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Abstract

A pilot plant papermachine trial was ran using 100% softwood stocks refined in a Jordan and double-disk refiner and then blended to give a gradual change in stock quality at a set freeness. Two freeness levels were used. WRV's and press section moistures were taken for each stock ran and evaluated. It was concluded that the WRV of a stock does vary with different refining techniques at a set freeness and in certain cases the WRV related to percent solids out of the press section. However, the sensitivity of the test to varying stock qualities varied widely. Problems arose with the mesh size of the fritted crucibles. A history of the development of the WRV test is also presented.

Keywords: Water Retention, Refining, Centrifugal Force, Moisture Content, and Wet Pressing

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History and Development of the WRV Test

The water-retention value test (WRV) is a measure of the ability of a papermaking pulp to retain water. This is in contrast to the usual freeness or slowness tests which measure a pulp's ability to shed water.(1) This test involves the use of a centrifuge and is defined as the amount of water retained by a centrifuged pulp calculated as percent of dry pulp. The test involves taking a small sample of pulp (0.15g - 1.20g) and centrifuging it under set conditions of speed and time. Immediately after centrifuging, the moist pad is weighed and then allowed to dry in a drying oven, which in turn is weighed again. To determine the WRV, the following calculation is used:

$$WRV\% = \frac{\text{moist weight after centrifuging - oven dry weight}}{\text{oven dry weight}} \times 100 \quad (2).$$

Centrifugal mehtods for estimation or determination of the water-holding capacity (i.e. hydration) of pulps go back at least as far as Hubert, Mathes, and Weisbrod in Germany in 1942.(3) Probably the most aggressive people who have pursued this path of investigation has been Jayme and his co-workers.

Jayme showed in 1944(4) that the centrifuge method is suitable for pinpointing differences in the swelling degree of pulps in caustic solutions as well as in water. Some of these differences were caused by hemicellulose content, type of pulping, heating, bleaching, drying, etc. In 1948, Jayme and Rothamel proposed a standard procedure after extensive investigations of the variables involved.(5) The test then

became widely used in Europe as a simple pulp evaluation test. In 1955, Jayme and Rosenfeld succeeded in proving that the swelling capacity of a pulp in water may provide virtually the sole basis for the development of sheet strength.(6) They were able to prepare pulps with a high sheet strength at a constant Schopper-Riegler freeness. The committee for Pulp Analysis of the Association of Pulp and Paper Chemists and Engineers in Germany asked for a re-examination of the various factors affecting this method since it had been adopted by industry in several locations. In January of 1957, the committee approved the recommendations of Jayme and his co-workers(7) that the originally used centrifugal force parameter of 800g be increased to 3000g in order to narrow the deviations of the experimental values. However, it was found that by using such a method, poor reproducibility was noticed for highly beaten pulps.

Jayme then proceeded with a study to modify the method.(8) The outcome was a change in the filter device in the centrifuge tube to a nickel sieve support approximately equivalent to a 100-mesh screen. A fiber layer is formed on the screen as soon as the centrifuging starts, thus retaining any short fibers. The swelling degree (WRV) could then be determined accurately over the entire range of freeness (14 - 80° S.-R. for unbleached spruce sulphite pulp) with only insignificant fluctuations.

One of the greatest factors affecting the level of the WRV is the centrifugal acceleration applied to the sample. Too low of a value of F_c will fail to overcome the forces of capillary pressure in the

interfiber voids and will yield a WRV which is higher than the solely intrafiber water responsible for the swollen volume. On the other hand, too high a value of F_c will result in fiber distortion and the loss of intrafiber water which will result in a falsely low estimate of swollen volume. F_c is determined by two factors, the rotating radius and the speed of rotation. In English engineering units, the expression

$$F_c = 2.84 \times 10^{-5} RN^2$$

describes the relationship(2,9), where R is the rotating radius in inches and N is the rpm's. The 3000g force introduced by Jayme(7) caused approximately 14-19% lower WRV's than when 800g was used despite the higher reproducibility.

Thode(9) did a study on the influences of centrifugal force on WRV of various pulp types. His results showed that an unbeaten, fines-free sulfite pulp was little affected by an increase of F_c from 1000 - 3000g. A moderately beaten, classified pulp leveled off at 3000g, and a highly beaten classified pulp showed strong effects of g-value which continued to be significant over 3000g. From this, he concluded that this test was inappropriate as a "fundamental" measure of a single basic property of pulp.

