4	229	7.41	1.9	151	7.00	1.9	155
	4.67	1.9	98	9.02	2.7	297	8.37	2.2	231	7.20	1.9	168	6.73	2.2	219
	4.90	2.1	129	9.17	2.7	319	9.02	2.4	273	7.72	2.0	165	8.00	2.3	214
	4.45	1.8	90	8.90	2.5	285	8.70	2.6	238	7.35	2.0	171	6.52	1.9	141
	4.35	1.7	87	8.48	2.4	258	8.25	2.4	227	7.92	1.8	151	7.57	2.1	195
	3.92	1.6	66				8.17	2.2			2.2		7.63	2.2	211
Avg.	4.50	1.8	97	8.68	2.6	280	8.45	2.4	250	7.14	1.9	149	6.94	2.0	169
Std*2	0.60	0.3	36	0.71	0.2	43	0.59	0.3	38	1.08	0.3	39	1.16	0.5	76
Corr. Ave/BW	5.32	1.8	97	8.35	2.6	280	8.26	2.4	250	7.20	1.9	149	7.35	2.0	169

Appendix 21 (Tensile, Elongation, TEA)

Tensile Test Trial Day#2	CD Control Tensile	Elong.	TEA	6% Tensile	Elong.	TEA	4% Tensile	Elong.	TEA	2% Tensile	Elong.	TEA	Dry Tensile	Elong.	TEA
	3.44	4.0	203	3.95	5.3	321	3.80	4.6	267	3.75	5.3	297	3.25	3.9	132
	3.50	4.1	221	4.07	5.5	336	4.05	5.2	356	3.23	3.9	197	3.55	4.6	240
	3.90	5.2	308	3.80	4.7	274	3.85	4.7	318	3.25	3.9	180	3.00	4.7	251
	3.72	5.3	294	3.77	4.6	270	4.03	4.7	268	3.52	4.2	217	3.40	4.6	235
	3.95	6.0	360	4.05	5.2	325	3.95	4.4	282	3.44	4.2	220	3.40	4.5	232
	3.72	3.4	171	4.23	5.7	372	3.90	4.9	257	3.52	4.8	252	3.05	4.2	222
	4.05	5.2	306	3.70	4.2	241	4.02	5.2	296	3.60	5.3	276	3.40	4.6	230
	3.68	5.9	370	3.90	4.6	278	4.15	5.0	324	3.15	3.7	177	3.33	4.4	238
	3.85	4.7	284	4.00	4.9	300	4.06	5.0	313	3.35	3.8	182	3.30	4.3	226
		5.7	343	4.13	5.2	332			303	3.55	4.2	214	3.40		
Avg.	3.76	5.0	286	3.96	5.0	305	3.98	4.9	298	3.44	4.3	221	3.31	4.4	230
Std*2	0.38	1.7	128	0.32	0.9	74	0.21	0.5	58	0.36	1.1	79	0.32	0.5	31
Corr Avg./BW	3.99	5.0	286	4.15	5.0	305	3.72	4.9	298	3.39	4.3	221	3.41	4.4	230
otal Corr Ave.	3.09	4.4	198	3.81	5.0	289	3.90	5.3	316	3.57	4.5	240	3.45	4.7	243

Trial Day#2	MD Control Tensile	Elong.	TEA	6% Tensile	Elong.	TEA	4% Tensile	Elong.	TEA	2% Tensile	Elong.	TEA	Dry Tensile	Elong.	TEA
	7.60	2.6	268	6.00	2.0	146	7.85	2.4	263	6.50	2.1	171	6.58	2.2	138
	7.45	2.4	229	6.75	2.3	209	7.13	2.1	182	5.38	1.6	105	7.10	2.2	218
	7.50	2.6	262	7.18	2.6	250	7.60	2.2	232	5.48	1.7	114	6.70	2.2	207
	6.13	2.4	147	7.00	2.4	216	6.93	2.2	190	6.30	2.0	153	6.39	2.1	171
	7.48	2.2	241	5.80	1.6	115	7.30	2.3	223	6.30	2.1	156	7.07	2.4	222
	6.55	2.4	180	5.92	1.7	135	7.35	2.3	210	6.43	2.2	182	7.10	2.4	237
	7.20	2.4	227	5.95	1.6	130	7.77	2.4	255	6.73	1.8	125	7.22	2.3	219
	6.92	2.6	220	5.02	1.6	95	7.85	2.5	246	6.15	2.0	146	6.90	2.3	214
	7.07	2.2	244	5.03	1.5	98	7.40	2.6	240	6.20	2.0	156	7.12	2.3	140
	6.85		195				7.88	2.4	267	6.50	2.2	185			240
Avg.	7.02	2.4	216	6.08	1.9	156	7.47	2.3	227	6.16	2.0	147	6.95	2.3	208
Std*2	0.90	0.3	71	1.47	0.8	106	0.64	0.3	56	0.83	0.4	52	0.54	0.2	71
Corr Avg./BW	7.46	2.4	216	6.37	1.9	156	6.98	2.3	227	6.08	2.0	147	7.16	2.3	208
otal Corr Ave.	6.39	2.1	157	7.36	2.2	218	7.62	2.4	238	6.64	1.9	148	7.26	2.1	188

