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Drainage Dynamics in a Linerboard Furnish

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by

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Objective

The objective of this project was to determine how a linerboard furnish drains. Then, devise a test that will predict how this type of furnish will react to drainage aids.

Keywords

Drainage

Drainage aids

Drainage rate

Freeness

Linerboard

Vacuum drainage

Abstract

Predicting the performance of drainage aids in a linerboard furnish is a difficult task. Existing tests such as the Canadian Standard Freeness test, Schopper-Riegler, and drainage tube are not adequate tests. These tests only simulate one-half of the paper machine. Unfortunately the section they model is of minor importance in linerboard.

The findings of this project suggest that linerboard is more dependent upon the vacuum induced drainage zone than it is on the free drainage zone. The vacuum zone is dependent upon the formation of the sheet. Therefore, if the formation of the sheet is improved the couch solids will go up. During the machine trial the formation was increased by dispersing the fibers with anionic polymers.

To better predict drainage aid performance it was found the stock should be deposited on a wire be a jet or slice rather than from a standing head of pulp. Once the stock is deposited, and a uniform mat formed, vacuum should be applied. This series of events is more realistic of a paper machine. The results obtained from such a test was found to be more representative of actual machine trial data.

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Introduction

In the paper industry maximum production while maintaining specifications is the goal of every mill. A major factor limiting production is the ability of the papermachine to remove water from the sheet to meet reel moisture specification. At the same time, the steam fed to the driers must be minimized for economic reasons. The wet end of the papermachine is by far the cheapest place to remove water. On a pound-to-pound basis water is ten times more expensive to remove in the drier section than it is on the wet end. Also, if sheet solids can be increased by one percentage point at the couch an 8-9% increase in production is possible. This all adds up to greater steam savings and greater machine speeds.

This is where the chemical companies who cater to the paper industry come in. A group of polymers known as drainage aids can be added to the papermaking furnish to increase the amount of water removed in the wet end. However, as seen by many of the chemical companies and mills, these polymers do not always work as predicted by laboratory tests. It is actually possible that these drainage aids will cause the sheet to be wetter coming off the couch. The reason for this is not known for sure. This type of behavoir is most often seen in linerboard furnishes. It appears that the suppliers are somewhat responsible for their own hardships in linerboard mills. It seems that most non-successful trials are the result of the supplier actually recommending the wrong drainage aid for that particular furnish. The typical chemical company has a wide variety of drainage aids. The difference between them may be chemistry, charge, charge density, or molecular weight. It is also important to remember that the stock used by every mill is different, and will respond differently to the various drainage aids. Therefore, in order to recommend a product to a mill for a trial, the supplier screens their products with an actual headbox sample from the mill. In this manner, the product which gives the best drainage is recommended. Typical drainage tests include the Canadian Standard Freeness, Schopper-Riegler Freeness, drainage jar, and the drainage tube.

However, as found by mills and suppliers alike, what happens on the machine as compared to what happens in the laboratory can be two different things. It would appear that existing test procedures used for drainage is not indicative of what happens on the machine. Existing drainage tests are used with good success for fine paper furnishes. Therefore, it becomes apparent that there is more than just the obvious differences between fine paper and linerboard furnishes.

It was the scope of this project to determine why what works for one stock will not work for another. The study was limited to only a single linerboard furnish since this is where the problem arises. Once the parameters by which a linerboard stock drains is better understood it will be possible to precict how drainage aids will truly affect drainage.

Background & Theory

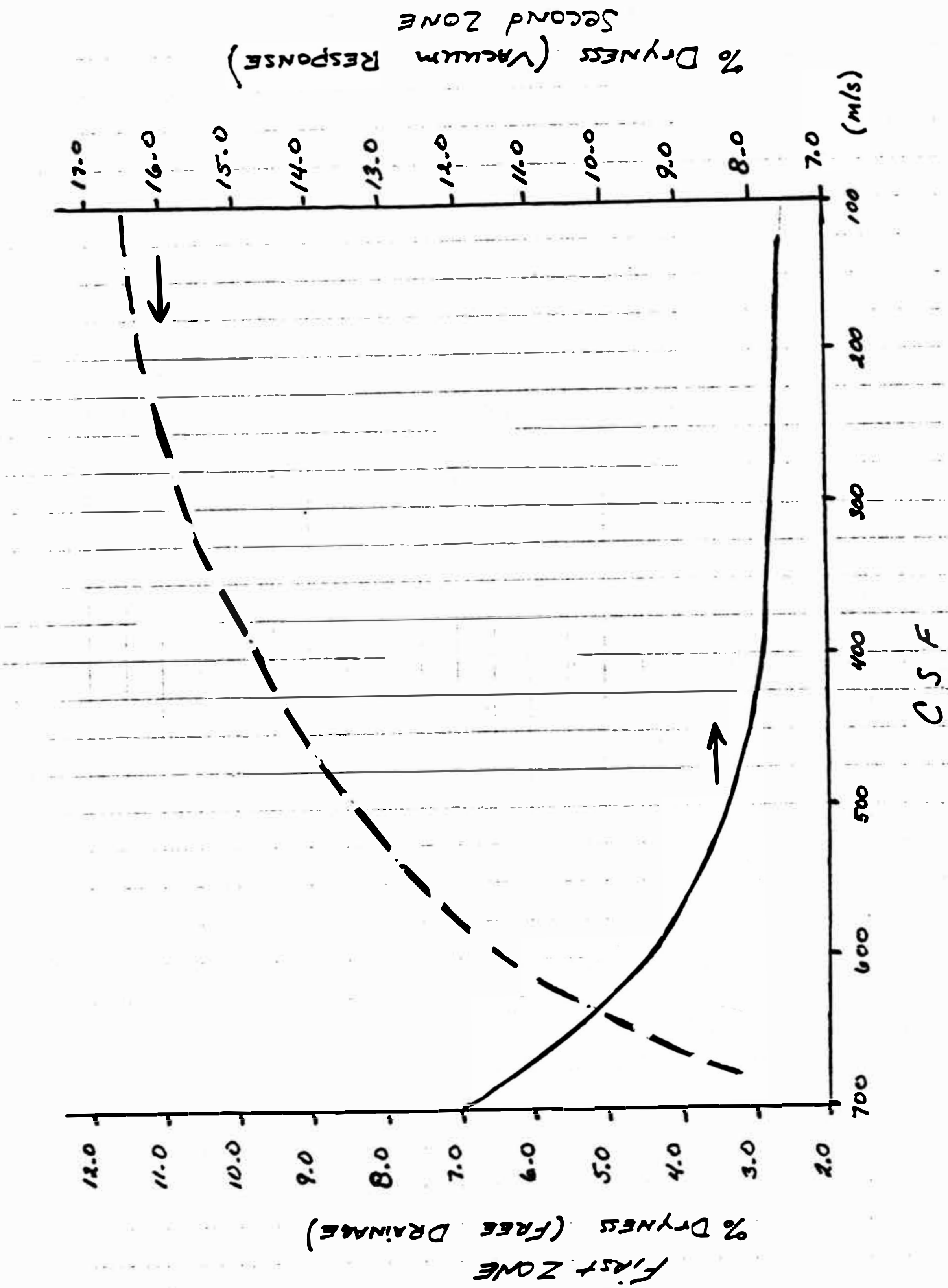
From the available literature it seems that the problem arises because test methods only take one-half of the typical fourdrinier paper machine into account. Many research papers describe the existance of two 'zones of drainage' between the headbox and couch roll. In the first zone water drains by gravity and low levels of vacuum and pressure. A small amount of mat formation takes place in the first zone. In the second zone the mat structure is better formed and water removal occurs mainly due to filtration of water through the mat. The filtration is induced by vacuum from the flat boxes. Air replaces the water as it is removed from the sheet. Depending on the furnish, these two zones are separated at about the 5% consistency mark. It must be remembered that for a machine with a forming table 75 feet long and running at 1500 fpm the time from the headbox to the couch roll is only three seconds. Therefore, while the two zones are very distinguishable the time differential between them is small. Existing laboratory test equipment used to measure drainage only model the first zone of the Fourdrinier. None of them expose the formed mat to vacuum, which is the critical drainage component in the second zone. Therefore, if the two zone theory is accepted, existing drainage tests will give good correlation with actual machine trial results only when the first zone is dominant, but lead to erroneous results when the second zone is dominant.

