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The Effect of Fines and Filler in Forward Centricleaners on Contaminant Removal Efficiency

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THE EFFECT OF FINES AND FILLER IN FORWARD CENTRICLEANERS ON CONTAMINANT REMOVAL EFFICIENCY

BY

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ABSTRACT:

In this study, the effect of fines and filler content on a forward centricleaner's contaminant removal efficiency is evaluated. The paper industry has assumed that centricleaner contaminant removal efficiency is not influenced by the presence of clay or fines. However, it has never been documented. Thus, at the paper machine, centricleaners operate at the same efficiency at 1.0% consistency with 15 or 30% clay. The same assumption has also been made with fines content in the white water loop, which can vary from day to day depending on what specific grade is being made. This thesis has concentrated on whether or not this assumption is true. The results indicate an increase in contaminant removal efficiency as the fines level increases. However, the effect of filler content nullifies this increase. As filler content increases, the contaminant removal efficiency decreases.

INTRODUCTION:

Centrifugal cleaners operate on the utilization of fluid pressure energy to create rotational fluid motion. This rotational motion causes relative movement of particles suspended in the fluid and forces a separation of these particles. (1) Stock enters the cleaner tangentially at the top of a conical pressure vessel; the velocity of the stock increases as it moves helically toward the apex of the cone. As the stock spins along this path, the separation of particles takes place. The heavier fraction is thrown radially outward to the wall of the cone and the lighter fraction displaced toward the center. As the stock approaches the apex of the cone, the diameter is increasingly smaller; the inability for all of the flow to be discharged through this nozzle forces some of the fluid to move toward the vortex in the center. This fraction reverses direction and follows a helical path upward toward the overflow end of the cleaner. (2) The overflow is therefore mainly comprised of the lighter weight fraction of the stock. The heavier contaminants are simultaneously discharged from the underflow of the cleaner.

Forward centricleaners are traditionally the most popular ones in the paper industry. They are employed to remove contaminants that possess a higher specific gravity than one, which is the approximate value of wood fibers. The contaminants removed include such abrasive material as glass, sand, bark, shives, chop, and even visually obnoxious specks of ink.

LITERATURE REVIEW:

Certain characteristics which have an impact on efficiency and which have been well studied and documented include design and operating parameters.

Design Parameters

Design parameters have a substantial effect on centricleaner performance. Small diameter cleaners generally clean more efficiently, but also plug more readily, and pass less flow. The same is true for the inlet size. The inlet tangency and shape also bestow certain characteristics on the cleaning efficiency. The cone angle can impart its own influence since smaller angles separate sharply but require more headroom and have a lower capacity. Cone surface disturbances such as bumps, ridges, threads, channels, offsets, rough interior surfaces, and other changes to the cone tend to increase capacity and reduce fiber reject rate, but the cleaning efficiency is reduced to some degree. Centricleaners with continuous reject discharge flows tend to clean more effectively, but they also generally require multiple stage systems to recover the fiber which is rejected. Discontinuous cleaners do not normally require this feature. (3)

Operating Parameters

Besides design parameters, operating parameters that influence all types of centricleaners include feed consistency, pressure drop, reject rate, temperature, and flush water volume (for forward cleaners only). Decreasing the feed consistency improves cleaning efficiency. Increasing the pressure drop across the cleaner in the range of 10 to 30 psi improves cleaning

efficiency but at the cost of more pumping energy. The rate of rejects has a significant effect on efficiency since the more that is rejected, the better the chances are that all the contaminants will be removed. This is because there will be less opportunity for the contaminants to escape with the accepts due to a smaller accept flow rate. The temperature can also change the efficiency. As the temperature rises, the centricleaner tends to clean better. This is because the fluid becomes less viscous, allowing an increased amount of contaminants to be rejected. (4) Along with the contaminants however, is an increased amount of fiber being rejected. For forward cleaners, increased flush water reduces fiber loss, but excessive flush water can reduce contaminant removal efficiency. (5)

Mathematical Modeling

The design of centricleaners for pulp cleaning is a science in itself. Mathematical models can be used to aid in this problem by helping to determine where energy losses occur in the centricleaners. These losses include effects of wall friction, internal fluid flow, inlet turbulence, and kinetic energy of the fluid through the accept tube. The study of fluid flow in the centricleaner is also based on energy losses, while an application of the momentum equation in the radial direction is also required.