Day #1	Mach. Speed (ft/min)	Basis Wt. (lb/3000ft^2 Before SP	Trim Width (inches)	Total Reel(lb/hr)	Solids (lb/hr) at reel	Starch Pickup (lb/hr)	Water (lb/hr) at reel
Control	71.3	48.70	26	150.47	144.15	0.00	6.32
6%	71.3	51.08	26	157.82	151.05	10.08	6.77
4%	71.3	52.83	26	163.23	152.36	8.00	10.87
2%	71.3	51.30	26	158.50	150.96	6.50	7.54
BD	70.7	50.70	26	155.33	147.93	5.41	7.39
Day #2							
Control	70.3	51.47	26	156.79	149.86	0.00	6.93
6%	70.6	51.60	26	157.86	152.72	11.00	5.15
4%	70.6	52.20	26	159.70	152.30	9.20	7.39
2%	70.8	52.43	26	160.86	154.68	7.30	6.18
BD	70.6	49.52	26	151.50	145.45	3.50	6.04

Total After SP	Solids (lb/hr) after SP	Water(lb/hr) after SP	Water Evap. at After Dr	Heat required fiber(BTU/hr)	Heat required water(BTU)	Latent Heat (Btu)
151.10	144.15	6.95	0.63	142.71	20.85	648.11
209.59	151.05	58.54	51.77	3838.17	4511.51	50907.96
206.70	152.36	54.34	43.47	3670.26	3969.58	42856.73
198.08	150.96	47.12	39.58	3586.70	3395.20	39043.87
197.88	147.93	49.94	42.55	3466.10	3548.07	42004.25
157.92	149.86	8.05	1.12	989.11	160.92	1143.16
212.78	152.10	60.69	55.54	3613.85	4372.43	54790.01
203.59	152.30	51.28	43.89	3367.42	3437.53	43428.67
206.38	154.68	51.70	45.52	3164.72	3206.25	45183.36
196.00	145.45	50.55	44.50	3023.98	3185.60	44112.61

Total After Main	after Main Fiber(lb/hr)	After Main Water(lb/hr)	Total After Press	After Press Fiber(lb/hr)	After Press Water(lb/hr)	Evap. At Main water(lb/hr)	Heat required fiber(BTU/hr)
151.10	144.15	6.95	384.39	144.15	240.25	233.29	6469.32
146.71	140.97	5.74	375.92	140.97	234.95	229.21	6373.24
148.16	144.36	3.81	384.95	144.36	240.59	236.79	7145.63
146.12	144.46	1.67	385.21	144.46	240.76	239.09	8485.30
143.88	142.52	1.35	380.06	142.52	237.54	236.19	9500.67
157.92	149.86	8.05	399.64	149.86	249.77	241.72	7121.56
146.95	141.72	5.23	377.91	141.72	236.19	230.96	6594.01
147.12	143.10	4.02	381.61	143.10	238.51	234.49	7461.40
150.57	147.38	3.19	393.01	147.38	245.63	242.44	8754.28
144.58	141.95	2.63	378.54	141.95	236.59	233.96	9368.92

