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The Effects of a Formation Shower and Serrated Slice on a Pilot Plant Papermachine

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THE EFFECTS OF
A FORMATION SHOWER AND SERRATED SLICE
ON A PILOT PLANT PAPERMACHINE

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ABSTRACT

The objective of this study was to examine the effects of a formation shower and serrated slice on formation, with comparison of an existing fourdrinier shake, at normal operating headbox consistencies and higher than normal consistencies. By replacing the shake with one of the other methods, metal fatigue could be stopped at the pivot point of the oscillating fourdrinier. The high consistency was used to determine if one of these alternative devices would eliminate flocculation tendencies and allow the reduction of water removal demand.

The papermachine used in this study was a pilot plant machine running at 60 FPM and producing a 60 lb sheet using a 50% hardwood and 50% softwood furnish.

The formation shower was difficult to utilize without making significant design changes, because of the configuration of the slice area. Because of this, its performance was unsatisfactory.

None of the methods deterred the tendency of the fibers to flocculate at high consistencies. It is possible that the formation shower could effect it to some degree if attached closer to the slice with a sufficient water jet pressure.

It was discovered that the serrated slice actually improved the formation quality significantly. This device is simple to construct and requires no fresh water or moving parts, and should be considered for further study.

There was also evidence from the tensile results which not only indicated directionality of fibers, but flocs as well.

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INTRODUCTION

It is believed that shake of the fourdrinier is more efficient than a serrated slice or formation shower at improving formation at papermachine speeds less than 400 FPM. The effects on formation may be equivalent or ultimately better at an increased headbox consistency due to increased microturbulence produced by the shower and slice. In anticipation of increased papermachine speeds and continued metal fatigue at the pivot point of the shake device, the benefits from a shower or shake may be proven substantial. This thesis examines the effects of a serrated slice and formation shower in comparison with the existing shake device, on formation.

ANALYSIS OF LITERATURE

SHAKE

The highest quality of formation is obtained by the ancient hand-made process. In this process, turbulence is induced in all directions. On a papermachine, this turbulence is accomplished by the use of a shaking device. The shake is the back-and-forth motion of the headbox end of the fourdrinier section, created by a rotating eccentric cam. If care is not taken when designing a shake device, metal fatigue can result at the points of pivot.

Shaking is done to reduce the tendency of the fibers to flocculate, which can occur in milliseconds once shear and turbulence to the stock dissipates (1). A well stated definition of a floc would be "an area of a sheet which exceeds the mean basis weight throughout, and which is surrounded entirely by material lower in weight than the mean weight (2)." These flocs must be dispersed with continuous microturbulence from the shake and shear forces from the machine direction by use of dewatering devices.

Shaking is most effective for papermachines running below 400 fpm (3). At these speeds, the cross-direction (CD) shake of 1/2 inch is very effective, because it is applied every few inches in the machine-direction (MD)(3). Above 400 fpm, there are not enough CD shear direction changes to keep the fibers dispersed.

SERRATED SLICES

With increasing speeds, it is expected to see an improvement in formation because there is an increase in induced turbulence from the drainage elements. Due to the evidence that the CD oriented shear from the shake device decreases and thus decreases formation quality, it can be seen that the need for a continuously-applied CD shear is essential.

In 1927, Colonel Thomas patented the serrated slice (see Figure 1). It consists of small circular indentations of approximately 1/4 inch deep and 3/4 inch to 3/2 inches apart, depending on the slice opening, on the upper edge of the slice. As the slice opening increases, the spacing, indentation depth and radius must increase.

Figure 1. Linerboard Machine Serrated Slice (1).

The indentations create MD ridges which are regenerated several times during their travel down-machine. The mechanisms involved will be discussed later.

The M/K Formation Index can be increased as high as 50% if used with a headbox with very uniform discharge (1). The disturbances found in approximately three out of every four headboxes will dampen the wanted turbulence from the serrated slice.

FORMATION SHOWERS

The formation shower was discovered by an unknown papermaker about the time the serrated slice was discovered. Along with the serrated slice, it can be used at any machine speed (1). It basically consists of a pipe with evenly spaced 0 degree nozzles in the CD of the machine. The needle jets of water must be directed at about a 15 degree angle to the stock surface and should have the same speed and direction.

Kallmes explains the reasoning for placement of a Precision Formation Shower (4). There are two perpendicular forces involved in the jets of water from the shower. One is the vertical component and the other is the horizontal component (see Figure 2).

The vertical component has two effects. One is the formation of stock ridges needed to create CD shear. It should be kept as small as possible to produce ridges. This will prevent the

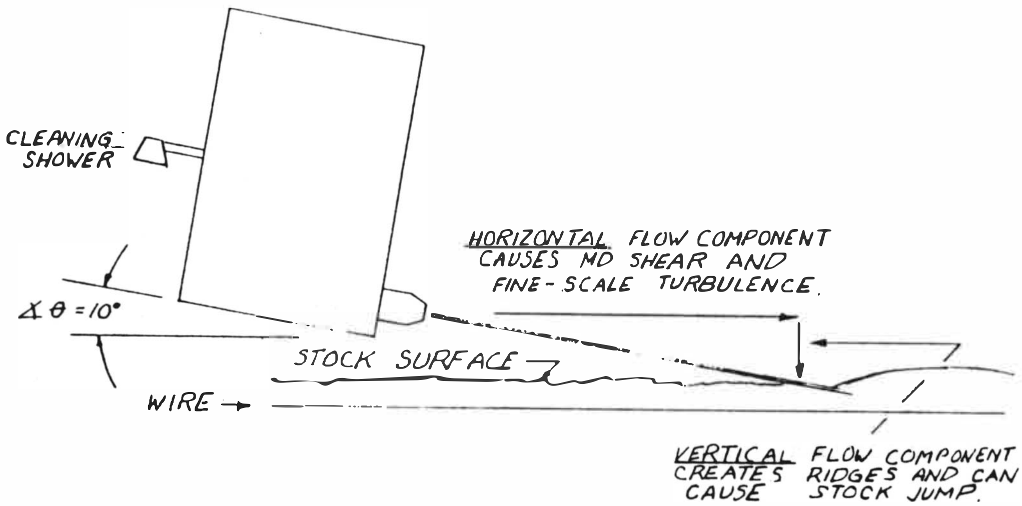


Figure 2. Mechanisms of a Formation Shower (4).

opposite, too much vertical force causing stock jump. Stock jump can destroy formation, especially on light basis weight grades.

The other effect is mixing. It helps formation but is very short lived because of the fact that it is vertical in nature.

The horizontal force component does most of the mixing due to the difference in velocity relative to the stock's. MD shear and fine-scale turbulence can be increased by increasing this difference as long as there are no adverse side effects.

It is also important to put the shower as close as possible to the stock to have the ability to maximize the horizontal flow and minimize the vertical flow. It was found that the greater the pressure that could be applied safely, the better the resulting formation (4).

Stock buildup on the lower back side of the formation shower can cause sheet breaks if it is allowed to drop into the stock at a high consistency. A fan shower aimed at the stock build-up area at low pressure can eliminate this problem.

The spacing of the nozzles depends on the slice opening, increasing with increased opening. The lowest possible pressure must be used to prevent stock jump, but must maintain a continuous jet of water. A Precision Formation Shower by M/K Systems Inc. is shown in Figure 3.

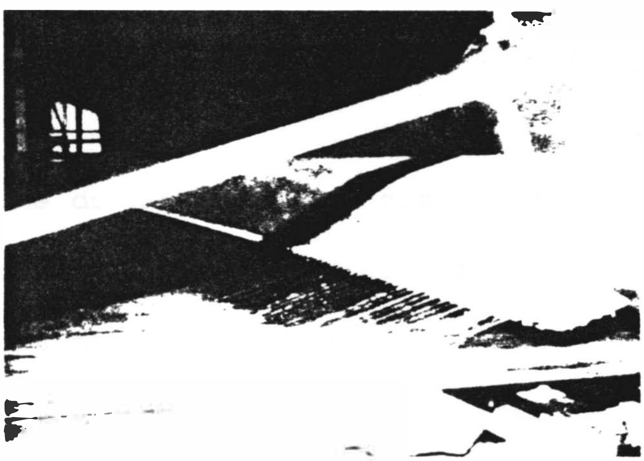


Figure 3. Precision Formation Shower (1).

Needle jets of water produce MD ridges similar to the serrated slice, by impinging on the surface of the stock. It is believed that the destruction and regeneration of MD ridges and their phase shifts produce CD oriented shear like the shake device utilizes (5). The collapsing of the ridges creates a CD mass transfer which causes CD shear.

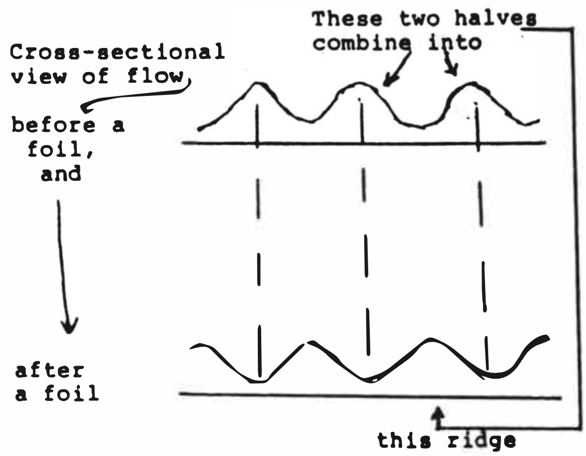


Figure 4. Foil Induced Phase Change (5).

Because of the downward forces created by drainage foils, the ridges are accelerated as they collapse (see Figure 4). When two adjacent ridges meet where there once was a valley, they are forced upwards by their momentum as they combine to form a new ridge. This is known as a phase shift. As many as seven shifts can be obtained.

If the vacuum pulses are of the correct amplitude, the new ridges will have the same height as the original two ridges. If the separation of these pulses are correct, there will be phase shifts occurring as long as there is water left for removal. This point would be around the dry line which has been determined to be at a consistency of 4-7% (6).

There are three characteristics of turbulence which disrupt flocculation: intensity, scale and rate of decay. Intensity will decrease floc size up to the 0.5-1.0% consistency range (5). At this range, the fibers are too concentrated to be completely separated. The scale of turbulence must be of the order-of-magnitude of the fiber's length. This is difficult to do because the scale of turbulence is in the same order of the order-of-magnitude of the generating device. The rate of decay is depended on the scale and increases with a decrease in scale.

In order for the above mechanisms to work there must not be any large scale turbulence present. This would dampen the effects of the microturbulence. These larger turbulence are usually the product of rectifier rolls or slice approach design.

Turbulence also reduces the filtration mechanism of drainage and enhances the thickening mechanism (7). Filtration occurs when there is a matt of fibers forming near the wire which act as a filter. There is a gradient of fiber density formed, increasing towards the wire. Thickening occurs with a relatively uniform

fiber density throughout the stock. This increases the drainage compared to that of filtering stock. It must be realized that a poor formation can also create a free draining environment. If formation is good, dewatering may be more difficult to do without the aid of turbulence.

STILL PHOTOGRAPHY

It is believed that we get about 80% of our information from the sense of sight (8). Therefore, any device which can aid in this sense is a powerful tool. The normal papermachine runs too fast to detect what is occurring on the wire. The least expensive way to stop the wire's motion is to use still photography, which has been used for the last twenty years. There is also the added advantage over the strobe light of having a picture for records or grade change comparisons. A 35-mm camera is usually used because of the large selection of accessories and interchangeable lenses.

Still photography is useful for observing phenomena which is unchanging. Looking at stock behavior on the wire by photographing gives a representation of what is occurring over an extended period of time. One phenomena which can be seen is stock jump. This is when actual droplets of stock are thrown above the surface of the forming web and indicates that there is too much turbulence present.