Thode gave as a reasonable explanation of the marked effect of g-value on WRV for highly beaten pulps and those containing much fines, the capillary suction hypothesis. This hypothesis assumes that water is retained in some of the interfiber pores because of capillary suction and that capillary suction will only be effective in those pores of such size that P_c (capillary pressure) is egual to or greater than F_c. He and his colleaques showed that the proportion of the pores in which capillary suction is actually effective may be estimated from

two values of water retention and two corresponding values of cumulative pore volume. From these estimated figures, they were able to predict the shape of the WRV vs. F_c curves from experimental pore volume data. While this isn't proof of the validity of the capillary suction hypothesis, it is a strong indication of the importance of this factor. For the highly beaten pulps whose fines content is high, there is a sizeable volume of interfiber voids in the range below 5 microns in diameter. To empty these voids against the force of capillary suction would require relative centrifugal forces well in excess of 3000g. However, those forces may cause severe fiber distortion which is undesirable.

Looking at the time allowed for centrifuging, Thode was able to show that more and more water is extracted from the pulp as time goes on, but at higher g-values the curves level off reasonably well even for beaten pulps after 15 minutes. This phenomenon is hard to explain since fluid flow calculations show that even one micron open-end capillaries should discharge completely in about one minute. This is thought to be a matter of the complication of two-phase (water and air) flow through the pad with unanalyzed resistances to flow being generated at constrictions by the forces of surface tension.

After looking at these factors, Thode and his colleagues continued investigation on the use of the WRV.(9) Relating the WRV to the swollen specific volume of a fiber, the WRV gave a lower estimate of this property than did the filtration resistance test for a well-beaten pulp with the fines removed. The filtration resistance test was the usual and standard method of measuring swollen specific volume. This

characteristic is probably the result of fiber deformation under the applied stress of the test. This deswelling also occurs in the filtration resistance test, but it's thought that this occurs to a much greater extent in the centrifuge test. Eventually this becomes more important than the interpore water retained in the fiber mat.

They found an excellent linear correlation of WRV and filtration specific volume which may suggest that this relatively simple centrifuge test yields a figure closely and consistently related to the desired specific volume. The WRV can be very useful in providing an accurate estimate of relative swollen volume if the basic limitations of the test are kept clearly in mind. Throughout Thode's work, his experimental conditions involved centrifuging a 0.15g sample for 15 minutes at a relative centrifugal force of 3000g.

Applying WRV to Strength Properties

In 1958, Jayme did another study of the WRV. This time he took five different pulps which were beaten for 10 minutes in a Jokro mill to WRV's varying from 180 - 230 and related these to their corresponding breaking length. He established that the relation between breaking length and WRV was represented by straight lines while breaking length as a function of degree of beating always gave curves that rose steeply at first, and then more slowly.(6) With Jayme's work and the work of others at that time(7,10), he helped confirm his claim that the WRV co-determines decisively the strength properties of a pulp while beating is only an indication of the draining quality of a fiber suspension. He also confirmed that the WRV is not an "absolute" measure of sheet strength, but that various pulps may develop different sheet strengths at the same WRV's.(8)

From this research, Wier(1) decided to use the WRV in conjunction with a measure of fiber length in a refiner evaluation study. Using the WRV to measure hydration and the fiber length index test (FLIT), he made a comparison between three different disk refiners. He deduced that at equal FLI, the refiner having the highest WRV gave an indication that it was hydrating the pulp to a larger extent than cutting and reducing length. Carrying out this same procedure except measuring fiber length by measurements of tear strength, he deduced that the refiner giving the highest tear strength at equal WRV indicates that it probably does less cutting than the other two. In a similar test using ultrasonic refining, Wier was able to get an increase in WRV without increasing freeness to help show the independance of the WRV test to freeness.

Thode(9) carried Wier's work a step further. Establishing an experimental system where formation and the intrinsic strength of the fibers could be held constant, he would then measure the fiber length and bonding degree which would then relate to final tensile strength. He thought that if the amount of swelling of the fibers was related to the fiber bonding potential dry,* then WRV test may be used as an approximation of such bonding potential. This would be coupled with a ready measure of fiber-length distribution.

Thode conducted a refining study using unbleached softwood sulfite pulp and subjecting it to successive treatments in a laboratory ball mill and Mead refiner. The idea was to create a trend from almost pure hydration refining to considerable cutting. He ran fiber-length index

*This assumption was made by an earlier study done by himself relating WRV to fiber flexibility and thus fiber bonding.

tests according to the procedure of deMontigny and Zborowski(11). In the study, all the handsheet tensile strengths related to the WRV's of the refined pulps to a highly significant degree. The correlation coefficient of the regression curve was 0.968 and at a very high degree of statistical significance. An increase in WRV was seen as the refined pulp went from hydration to cutting.