Heat required water(BTU)	Latent Heat (Btu)	Total Heat After Dryer	Total Heat Main Sect.	Total Heat Required(Btu)	Cost Main Sect. ($/year)	Cost After Dr. ($/year)	Total Heat Cost ($/Year)
32690.17	227252.44	811.67	266411.94	267223.61	37505.64	114.27	37619.91
32206.87	223127.67	59257.64	261707.78	320965.42	36843.39	8342.33	45185.72
36132.35	228545.65	50496.57	271823.63	322320.19	38267.50	7108.94	45376.44
42977.86	226373.31	46025.77	277836.48	323862.24	39114.00	6479.54	45593.53
48206.47	219732.82	49018.42	277439.96	326458.38	39058.18	6900.84	45959.02
36002.44	234251.09	2293.19	277375.09	279668.27	39049.04	322.84	39371.88
33324.36	224055.16	62776.30	263973.53	326749.83	37162.36	8837.69	46000.05
37745.86	225109.44	50233.63	270316.70	320550.33	38055.36	7071.92	45127.28
44333.88	229177.18	51554.33	282265.34	333819.67	39737.49	7257.85	46995.35
47530.73	217931.48	50322.19	274831.14	325153.33	38690.90	7084.39	45775.29

* Note: Heating cost was arrived at with an assumed $00.055/Kwh.

Appendix #24 (Linear Regression)

Y Range	MIT Fold Regression Output:		
	Constant		30.4270
46.9	Std Err of Y Est		1.7712
42.9	R Squared		0.9641
34.8	No. of Observations		4.0000
30.4	Degrees of Freedom		2.0000
	X Coefficient(s)	1.3740	
	Std Err of Coef.	0.1875	

Y Range	Tensile Regression Output:		
	Constant		63.0423
58.6	Std Err of Y Est		0.6871
59.7	R Squared		0.9295
61.9	No. of Observations		4.0000
63.0	Degrees of Freedom		2.0000
	X Coefficient(s)	-0.3735	
	Std Err of Coef.	0.0727	

Y Range	Tear Regression Output:		
50.1	Constant		42.8512
48.3	Std Err of Y Est		1.1447
44.8	R Squared		0.9251
42.9	No. of Observations		4.0000
	Degrees of Freedom		2.0000
	X Coefficient(s)	0.6024	
	Std Err of Coef.	0.1212	

Y Range	Burst Regression Output:		
43.1	Constant		35.9488
41.3	Std Err of Y Est		0.0604
37.8	R Squared		0.9998
35.9	No. of Observations		4.0000
	Degrees of Freedom		2.0000
	X Coefficient(s)	0.5920	
	Std Err of Coef.	0.0064	

Appendix #25 (Linear Regression)

Y Range	Brightness Regression Output:		
72.2	Constant		74.8456
72.9	Std Err of Y Est		0.2301
74.2	R Squared		0.9756
74.8	No. of Observations		4.0000
	Degrees of Freedom		2.0000
	X Coefficient(s)	-0.2180	
	Std Err of Coef.	0.0244	

BEATER SHEET

DATE: 1/11/87

CLIENT: THESIS

NOTES: DAY #1

FURNISH: 50 % CANADIAN SW
50 % CANADIAN HW

Beaters	Fiber Moisture HW	Fiber Moisture SW	Fiber Lbs. A.D. SWD	Fiber Lbs. A.D. HWD	Fiber Lbs. A.D. GWD	Additives Freeness	Acid	$CaCl_2$	Freeness (~~Clay~~)	TiO_2	$CaCO_3$
	16%	14.8%	258	262							
11			258						435	24½ min	
12				262					590	1½ min	
13			258						435		
14				262					577		
15			258						428	27 min	
16				262					570	1½	
17			258								
18				262							

Appendix #26 (Stock PreP.)

BEATER SHEET

DATE: 1/12/89

CLIENT: THESIS

NOTES: DAY #2

FURNISH: 50% CANADIAN SW
50% CANADIAN HW

Beaters	Fiber Moisture		Fiber Lbs. A.D.			Additives					
	HW	SW	SWD	HWD	GWD	Freeness	Acid	$CaCl_2$	*Freeness*	TiO_2	$CaCO_3$
	16%	148%	258	262							
11			258						435	24½ min	
12				262					590	1½ min	
13			258						435		
14				262					577		
15			258						428	27 min	
16				262					570	1½	
17			258						440	28 Min	
18				262					596	1½	

Appendix #27 (Stock Prep.)