The core elements of the equation are, 1) Postulating velocity profiles for the three-dimensional flow, 2) Realizing the concept of the skin friction coefficient along the solid boundaries, 3) Using the viscous dissipation function for

internal fluid flow losses, 4) Estimating the kinetic energy leaving the overflow stream, 5) Determining the kinetic energy losses an the inlet resulting from and variations between inlet and centricleaner velocities, and 6) An integration of the momentum equation in the radial direction along the radius from the outer boundary to the radius of the overflow tube inside diameter; this corresponds to the radial position at which the lower pressure of the centricleaner is usually measured. (6)

In evaluation of the contaminant separation to the underflow reject outlet, the particle that would be in radial equilibrium at the inside diameter of the overflow tube would most likely be discharged. This concept coincides with the idea that there are two flow patterns in a hydrocyclone. there is an outer free vortex flow and inner solid-body type flow. The inner solid-body flow profile should be smaller than the inside diameter of the overflow tube.

Centricleaner Internal Forces

Four distinct forces act on a particle entrained in the fluid flowing through the hydrocyclone. These four forces determine particle trajectory within a flow field. The forces included are drag, buoyancy, centrifugal, and lift. (7) Since the majority of dirt in a papermill pulp suspension is spherical, the analysis of these four forces is based on a spherical particle.

The drag forces can be determined by use of the drag coefficient. It can be determined that the particle is moving with the fluid in the tangential and axial direction, but is not

moving with the fluid in the radial direction, thus resulting in a radial direction drag force which can then be calculated with use of the drag coefficient.

Buoyant forces for spherical particles can be approximated by assuming the pressure gradient on the particle is the same as the pressure gradient on the flow field. In the centricleaner, this force in the radial direction is dependent on the radial position and the swirl velocity.

The particle centrifugal force is from the rotary motion caused by the centricleaner.

There is a transverse force on a spinning sphere moving through a liquid, and it is called the Magnus Effect. (8) Analogous to this particle phenomena is the motion of a baseball pitcher's curve ball.

Forward Centricleaners

Typical fine forward cleaners, which were studied here, have relatively small diameters of around three to twelve inches and operate at consistencies of less than one percent. The most common cleaners of this type operate with a continuous flow of rejects from the underflow tip.

Fine forward cleaners are capable of removing a wide range of contaminants and are normally found in several applications including the following. First, in the pulp mill to remove shives, bark, and sand. If the mill is mechanical, grindstone, grit, and chop will be removed by the cleaner. Second, in the bleach plant to remove unwanted unbleached shives. Third, in the paper mill at the paper machine headbox to remove dirt, and

reduce abrasion wear in the wet end. Other applications include deinking plants and secondary fiber processing operations where ink balls and residual grit are removed respectively.

ANALYSIS:

Due to the versatility of the fine forward centricleaner described above, it was decided to use this as the cleaner to be used in this project.

Choice of Forward Centricleaner

The Celleco "Cleanpac 350" twin wall cleaner has been very successful in the industry and therefore is an excellent unit to use. Analysis of the literature indicates that there are several important factors to consider for the success of fine forward centricleaners.

Benefits of Forward Centricleaner

The benefits of the Celleco cleaner include high cleaning efficiency, low pressure drop and thus low energy consumption, and a pressurized reject system which allows the cleaner to operate at high temperatures. It is also compact and easy to install, and is accessible for inspection and service during operation. This model also is designed to optimize the internal hydrodynamic flow pattern and reduce the thickening ratio. The thickening ratio is defined as the reject consistency divided by the feed consistency. It is primarily dependant on the dewatering properties of the fiber material and process temperature. At temperatures above 50 degrees Celsius, this ratio could exceed ten which would cause the centricleaner to plug up. The design of the internal hydrodynamic flow pattern of

the feed and reject areas of the "Cleanpac 350" maintains the thickening ratio within desirable limits.

The pressurized reject system allows the size of the reject opening to be large, consequently reducing the likelihood of blocking. However, the cleaner which was used in this venture did not include a pressurized reject system since the line was fed back into the stock chest which was at atmospheric pressure.