The adverse effects of drainage aids on drainage in a liner-board furnish might be illustrated as follows: A particular cationic drainage aid is selected as the best product for improved drainage as indicated by mililiters of overflow in a Canadian Standard Freeness tester. Also, this product gives increased retention as measured by clarity of the overflow. However, when a machine trial is run with this product the couch moistures go up and the machine slows down, eventhough the white water solids drop. Many suppliers have seen this happen. A possible explanation for this may be the large flocs created by the cationic drainage aid increased the first zone drainage, but these flocs held more water internally and help form a very open sheet structure. This open structure will not respond well to vacuum, and therefore, the water contained in the flocs will remain there.

If, in the previous example, an anionic polymer was added the fibers would be dispersed rather than flocculated. This would greatly reduce the first zone drainage, but help form a tighter mat structure. The closed mat will respond much to vacuum than the open sheet structure. As can be seen in this example, what can help one zone can hurt the other. This is illustrated in figure 1.

As mentioned earlier, existing drainage tests work reasonably well for fine papers. Therefore, it would appear that a fine paper furnish is first zone dependent. At the same time it seems that linerboard is second zone dependent since drainage tests do not accurately predict how this furnish will drain.

Drainage aids act to change the freeness of the pulp without actually changing the fibers in a physical way. The change in freeness is accomplished using chemical means. Drainage aids work on the same principle as retention aids. Drainage aids are primarily polyacrylamides with a molecular weight varying from 1-10 million. They may carry a positive or negative charge. However, due to the negative charge possessed by most paper furnishes cationic drainage aids are the most popular. The principle behind drainage aids is the formation of flocs. Flocs are formed by cationic polymers bridging together several anionic fibers. The formation of flocs creates a greater void volume



% Dryness (Vacuum Response)
Second Zone
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
(ml/s)
100
200
300
400
500
600
700
CSF
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
% Dryness (Free Drainage)
First Zone

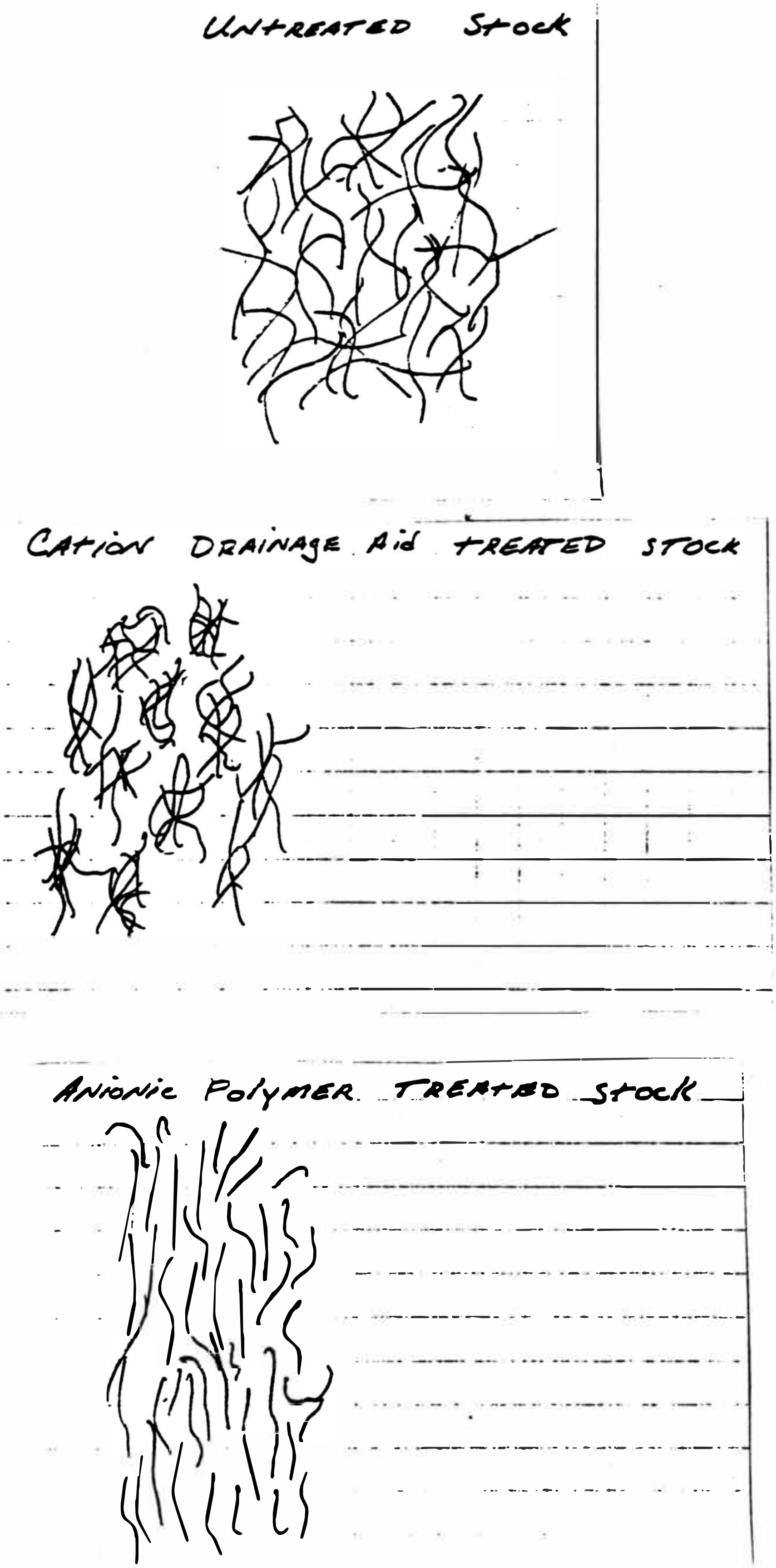
Figure 1

in the furnish which is filled with water. Once the furnish leaves the headbox and contacts the wire the water filling the voids between the flocs is able to quickly drain from the furnish. This is an example of increasing the first zone drainage rate. This is also an example of increasing stock freeness without physically altering the fibers by using a cationic drainage aid. On the other hand, if an anionic polymer is added to the furnish it would disperse the fibers, thus chemically reducing the freeness or drainage rate of the first zone. Figure 2 shows the flocculation and dispersion of fibers.