In 1972, Scallan and Carles(12) investigated the relationship between WRV and the measure of the fiber saturation point (F.S.P.) of a fiber by the solute exclusion technique (13). They stated that like the F.S.P., the WRV can be used to follow the progress of these processes. As an example, there is a correlation between the F.S.P. (17) and the increase in the breaking length of the pulp just as with the WRV. These two methods had never been applied to samples of the same pulp even though from literature, it appeared that both quantities had values of very similar magnitudes for similar pulps. It would seem that these two tests maybe determining essentially the same property. If so, the WRV method is a much simpler method of estimating the F.S.P.

Scallan and Carles's study compared WRV figures and corresponding F.S.P. values of certain stocks. Their objective was to see if the adopted standard conditions for the WRV in fact do give an exact measure of the F.S.P. Failing this, they would then seek conditions under which the centrifugal method could be universally employed as a rapid and convenient method to determine this fundamental property.

They adopted the conditions of 900g at 30 minutes after various data had been collected from varying time and F_c and relating it to F.S.P. There was good agreement between WRV and F.S.P. up to a value of 1.80g/g

and thereafter the WRV method gave an increasingly low value. The lowest extreme though, was only 10% relating to a 63% yield stock which was further swollen by beating. They concluded that the WRV was a close estimate of the fundamental parameter - the F.S.P. By adjusting the conditions used, the WRV can give an even closer value of the F.S.P. except for the most highly swollen pulps. The simplicity of this test makes it attractive where rapid evaluation of many samples might be required, although, it is not an absolute method.

Discussion of Mechanism of Water Retention

Scallan and Carles also reported(12) that it is probable that the water which is retained after centrifuging is not solely within the cell wall. They thought it was more probable that the water was partly confined within partially dried cell walls and partly confined in inter-fiber spaces or lumina. However, the sum of the amounts of water held did correspond to the F.S.P., i.e. that amount of water the cell walls would contain if saturated. It had been shown that a pad of glass fibers (which do not swell in water) retained some water in interfiber spaces after centrifugation at high speeds(18). Their conclusion was if a pulp at a WRV corresponding with the F.S.P. contains interfiber water, then it is only reasonable to assume that some water had been squeezed out of the water-swollen cell wall by the application of centrifugal force.

However, just recently, Abson and Gilbert(19) published an article questioning Scallan and Carles's theory. After examining the parameters of their procedure, Abson and Gilbert observed two significant facts. The first being the presence, in a centrifugal pulp mat, of a gradient in

retained water such that the lower portion of the mat always has a higher WRV than the upper portion. The second being that WRV increases with decreasing basis weight. They backed up both of these observations with experimental data.

Their explanation of their results was that water retention is strongly influenced by wet pulp compactibility. Centrifuging sets up a gradient of compacting forces in the fiber network so that pad porosity decreases in the direction of water removal. Some of the pores which could originate from collapsing lumens as well as interfiber voids, are sufficiently small to retain water against the applied centrifugal pressure. The WRV increases in the direction of compaction. At equilibrium, the total water remaining is the sum of water held in the small pores resulting from pad compaction that are below a critical size. The contribution from the latter depends on the mass of wet pulp, the centrifugal force, and the compactibility of the network. This in turn will be determined by intrinsic fiber properties such as length, slenderness, and flexibility. The WRV will be at a maximum when these various factors combine to give a large number of small water-retaining pores outside the fiber wall that are only just below the critical size for water retention.

Their data suggests that WRV probably corresponds fairly close with F.S.P. at extremely low basis weights, where the effects of pad compaction are minimal. But, as the basis weight increases, WRV initially increases rapidly to a level significantly higher than the F.S.P., as a gradient of small water-holding pores builds up by increasing compaction. This continues up to a point beyond which higher compacting forces resulting from the increasing mass of wet pulp then cause a

progressive reduction in the relative volume of small pores that can retain water external to the fiber wall. Thus, WRV moves closer to the F.S.P. as the sample size increases beyond this transition point.

Because of these findings, Abson and Gilbert state that the test parameters for WRV determination are not sufficiently defined by centrifugal force, time, and sample weight alone. It is necessary to describe sample size in terms of weight per unit area, i.e. basis weight.

Application of WRV to Papermachine Runnability

A recent advancement in the use of the WRV was published by Lebel, Nobleza, and Pacquet(20) in 1979. They reported the use of WRV has helped them predict papermachine runnability. In their study, they used a modified version of the Jayme method for determining WRV of a newsprint furnish for relating pulp dewatering and papermachine performance. Their furnish make-up is composed of 70% groundwood and 30% unbleached, calcium-base sulfite. The modified conditions used included using 1.20g O.D. sample and a centrifugal force of 840g (2500 rpm) for 12 minutes.