STATEMENT OF THESIS

The previous literature analysis stated that the shaking device is superior at papermachine speeds of less than 400 fpm, to other formation enhancing devices. It was also stated that a serrated slice or formation shower could be used at all speeds.

A communication with Otto Kallmes and the fact that literature could not be found on the comparison studies of the effects of a serrated slice, formation shower and shake device leaves the question; is it possible to replace the shake mechanism by either of these other devices; if not, at a higher consistency? By doing so, the metal fatigue factor on Western Michigan University's Pilot Plant papermachine could be eliminated.

To decide how to answer the above question, the formation comparisons will be analyzed using a M/K Microformation Tester with secondary measurements being opacity variance and tensile indices.

This thesis proposes to analyze the effects of the three mentioned devices at normal and higher than normal consistencies on a formation index.

EXPERIMENTAL DESIGN

Below is a list of materials and equipment for the serrated slice and formation shower:

Serrated Slice

- 3"x 24" flexible plastic
- 1/2" diameter hole punch
- Hammer
- file
- hack saw
- flame source
- 2 C-clamps

Formation Shower

- 1" diameter pipe, 30" in length
- 30, 0.055" nozzles, 0 degree
- Rubber gasket material
- Punches for producing nozzle washers
- Pipe end cap
- Pipe fittings (male)
- Securing wire
- Garden hose (with female fitting)
- Teflon thread seal tape
- Pipe wrench
- Pliers
- Pipe threader
- Craftsman #3 tap (1/4-28, 9-5221)
- Drill press
- Drilling lubricant and coolant

SERRATED SLICE

The serrated slice was not designed as part of the slice as was described earlier. It consisted of a thin rectangular piece of flexible plastic with a serrated edge.

To get the serrated edge on the plastic, 1/2 inch diameter holes were punched out at 1 inch intervals from center to center.

Then the plastic was cut along the holes leaving 1/4 inch indentations as Kallmes suggested (9)(see Figure 5).

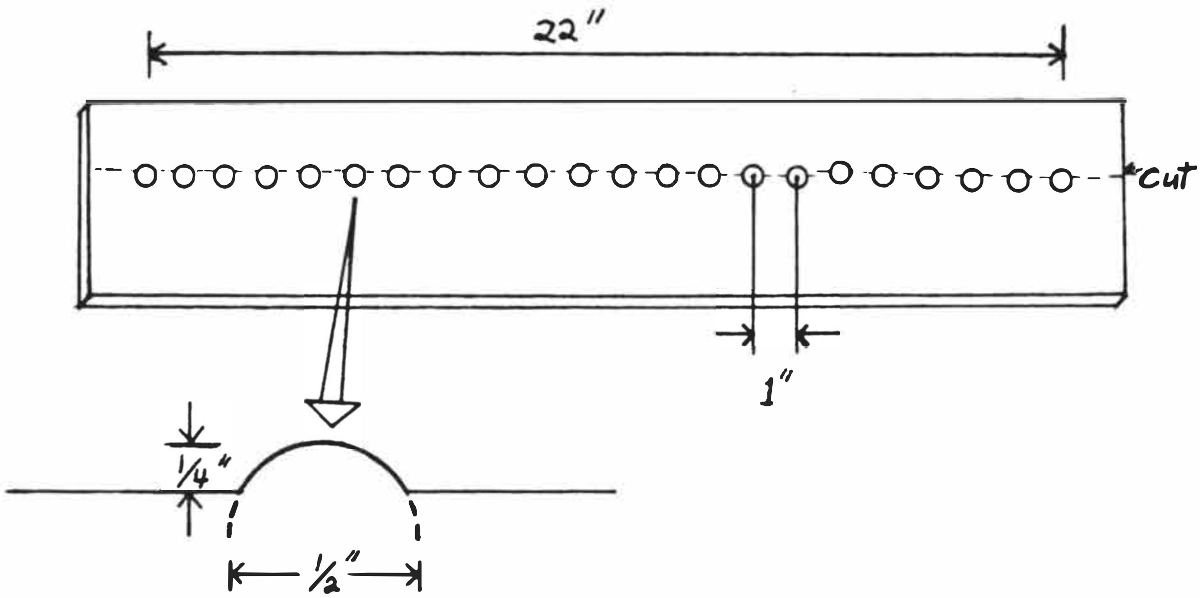


Figure 5. Serrated Slice Design

The rough edges were sanded and then smoothed by applying a flame. This was done to eliminate the possibility of snagging fibers and decreasing formation quality, especially at the higher consistency.

When it was time to use this device, it was fastened to a dam, 5 inches in front of the slice and 1/4 inch from the wire. Using C-clamps, it was secured to the dam so that the bottom edge extended below the dam to utilize the serration. The dam is normally used to create a secondary head.

FORMATION SHOWER

Dave Smith from Johnson Foils, Incorporated suggested the use of 0 degree needle showers with an orifice diameter between 0.047 inch and 0.055 inch and 1-2 psi pressure (10). It was also suggested to use the rule of thumb to space the nozzles at distances approximately equal to the thickness of the slice. In this case the thickness was about 3/4 inch.

John Crawford of Albany International, Drainage Systems suggested a minimum of 1 inch pipe diameter for the given orifice sizes (11). Albany International donated 32, 0.055 inch, 0 degree nozzles.

Thirty of these nozzles were used at 3/4 inch centers in order to span the 22 inch trim on the fourdrinier. The recommended flow rate for each nozzle was estimated to be 0.13 GPM using BETE Catalogue from Mueller Sales Incorporated. The fresh water flow available at the paper is 6-8 FPS. This gives a possible flow for each nozzle of approximately 0.49 GPM. The actual flow which was used was 0.04 GPM for each nozzle (see Appendix I).

The pipe was first threaded at one end for later capping with Teflon thread seal tape. Next, holes of 1/8 inch diameter were drilled with a drill press at 3/4 inch intervals. Marks were put along the length of the pipe to help align the holes in a straight line. It was difficult to drill the holes at similar

angles due to the equipment available. This resulted in slightly staggered water jet angles seen later, especially near the back side. The holes were then threaded using a #3 tap. The female nozzle bases were not used in order to get the nozzles close enough together and to simplify the design (see Figure 6).

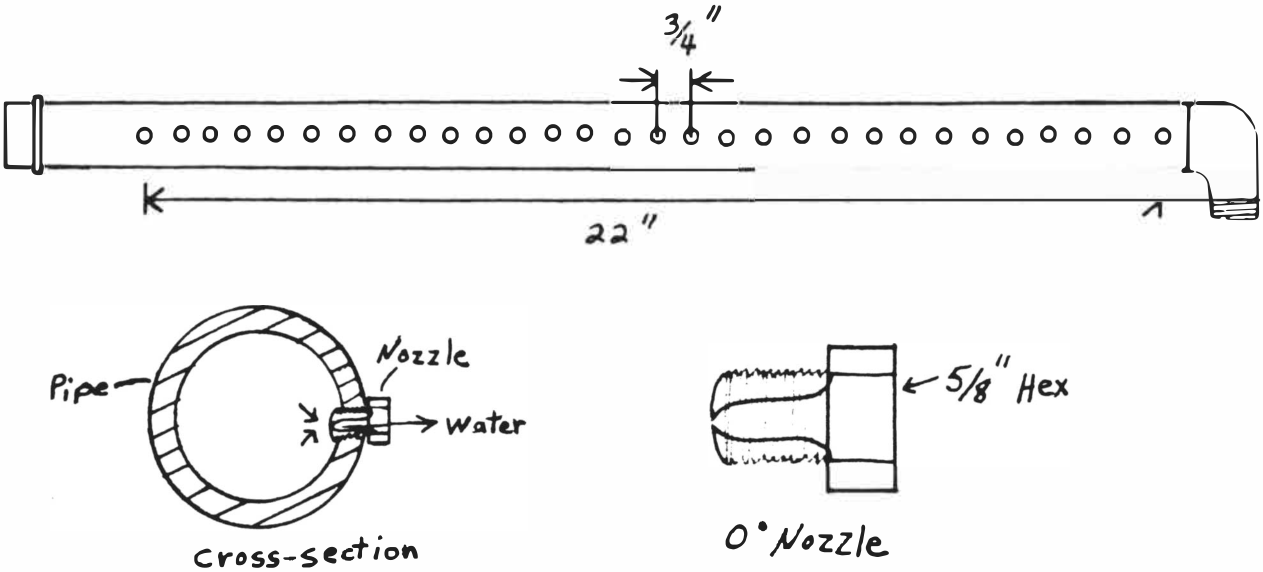


Figure 6. Formation Shower Design

Washers were made for the nozzles to prevent leakage by punching circular rings out of a rubber gasket material.

After attaching the nozzles and the end cap, fittings were applied to,the water receiving end to allow the correct connection to the garden hose at the wet end.

The formation shower was connected to the fresh water hose and then secured to the top of the deckle boards with securing

wire. This allowed easy changing of water jet impingement angle and removal of the shower for the serrated slice application. Water pressure could be adjusted by a hand valve at the opposite end of the fresh water hose.

The shower center was approximately 4 inches from the slice. It is desired to locate it as close as possible to the slice to minimize the water jets' vertical velocity components. The shower was as close as possible without removing the deckle boards (see Figure 7).

$$\theta = \mathrm{Tan}^{-1} \frac{1\frac{3}{4}}{11} \approx 9^\circ$$

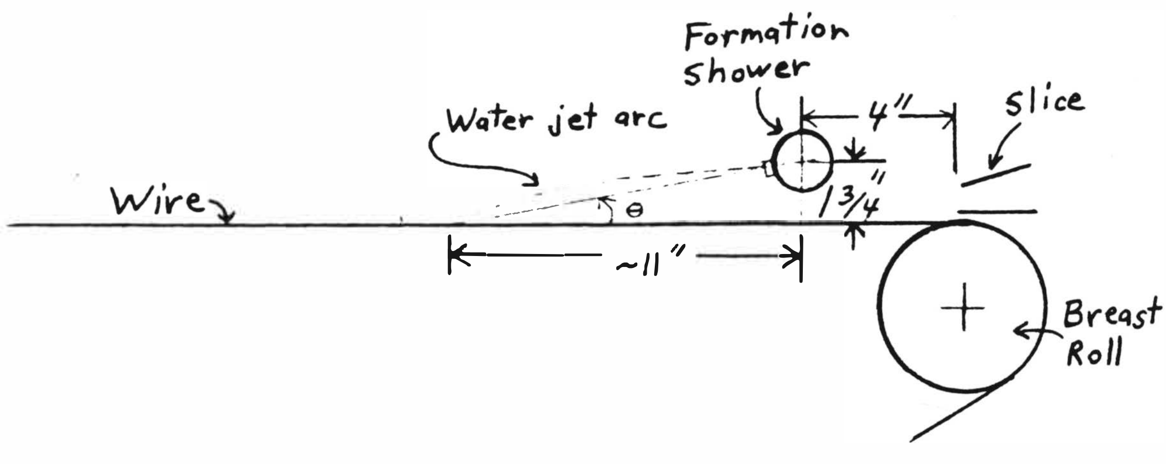


Figure 7. Formation Shower Placement

Once the shower was in place and the stock was applied to the running fourdrinier, the angle of impingement was adjusted.

The actual angle was closer to the desired 15 degrees when considering the slight arc of the water jets.

The shower pressure was adjusted by visually examining the open draw of the sheet. The pressure was reduced until the streaks from the water jets were eliminated. The allowed pressure was limited by the location of the shower. Still photography showed that the water jets were, unfortunately, not continuous.

EXPERIMENTAL PROCEDURE

PRELIMINARY

Attempts were made to use the opacity meter in a unique way by trying to utilize a smaller circular testing area. A black washer was placed over the light window of the opacity meter, restricting the area of light passing through the paper sample. By accomplishing this, it was speculated that a higher opacity variance could be measured. This would be done by measuring areas which would be closer to the actual size of flocs and light basis weight areas between the flocs.