Experimental Procedure

The ultimate goal of the project was to determine which factors influence drainage in linerboard. Therefore, it was necessary to develop the laboratory work around the results of a machine trial rather than the other way around. The machine trial was run on Western Michigan University's paper pilot plant Fourdrinier paper machine. The parameters for the trial were chosen as to closely represent those used in actual production. The furnish used was 100% unbleached, virgin softwood kraft. The pulp was received in dry lap form and no additional refiniing of the pulp was done. The stock had a Canadian Standard freeness of 575 mililiters. The pH of the stock was held at 4.7 using sulfuric acid. This pH is typical in board mills. Linerboard is produced in a variety of weights, but 42 lb./ 1000 ft^2 is a very commaon weight, and for this reason was chosen. At this high of a basis weight the pilot machine was only able to run at 35 ft/minute.

FIGURE 2


UNTREATED Stock
CATION DRAINAGE Aid TREATED STOCK
Anionic Polymer TREATED Stock

Four common cationic drainage aids were chosen for the machine trial. These four consisted of one with a high molecular and a high charge density. Another one had a high molecular weight and a low charge density. The other two both had low molecular weights and low charge densities, but varied in chemistry. Along with the four cationic polymers two anionics were chosen. One had a high molecular weight and a high charge density, and the other had a medium molecular weight and medium charge density. During the trial all of the polymers were fed at the same feed rates of 1/8, 1/4, and 3/8 pound of active polymer per ton of fiber. The drainage aids were fed to the stock line just before the fan pump. This is not the most desirable place to feed polymers due to the shearing action of the fan pump. However, if the polymers were fed after the fan pump it is unlikely they would have had adequate mixing with the stock. Before adding to the stock all polymers were made down to .1% active.

During the trial samples were removed just after the couch roll. The samples were stored in plastic bags and were later tested for percent solids. The final reel of paper was marked to indicate the polymer and feedrate. Samples from the reel were evaluated for formation on a M K formation tester.

The next step was to evaluate drainage tests used in industry. The Canadian Standard freeness tester is widely used. The method used was a modification of TAPPI Standard T 227. Stock for drainage evaluation was prepared to the same standards used in the machine trial. The variation from the TAPPI Standard occurred when the stock was tested at .50% consistency rather than the described .30% consistency. The stock used during the trial

