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The Cross Flow Filtration Concept Used as a Deinking Method

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THE CROSS FLOW FILTRATION CONCEPT USED AS A DEINKING METHOD

BY

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ABSTRACT

The cross-flow filter was used to deink a 70% news and 30% coated section furnish. This has never been attempted before so the main objective was to determine if it would work. The secondary objective was to find the highest operating consistency possible. The filter can be used to remove ink, fines and filler from a stock suspension. The feed, accept and effluent samples were analyzed for percent ash, brightness, clark classification, Kajanni fiber length analysis and image analysis. The effluent had a 29.81% ash compared to the feed ash of 8.32%. The accept brightness was 42.9 while the feed brightness was 41.0. Image analysis showed that there were more ink particles per oven dry fiber in the effluent than in the feed or accepts. It also determined that the mean particle diameter in the effluent was 6.26 microns while the feed was 6.18 microns. The cross-flow filter was effective in removing ink and filler. One percent consistency was the highest operating consistency due to pump limitations. The cross-flow filtration concept has a great potential as a deinking method. Further work should be conducted to look at the screen design, stock temperature and feed consistency. Theoretically this device could be operated at any consistency if turbulent flow could be maintained.

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INTRODUCTION

Cross-flow filtration is a simple concept in theory. The filter has no moving parts and works on the basis of a differential pressure. This is a new concept and had only been used to control the consistency within a small range in a lab situation. This filtration concept was used as a deinking method. The most important parameter is the velocity through the filter. Turbulent flow must exist within the filter to keep the screen from plugging. Conventional deinking uses a large amount of water, but the cross-flow filter could theoretically be run at any consistency as long as turbulent flow exists. Since this concept had never been used before, the overall aim of this project was to determine if it would work. The secondary objective was to find the highest consistency at which the filter would still run.

BACKGROUND

There has been no written literature on the cross-flow filtration concept, but there are numerous articles about conventional deinking.

Currently there are basically two types of deinking; washing and flotation. The problem with these methods is that they require a low inlet consistency (high rate of water consumption). New legislation will increase the demand for recycled fiber which will likely increase the need for deinking.

A common type of washing deinking is a sidehill screen. It typically requires an inlet consistency of 0.6% to 1.4%, the discharge consistency is 3% to 4%. For example, if the inlet consistency is 0.8% with a discharge consistency of 3% then 29,735 gal/BDT of dilution water would be required.(1) The sidehill screen is unique in that no fiber mat is formed. The stock is introduced into a headbox and then tumbles down the screen. The water, ink, fines and filler are removed through the screen by gravity. Due to this tumbling action, new possibilities of water removal appear. Sixty to one hundred mesh stainless steel screens are often used and the sidehill is usually angled at about 40 degrees from the horizontal. Theoretically conventional washing is most efficient if the ink particles are in the 2 micron size range. Figure 1 shows how the efficiency increases as the discharge consistency is increased.

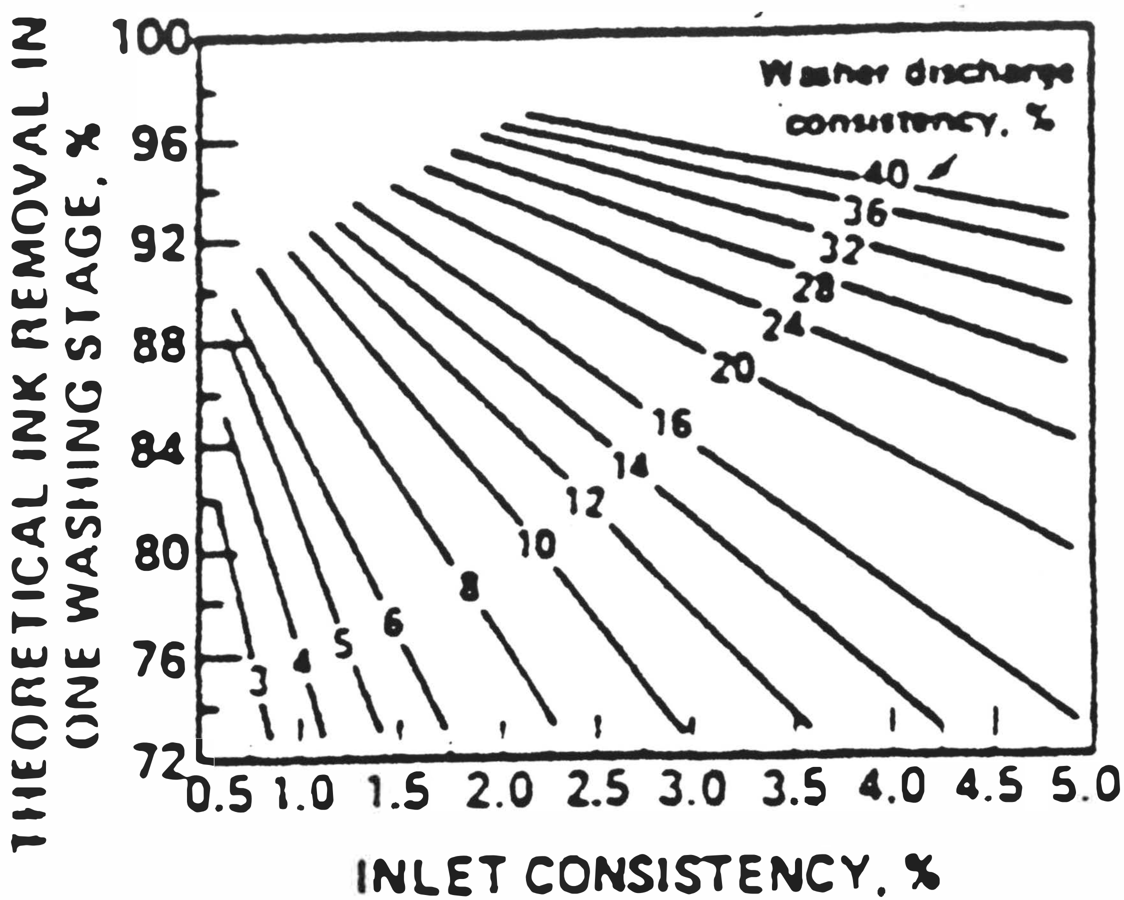


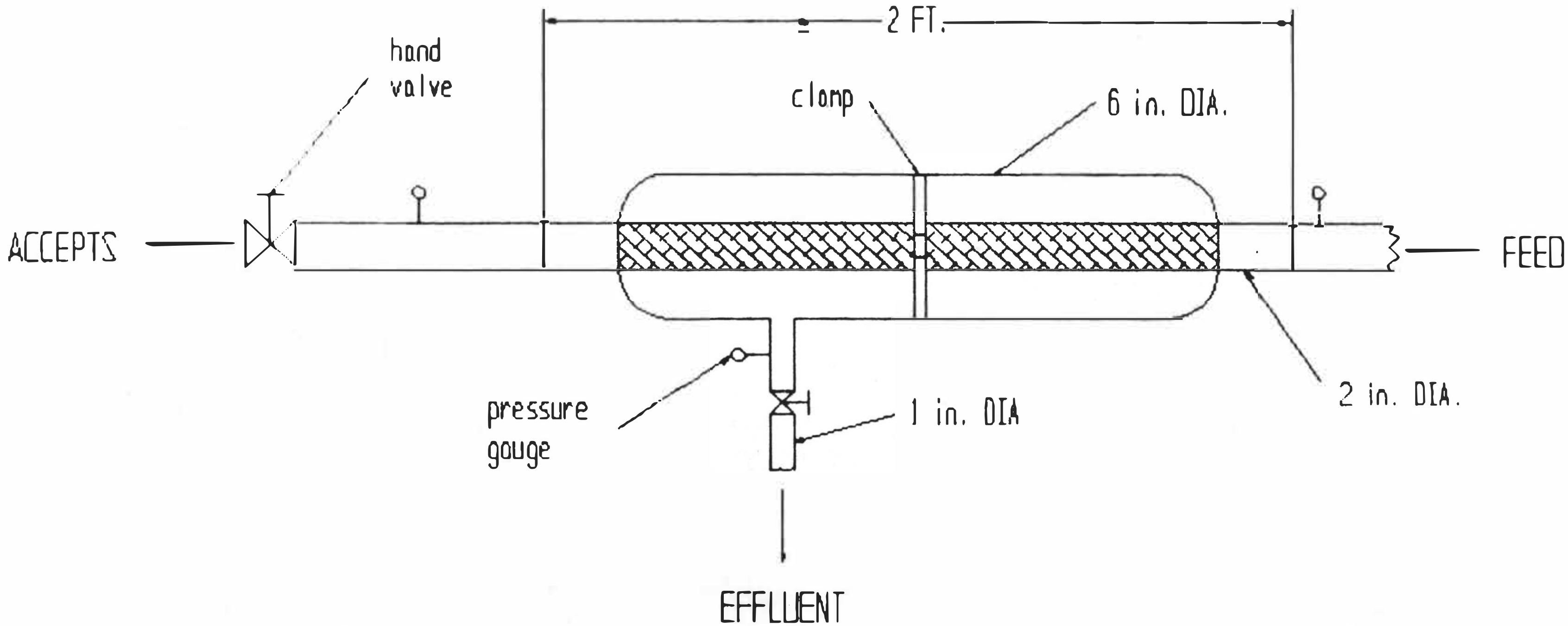
Fig. 1 Theoretical ink removal in one washing stage (1)