The overall opacity was higher when the washer was in place. The reason could be that wight light was reflecting back to the opacity sensor from the smooth metallic surface of the washer. Unexplained was the decrease in opacity variance using the washer.

Pictures were taken of the area on the fourdrinier which were to be studied. It was uncertain whether the flash from the instamatic camera would bright enough and whether the camera would stop the image without blurring. It was concluded that it would be satisfactory for an aid in the discussion of the results.

Below is a list of the materials and equipment used in this thesis:

Machine Run

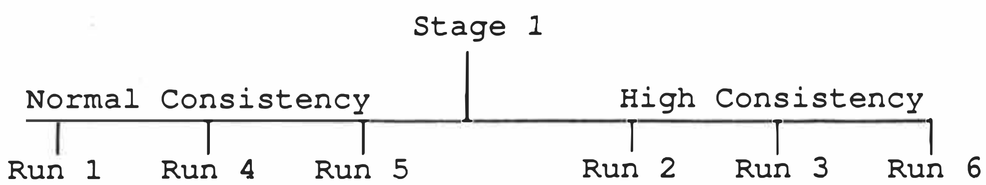
- Roll markers
- Felt markers
- Instamatic camera with flash
- Instamatic film
- Sample bottles
- Labels
- Bucket
- Scale
- Watch with second hand
- Bleached softwood (50%)
- Bleached hardwood (50%)

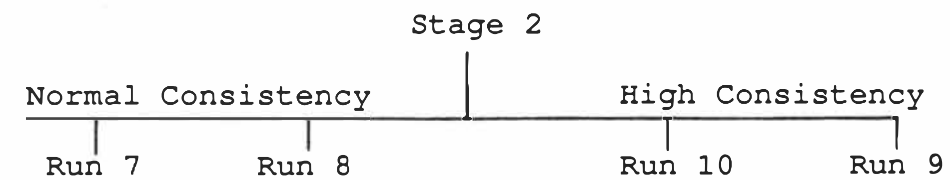
Testing

- Tensile tester
- Opacity meter
- Weight scale
- Vacuum funnel
- Filter pads
- Dryer plate
- Freeness apparatus
- M/K Microformation Tester

MACHINE RUNS

The following flow chart was used for the machine run:





Run #	Method
1	No Shake
2	No Shake
3	Shake
4	Shake
5	Shower
6	Shower
7	Slice
8	Slice and Shake
9	Slice and Shake
10	Slice

First, the furnish was produced by using 50% bleached hardwood and 50% bleached softwood with no additives. Since the effects which were studied were non-chemical, a simple basic furnish was used. The freeness was dropped to 477 SCF by a Hollander Beater to give a common freeness value at the pilot plant.

Next, the formation shower was attached to the deckle, as mentioned earlier. As the stock entered the wire, the shower fresh water supply was opened to the desired pressure and angle of impingement.

A target of 60 lb (24"x 36"x 500 sheets) basis weight was aimed at. The intention was to use the highest basis weight possible which could be accurately measured on a M/K Microformation Tester so that flocculation would be encouraged. The 60 lb basis weight was suggested by Jessica Carr of James River Corporation because of the good strong reading resulting on the M/K Microformation Tester (12).

Finally, the basis weight was achieved at about 61 lb as indicated by an on-line Accuray basis weight scanner readout. The roll of paper was marked and flagged to indicate the start of the first stage of six runs.

During each run, a sample was extracted from the recirculation of the headbox for consistency checks. Two to four pictures were taken of the experimental area during each run. The machine speed, wet line location, basis weight reading, and stock flow were recorded at the time of sampling. Other parameters noted were the amperage drawn on the shake motor before stock entry to the wire and the use of the dandy roll. Observations were also recorded and mentioned in the Discussion and Results section of this report.

There was a break in the production between the two stages in order to remove the shower and attach the serrated slice. After the machine had settled down at a normal headbox consistency and the correct basis weight, four more runs were completed. It was decided to run the shake with the serrated slice in order to see if the shake would improve the formation. Also, time and excess furnish allowed this extra information to be obtained.

TESTING

After the two stages were completed, the finished roll of paper was placed in a test station at standard conditions for at least 24 hours, along with the consistency samples. The roll was then slabbed down and separated into individual runs and placed in plastic bags and sealed until needed for testing.

Non-constructive tests were completed first. Six, 8.5 inch x 11 inch samples per run were cut, placed in plastic bags, and then sealed. They were brought to James River Corporation in Parchement, Michigan to be tested on the M/K Microformation Tester.

Twenty five opacity readings per run were completed in the same direction according to TAPPI Standards T425. Opacity standard deviations were examined as an indication of formation quality. It is assumed that the poorer the formation, the greater the resulting opacity variance; especially if the area of measurement is equivalent to the size of the flocs.

Ten basis weight samples per run were measured using three, 6 inch diameter circles per sample according to TAPPI Standards T410.

Twenty MD and CD tensile samples per run were measured according to TAPPI Standards T494. The smaller 15 mm width sample size was chosen in order to increase the sensitivity of the test to low basis weight areas. The analogy to this is the fact that a

chain is only as strong as its weakest link. Here, the chain is the sample and the weakest link is the point of lowest basis weight. Tensile indices were calculated to eliminate the influence basis weight variations have on tensile strength.

Consistency measurements were made according to TAPPI Standards T240. Do to lack of sample size, only one consistency measurement was taken for each run, except Run 9. The sample for Run 3 was missed, but was assumed to be equivalent to that of Run 2 . This is a fairly accurate assumption because the only change which was made was the shake was started.

The results were recorded and analyzed with the assistance of Western Michigan University's Statistic Department. A program called SAS General Linear Models Procedure using least squares means.

RESULTS AND DISCUSSION

The general idea was to have two sets of data for each method (10 runs), one at normal headbox consistency, and one at higher than normal consistency. As can be seen in figure 8, the consistency varied considerably. The normal consistency for the shake method was actually higher than normal and equivalent to the higher than normal slice and shake (Run 9) consistency. This variation brought about difficulty in evaluating the results. Although this was undesirable, it did bring up several questions for further recommendations which will be stated later. More evidence of stock flow problems was seen in the variation in basis weight between the methods (see figure 9). The only indication that the basis weight was off target by a significant amount was at the end of the shower method run when the Accuray display showed a 52.8 lb basis weight (see Appendix II). The Accuray readings at the time of consistency sample taking were from 58.6 lb to 61.9 lb. For practical purposes, formation index results are said to be comparable within weight ranges of plus or minus 20%. The resulting variations in this report are within these tolerances.

There was also an upset in the stock flow at the normal consistency, shake run as can be seen by the 18.8 GPM reading as apposed to the normal 16.0-16.5 GPM (see Appendix II).