BRITT DRAINAGE TEST

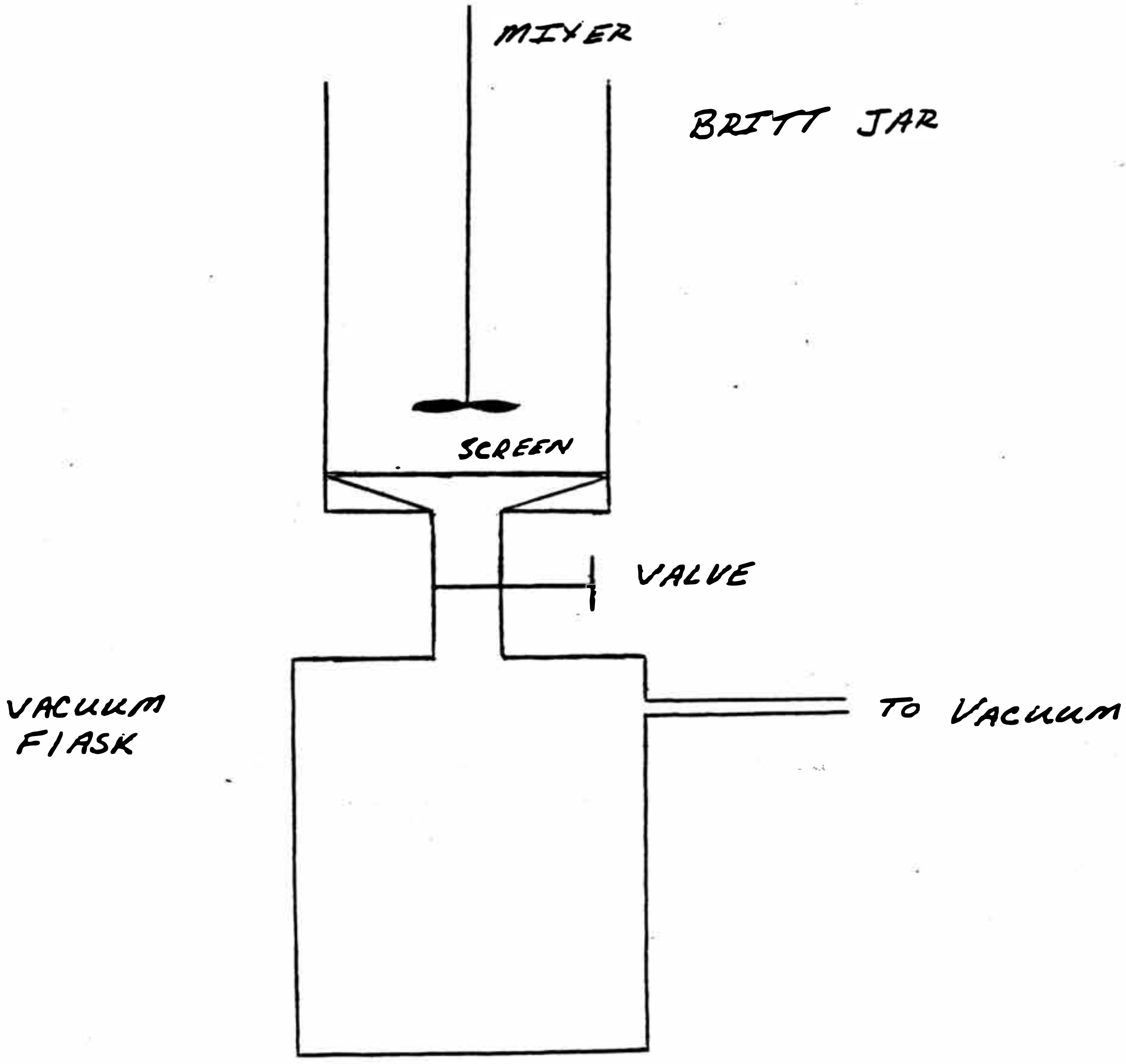


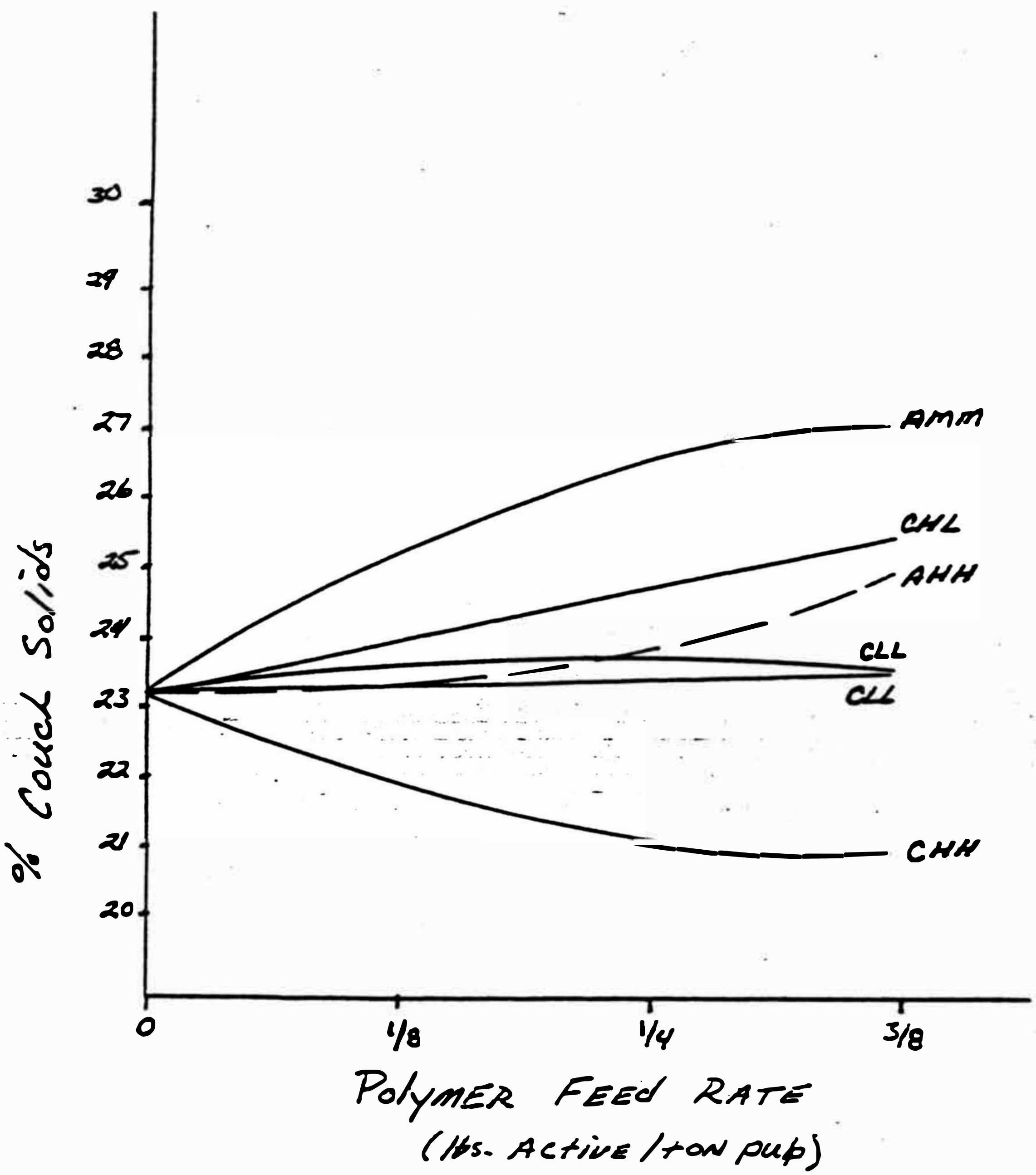
Figure 3. Britt Drainage Test

was approximately .55% consistency. The same polymer addition rate was used for CSF testing as was used for the machine trial.

The next test that was evaluated was the Britt Drainage test (fig. 3). This test incorporates a Britt Jar with a valve attached to the exit hole. The other end of the valve is connected to a vacuum flask. This test is unique in that free drainage and vacuum forced drainage is possible. The stock is added to the Britt Jar with the valve in the closed position. The impeller is set to rotate at 750 rpm. After mixing the stock for 15 seconds the polymer is injected into the pulp and allowed to mix for 30 seconds. At this point the valve is opened and the mixer turned off. Adequate time is given for a mat to form on the screen of the Britt Jar. Once the mat is formed vacuum is applied to the mat for ten seconds. After the vacuum is turned off the mat is removed and weighed while wet. It is then dried and weighed again. The percent solids then represent a possible couch solids. The stock conditions were maintained at the same standards for this test as the others. However, the consistency of the stock was cut in half. This was done because adding 500 mls of stock at .50% consistency formed a mat that was too thick.

Figure 4

Machine Trial Couch Moistures



CHH	CATIONIC	HIGH M.W.	HIGH CHARGE DENSITY
CHL	CATIONIC	HIGH M.W.	LOW C.D.
CLL	CATIONIC	LOW M.W.	LOW C.D.
AHH	ANIONIC	HIGH M.W.	HIGH C.D.
AMM	ANIONIC	MEDIUM M.W.	MEDIUM C.D.