In the two micron size range the ink is removed in proportion to the water removed.(1)

Flotation involves injecting the dilute stock with many small air bubbles. Chemicals are added which make the ink particles hydrophobic, so they will attach to the air bubbles and float to the top of the cell. This inky foam is then removed by scrapping devices. Filler and fines are not generally removed in this deinking method. Flotation theoretically removes 10 to 100 micron ink particles most efficiently.(2) This method can remove non-dispersible inks and does not require as much water as low consistency washing.

The cross-flow filter consists of a screen, pressure chamber and an effluent discharge line. Figure 2 shows a detailed drawing of the device. The filter operates because of a differential pressure between the inside and outside of the screen. When a lower pressure exists outside the screen than inside the screen, the stock flows outward through the screen. The most important parameter is the velocity of the stock flowing through the filter. There are two types of flow; laminar and turbulent. The flow type is determined by its Reynolds number: $Nre = DVp/u$ where: D = pipe diameter, V = average linear velocity, p = density of fluid, and u = viscosity of the fluid.(3) This equation is for Newtonian fluids only (such as water). Reynolds found that, "laminar flow is always encountered at $Nre < 2100$, but can persist up to Reynolds numbers of several thousand under special conditions..."(3) Above Reynolds number

FIGURE 2 - CROSS FLOW FILTER



of 4,000 turbulent flow exists and between 2,100 and 4,000 a transitional region exists.(3) All of this is for Newtonian fluids and the problem is that a pulp suspension is a pseudoplastic fluid. At low consistencies it resembles Newtonian fluids, but as the consistency is increased it behaves less and less like a Newtonian fluid and more like a pseudoplastic fluid. Due to the fact that non-Newtonian fluids are shear rate dependant, they follow a different equation for Reynolds number. This equation is somewhat arbitrary, but one has been proposed.(3) It is necessary to have turbulent flow because the viscous shear of the fluid will clean the screen. So the critical velocity (that velocity at which turbulent flow begins) changes with the consistency. The cross-flow filter is similar to a sidehill in that no fiber mat is formed. The turbulent flow not only clears the screen, but provides new possibilities of water removal.

EXPERIMENTAL PROCEDURE

The first step was to make a detailed drawing of the filter. One problem was to find a way to make the filter so that the screen could be removed. Ronningen-Petter, Portage, Michigan manufactured two filters and used a victrolic clamp to hold the pressure chamber together. This makes it possible to remove the screen for cleaning or to make screen mesh changes. George Shrink of Ronningen-Petter also suggested rounding off the corners of the pressure chamber to minimize dead flow areas.(4)

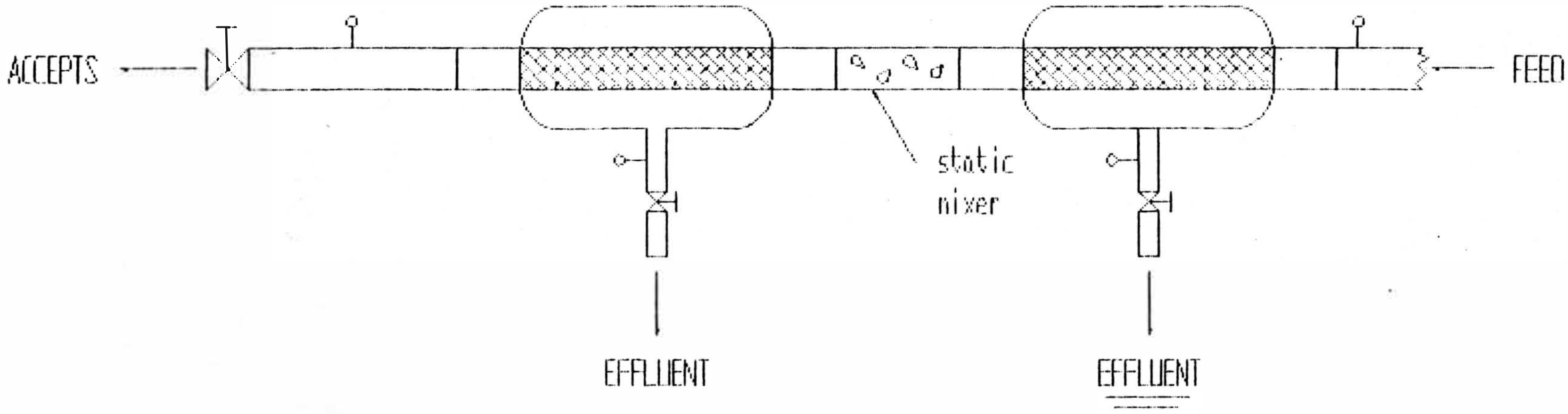
The filter actually consists of four pieces (two halves of the pressure chamber, a drilled hole screen support pipe and a screen). The 2" diameter drilled hole support pipe has 1/8" diameter drilled holes and the 100 mesh screen is spot welded on the outside of the pipe. The support pipe decreases the open area by about 50%. The support pipe has O-rings on each end so that it fits into the ends of the pressure chamber. The stock flows in contact with the inside of the drilled support pipe and must pass through the holes before passing through the screen. The whole filter is 2 feet in length and the diameter of the pressure chamber is 6". The effluent pipe is connected to the pressure chamber and is one inch in diameter. The effluent pipe is equipped with a hand valve so that the pressure in the pressure chamber can be controlled. There is also a hand valve after the filter to control the accept flow and pressure. There are three pressure gauges, one before the filter, one after the filter and one on the effluent line, as can be seen in figure 2. The filters were manufactured of 316 stainless steel and pressure tested to 160 psi. The only difference between the two filters is the screen. One is stainless steel mesh and the other is a synthetic sleeve. The metal screen had a wire wrapped around the outside so that it would not deform during operation. The synthetic sleeve simply slides over the support pipe and is held in place by hose clamps.

A furnish of 70% news and 30% coated sections was chosen. This furnish was soaked in distilled water for four hours and run at 1.25% consistency in the British Disintegrator for 45,000 revolutions. The pH was adjusted and kept constant at 8 with a sodium hydroxide solution. This was then classified in terms of freeness, ash, clark classifier and kajanni fiber analyzer. These results can be seen in appendix 1, Raw Material.

Four trials were performed in the pilot plant at Western Michigan University. The first three trials were done to find a start-up procedure and to determine if any modifications were necessary. The furnish for these trials was 100% news.