Their first work showed that the WRV of their mixed stock was related to the web moisture entering the dryers. Over a one month period of at least two WRV's per week, they saw evidence that higher moisture of the web entering the dryers is associated with high WRV of their mixed stock. This evidence was seen on all four of their papermachines. From chronological plots, the effect of WRV on percent moisture entering the dryers was estimated to be approximately a 0.14% point increase in moisture for each point increase in WRV. Even though press conditions

like felt type, nip loading, felt conditioning, and felt life were not controlled, the data illustrates that dewatering in the press section is seemingly influenced by the WRV of their furnish.

Their next step was to find the conditions previously mentioned which related best to the dewatering characteristics of their machines. In a simplistic statement, with other things remaining constant, they felt that the dewatering of a machine furnish by lab centrifuging should relate to the dewatering performance of that same pulp on the machine provided the conditions of centrifuging were chosen judiciously. The standardization of conditions were made from considering centrifuge speed and time to obtain a pulp solids content approaching that of the web leaving the press section. They felt the conditions chosen did simulate reasonably well the performance of water removal of their papermachines.

To have good runnability in relation to web breaks, the water removal performance must give a sheet dryness which would provide adequate wet web strength for the furnish used. Web breaks will increase at lower solids levels because the strength of the web diminishes, and the ability to carry sheet defects is hindered. They thought that since web dewatering was influenced by the WRV of the furnish, then the WRV level of the pulps should therefore relate to runnability on the paper-machine.

Data of break frequencies obtained from mill records were tabulated for the four machines, and monthly averages of total weekly breaks were calculated. When the number of machine breaks were corrected for speed, there was a remarkable association between average mixed stock WRV and the monthly average of the weekly total breaks. They were able to confirm that lost time due to web breaks, uncorrected for speed, is most

likely to increase when the mixed stock WRV and wet press moisture increase. They concluded from this that even in consideration of the large number of variables which can affect performance and of limited sampling, their finding still showed a surprising strong relationship between machine furnish WRV and machine runnability. They believe that WRV is a key stock property, and that combined with web strength testing, it has the potential for use as a control/prediction variable in a papermill.

A five week study was run with daily WRV's taken along with a wet web strength determination on the machine furnish. From the data, the mixed stock wet web strength did not correlate as strongly to machine performance as WRV when used alone. Nonetheless, it showed a reasonable correlation with web breaks. On the otherhand, freeness correlated only slightly with breaks. However, combining the properties of strength and dewatering behavior should have some merit as to pulp runnability. The ratio of wet web strength vs. WRV was then plotted with a high ratio giving the desired pulp characteristics as high intrinsic wet web strength and low WRV. The ratios when plotted against machine breaks corrected for speed gave a strong correlation with machine performance increasing as the ratio increased. They therefore concluded that papermachine performance can be predicted by this ratio so called the RI value.

Summary

WRV appears to be a key property that has a significant potential for the use as a control/prediction test. The main advantage of the WRV test is in its simplicity and high reproducibility, making it easily adaptable to routine measurements in the mill. I see the strongest potential for this test in three areas.

First, this test has the potential ability to control more closely the refining of pulps in the stock preparation system of papermills. This would be the alternative of relying on the traditional use of freeness and/or the practice of constant load application at a set throughput of pulp.

Secondly, this test will grow in the area of predicting water removal performance of a furnish at the wet end of a papermachine with also a strong push to relate it to total machine performance.

The third area deals with the topic of this thesis. The WRV test can be used in studies of pressing pertaining to the evaluation of water removal variables. WRV measurements can be used for normalizing the dewatering behavior of pulps on papermachines. It can also be used as a trouble-shooting test to help determine if poor runnability is due some section of the machine as for example the wet end or press section, or is it in the stock itself. This is where my thesis topic fits in.

Experimental Procedure

Design of Experiment

To carry out the investigation of my hypothesis, I planned a one day machine trial on the Department's pilot papermachine. The trial consisted of making up six different batches of stock and running each separately on the machine. The batches differed in refining techniques and freeness. The first three batches would be approximately 600 CSF with one batch comprising of 100% Jordan refining, one of 100% double disk refining, and one being a 50/50 blend of each of them. The other three batches would be the same as aboye except refined to 350 CSF. Basis weight, wire speed, press loadings and dryer temperatures would all be kept constant. Moisture samples of the sheet would be taken for each run before and after the press section, at the size press and at the reel. Other data taken per run include the vacuum box and couch vacuum readings, and the dry location (see Appendix 1).

The Mill Trial

To prepare for the run, the 600 CSF 100% Jordan and double-disk stocks were made up the night before. The 350 CSF Jordan stock was also prepared. It took thirteen hours to prepare these stocks with the majority of the time spent to refine the Jordan stocks. The Jordan is set up as a single passloop instead of a continuous loop and much of the time was spent pumping the stock to and from the holding chests.