Figure 5

MACHINE TRIAL FORMATION INDICES

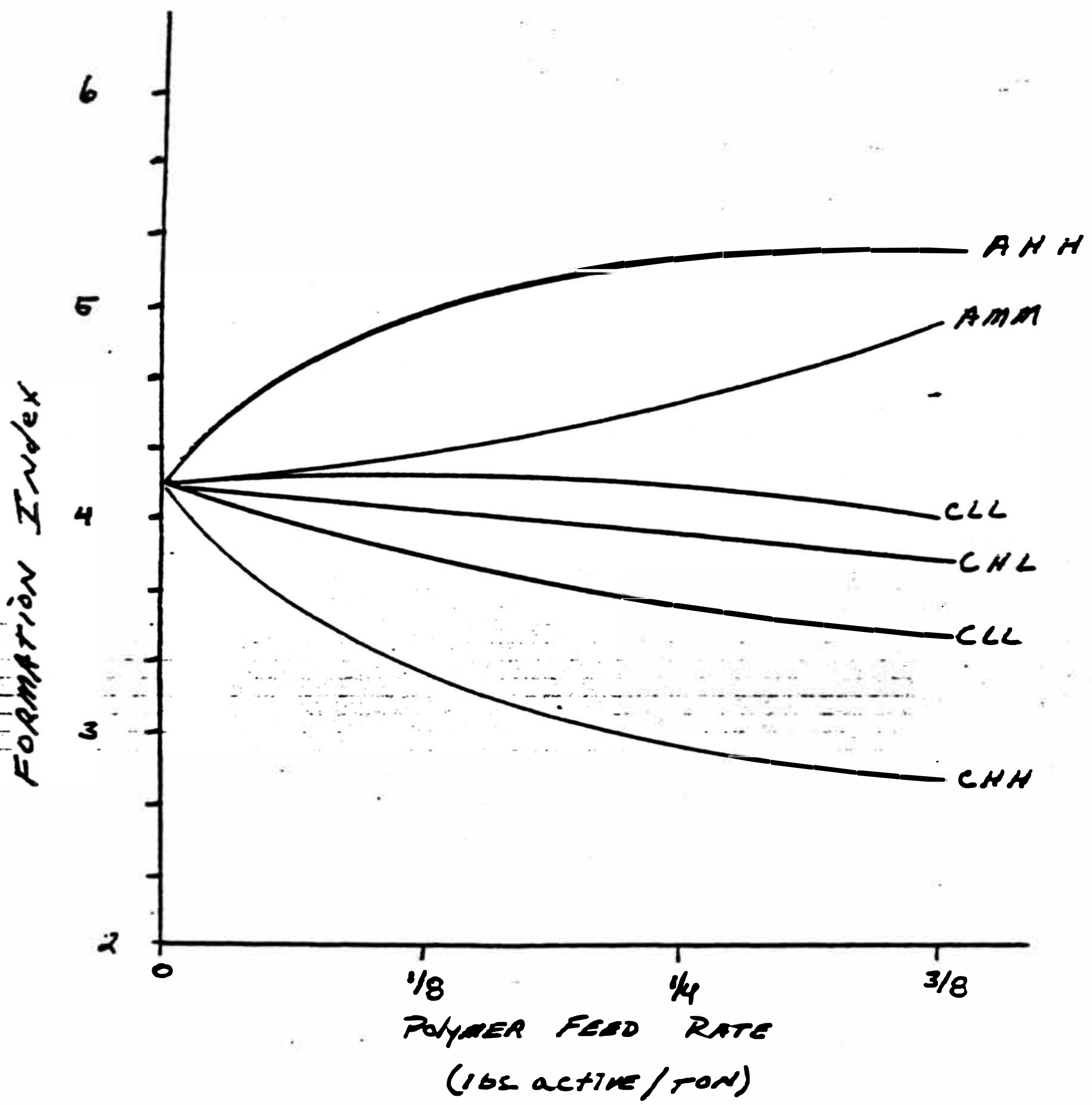


FIGURE 6

CSF

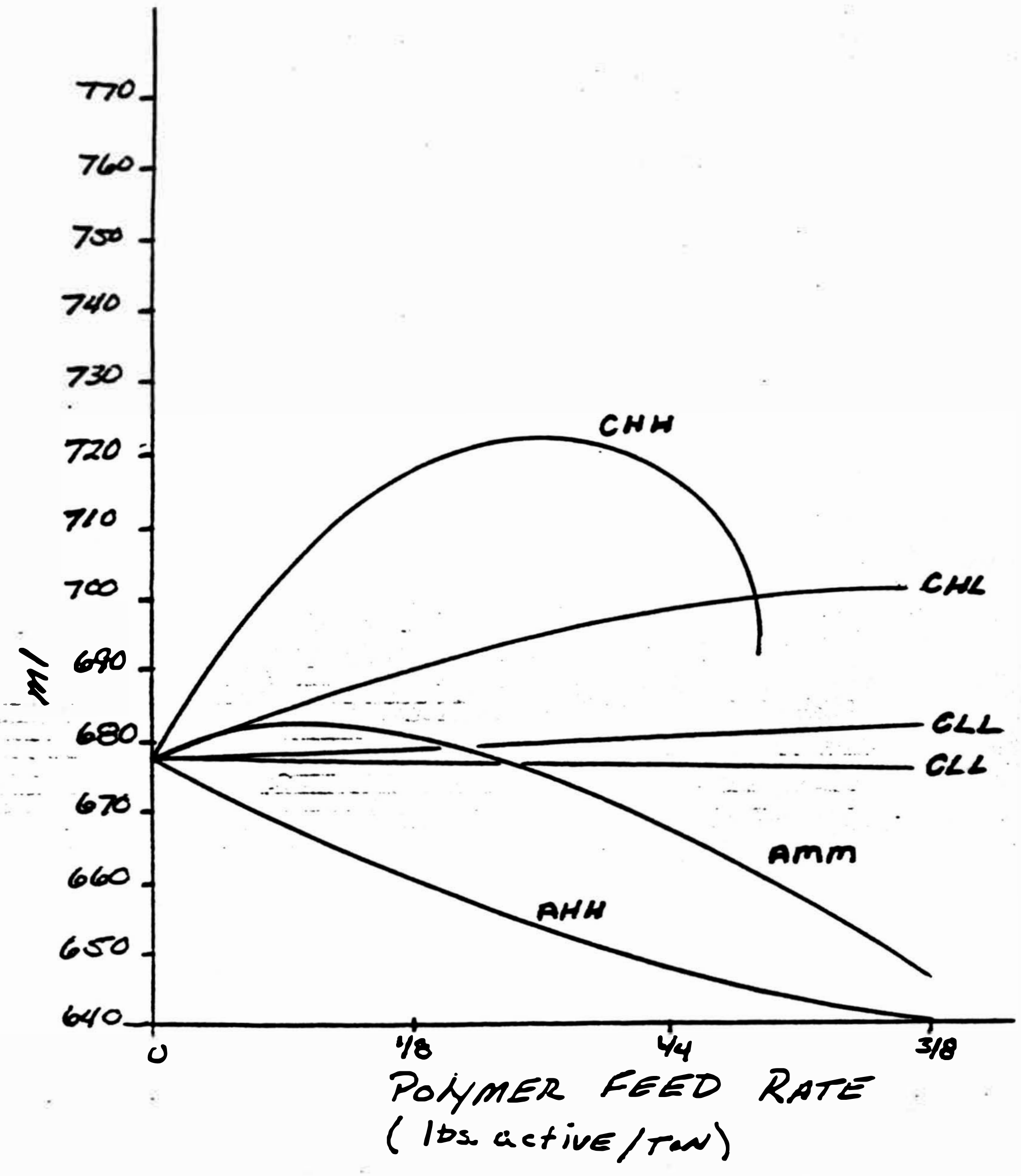
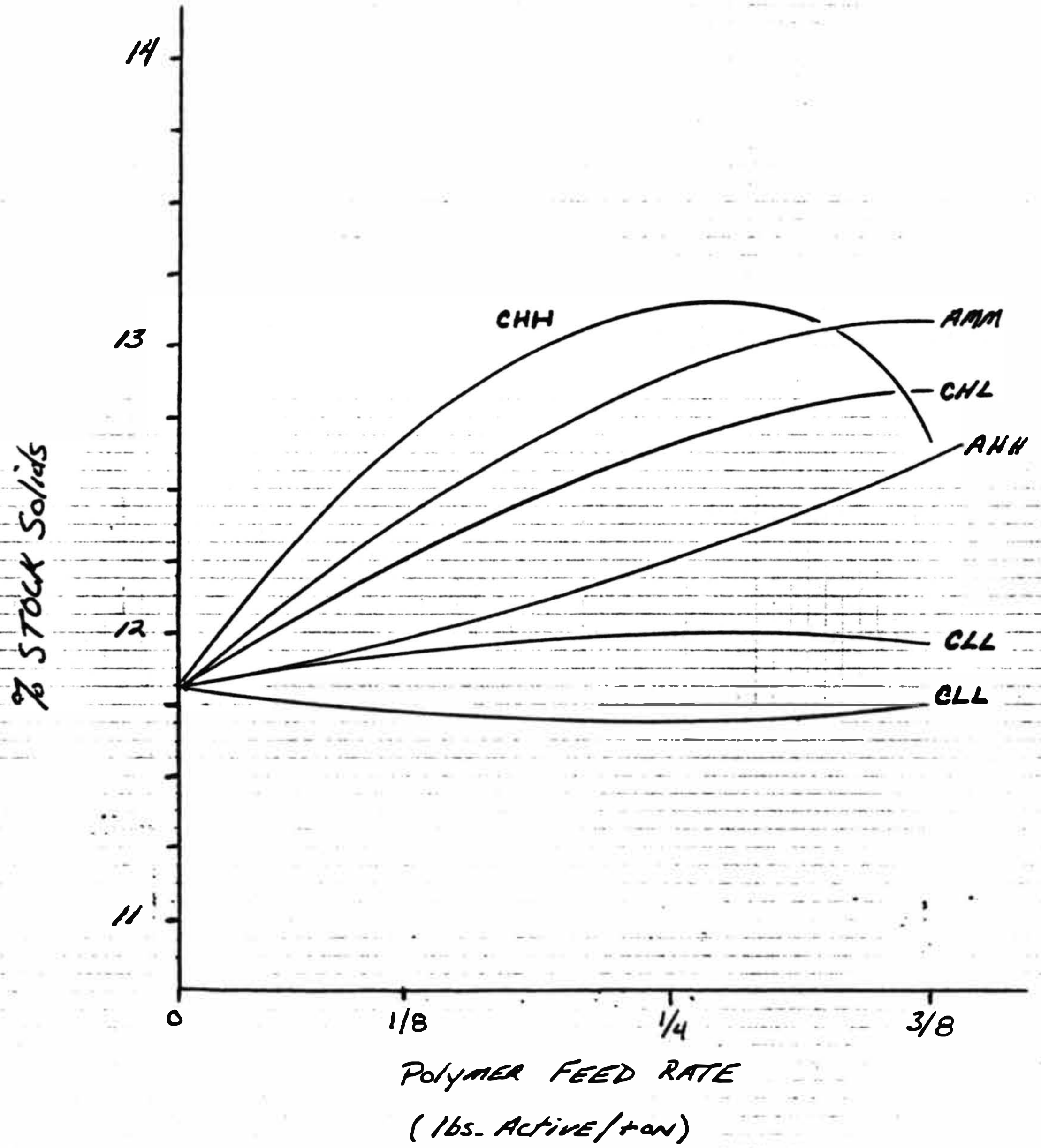