In the first run the two filters were configured in a type of countercurrent system, as can be seen in figure 3. A static mixer was placed between the two filters to help keep turbulent flow. The feed consistency was 0.85% with a 110ml Canadian Standard Freeness. Water was initially run through the filters to wet them. The stock was then run through the filters and the flow rate was gradually increased to 380 gpm. The wire screen

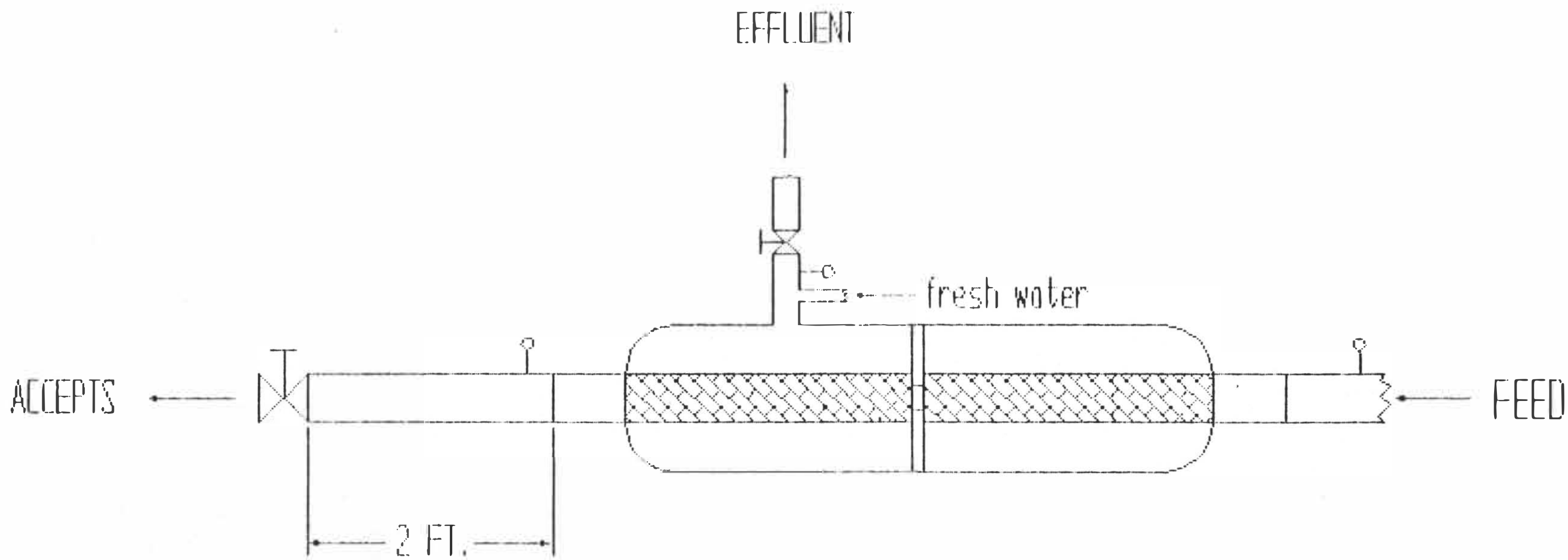
FIGURE 3 - COUNTER CURRENT TYPE SYSTEM



blinded immediately and stock became trapped between the support pipe and the synthetic sleeve on the second filter. Since there was a lower pressure in the pressure chamber than in the stock line, the fibers began to flow through the screen before the critical velocity was reached and this caused the screens to blind.

There were a few modifications before the second trial. The filter with the synthetic sleeve was completely removed form the system. The other filter was turned upside-down, as can be seen in figure 4. The hand valve after the filter was also moved further away from the device to about two feet. In order to keep equal pressure between the outside and inside of the screen during start-up, a fresh water line was added before the hand valve on the effluent line. The start-up procedure consists of filling the pressure chamber with water and ensuring all air is removed. The water is left on until the critical velocity is reached, at which time the water is turned off, then the effluent valve is gradually opened and the stock begins to flow through the screen. The feed consistency was also 0.85% with a feed freeness of 110 and an accept freeness of 120ml. This design worked and an effluent flow rate of 5 gpm was achieved. The pressure gauges were fluctuating with the feed and accept pressures between 12 and 17 psi and the effluent pressure between 10 and 15 psi. The feed flow rate was 380 gpm. When the screen did blind, the water valve was opened which effectively cleaned the screen, at least part of it.

FIGURE 4 - MODIFIED CROSS FLOW FILTER



Since a design and start-up procedure was determined a third trial was run to find the highest possible operating consistency. The initial feed consistency was 3% with the same filter system and start -up procedure as in run two. At 380 gpm the feed pressure was constant at 10 psi and gave no flow. The filter was back flushed with the water and then the consistency was diluted to 2%. Three flow rates were tried, but no effluent flow was seen. At this time it was noticed that there was about a 10 psi difference between the feed and accept pressures, the feed being higher. The stock was further diluted to 1.5% then to 1% consistency, but gave no effluent flow. The screen had blinded and was unable to be cleared with the water or with the shear of the stock.

Trial four was with the same raw furnish that was classified earlier (70% news and 30% coated sections). It was hydropulped at 5% consistency for 30 minutes with a pH of 7 and a temperature of 19 degrees celsius. It was then diluted to 1% consistency before being run through the filter. The start-up procedure was followed and a feed flow rate of 380 gpm gave an effluent flow rate of 3 gpm. The feed, accept and effluent pressures were 18-22psi, 16-20psi and 10-14psi respectfully. Samples of the feed, accept and effluent were analyzed for ash, brightness, clark classifier, kajanni fiber length analyzer and image analysis. A mass balance was also done around the filter.

Duplicate tests of percent ash were done at 550 degrees celsius and each sample had at least 0.2 g of ash.

For the feed and accept samples six brightness pads of at least 3 grams oven dried fiber were made and air dried for 24 hours. The filter paper was removed while the pads were dry. Three readings on each sample were performed to give a total of 18 readings per sample. Three brightness pads were made for the effluent sample and four readings were taken per pad.

The clark classifier was run with five grams oven dry fiber for five minutes. The fiber length of each fraction was determined by the kajanni fiber length analyzer. The fractions were dried, weighed then redispersed in water and at least 6,000 fibers were counted except for the first fraction of the accept sample in which 3,500 fibers were counted. While running this test it was noticed that the stock contained fiber flakes. The feed and accept samples were six cut, but still contained flakes.

At least 6,000 fibers were measured with the Kajanni fiber length analyzer for the feed, accept and effluent samples.

Image analysis was used to determine the ink particle diameter distribution for each sample. One gram oven dry fiber was used and diluted with 6 liters of water for each sample. Ten milliliters was then filtered, air dried and then analyzed. Four pads were made and 10 fields were taken per pad. The image analysis program also gave the particles counted, minimum and maximum diameters, mean and standard deviation of each sample.