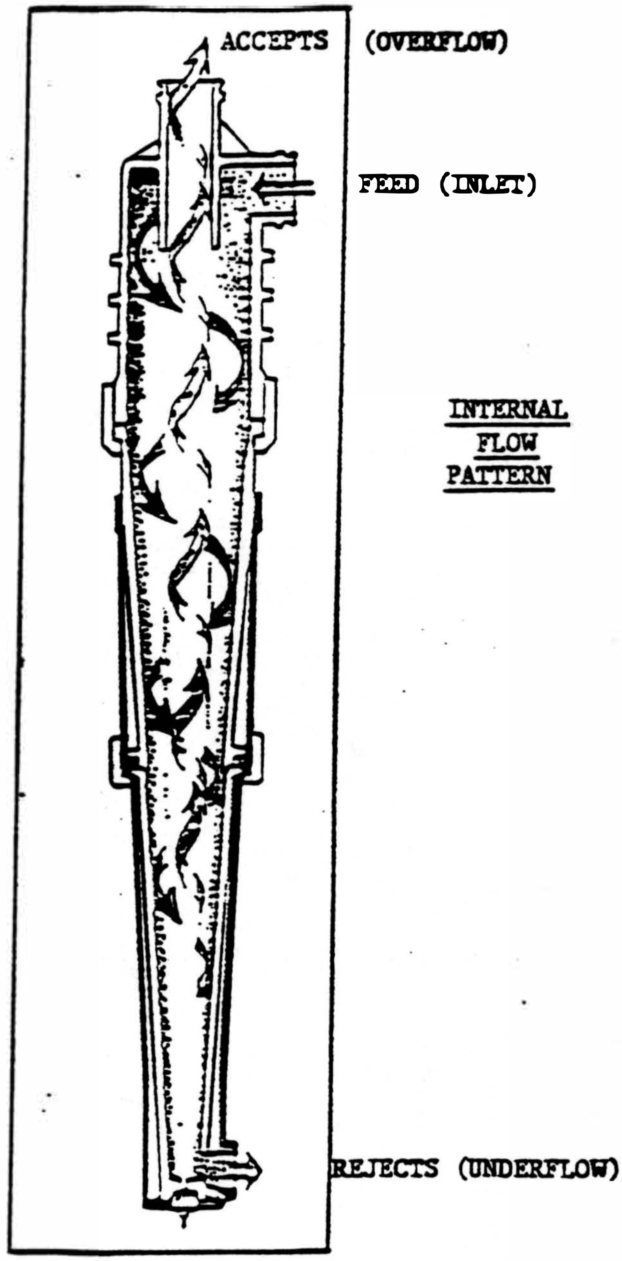
The use of centricleaners in the paper industry has been one method of removing contaminants throughout the mill. The removal of contaminants is necessary in the paper industry to prevent three major problems: deviations in sheet quality, appearance problems, and machine dirt buildup and converter problems such as rough edge cutting, paper breaks, and sheet picking. Any of these problems can increase downtime and/or rejection of product resulting in escalated costs.

PROBLEM STATEMENT:

This thesis recognized the influence of the predescribed factors and laws governing centricleaner flow and contaminant separation. Many design and operating parameters have been studied thoroughly and subsequently documented. However, the effect of clay and fines content on the contaminant removal efficiency of centricleaners has not been documented. This thesis has probed this problem comprehensively in order to determine if the level of either clay or fines in the furnish influences the contaminant removal efficiency. Also studied was if clay and fines produced a synergistic effect on the cleaning efficiency. The goal of this study was also to investigate any economic factors which may need to be considered to fully understand the complete impact of fines and filler content on contaminant removal efficiency.