CHH
CHL
CLL
CLL
AMM
AHH
770
760
750
740
730
720
710
700
690
680
670
660
650
640
ml
0
1/8
1/4
3/8
POLYMER FEED RATE
(lbs. active/TON)

Figure 7
BRITT DRAINAGE TEST



Results Discussion

Figure 4 is a graph of changing couch moistures with the various polymers. The untreated stock had an initial couch solids of just over 23%. The polymer CHH shows a steady decrease in solids. However, based on CSF testing (fig. 6) this polymer gives the best drainage. Results such as this is typical of what many chemical companies have seen. With CSF only representing one-half of the paper machine erroneous predictions are made. At the same time CSF shows polymers AMM and AHH hurting drainage. On the other hand, during the machine trial these two polymers gave improved sheet dryness at the couch.

The differences between the CSF testing and the actual machine data can be explained by the formation of the sheet (fig. 5). As mentioned earlier, cationic polymers flocculate the fibers and the anionic polymers act to disperse the fibers. As the fibers are flocculated the freeness increases. When they are dispersed the freeness decreases. Excessive flocculation can occur as seen with CHH in figure 6. This occurs when a threshold limit is reached by the charge on the stock. Once this limit is reached additional cationic polymer will act to disperse the fibers. From figure 5 it can be seen that all of the cationic polymers hurt formation with floc accumulation. However, the anionics dispersed the fibers and formation increased. Comparing figures 4 and 5 a correlation between formation and couch consistency seems to exist.

Since CSF, which is a first zone test, does not accurately predict how a linerboard furnish will drain it is reasonable to assume that this type of furnish is more dependent upon the second the second zone. The second zone displaces water in the pulp mat with air by using a pressure difference across the web. However, when a stock is flocculated voids will occur between the flocs when the mat is formed. These voids provide a thin spot for air to be pulled through the sheet. As a result, the vacuum across the sheet is broken and less water is removed. When an anionic polymer is added the formation goes up. The increased formation is an indication of a tighter, more uniform procuct. With an even sheet crossing a vacuum box more air is pulled into the entire web and displaces a greater quantity of water. The improved formation prevents the breaking of the vacuum.

If the preceding is true it is then necessary to expose the formed mat to a level of vacuum in order to truly predict the performance of a drainage aid. This is what the Britt Drainage test accomplishes. This test has served well in predicting water drainage in newsprint furnishes. However, the results were somewhat mixed in evaluating the linerboard furnish (figure 7). The results from this test shows all polymers improving the final solids content. This test also shows polymer CHH imparting the greatest improvement. The machine trial showed CHH decreasing couch consistency (fig. 4).

While this test simulates both the free drainage zone and the forced drainage zone that is seen on an actual paper machine it does something that is not seen on a real machine; it forms a mat from a standing head of pulp. With the addition of 500 mililiters of stock to the Britt Jar a head of about four inches is developed. When the valve is opened the stock flows straight down. Once a fiber or floc contacts the wire the current flows around it. This deposits the next fiber on floc next to it. As this four inch column of stock falls to the wire and the water passes through the wire a uniform mat is formed. This will occur whether the stock dispersed or flocculated. As discussed earlier, a uniform mat responds well to vacuum.

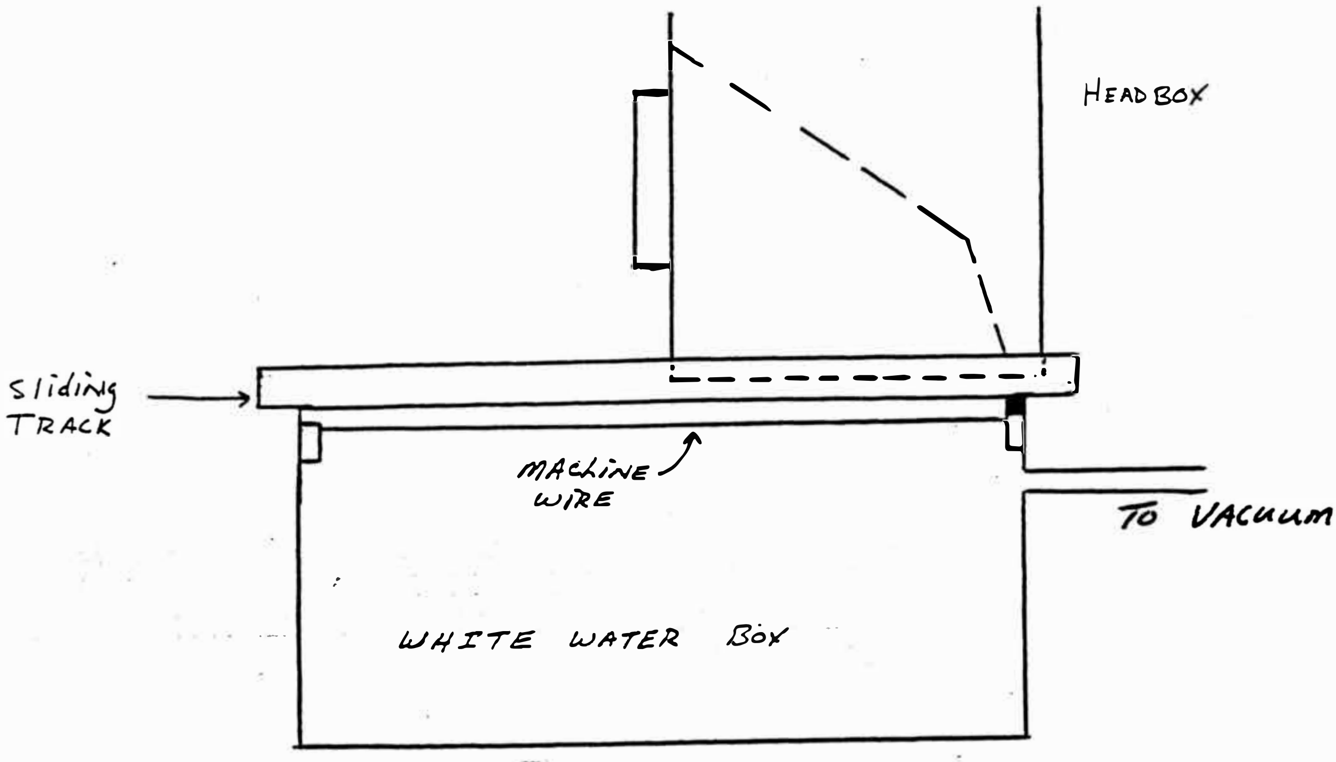
Upon evaluating the CSF test and the Britt Drainage test several shortcomings were found for each test. Neither of the tests would have been able to predict the optimum drainage aid for use in the machine trial. With the results indicating a correlation between formation and couch solids, and the necessity to simulate both drainage zones, it becomes apparent why the usual drainage test do not accurately predict machine drainage.