The initial run the first morning was with the 600 CSF Jordan stock. After reaching the set basis weight of 40#, the samples and data were taken which approximately took 10 minutes. Next the 100% double disk stock at 600 CSF was run. Following this, a given amount of the double disk stock was mixed with the remaining Jordan stock at

600 CSF to equal a 50/50 blend. It was then run on the machine for the third run.

Next, the remaining half batch of the 600 CSF double disk stock was then refined to a target of 350 CSF. The actual freeness was 295 CSF. The fourth run was with the 350 CSF Jordan stock. The fifth with the 295 CSF double disk stock and the sixth with a blend of these two.

For the WRV determinations, I diluted my stock samples to approximately 0.3% consistency and then measured out the appropriate volume to give me exactly 1.00g O.D. fiber. The volumes were in the range of 200-400 ml each. The crucibles used were those used by the proposed TAPPI standard procedure included in the Appendix. There was a difference in the crucibles in that they had the medium fritted glass and not the coarse fritted glass that the procedure recommends. It's effect on the results is unknown but it greatly affected the time involved in filtering the samples before centrifuging. Instead of taking 10-15 minutes under 8" of water vacuum, it took 20 minutes to 3 hours under 15-28" vacuum. This may have affected the results but I have no way of telling. Another difference in the crucibles is that twelve of them were new from the manufacturer and the other twelve had been used previously by the chemistry department. It was not known how old they were. From observations during the filtrations, the used crucibles and the new crucibles seemed to filter the same but the testing results showed a difference in the WRV values. I ran six determinations per centrifuge run with four determinations per stock sample. In case of a difference in the used versus the new crucibles, I ran two of the four determinations of each sample with new crucibles and two with the used. After centrifuging, they were weighed, dried over night at 105°C and then weighed again as stated in the procedure.

The fiber classifications were done by the Clark classifier. Two runs were done for each sample with the stated results being an average of the two. The moisture samples were placed in microwave bags and weighed to get the wet weight. They were then opened and allowed to dry in a 105°C oven for two days. Only one moisture value was done per sample.

In reviewing the results of the data taken, there seems to be three significant areas which need to evaluated. The first area is in comparing how the progression of different refining techniques affected the stock. Second, a difference in WRV values of the machine chest and the couch samples was noticed. Third, a difference was also noticed in the WRV values using the new versus the old crucibles. I will discuss each separately.

For a matter of comparison in reviewing the results pertaining to the different refining conditions, I will use the WRV values of the couch stock using the new crucibles only. This is because of the differences noted. First of all, it can be seen that the stock quality did change at both freenesses from refining in the Jordan to refining in the double disk refiner. The Clark classifications show a significant increase in the amount of fiber held by the 20 mesh screen and a decrease in the amount of fiber held within the 100 mesh screen. This shows that the Jordan did more cutting while the double disk gave more fibrilization while both gave the same freeness. Reviewing the wet end performance, the dry line moved back towards the headbox as the stock changed from the Jordan to the double disk. The line did move up the wire significantly from the 600 freeness runs to the 350 freeness runs. A decrease in both the couch vacuum and second vacuum box values was seen at the 600 freeness going from the Jordan to the double disk. No change between stocks at 350 CSF was noticed.

From these observations, there is evidence to show that the stock quality did change as the stock was refined in the Jordan and double disk refiners. A study of the WRV values at the couch shows

a moderate increase in the WRV from the Jordan refined stock to the double disk at both freeness levels. Calculating these values as percent solids indicates that as the refining technique changes from severe cutting toward more hydration, the theoretical maximum amount of solids that can be achieved out of the press section will decrease. This is seen at the 600 freeness level when comparing the percent solids coming into the press section. Coming out however, there is no significant change of the percent solids out. This is to say that the press section was able to remove the extra water in the sheet at the 600 level. At the 350 CSF level, there was a decrease in percent solids out (an increased WRV) from the 100% Jordan stock to the 50/50 blend but no difference from the 50/50 to the 100% double disk. Looking at the solids into the press section at the 350 level, there was no change. In contrast to the 600 level, the ingoing moistures changed very slightly where the outgoing moisture changed significantly.

The second area in which there were significant differences was with the chest and couch WRV's. In every case the couch samples gave a lower WRV than did the machine chest samples. The largest difference came with the 350 CSF Jordan stock. There was also a large difference in the 50/50 blended stock at the 350 CSF level but the couch sample values are questionable as reported in the procedure. The differences in the 600 level values were less overall than the differences seen at 350 CSF.

The third area of consideration is the differences seen in the new versus the old crucibles. Here again, in every case the new crucibles yielded lower WRV's than did the old crucibles. The differences were not much higher than the reported 2% error indicated from the WRV test procedure. The difference was approximately the same for both the

couch and chest samples and at both freenesses.