figure 5 — ASH

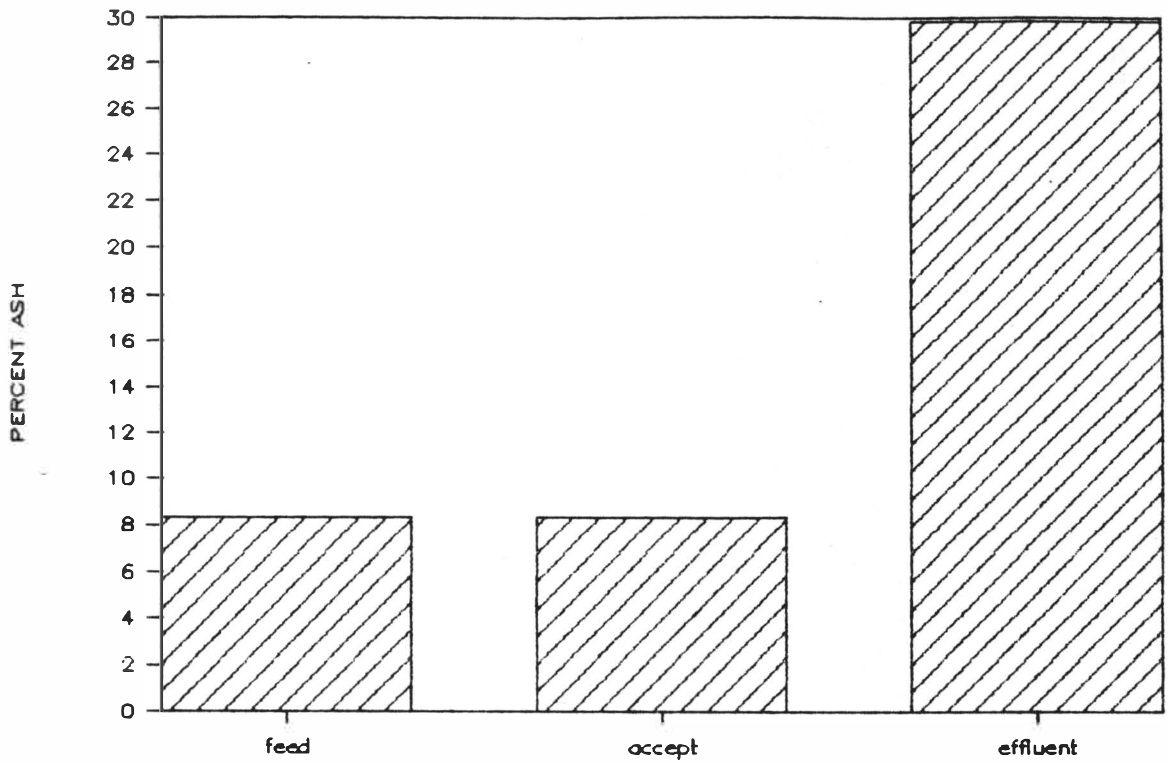
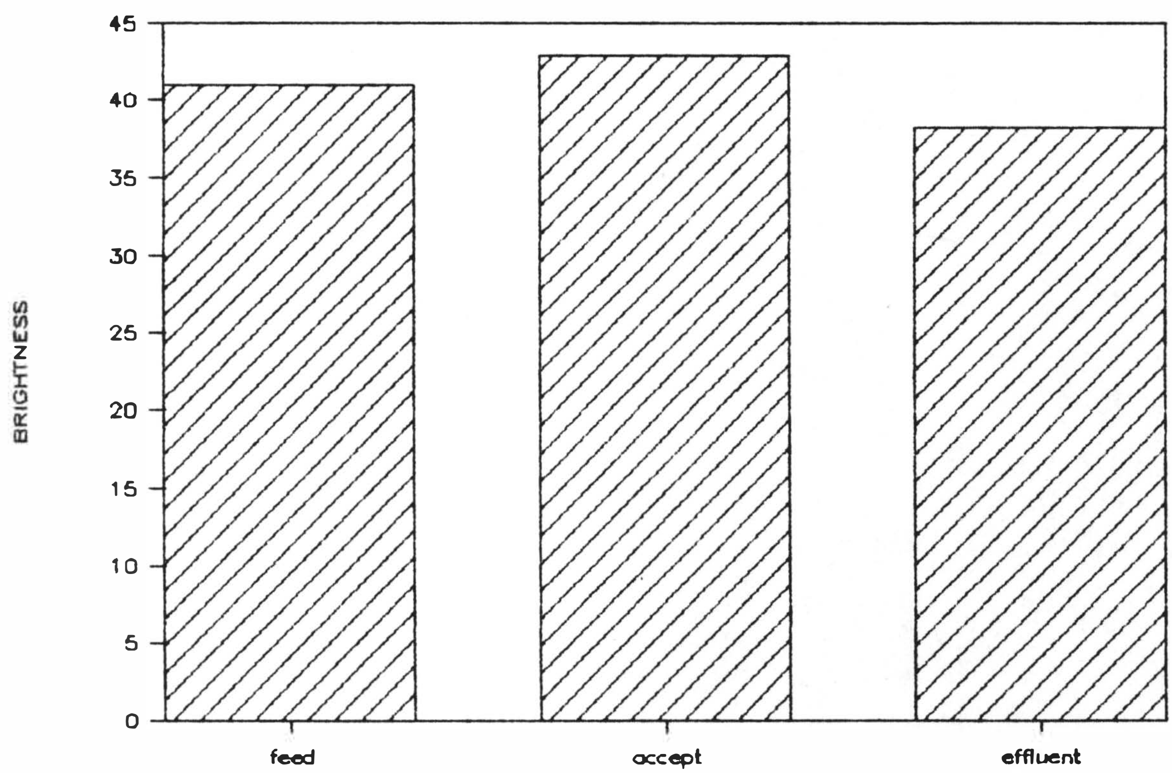


figure 6 — BRIGHTNESS



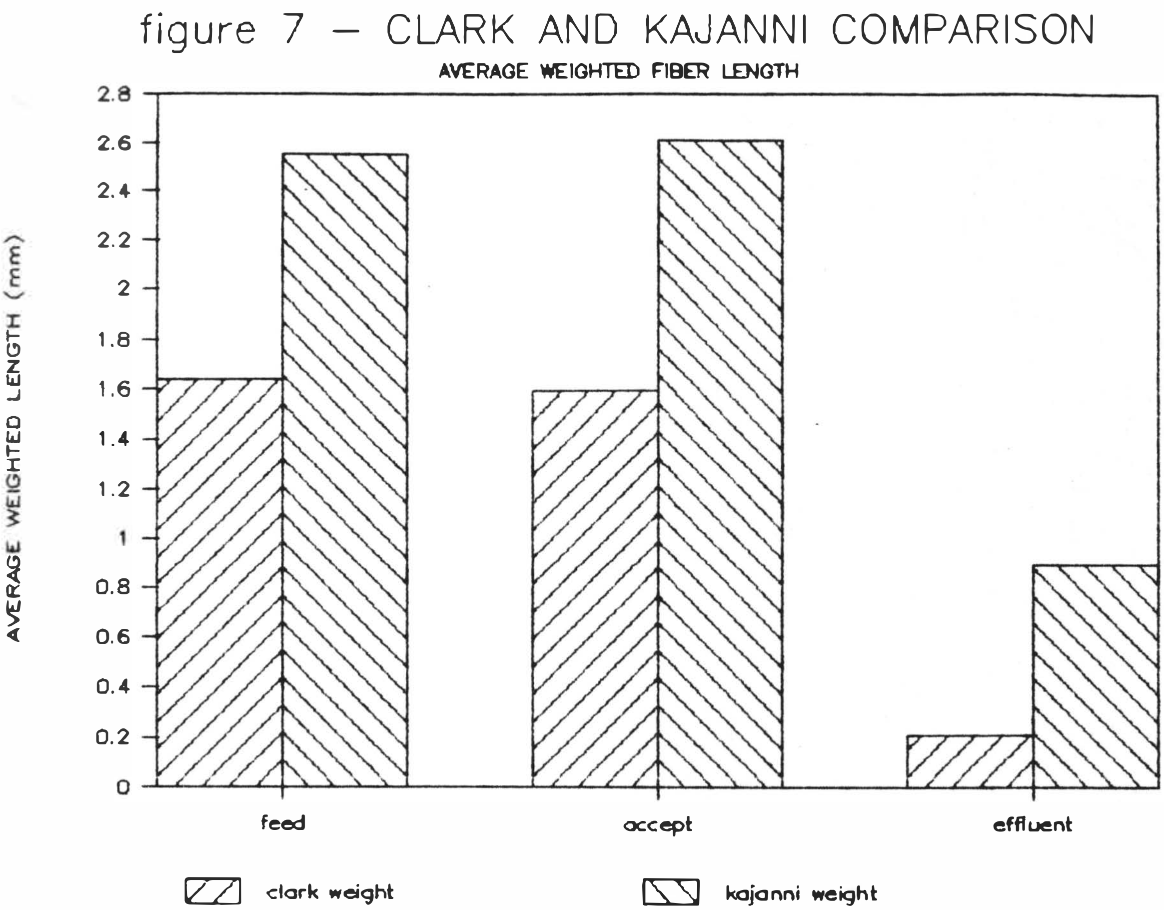


figure 7 - CLARK AND KAJANNI COMPARISON
AVERAGE WEIGHTED FIBER LENGTH
AVERAGE WEIGHTED LENGTH (mm)
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
feed
accept
effluent
clark weight
kajanni weight