Engineering Design

In order to accurately predict drainage aid performance in linerboard furnishes all of the components found on an actual paper machine should be present. The Britt Drainage device is close to this since both first and second zone dynamics are present. Its shortcoming is the standing head of stock.

In an attempt to remove this variable a headbox was built with a 3/8 inch slice to deposit the stock (firure 8). Underneath this headbox is an actual machine forming fabric held in place by clamps. The headbox is held in a slotted track so that it can be pulled across the wire. As the headbox is moved across the wire stock is deposited to form a sheet. After depositing the stock to the wire the vacuum is turned on for 15 seconds. The wire is then removed from the clamps and the sheet weighed. The sheet is weighed again after drying. Caution must be taken

FIGURE 8
SHEET FORMER TEST

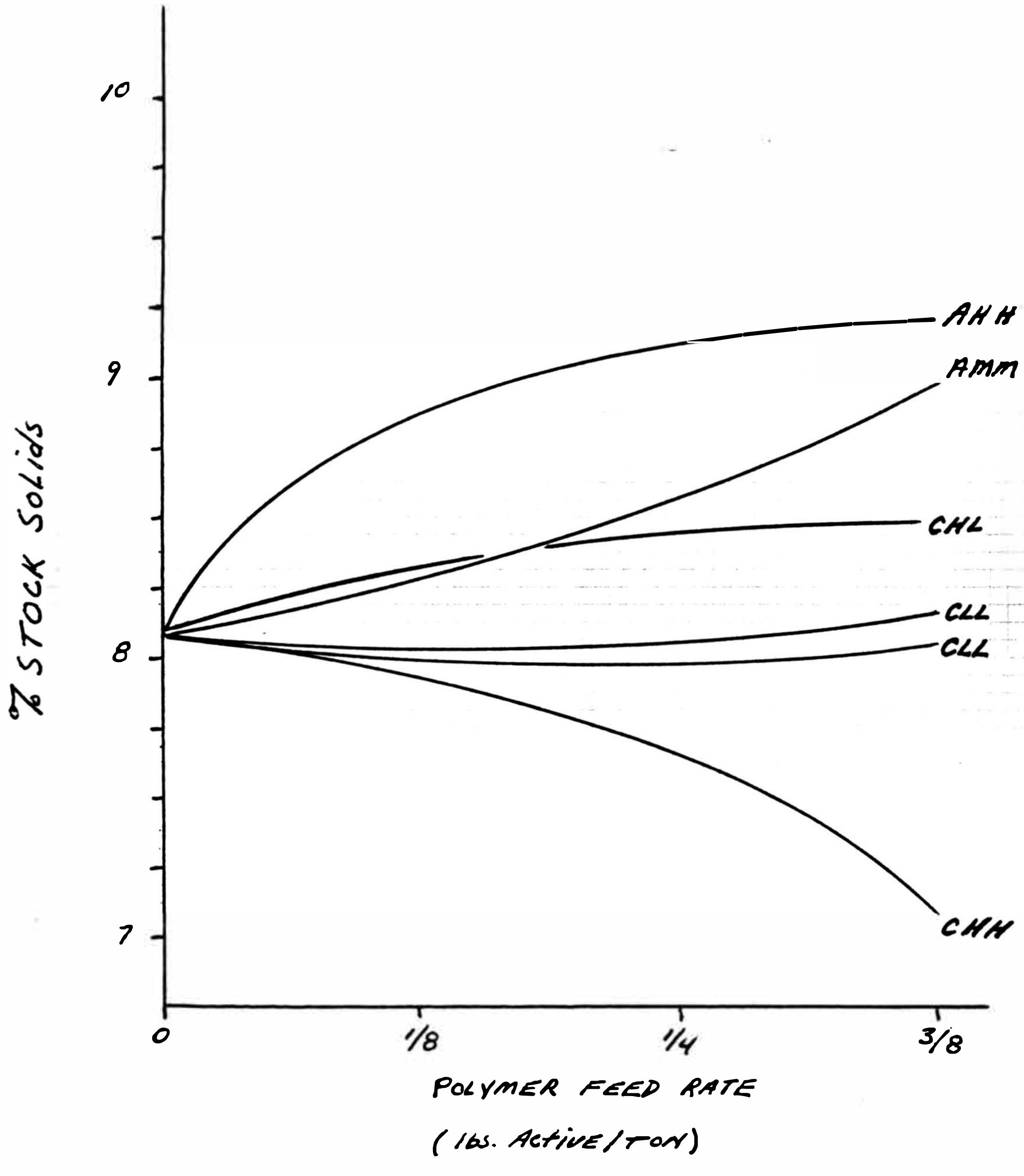


to ensure a uniform basis weight profile of the formed web or else the resulting 'couch solids' are invalid.

By depositing the stock on the wire through a slice the standing head of stock is removed. The stock experiences free drainage as it contacts the wire. The applied vacuum simulates the flat boxes. Drainage aids are then compared on what the final 'couch moistures' are, and not by mililiters of overflow like the CSF test.

The results of testing are shown in figure 9. Of all the drainage tests this is the most indicative of what actually occurred on the machine. This test is the only one which shows polymer CHH decreasing the couch solids. It also shows both anionic polymers helping to improve the final couch consistency. However, this test is still unable to predict the best polymer for drainage. The sheet former test shows polymer AHH to be the best for this stock. On the other hand, polymer AMM was the best performer during the machine trial. None the less, the trends for all polymers evaluated on the sheet former is closer to the machine trends than any of the other tests.