Conclusions

From the results, I can conclude that the WRV of a stock can vary with different refining techniques at a set freeness. I can also conclude that the WRV can relate to the percent solids out of the press section in certain cases. With high freeness stock, the press section seems to be able to compensate for any small moisture changes coming into it. Thus the WRV may not be able to predict outgoing moisture. At the lower freeness levels, such as the 350 CSF level, the press section was not able to compensate for any excess moisture thus yielding a decreased percent solids on the outgoing side. Here the WRV may be able to predict outgoing press solids.

However these conclusions are based upon average WRV values where error may be introduced do to the differences in crucibles. When running the WRV test, you must be sure that the porosities of the fritted glass crucibles are fairly equal. If they start to plug, they may incorrectly increase the WRV and throw off your results.

Another conclusion which has been stated by others and proven to be true in this study is that the WRV is not an absolute measure of a single basic stock property. The theoretical assumption that the WRV through a conversion factor can be transformed to the maximum percent solids achieveable out of a press section is not an absolute number. For instance, in the case of the 350 CSF level, the calculated percent solids from the WRV ranged from 34 to 31%. The actual values measured showed a range of 37 to 36% solids. Even though the theoretical was lower, they relatively correlated when a difference was recorded.

The difference between the actual and theoretical values were larger at the lower freeness level. There was no differences between the two at the 600 CSF level.

A final conclusion which has also been backed up by previous studies is that the fines content or distribution of the stock sample does influence its WRV. This is the explanation for the differences seen between the chest and couch samples. It may also explain the differences between the Jordan and double disk stocks. This test may be yielding values that are influenced by the change in fines distribution other than the differences in the conditions of the individual fibrils.

This study was successful in showing that there may be a strong direct correlation between WRV and percent solids attainable out of the press section. However, I was not able to determine the sensitivity of the test to varying stock qualities. The WRV test may or may not be sensitive enough to be used as a troubleshooting tool on the machine or as a refiner control parameter. I would recommend further investigation into this area. I feel this test may have the potential to become a troubleshooting tool and for a refiner control parameter.

A second line of investigation could lead into the relative effects of the fines content of the sample in relation to where the sample is taken. One sample location may be more sensitive to the stock quality than another.

Another area of study could be in using the wet web strength test along with the WRV test to study wet web performance. This would help back up the work done by Lebel, Nobleza, and Pacquet(20). They used 70% groundwood in their study. It may be interesting in applying this to kraft papers.

Appendix A

Machine Trial Outline

Stock Prep:	Jordan	600 and 350 CSF
	Double-Disk	600 and 350 CSF
Stock Blends:	100%/0%, 50%/50%, 0%/100%	
WRV Samples:	sample at machine chest	
	sample at Couch	
Clark Classifications:	sample at machine chest	
	sample at Couch	
Moisture Samples:	sample at Couch	
	sample after 2nd press	
	sample at size press	
	sample at reel	
Data Recorded for each Sample:	wire speed	
	basis weight	
	percent moisture at reel	
	dryline location	
	couch and vacuum box vacuum	
Total Labwork per Run:	12 WRV's quadduplicate	
	12 Clark Classifications in duplicate	
	24 Moisture Samples	

Appendix B

Data Table

	J	J/D	D	J	J/D	D
eeness	588	---	592	365	---	295
V*	1.510	1.542	1.572	1.896	2.046	2.068
Solids (WRV)**	39.8	39.3	38.9	34.5	32.8	32.6
Solids (out)	39.2	39.4	39.3	37.6	36.4	36.5
Solids (Total)	15.2	15.7	16.5	14.8	13.4	14.1
uch Vacuum nches H_2O)	11.0	10.5	9.0	17.5	18.0	17.5
d Vacuum Box nches H_2O)	2.0	2.0	1.0	5.0	5.0	5.0
yline	3rd foil	2nd foil	B4-1st foil	2nd TR	1st TR	1st TR
Solids (In)	24.0	23.7	22.8	22.8	23.0	22.4

These values represent average of the two WRV's taken at the couch and centrifuged with the new crucibles.