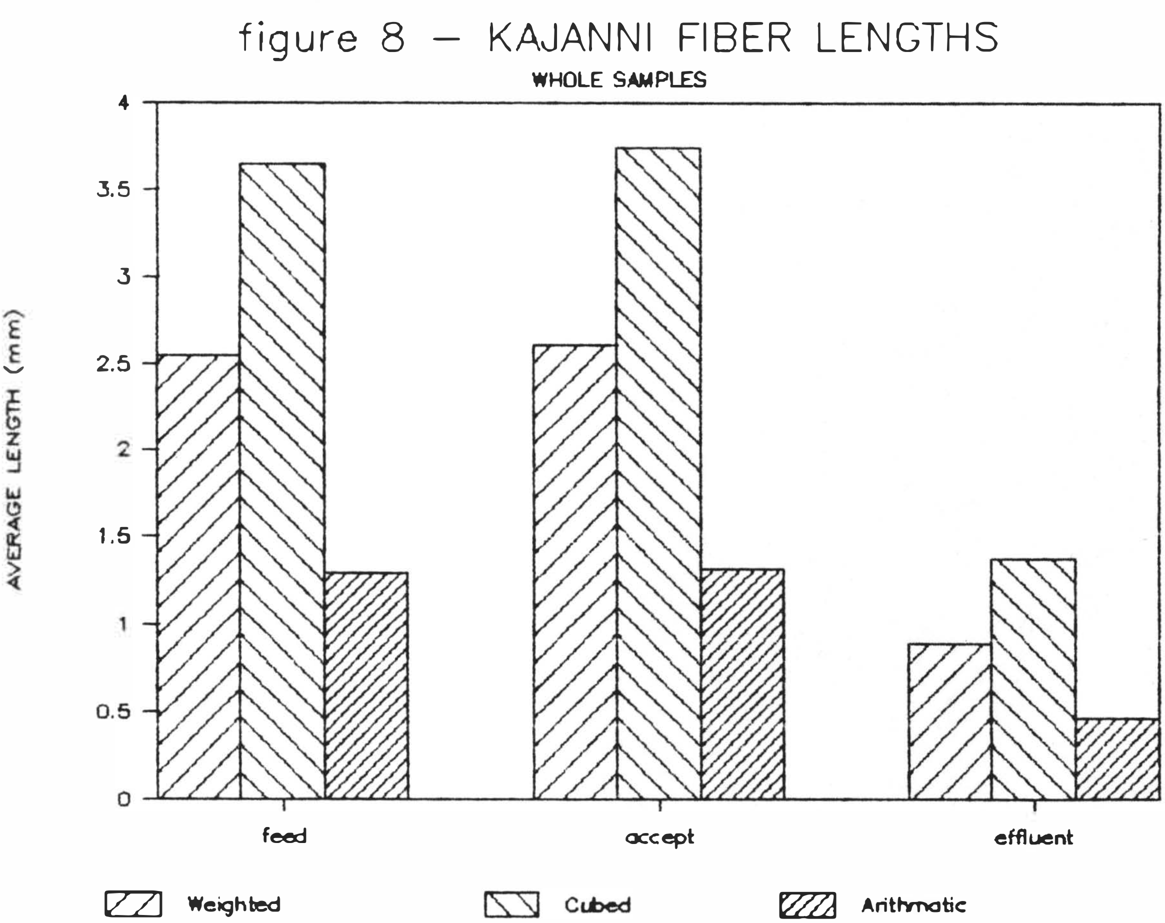


figure 8 - KAJANNI FIBER LENGTHS
WHOLE SAMPLES
AVERAGE LENGTH (mm)
4
3.5
3
2.5
2
1.5
1
0.5
0
feed
accept
effluent
Weighted
Cubed
Arithmatic