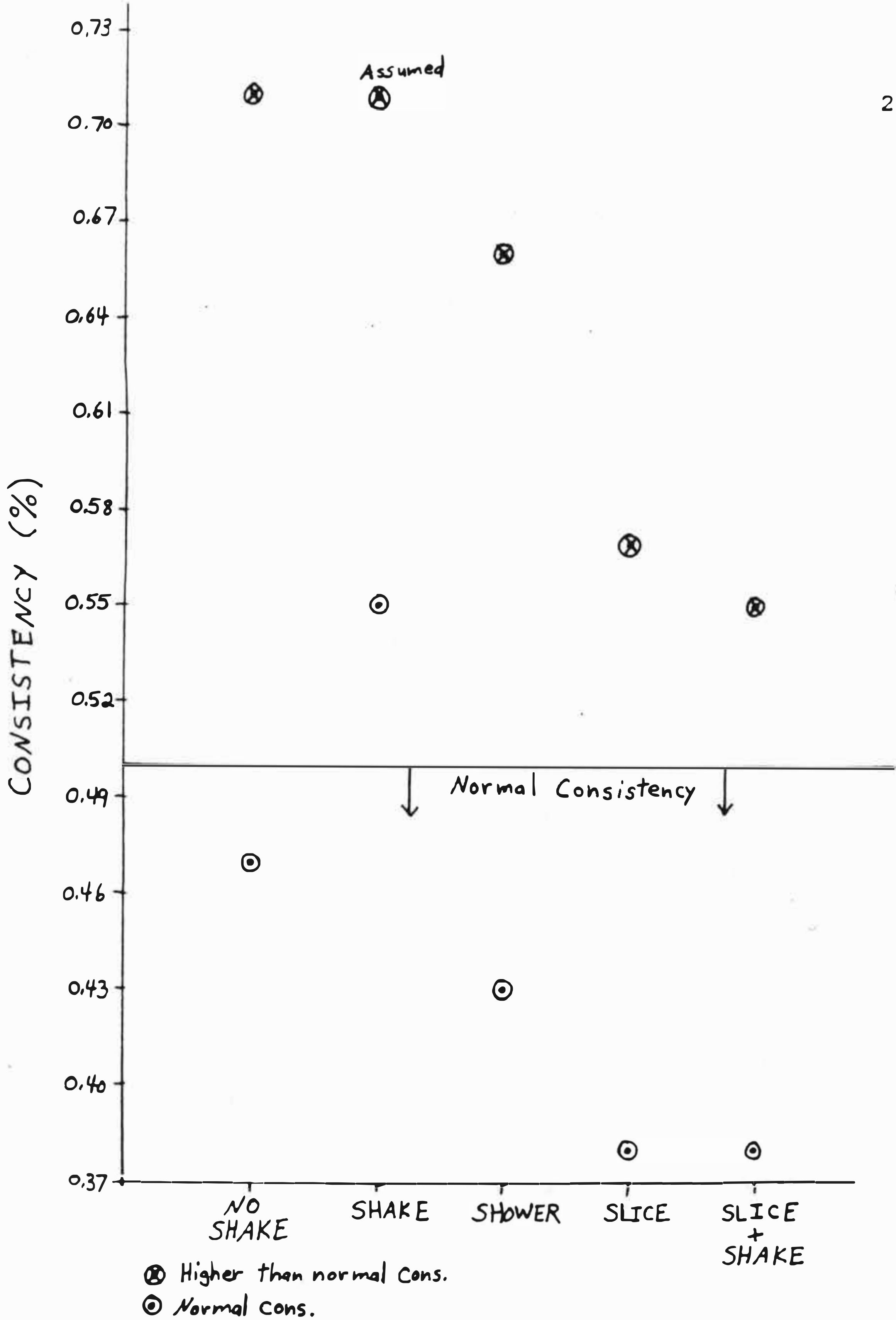


Figure 8. Consistency Reproducibility
Within the Methods

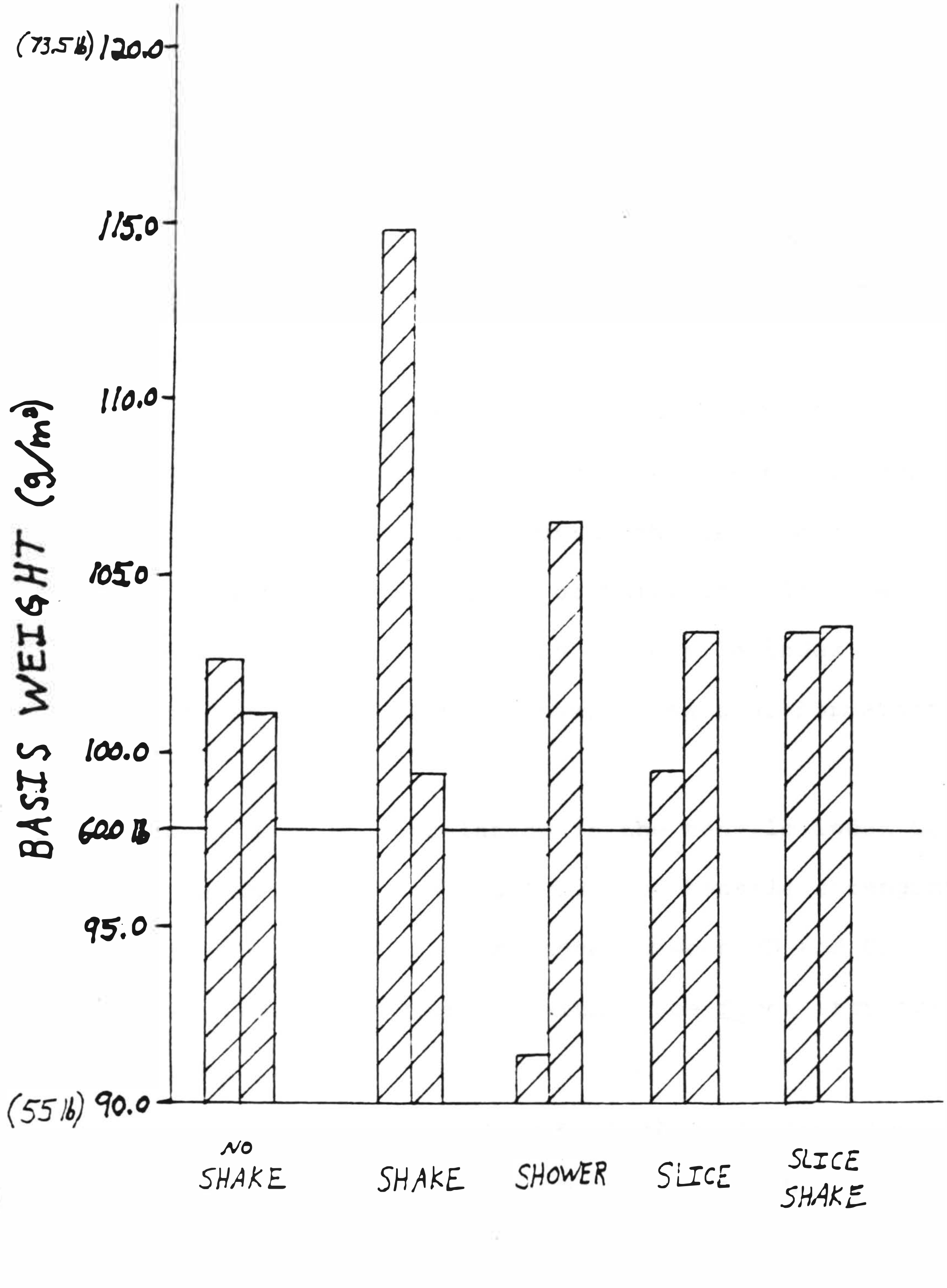


Figure 9. Basis Weight Reproducibility Within the Methods

MD AND CD TENSILE INDICES

Looking at figures 10 and 11, there is an indication that the MD tensile index was affected by the method more than the CD tensile index.

There is an obvious improvement in tensile at the lower of the two consistencies, giving reason to believe that the consistency effects tensile.

It is assumed that tensile would be susceptible to variations in formation, as stated earlier. The sensitivity was enhanced by using a narrow test strip during the tensile procedure. There is a slight indication of this, especially with the CD tensile index (see figure 12). The CD tensile index standard deviation bars are slightly longer below 5.00 formation index.

There is a well defined correlation in the tensile index to formation index. As the formation improved, the tensile strengths increased, MD more than CD. This difference between MD and CD indicates there is something occurring within the fiber structure which is directional in nature.

One speculation is there may be an elongation in the floc structures which is more pronounced as the flocculation increases. There are many physical phenomena occurring within the sheet which are beyond the scope of this thesis.