The conversion from WRV to % Solids is:

$$\% \text{ Solids} = 1 - \frac{WRV}{WRV+1} \times 100$$

Appendix C

WRV Evaluation
(calculated as % solids)

	590 CSF				365/295 CSF			
	Chest		Couch		Chest		Couch	
Jordan								
Old	39.4	(39.3)	39.7	(40.0)	31.6	(30.8)	34.1	(34.0)
	39.2		40.2		29.9		34.0	
New	39.9	(39.8)	40.6	(40.5)	31.2	(31.2)	34.1	(34.5)
	39.8		40.4		31.2		35.0	
Jordan/DD								
Old	38.9	(38.8)	39.0	(39.0)	22.6	(22.6)	33.1	(30.8)*
	38.7		39.0		22.7		28.4	
New	39.5	(39.4)	40.1	(40.0)	32.6	(32.8)	31.7	(32.9)*
	39.2		39.8		33.0		34.0	
Double Disk								
Old	37.9	(37.9)	38.3	(38.8)	25.1	(25.4)	32.4	(29.5)*
	37.9		39.4		25.7		26.5	
New	38.6	(38.8)	39.6	(39.5)	32.8	(32.2)	31.9	(32.6)
	39.1		39.4		31.7		33.0	

Appendix D

Clark Classifications

(mesh sizes: 20, 40, 50, 100)

590 Freeness	Chest	Couch
Jordan	1.8, 49.4, 29.8, 18.5	1.3, 49.5, 28.8, 20.4
Jordan/DD	9.5, 47.0, 25.9, 17.6	9.7, 47.0, 25.9, 17.4
Double Disk	14.0, 45.6, 24.2, 16.1	14.7, 45.5, 23.8, 16.1
365/295 Freeness		
Jordan	0.2, 21.6, 45.6, 32.7	0.2, 23.4, 44.8, 31.7
Jordan/DD	1.6, 38.6, 34.6, 25.2	1.9, 38.5, 42.3, 17.3
Double Disk	6.8, 46.1, 27.5, 19.6	7.2, 44.5, 28.5, 19.7

Appendix E

PROPOSED

USEFUL METHOD

FOR DETERMINING

WATER RETENTION VALUE (WRV)

CA NO. 4531

PRESSING SUB-COMMITTEE

TASK GROUP:

L. H. Busker, Chairman

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WATER RETENTION VALUE (WRV)

1. SCOPE

1.1 Water Retention Value is a measure of the water retained by a wet pulp specimen after centrifuging under standard conditions.

2. SIGNIFICANCE

2.1 Water Retention Value can be a useful tool in evaluating the performance of pulps relative to dewatering behavior on the paper machine. The usefulness of the method on a particular application may vary depending on type of stock, additives, machine configuration and other factors. The method is established to provide standard values of centrifugal force, time of centrifuging, and sample preparation so that results can be compared between investigators at standard values.

3. APPARATUS

3.1.1 Laboratory centrifuge with free swinging head or horizontal heads.
3.1.2 Centrifuge cups (e.g., I.E.C. No.362)
3.2.1 Glass filtering crucible (e.g., Corning Pyrex No. 32940, high form, coarse grade) or any suitable equivalent specimen holder. Various metal cups with fine wire screens are in common use. Fines loss on coarse mesh screens may significantly influence results.
3.2.2 Plastic caps for filter crucible with small vent hole.
3.3 Disposable blotter or wipes
3.4.1 Erlenmeyer flask, 2000 ml
3.4.2 Rubber adaptor - crucibles to Erlenmeyer flask
3.5 Glass rod
3.6 Beaker, 250 ml
3.7 Balance suitable for weighing crucibles or specimen holders sensitive to .001 g
3.8 Drying oven
3.9 Laboratory glassware cleaner
3.10 Dessicator jar

4. TEST SPECIMEN

A representative specimen of the pulp to be evaluated should be available in an amount to provide for a pad of 1400 g/m^2 of oven dry fiber for each specimen desired. The consistency of the specimen should be known or be determined by TAPPI test procedure T240.

5. PROCEDURE

5.1 Measure a quantity of pulp in suspension to yield a specimen of 1400 g/m^2 oven dry grammage on the filter disk or screen of the specimen holder. The volume of suspension may be determined according to calculations given in Appendix A.

5.2 Place a preweighed filtering crucible or equivalent specimen holder on the rubber adaptor atop the Erlenmeyer flask and apply a gentle vacuum to the flask. Pour the pulp suspension uniformly over the surface of the filter disk or screen to form a pad of uniform grammage. A glass rod may be useful in stirring or gentle movement of fibers.

5.3 Place a cap containing a tiny vent hole over the crucible or specimen holder and insert the assembly into a suitable centrifuge cup containing sufficient blotter or absorbent wipe in the bottom of the shield to absorb the expressed water. See diagram in Appendix C.

5.4 Centrifuge the specimens at 900 G's for exactly 30 minutes at a temperature of 21° ± 3°C. The speed of the centrifuge required to produce 900 G's may be calculated according to the procedure of Appendix B.