figure 9 — IMAGE ANALYSIS DATA

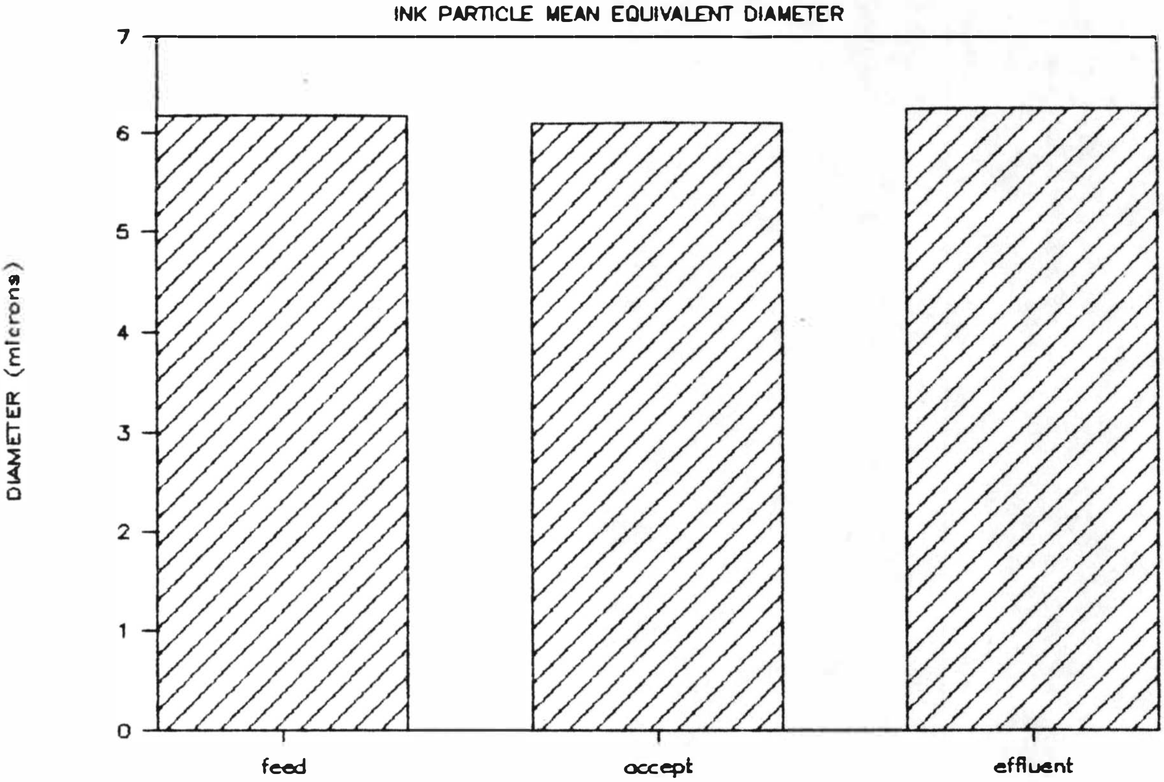


figure 10 — IMAGE ANALYSIS DATA

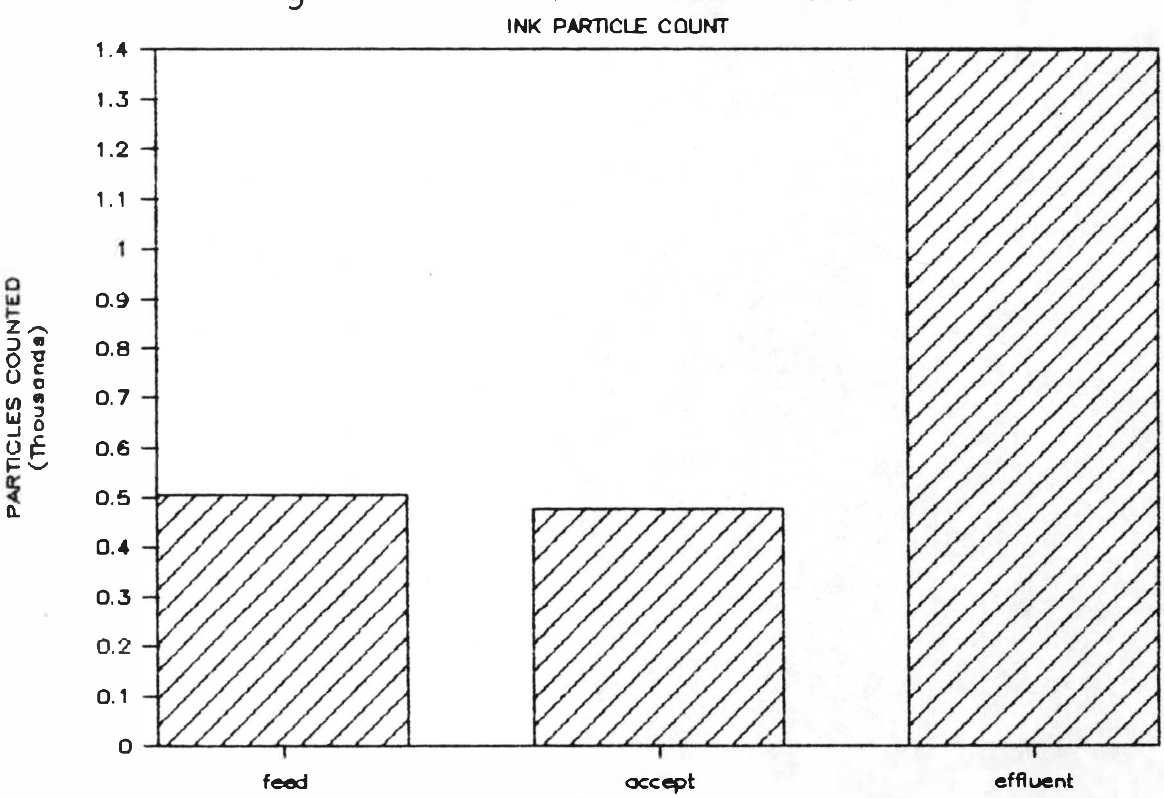
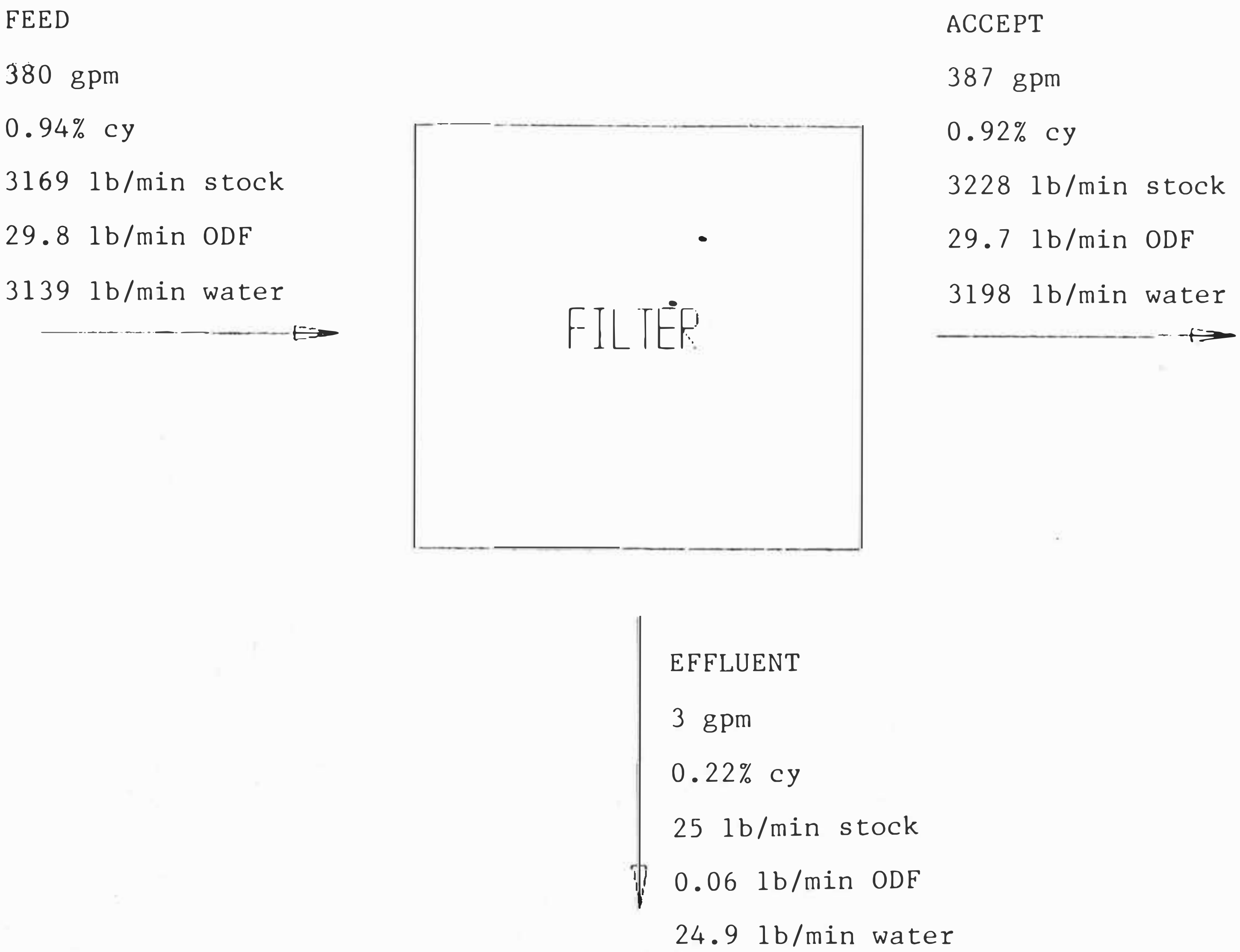


Figure 11 - MASS BALANCE



DISCUSSION

The ash results were as expected. The filler particles are small and because of the screen mesh size used, they were expected to be removed. As can be seen in figure 5, the percent ash of the effluent was 29.81% which means the filler particles were concentrated in the effluent stream.

The brightness was also as expected. As can be seen in figure 6, the effluent gave the lowest readings and the accepts gave the highest readings. The accept brightness was higher than expected. Since the stock flow was 380 gpm and the effluent flow was only 3 gpm, a large brightness increase was not expected. The standard deviation of the feed, accept and effluent samples was 1.8, 0.7, and 0.9 respectfully, so the readings are not statistically verifiable. There is a difference between the accept and effluent readings. The effluent is lower as expected. The lower effluent brightness is due to the fact that the ink particles were removed.

The clark classifier weights are not correct for the feed and accept samples because the stock contained small fiber flakes which stayed in the first compartment of the classifier. If these flakes were broken up then the weights of the other three fractions would have increased and the weight of the first fraction would decrease. The feed and accept samples were six cut, but these flakes where accepted. Since the weights are wrong, the weighted average fiber length does not correspond with the weighted length of the whole sample as analyzed by the Kajanni. Most of the effluent sample passed through the last screen (over 80%), as expected. This weighted length from the classifier does not correspond with that from the Kajanni. The length of the sample that passed through the screen was not determined by the Kajanni, but assumed to be 0.2 mm. Since most of the sample passed through the screen, the length of those fibers is the major contributor to the weighted average length. The assumed 0.2 mm is not valid here. The weighted fiber length of the raw material from the classifier data was 0.73mm and the Kajanni gave 0.77mm, so the two do correspond. Figure 7 shows the comparison between the weighted average fiber length from the clark classifier and the Kajanni. The weights and lengths of each fraction can be seen in appendix 2.

As can be seen in figure 8, the feed and accept samples were basically the same as analyzed by the Kajanni. The accept sample gave slightly higher lengths than the feed sample. This may be because there are less fines in the accept than in the feed, so out of 6,000 fibers counted, a higher percent of them were long fibers which accounts for the average lengths being higher than the feed. As expected the average length of the effluent was less than half of the feed or accept values. Fines are removed with the filter because the screen mesh was large enough to allow them through, but small enough not to let the large fibers through.

Image analysis was performed to determine the average ink particle diameter in each sample. Theoretically, washing will remove ink particles in the 2 micron size range in proportion to the water removed.(2) There was not expected to be many large particles in the effluent, but image analysis showed that there were large particles as can be seen in figure 9. In fact the mean particle size was largest in the effluent. A 6 micron particle is equal to a 6 x 10 -5 mm ink particle. The average arithmetic length of the effluent was 0.46mm so it is definitely possible for a 6 micron particle to pass through the screen. The turbulence within the screen may also aid in allowing these particles to pass through the screen by providing many possible areas that are subjected to the screen. Figure 10 shows how many ink particles were counted by the image analyzer. These results were as expected with the effluent containing the most ink. This is based on one gram oven dry fiber so the results mean that there was more ink per fiber in the effluent than in the feed or accepts. The complete image analysis distribution for each sample can be seen in appendix 3.