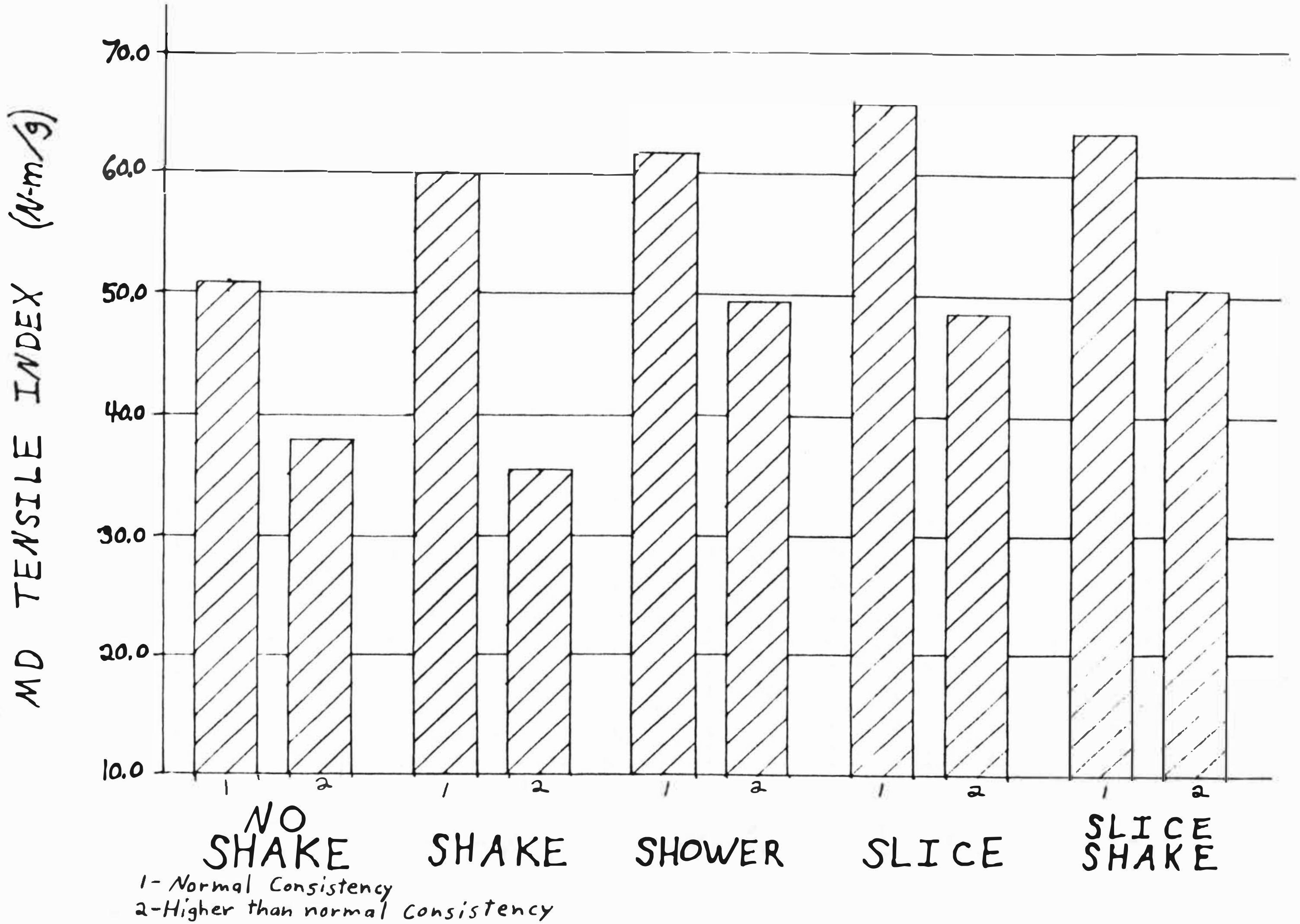


Figure 10. MD Tensile Index Vs. Method

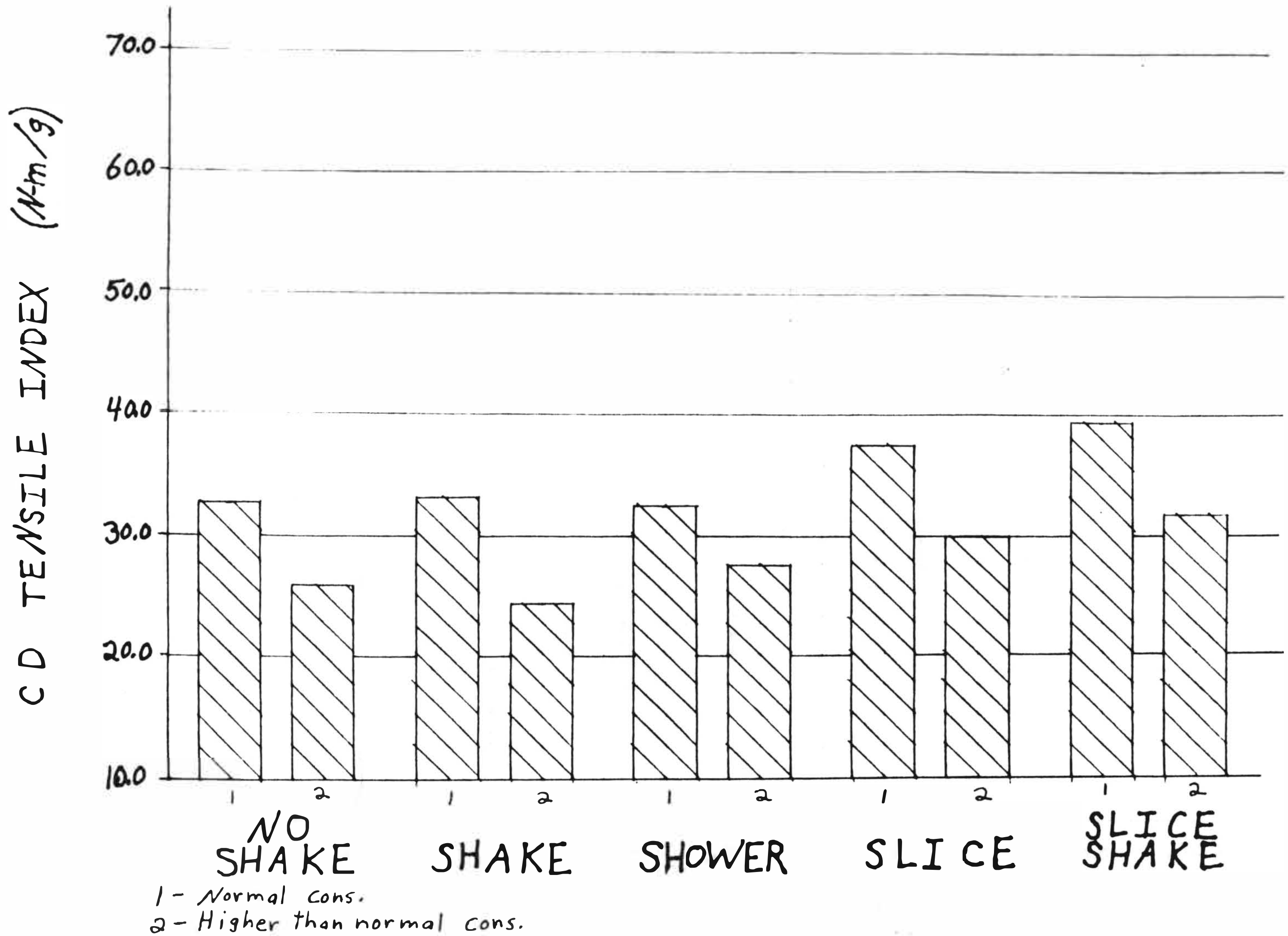


Figure 11. CD Tensile Index Vs. Method

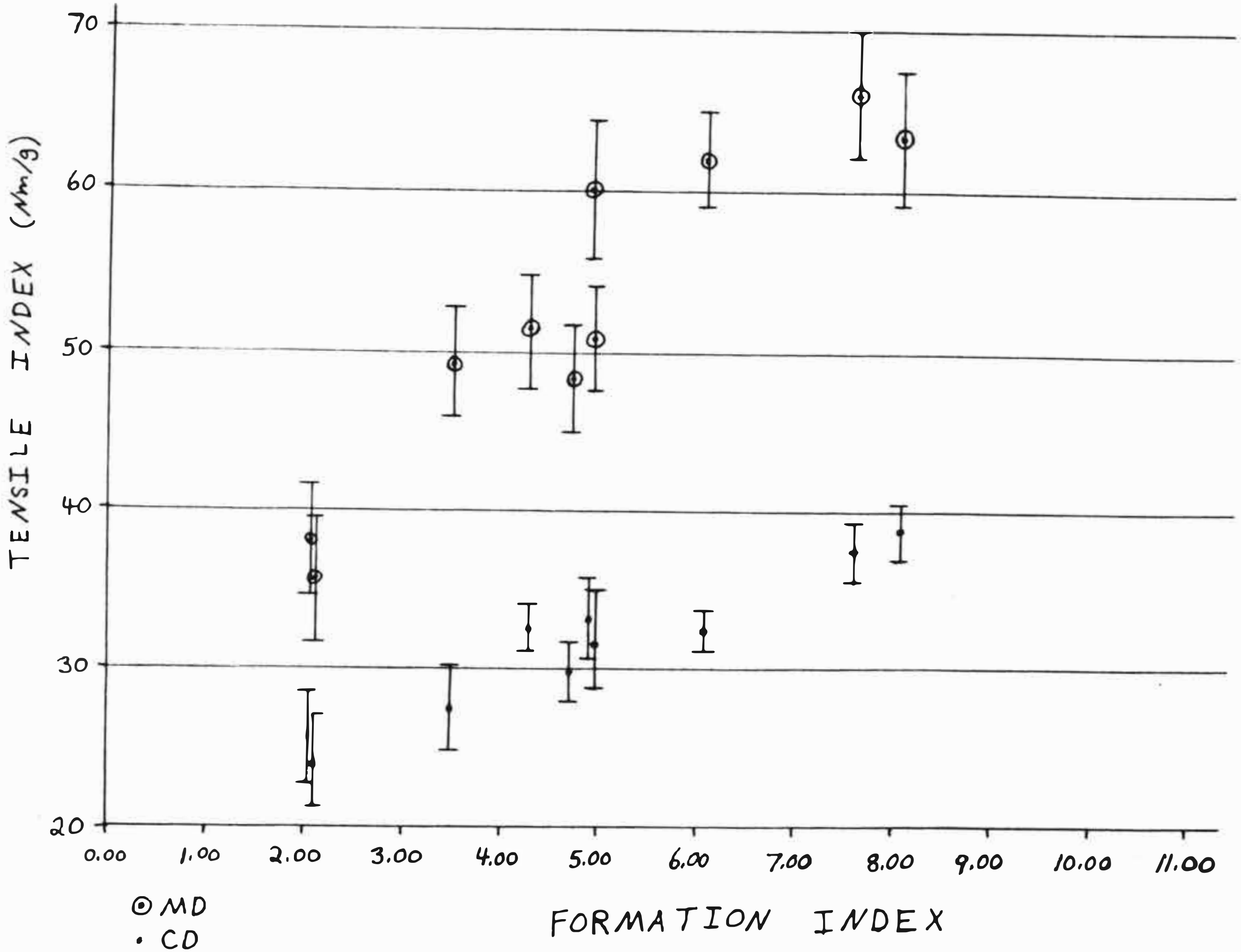


Figure 12. Tensile Index Vs. Formation Index

The problem of the varying consistency created the questions:

- Is the tensile being improved by the improvement of formation?
- Is the formation being improved by a decrease in consistency?

These questions will be studied in more detail later in the discussion.

Indication that the consistency influenced the formation index can be seen by the similar correlation between the tensile and formation index (figure 12), and that from the tensile and consistency (figure 13).

OPACITY DEVIATIONS

There is a strong indication of influence on opacity standard deviations by the methods (see figure 14). As explained earlier, the higher the quality of formation, the lower the deviations in opacity. As will be seen next, the formation index was greater for the slice method and the slice with shake method.

Figure 15 shows that the opacity became more stable at the higher formation index. The lines connecting the dots have no significance in values between the dots, but only show the general trends of the opacity deviations with increasing quality of formation.