5.5 Remove the filtering crucibles or specimen holders from the centrifuge cups, remove the vented caps, and weigh each specimen and holder to the nearest .001 g. Specimens should be weighed as quickly as possible after centrifuging to avoid evaporation loss. Alternately, the specimen or specimen and holder may be placed in tared weighing bottles to obtain the weight.

5.6 Dry the specimens and holders in a preheated oven for 2 hours or more at 105 ± 3°C. After drying, place the specimens and covered holders in a desiccator jar to cool for 30 minutes. Then weigh each specimen and holder to the nearest .001 g keeping the desiccator jar covered except when removing holders. Alternately, the specimen or specimen and holder may be placed in tared weighing bottles to obtain the weight.

5.7 Remove the dry specimens from the filtering crucible, specimen holder, or weighing bottle and discard. Thoroughly clean and dry the filtering crucible or specimen holder after each use using a laboratory glassware cleaner or equivalent.

6. REPORT

6.1 Obtain the wet specimen weight (W_5) by subtracting the weight of the filtering crucible or specimen holder alone (W_1) from the weight of specimen and holder after centrifuging (W_2).

6.2 Obtain the dry specimen weight (W_3) by subtracting the weight of the filtering crucible or specimen holder alone (W_1) from the weight of specimen and holder after drying (W_4).

6.3 Water Retention Value is reported to 3 significant figures, as ratio of grams of water to grams of fiber after centrifuging.

$$WRV = \frac{W_2 - W_4}{W_4 - W_1} = \frac{W_5 - W_3}{W_3}$$

7. ADDITIONAL INFORMATION

Water Retention Value is known to be sensitive to the number of G's, the specimen grammage, and time of centrifuging. Stock temperature, beginning pad moisture content, degree of packing of the moist pad, type of centrifuge (fixed angle or swinging cup) and other factors may have an unknown influence on results.

APPENDIX A

A.1 Pad Grammage (Basis Weight) - 1400 g/m^2 (860 lb/3000 ft^2)

A.2 Dry fiber required = grammage times filter disk or wire screen area (e.g., 1400 $g/m^2 \times \pi \times (.015m)^2$ = .99 g)

A.3 Milliliters of suspension required (M) = grams of oven dry fiber required divided by consistency where consistency is expressed as the ratio of grams of oven dry fiber over the milliliters of water in which the fiber is suspended. (e.g., $M_{(ml)} = \frac{.99\ g}{.01 g/ml}$ = 99 ml)

APPENDIX B

B.1 Measure the radius in meters (or feet) at which the specimen will be centrifuged (use the bottom of the pad or the top of the filter disk or screen).

B.2 The number of G's (ratio of acceleration on specimen to acceleration due to gravity) is given by the following equation:

$$G's = \frac{4\pi^2 W^2 r}{3600\ g_0}$$

where W = revolutions per minute
r = radius in meters (or feet)
g_0 = acceleration due to gravity - 9.8 m/sec^2 (or 32.2 ft/sec^2)

B.3 The speed of the centrifuge at 900 G's can be calculated

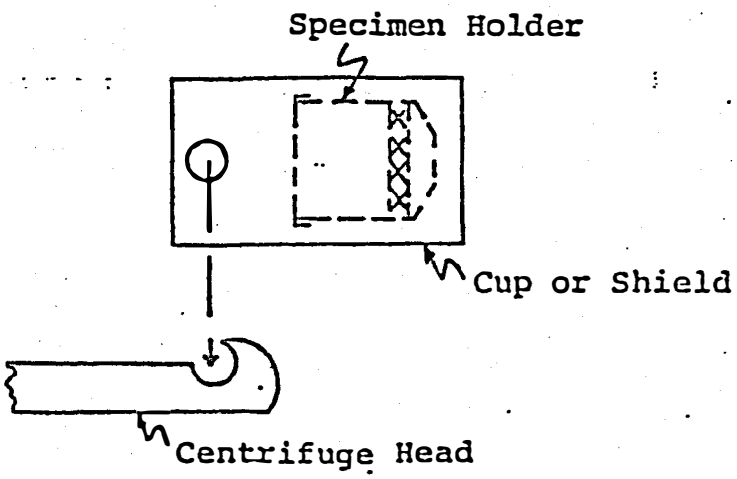
$$W = \left(\frac{3600 \times G's \times g_0}{4\pi^2 r}\right)^{\frac{1}{2}}$$

where W = RPM
G's = 900 by definition of test procedure
g_0 = 9.8 m/sec^2 (or 32.2 ft/sec^2)
r = radius in meters (or feet)

or $W = \left(\frac{804287}{r_{(m)}}\right)^{\frac{1}{2}}$ or $\left(\frac{2642659}{r(feet)}\right)^{\frac{1}{2}}$

APPENDIX C

C.1 Diagram of components for centrifuging



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