FIGURE 9
SHEET FORMER TEST



Conclusion

A linerboard furnish is dependent upon the vacuum forced removal of water. The vacuum response of the pulp is greatest when the formation of the sheet is increased (figure 10). While the flocculation of fibers increases free drainage in the first zone, the second zone water removal is hurt by poor mat structure. Dispersion of fibers slows first zone drainage, but the increased formation helps the vacuum response make up for it.

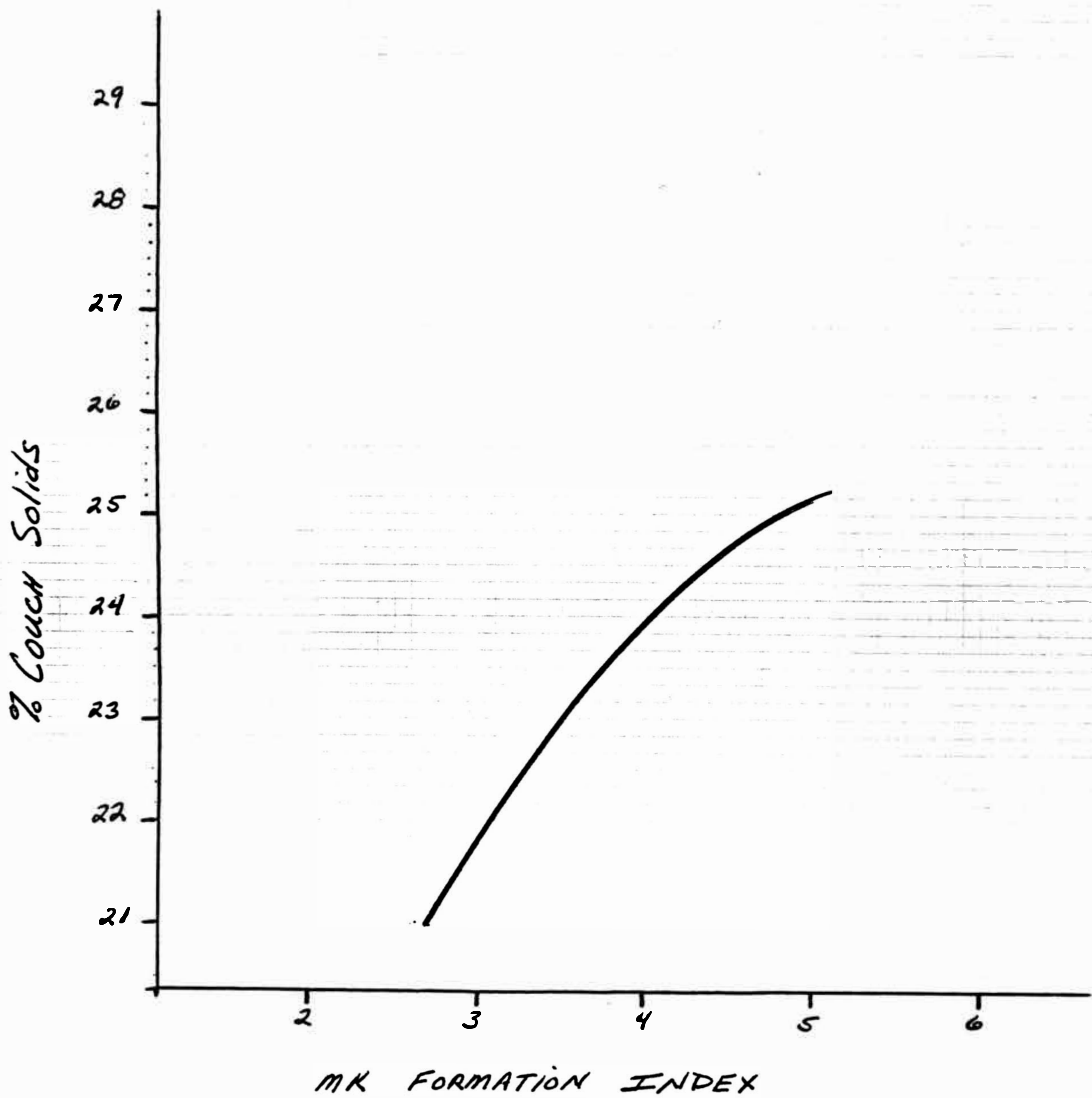
Current laboratory test methods used for drainage are not realistic in predicting how a linerboard furnish will drain. A better test method should simulate both free drainage and and vacuum forced drainage. Due to possible differences between freeness and drainage rate final solids should be measured rather than overflow. The stock should not be settled out on a wire from a standing head. It should rather be dispersed onto a wire from a jet or slice to form a sheet. This will result in a better simulation of what actually occurs on a paper machine.

Recommendations

As mentioned in the report, the CSF test is a fairly good test to predict drainage in a fine paper furnish, and the Britt drainage test seems to work for newsprint. There are many possible areas of study concerning drainage in these two furnishes. In some furnishes there is a correlation between freeness and drainage rate; while in others there is very little if any at all. What does it mean when there is a correlation? Or, what does it mean when there is no correlation? This information may be useful in further developing the model for linerboard drainage.

FIGURE 10

MK FORMATION VS. COUCH CONSISTENCY



While a virgin kraft furnish was used for this study the board industry is using more and more recycle in their board furnishes. What effect does this have on drainage? It must be kept in mind that long fibered board furnishes are dependent on vacuum forced drainage. Also, how will these furnishes containing recycle respond to drainage aids?

Then there is the theory part of drainage. What effects do the structures of flocs and the hydrodynamic forces within the floc have on drainage? Around every fiber there is a boundary layer of water. How does this boundary layer affect water removal when these fibers form a floc? While it is generally accepted that the drier the sheet is when it enters the presses the drier it is when it comes out, this is not always true. What affect does flocculation and dispersion have on pressing efficiency?

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Appendix I

Stock Preparation

The stock used for this project was 100% Canadian, kraft softwood. The pulp was unbleached and had an initial freeness of approximately 670 mls. The stock was received in drylap form. For the machine trial it was dispersed in the beater. No additional refining of the stock was performed. Stock for the lab work was prepared in a similar fashion. However, the dry lap pulp was soaked in water for 24 hours before repulping it. Repulping was done in a laboratory slusher. After the dry lap was pulped the pH was adjusted to 4.7 with sulfuric acid. This was the same for both the lab work and the machine trial.

Appendix II

Drainage Aid Preparation

All drainage aids used were received in emulsion form at 25% active polymer. At this concentration these polymers cannot be pumped. The usual concentration used for feeding these polymers are 0.1% active polymer. However, due to the nature of these polymers a direct dilution is not possible. Therefore, a two stage make up system is used. The polymer is first diluted with water to 0.4% active polymer. During the first dilution the solution is mixed at 650 rpm for 30 minutes. This solution is then diluted to 0.1% active polymer. The speed of mixing in this stage does not matter, but it should be mixed for at least 30 minutes. During the first dilution care must be taken in bringing the polymer in contact with the water. If the polymer is suddenly dumped into the water the polymer will form globules and fisheyes rather than disperse.