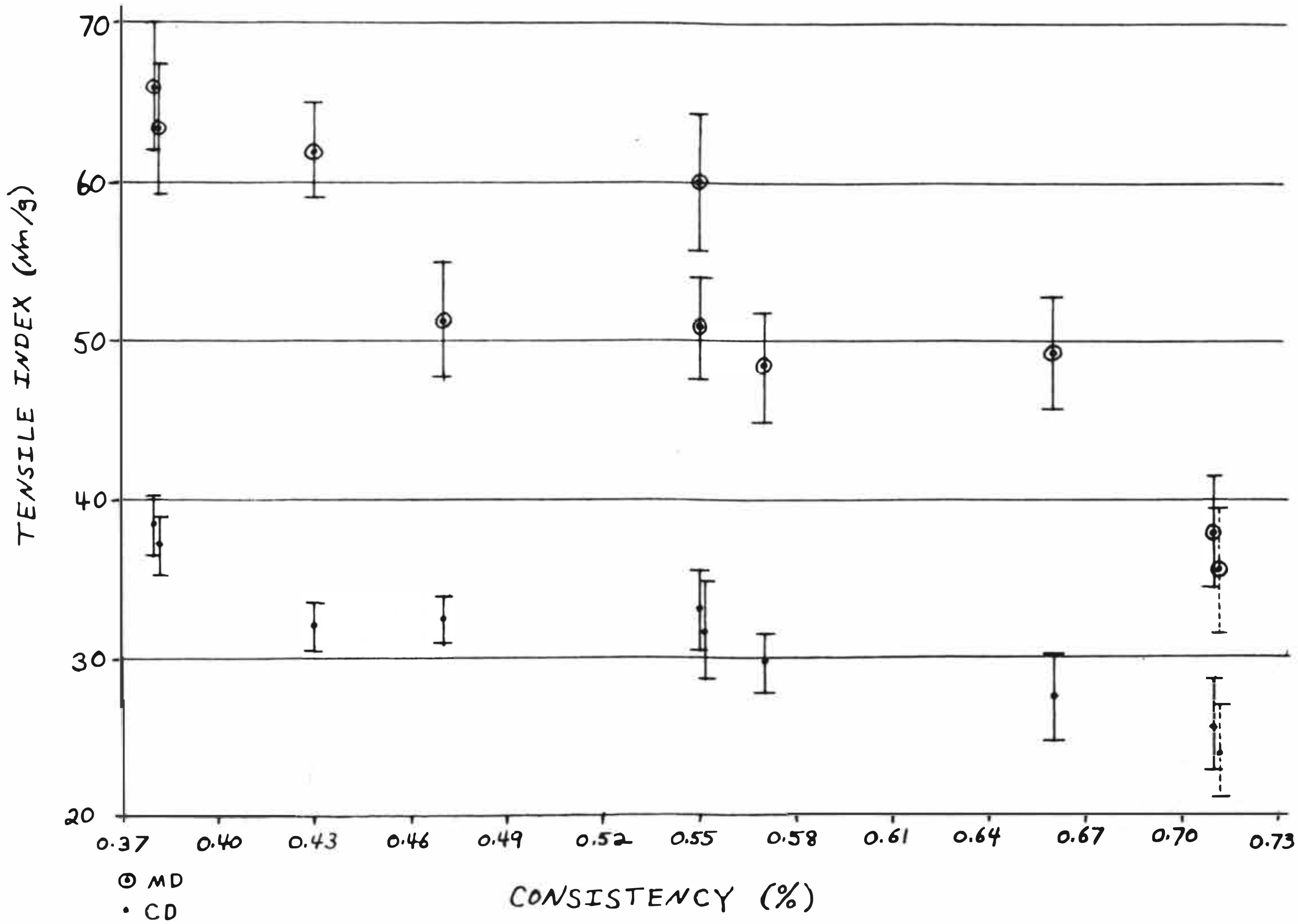


Figure 13. Tensile Index Vs. Consistency

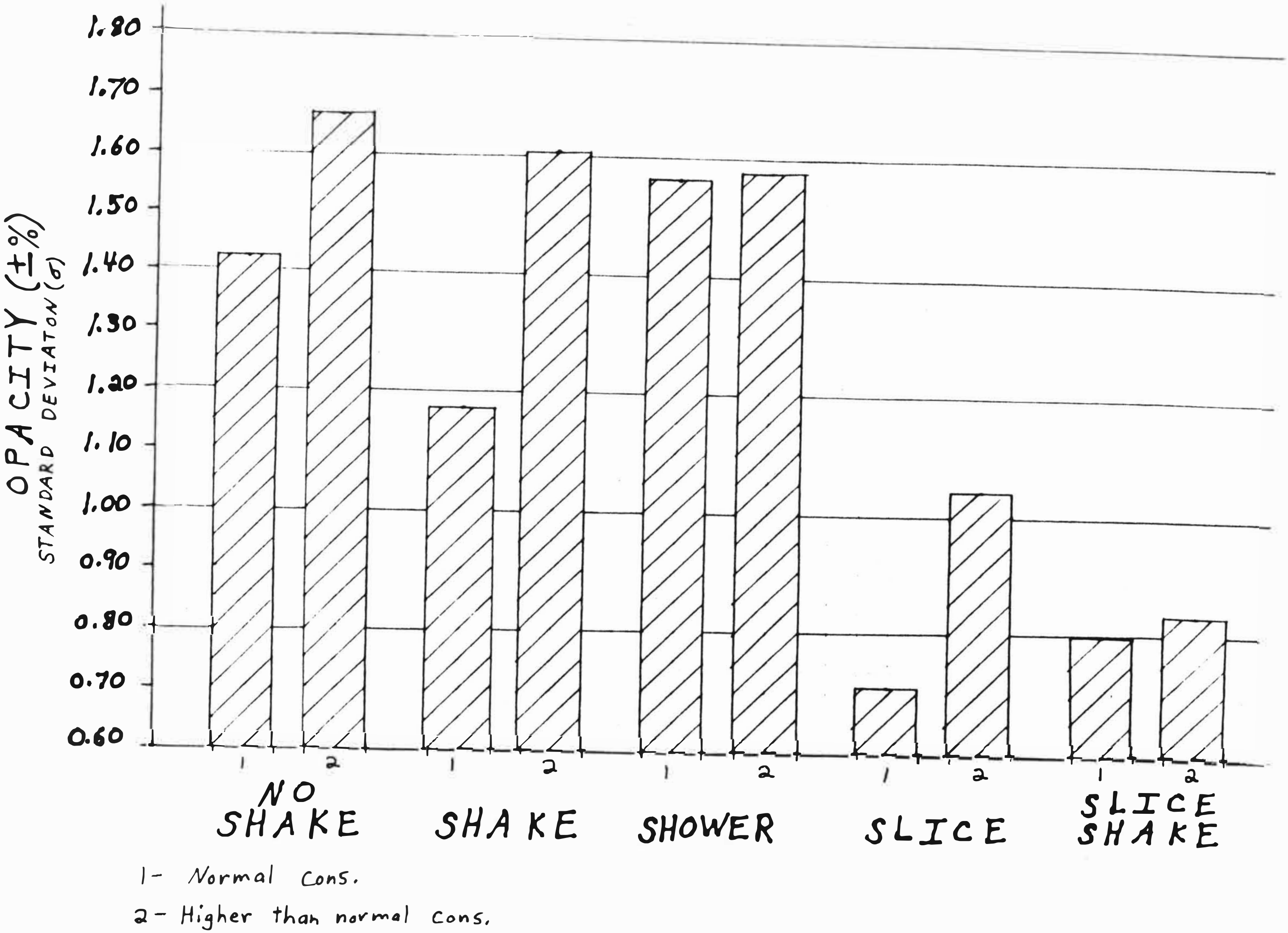


Figure 14. Opacity Deviation Vs. Method

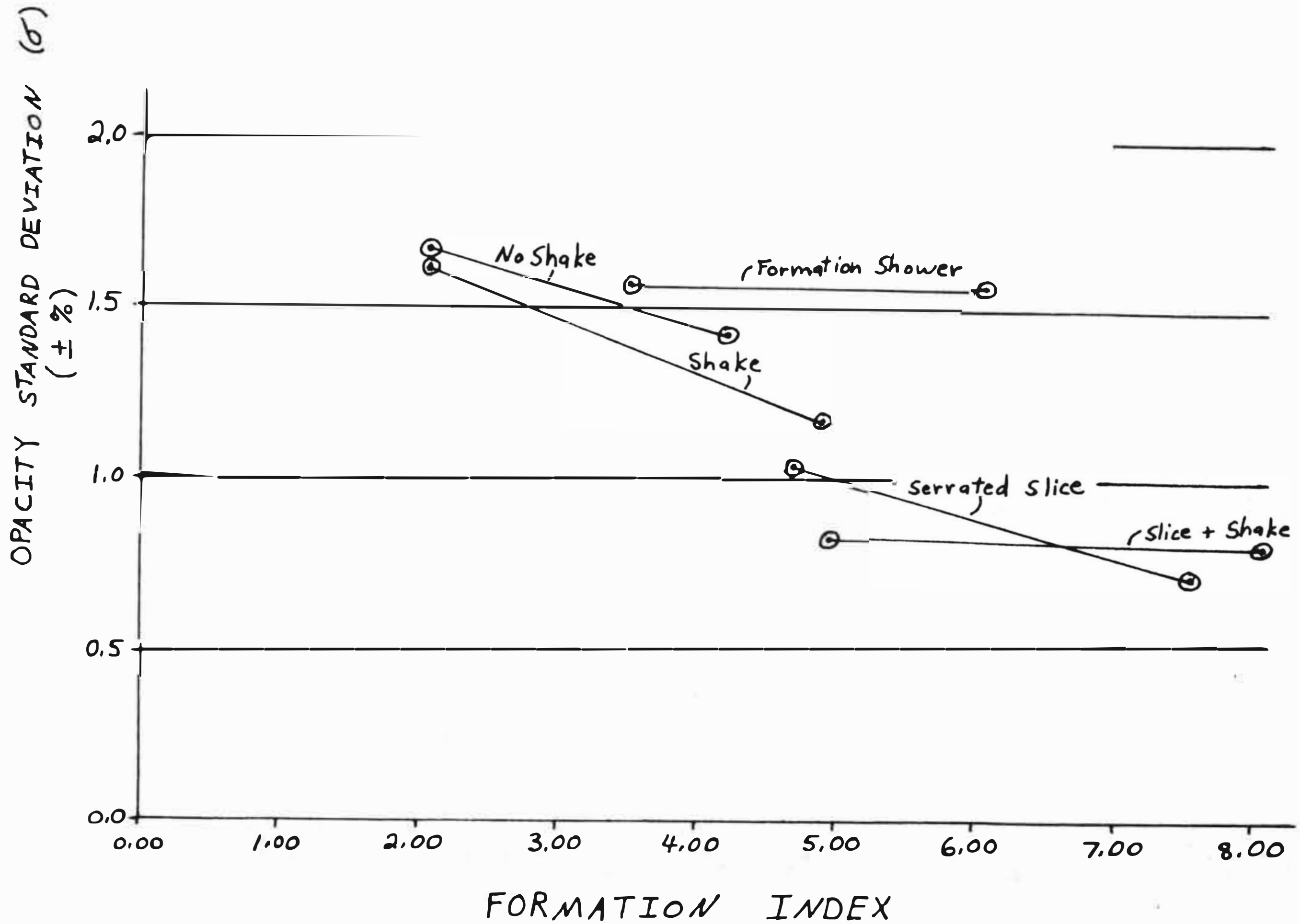


Figure 15. Opacity Deviation Vs. Formation Index
for Individual Methods

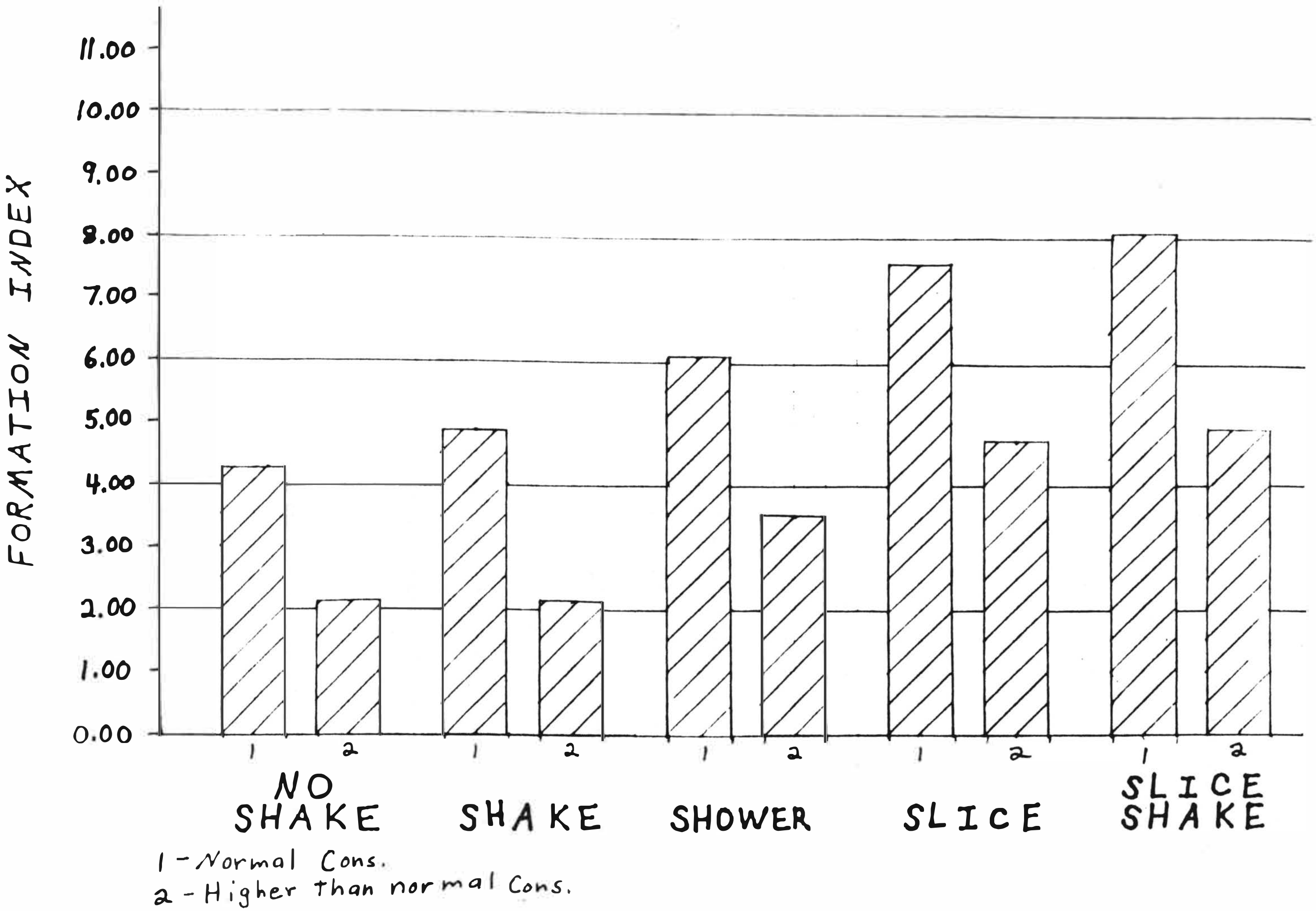


Figure 16. Formation Index Vs. Method

FORMATION INDEX

Now is the time to analyze the question of the significance of the method and consistency on the formation index. If figure 16 was used to evaluate the method's effect on formation, it would seem as if each consecutive method increased the quality of the formation. Before this evaluation is considered, the effects which the basis weight and consistency have on the formation index must also be studied for a correlation.

To see if the basis weight correlated with the formation index, figure 17 was constructed. It appears obvious that there is very little due to the scattering of the data points.

Looking at the correlation of consistency to the formation index, there is much more evidence in a straight line correlation within the data points (see Figure 18). It is a well known fact that the higher the headbox consistency, the more flocculation results. Kallmes and Perez state that it is impossible to disperse flocs in the 0.5%-1.0% consistency range by using turbulence intensity (5).

The manual for the M/K Microformation Tester indicates that a bin number difference of at least 2 was needed to indicate a significant difference in formation index. Using this criteria, there is a significant increase in formation index when replacing the shake method with the shower method, and again when going