Figure 11 shows the results of the mass balance around the filter. Since the flow and consistency of the feed and effluent were known, the amount of oven dry fiber (ODF) and water per minute can be calculated. The ODF of the effluent was subtracted from the ODF of the feed to find the ODF of the accept stream. Since the consistency of the accept stream was known, the other values can be calculated. These calculations can be seen in

Appendix 4, Mass Balance. The ODF balances because it was the tie element. The stock flow of the accept stream was calculated from the ODF and the consistency, and then the water was found. As can be seen in the figure, the water does not balance. The accept consistency was not expected to be higher than the feed consistency because of the way the filter works. The feed consistency may be incorrect because of the times that the samples were taken. The feed sample was taken in the stock chest before the filter was started. During the start-up procedure water is added to the pressure chamber and then it is forced out of the chamber and back to the feed chest. So the feed consistency may actually be lower than what was determined.

CONCLUSIONS

The cross-flow filtration concept does remove ink, fines and filler from a stock suspension. Almost a three point brightness increase was noticed. The ash results showed that the filler was removed and the Kajanni showed that the smaller fibers were also removed. Image analysis results indicate that more ink particles per amount of fiber was removed as effluent. The results also showed that all sizes of ink particles were removed and not just the 2 micron size range particles.

RECOMMENDATIONS

The filter has great potential as a deinking method. Four areas that could be examined include the feed consistency, percent open area of the screen, screen design and stock temperature. Theoretically it should be possible to run the filter at any consistency given that turbulent flow can be maintained. By increasing the percent open area of the screen, a higher effluent flow rate may be achieved. The drilled support pipe may be helping the screen clean itself by providing wall turbulence, but it may also be detrimental. Since higher temperatures give faster drainage, by increasing the temperature the effluent flow may increase.

LITERATURE CITED

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2. Harrison, A. Pulp & Paper 63(3):61 (1989).

3. McCabe, W. L., Smith, J. C., and Harriott, P., "Unit operations of Chemical Engineering", McGraw-Hill Book Company, 1985, pp. 43-44.

4. Shrink, George. Vice President Engineering, Ronningen-Petter, Portage, Michigan. Interview, 13 November 1990.

APPENDIX 1 — RAW MATERIAL

ASH = 8.8%

CLARK CLASSIFIER

fraction	1	2	3	4	pass through
weight (g)	0.09	1.1	0.59	0.85	2.37
length (mm)	1.97	1.79	1.07	0.51	0.2

KAJANNI WHOLE SAMPLE LENGTHS

weighted average length = 0.77

cubed average length = 1.28

arith. average length = 0.3

APPENDIX 2 - CLARK CLASSIFIER WEIGHTS

FEED:

fractions	1	2	3	4	pass through
weight (g)	0.23	1.05	0.68	1.08	1.96
length (mm)	1.68	3.69	2.89	1.47	0.2

ACCEPT:

fractions	1	2	3	4	pass through
weight (g)	0.14	1	0.63	1.04	2.81
length (mm)	2.01	3.66	2.98	1.52	0.2

EFFLUENT:

fractions	1	2	3	4	pass through
weight (g)	0	0	0	0.11	4.89
length (mm)				0.46	0.2

APPENDIX 3 - IMAGE ANALYSIS DATA

OMNICON 3600 MEASUREMENT REPORT
10:17 A.M. on Fri., Apr. 5, 1991
Calibration : 1x 2.3771E+00 μm²/pp
SAMPLE NAME : FEED

DISTRIBUTION ANALYSIS on Equiv Diam.
UnderSize : 0
OverSize : 11

BIN	START	END	COUNT	BIN	START	END	COUNT
1	1.7397	2.2448	64	17	9.8210	10.326	11
2	2.2448	2.7499	60	18	10.326	10.831	6
3	2.7499	3.2549	40	19	10.831	11.336	11
4	3.2549	3.7600	33	20	11.336	11.841	8
5	3.7600	4.2651	47	21	11.841	12.346	5
6	4.2651	4.7702	12	22	12.346	12.851	4
7	4.7702	5.2753	31	23	12.851	13.356	4
8	5.2753	5.7803	27	24	13.356	13.862	6
9	5.7803	6.2854	18	25	13.862	14.367	5
10	6.2854	6.7905	8	26	14.367	14.872	4
11	6.7905	7.2956	10	27	14.872	15.377	3
12	7.2956	7.8006	18	28	15.377	15.882	0
13	7.8006	8.3057	13	29	15.882	16.387	2
14	8.3057	8.8108	11	30	16.387	16.892	6
15	8.8108	9.3159	12	31	16.892	17.397	4
16	9.3159	9.8210	7	32	17.397	17.902	4

OMNICON 3600 MEASUREMENT REPORT
10:17 A.M. on Fri., Apr. 5, 1991
Calibration : 1x 2.3771E+00 µm²/pp
SAMPLE NAME : FEED

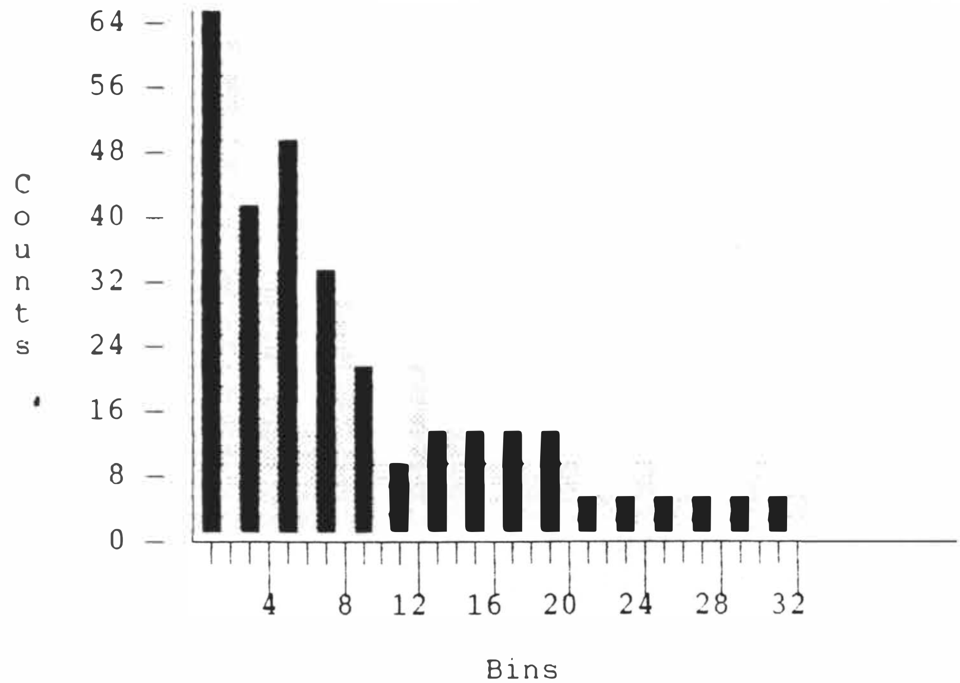
Frequency Histogram - FEED

Linear Distribution

Equiv Diam.

Offset : 1.7397
Size : 0.50508
Range : 17.902
Under : 0
Over : 11

Cal. : µm



Equiv Diam.

d Of Measurement.