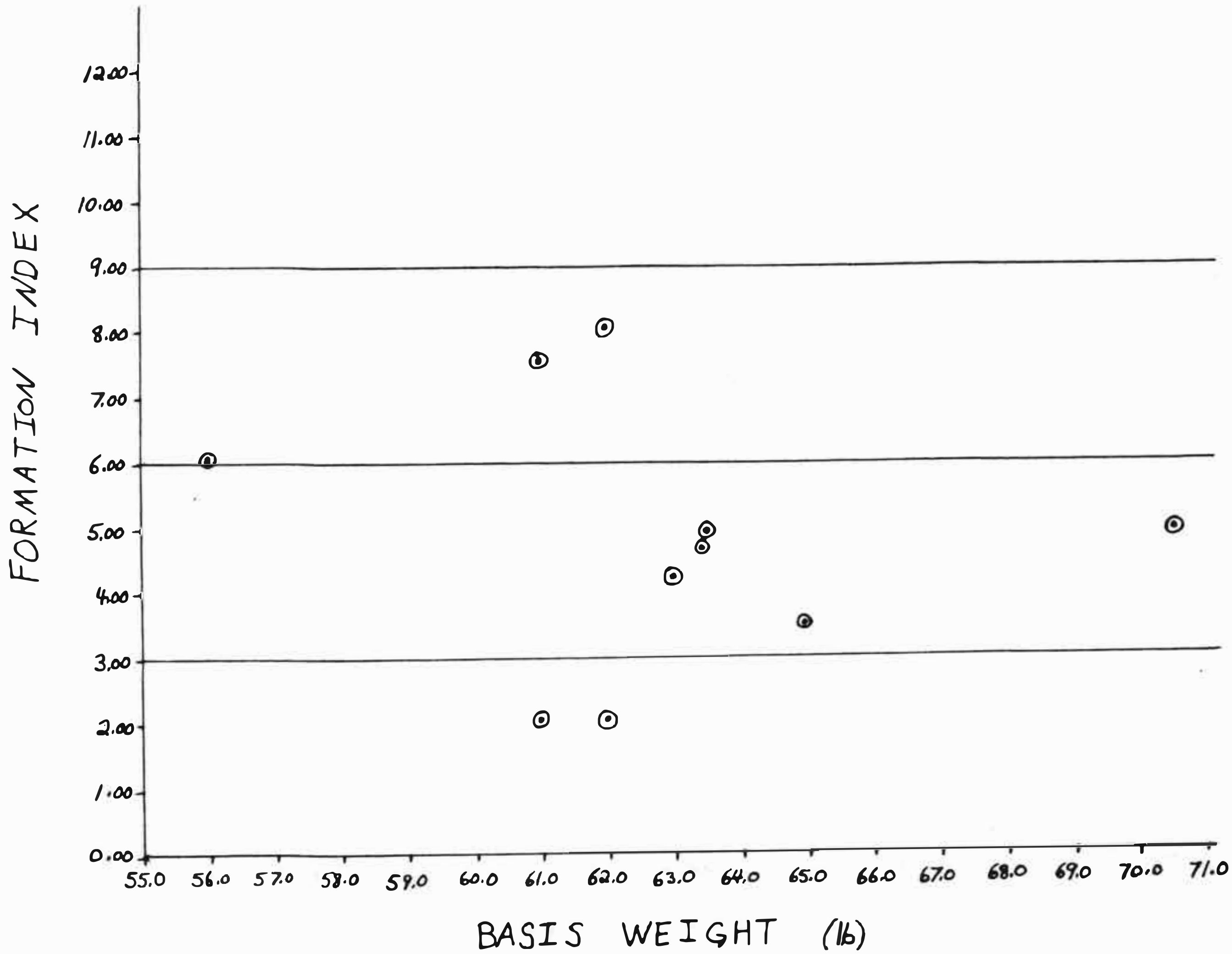


Figure 17. Formation Index Vs. Basis Weight

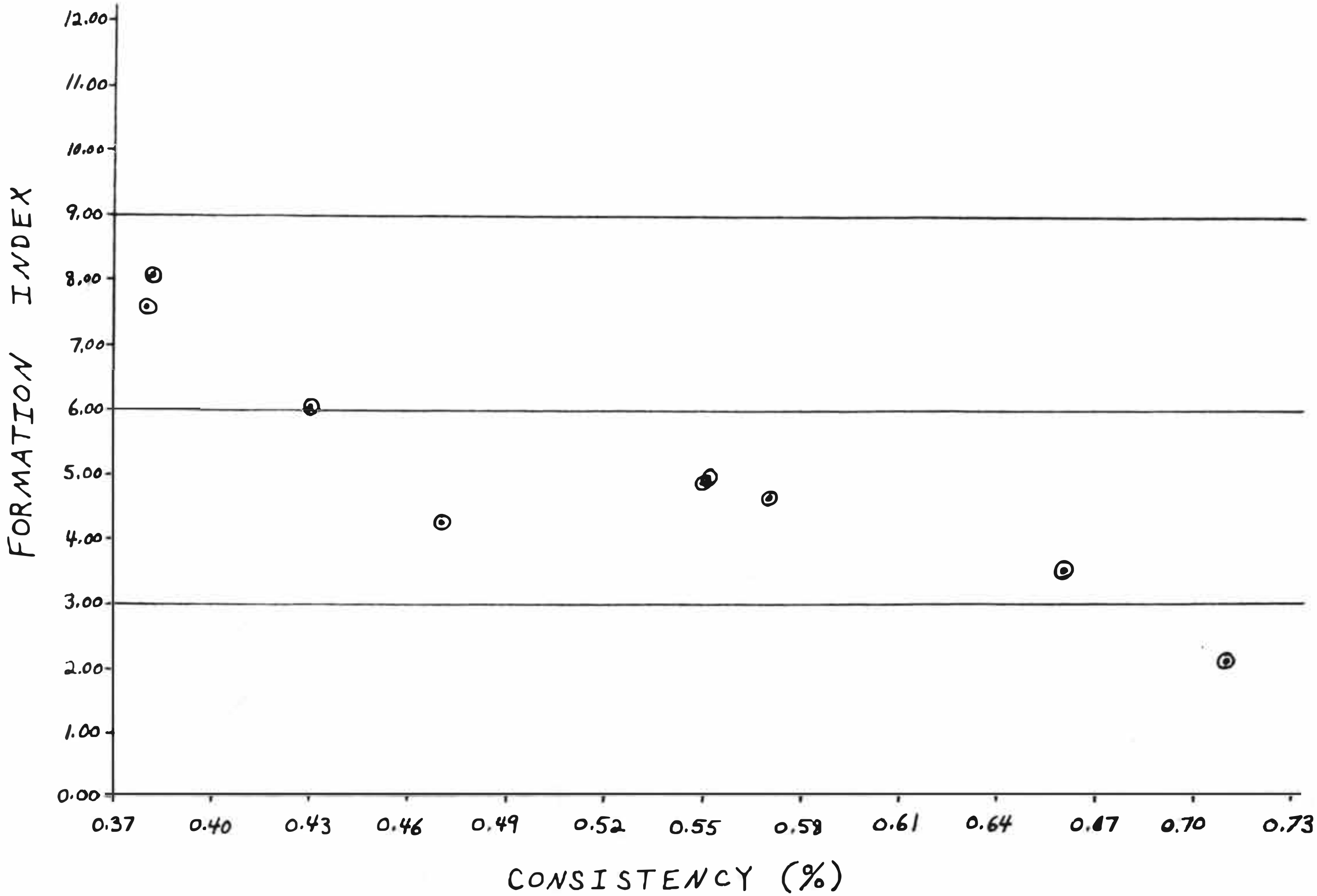


Figure 18. Formation Index Vs. Consistency

from the shower to the slice method. Because of the varying consistency, these conclusions are not valid. A way of eliminating the variations in basis weight and especially, consistency, was needed to help make sound conclusions.

A Linear Models Procedure was used with a 95% confidence level. A value in Table 1 and 2 of more than 0.05 indicates a less than 95% confidence that the two methods are significantly different. The methods 1,2,3,4 and 5 coincide with no shake, shake, shower, slice, and slice with shake.

In Table 1, there is only one method change which significantly improved formation index over the previous method. This was the use of the slice over the shower. There was a 92.2% confidence level that the shower method was significantly different than the shake. The same two method changes were significant using the minimum of 2 bin number differences for significance earlier.

When looking at Table 2, it is conclusive that the slice method again, was significantly better than the shower, as well as the shake method. It also indicates that the shake was significantly better than no shake, which was expected.

Table 1. Methods Comparison with Constant Basis Weight

GENERAL LINEAR MODELS PROCEDURE
LEAST SQUARES MEANS

METHOD	FORM LSMEAN	PROB > T I/J	HO: LSMEAN(I)=LSMEAN(J) 1	2	3	4	5
1		1	.	0.5375	0.0104	0.0001	0.0001
2		2	0.5375	.	0.0778	0.0002	0.0001
3		3	0.0104	0.0778	.	0.0432	0.0108
4		4	0.0001	0.0002	0.0432	.	0.5271
5		5	0.0001	0.0001	0.0108	0.5271	.

Table 2. Methods Comparison with Constant Consistency

GENERAL LINEAR MODELS PROCEDURE
LEAST SQUARES MEANS

METHOD	FORM LSMEAN	PROB > T I/J	HO: LSMEAN(I)=LSMEAN(J) 1	2	3	4	5
1		1	.	0.0001	0.0001	0.0001	0.0001
2		2	0.0001	.	0.4445	0.0049	0.0002
3		3	0.0001	0.4445	.	0.0220	0.0008
4		4	0.0001	0.0049	0.0220	.	0.2157
5		5	0.0001	0.0002	0.0008	0.2157	.

VISUAL OBSERVATIONS

Moisture wrinkles were predominate in the paper made with the higher than normal consistencies. The heavy flocs created difficulty in removing water and problems with local curling. The sheet had a mottled appearance, also. This supports the statement made earlier that 0.5%-1.0% consistency was difficult to deflocculate. The mottled appearance was seen on the wire during the runs of high consistency (see figures 20,23,26 and 27). The microturbulence was dampened by the high density of the stock.

Streaks were seen in the paper made with the formation shower due to an excess in water jet pressure. This probably attributed to the higher opacity variations. The dandy roll helped to smooth out the streaks to some extent.

In figures 22 and 23, there is some indication of stock jump as well as non-continuous water jets. The shower should have been lowered to try to eliminate these problems.

The serrated slice created the best looking sheet. There were six phase changes seen after the slice during the slice and slice with shake runs at the lower consistencies (see figures 24 and 25). This phenomena was desireable for the provisions of microturbulence and was expected according to cited literature.