Statistics :

Count: 505
Min: 1.7397
Max: 39.519
Total: 3122.9
Mean: 6.1839
StDev: 4.6948

OMNICON 3600 MEASUREMENT REPORT
10:41 A.M. on Fri., Apr. 5, 1991
Calibration : 1x 2.3771E+00 µm²/pp
SAMPLE NAME : ACCEPTS

DISTRIBUTION ANALYSIS on Equiv Diam.
UnderSize : 0
OverSize : 7

IN	START	END	COUNT
1	1.7397	2.3085	71
2	2.3085	2.8773	53
3	2.8773	3.4461	36
4	3.4461	4.0149	40
5	4.0149	4.5837	16
6	4.5837	5.1525	42
7	5.1525	5.7213	21
8	5.7213	6.2901	26
9	6.2901	6.8589	12
10	6.8589	7.4277	18
11	7.4277	7.9965	28
12	7.9965	8.5654	10
13	8.5654	9.1342	11
14	9.1342	9.7030	7
15	9.7030	10.272	9
16	10.272	10.841	8

BIN	START	END	COUNT
17	10.841	11.409	7
18	11.409	11.978	5
19	11.978	12.547	12
20	12.547	13.116	5
21	13.116	13.685	6
22	13.685	14.253	3
23	14.253	14.822	5
24	14.822	15.391	7
25	15.391	15.960	2
26	15.960	16.529	3
27	16.529	17.097	0
28	17.097	17.666	1
29	17.666	18.235	2
30	18.235	18.804	1
31	18.804	19.373	0
32	19.373	19.941	2

OMNICON 3600 MEASUREMENT REPORT
10:41 A.M. on Fri., Apr. 5, 1991
Calibration : 1x 2.3771E+00 µm²/pp
SAMPLE NAME : ACCEPTS

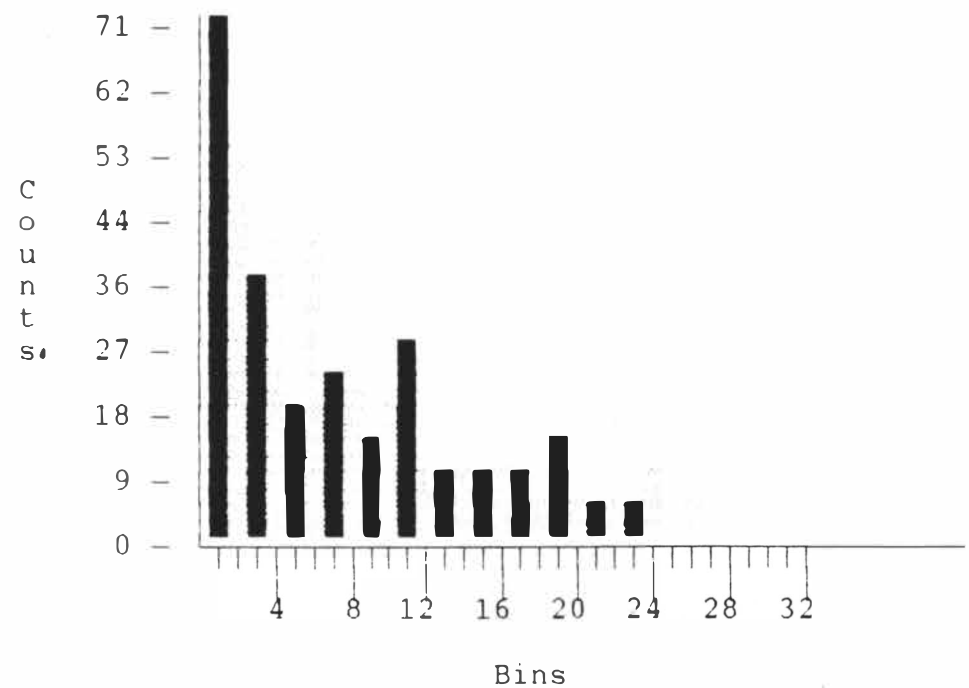
Frequency Histogram - ACCEPTS

Linear Distribution

Equiv Diam.

Offset : 1.7397
Size : 0.56880
Range : 19.941
Under : 0
Over : 7

Cal. : µm



Equiv Diam.

d Of Measurement.

Statistics :

Count: 476
Min: 1.7397
Max: 45.333
Total: 2907.6
Mean: 6.1084
StDev: 4.6701

OMNICON 3600 MEASUREMENT REPORT
11:07 A.M. on Fri., Apr. 5, 1991
Calibration : 1x 2.3771E+00 μm^2/pp
SAMPLE NAME : EFFLUENT

DISTRIBUTION ANALYSIS on Equiv Diam.
UnderSize : 0
OverSize : 7

BIN	START	END	COUNT	BIN	START	END	COUNT
1	1.7397	2.4260	195	17	12.720	13.406	20
2	2.4260	3.1123	226	18	13.406	14.093	19
3	3.1123	3.7985	103	19	14.093	14.779	19
4	3.7985	4.4848	134	20	14.779	15.465	7
5	4.4848	5.1711	88	21	15.465	16.151	16
6	5.1711	5.8574	100	22	16.151	16.838	3
7	5.8574	6.5436	58	23	16.838	17.524	8
8	6.5436	7.2299	63	24	17.524	18.210	11
9	7.2299	7.9162	49	25	18.210	18.897	5
10	7.9162	8.6025	57	26	18.897	19.583	7
11	8.6025	9.2887	40	27	19.583	20.269	4
12	9.2887	9.9750	31	28	20.269	20.955	6
13	9.9750	10.661	37	29	20.955	21.642	3
14	10.661	11.348	32	30	21.642	22.328	0
15	11.348	12.034	24	31	22.328	23.014	2
16	12.034	12.720	22	32	23.014	23.701	1

OMNICON 3600 MEASUREMENT REPORT
11:07 A.M. on Fri., Apr. 5, 1991
Calibration : 1x 2.3771E+00 μm^2/pp
SAMPLE NAME : EFFLUENT

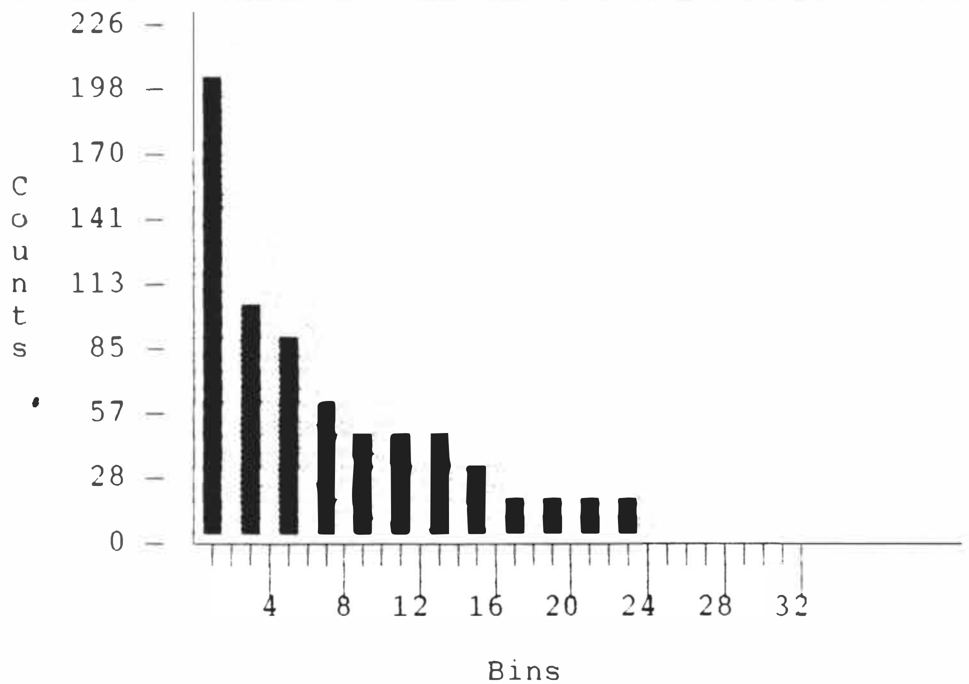
Frequency Histogram - EFFLUENT

Linear Distribution

Equiv Diam.

Offset : 1.7397
Size : 0.68627
Range : 23.701
Under : 0
Over : 7

Cal. : µm



l Of Measurement.

Equiv Diam.

Statistics :

Count:	1397
Min:	1.7397
Max:	54.267
Total:	8744.7
Mean:	6.2596
StDev:	4.8273

APPENDIX 4 - MASS BALANCE

FEED

380 gpm x 8.34 lb/gal = 3169 lb/min stock

3169 lb/min stock x .0094 = 29.8 lb/min ODF

3169 lb/min - 29.8 lb/min = 3139 lb/min water

EFFLUENT

3 gpm x 8.34 lb/gal = 25 lb/min stock

25 lb/min stock x 00.22 = 0.06 lb/min ODF

25 lb/min - 0.06 lb/min = 24.9 lb/min water

ACCEPT

29.8 lb/min - 0.06 lb/min = 29.7 lb/min ODF

29.7 lb/min / .0092 = 3228 lb/min stock

3228 lb/min - 29.7 lb/min = 3198 lb/min water