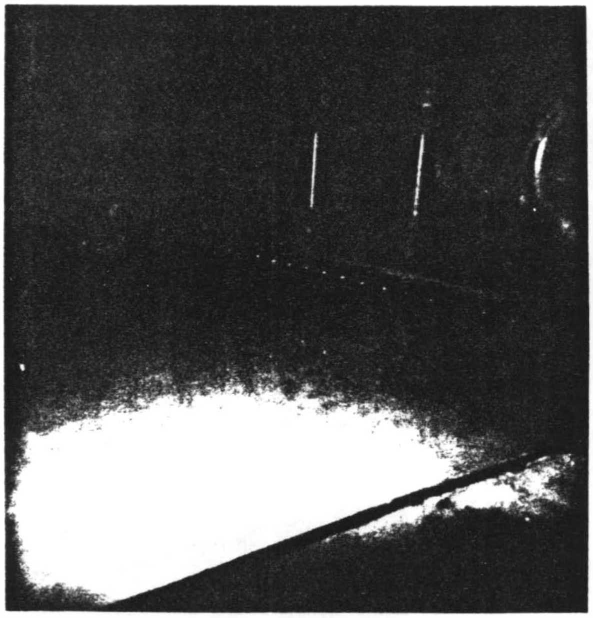


Figure 19. Stock Appearance with
No Shake at Normal Consistency

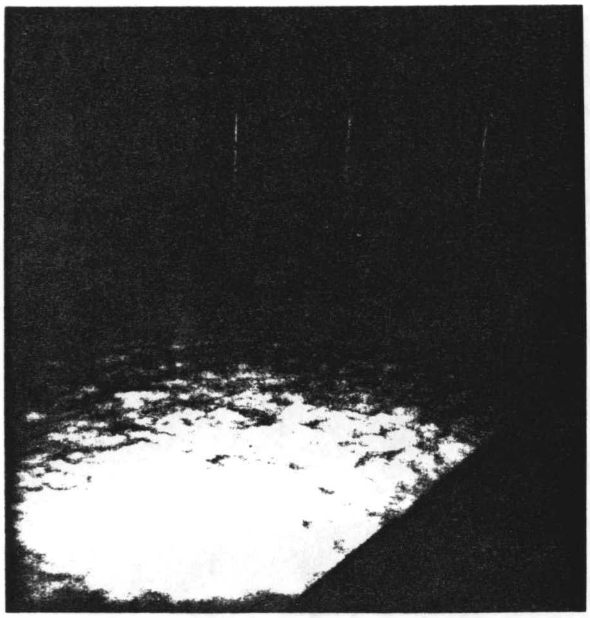


Figure 20. Stock Appearance with
Shake at High Consistency

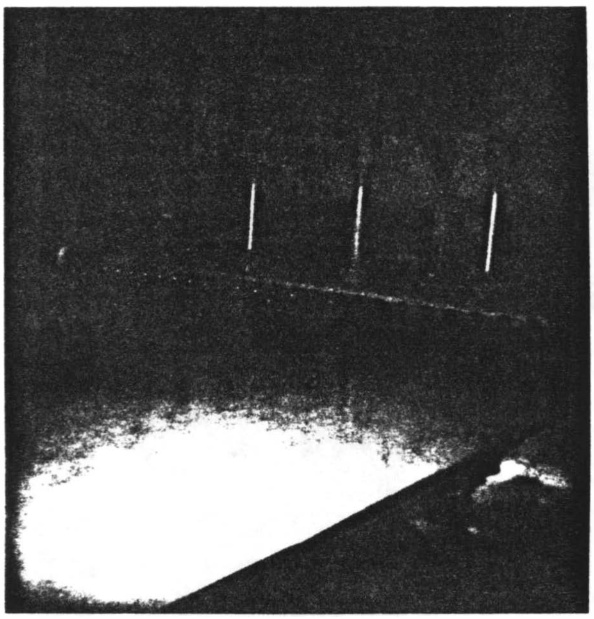


Figure 21. Stock Appearance with
Shake at Normal Consistency

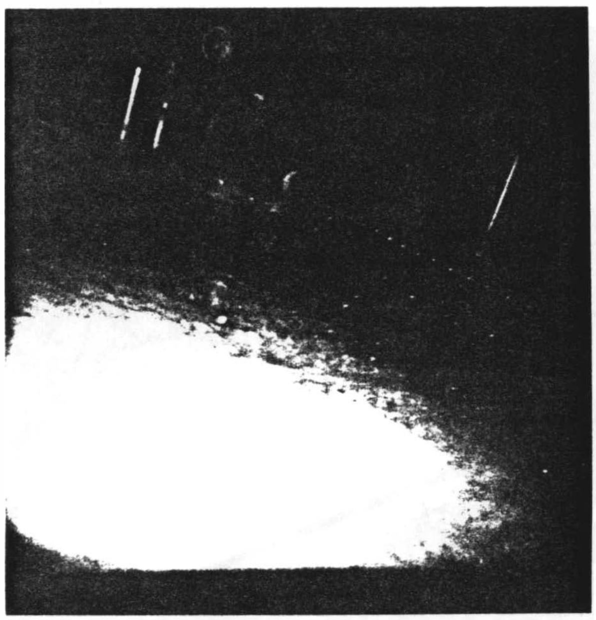


Figure 22. Stock Appearance with
Formation Shower at Normal Consistency

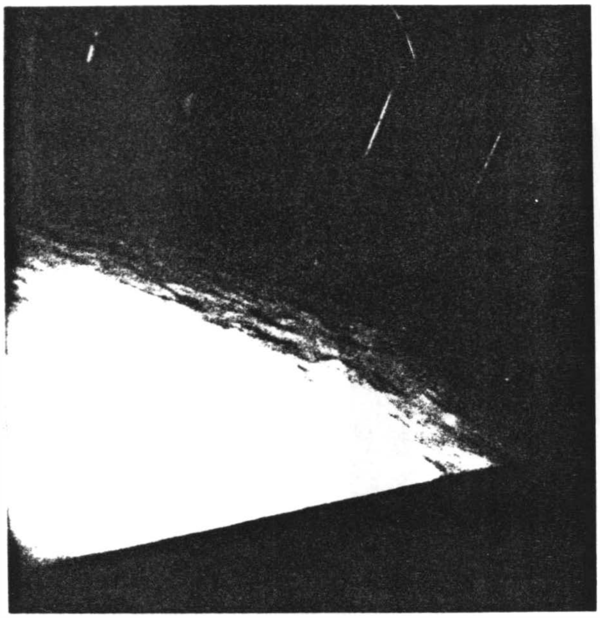


Figure 23. Stock Appearance with Formation Shower at High Consistency

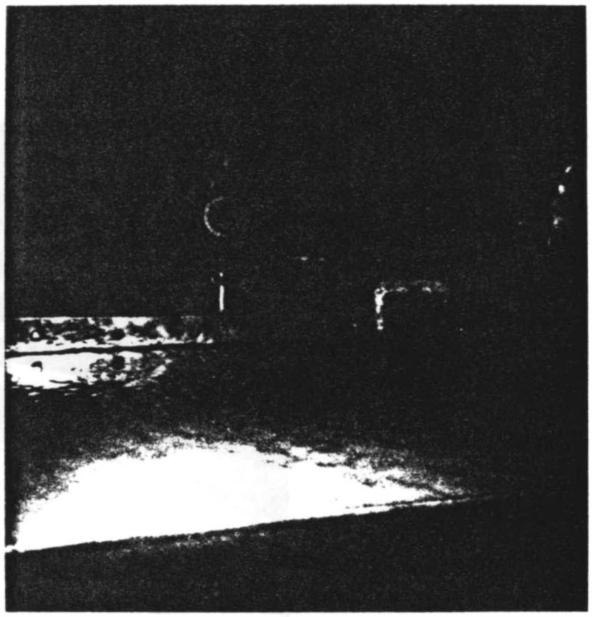


Figure 24. Stock Appearance with Serrated Slice at Normal Consistency

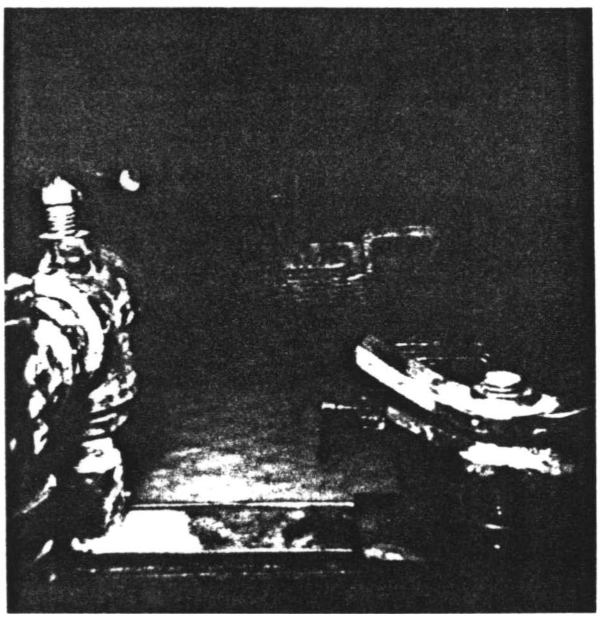


Figure 25. Stock Appearance with Serrated Slice and Shake at Normal Consistency

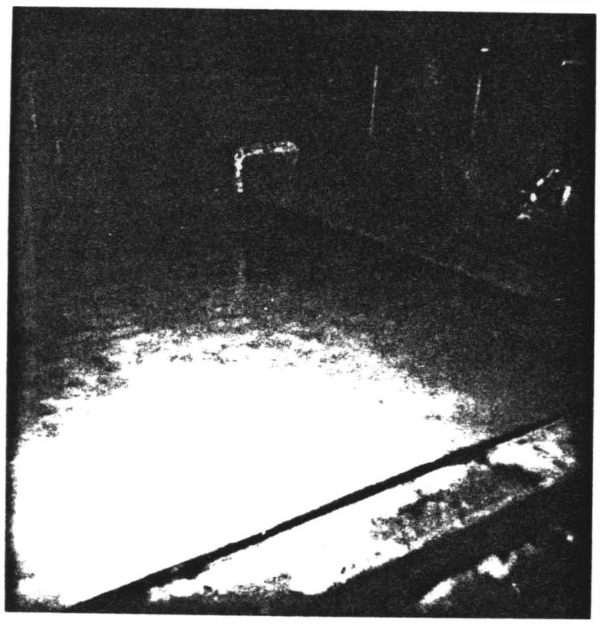


Figure 26. Stock Appearance with Serrated Slice and Shake at High Consistency

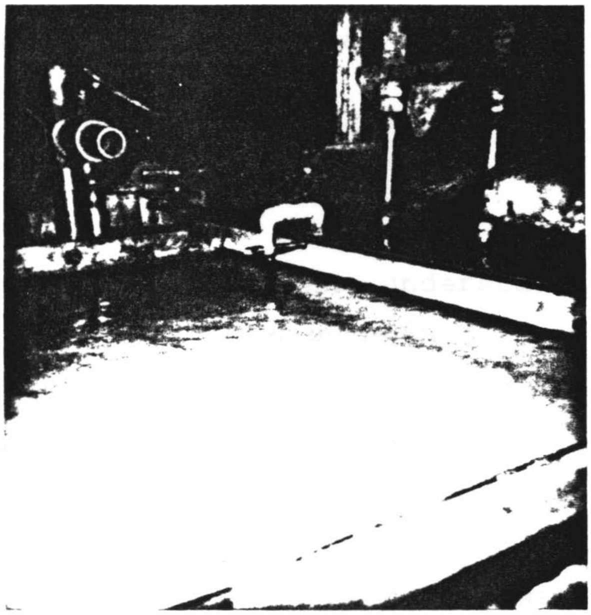


Figure 27. Stock Appearance with Serrated Slice
at High Consistency

CONCLUSIONS

The following conclusions can be made based on the results from this thesis. These conclusions may not apply to different furnishes and basis weights.

(1) Although it has been the understanding that shake is the best known method for improving sheet formation at machine speeds less than 400 FPM, the slice designed for this thesis was superior for the pilot plant papermachine at about 60 FPM.

(2) Evidence of floc directionality was found from the evaluation of MD and CD tensile indices at different formation indices.

(3) Although tensile index is not a good indication of formation changes, opacity variations can aid in the indication of varying formation.

RECOMMENDATIONS

The following recommendations are essential for considering further studies of the effects of different methods on improving formation.

(1) The study of floc orientation would result in a better understanding of the effects which rush/drag ratios have on formation and tensile strengths.

(2) A better control of basis weight and consistency is needed to remove any uncertainties about the results from the use of the formation shower and serrated slice.

(3) A further study on the effects of the simple and inexpensive serrated slice should be completed with different furnishes and grades. The evidence leads to the conclusion that it may be beneficial to use this device, but more confidence is needed.

(4) The application of the formation shower needs further study with a design change. The shower should be attached closer to the slice while different pressures and impingement angles are tried.

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APPENDIX I

Formation Shower
Fresh Water Calculations

Fresh Water Flow Available (GPM/nozzle)

$$\frac{6\ ft}{sec}\ \frac{60\ sec}{min}\ \frac{7.48\ gal}{ft}\ \frac{}{30\ nozzles} = 0.49\ GPM/nozzle$$

where; radius of pipe = 1/24 ft

Fresh Water Flow Actually Used (GPM/nozzle)

	#1 (lb/min)	#2 (lb/min)
Bucket and Water	12.25	12.25
Bucket	2.125	2.125
Water	10.125	10.125

$$\frac{10.125\ lb}{min}\ \frac{ft}{62.4\ lb}\ \frac{7.48\ gal}{ft}\ \frac{}{30\ nozzles} = 0.04\ GPM/nozzle$$

APPENDIX II

Papermachine Parameters and Observations

Papermachine Parameters

METHOD (RUN #)	CONS. (%)	MACHINE SPEED (FPM)	ACCURAY BASIS WEIGHT (lb-24x36x500)	STOCK FLOW (GPM)
1	0.47	60.4	61.0	16.0
2	0.71	60.5	61.5	missed
3	missed	60.4	60.7	missed
4	0.55	60.5	60.6	18.8
5	0.43	60.4	58.9	missed
6	0.66	60.4	58.6	16.4
7	0.38	60.4	60.0	16.4
8	0.38	60.4	60.3	16.5
9	0.55	60.5	61.9	16.5
10	0.57	60.4	61.3	16.4

- Shake Power: 6.5 amps (110 V) with no stock on wire.

- Wet Line: 1st suction box every run.

- Observations: Accuray reading at end of Run 5 was 52.8 lb.
  Observed streaks before Dandy during Runs 5 and 6.
  Observed six phase changes during Run 7.
  Back few water jets were staggered on formation shower.

APPENDIX III

*M/K Microformation Tester Notes

- Formation Index (F.I.) = $\frac{\text{Peak Height (P)}}{\text{No. of Bins (B)}}$

- Eliminates weight classes in F.I. calculations with less than 100 data points.

- The more uniform a sheet, the greater is its peak height and the fewer the number of Bins into which the data falls.

- F.I. is fines or small-scale variations sensitive.

- For most papers, use 1/32" x 1/4" x 1" Aperture "A".

- For extremely heavy papers (heavier linerboards) use larger "B".

- For extremely uniform, lightweight papers (glassine) use "C".

- Use Range 1 (more sensitive) on all papers except extremely non-uniform ones (corrugating medium or tissue).

- If measured F.I. is below 3.0 in Range 1, use Range 2 instead.

- Range 1 was used for this thesis for reproducibility.

- Aperture "D" was used for this thesis as recommended.

* Reference to M/K Microformation Tester Manual.