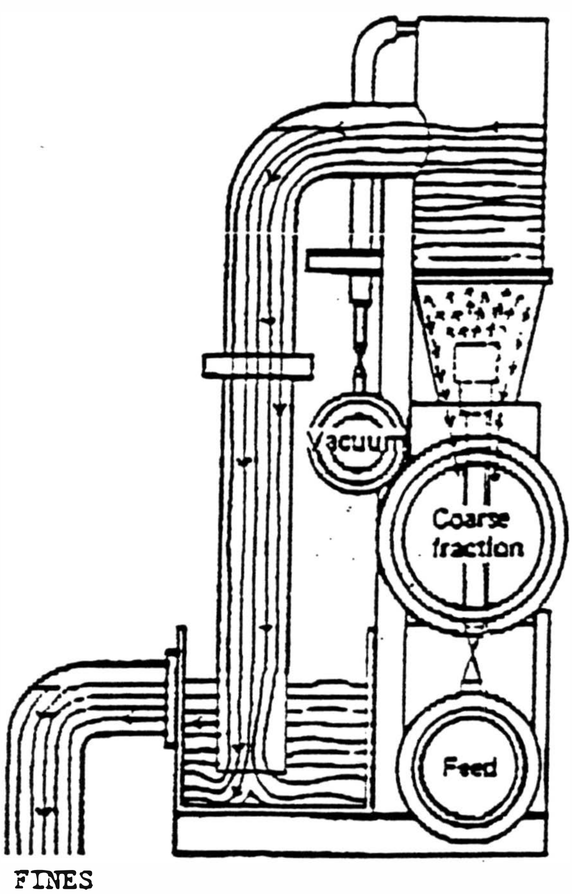
EXPERIMENTAL DESIGN:

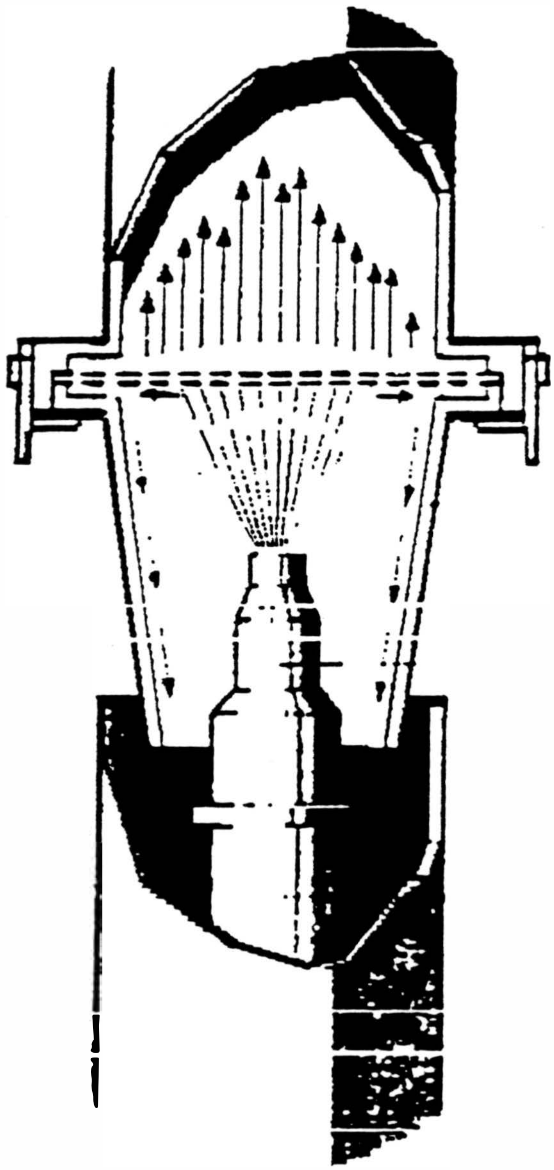
The first step of the experimental design of this project was to determine what equipment to use and how big a scale the experiment would need to be conducted on to produce acceptable results. The decision to use the Celleco "Cleanpac 350" centricleaner was based on its popularity in the industry and its unique design features which make it an excellent cleaner to use for this study (see appendix). The capacity of this cleaner determined the scale at which this experiment would be carried out. Therefore, the Western Michigan University Recycling Pilot Plant Facilities, which already contained a Celleco "Cleanpac 350" was chosen as the testing site.



At this point, it was decided to run Old Corrugated Container (OCC) Stock through the centricleaner at nine different levels of fines and filler. OCC was chosen because it already contained contaminants which subsequently eliminated the need to add some type of contaminant. The filler utilized was a basic clay filler. The fines which were required were obtained by running the stock through a device called a "Float Wash".

FLOAT WASH





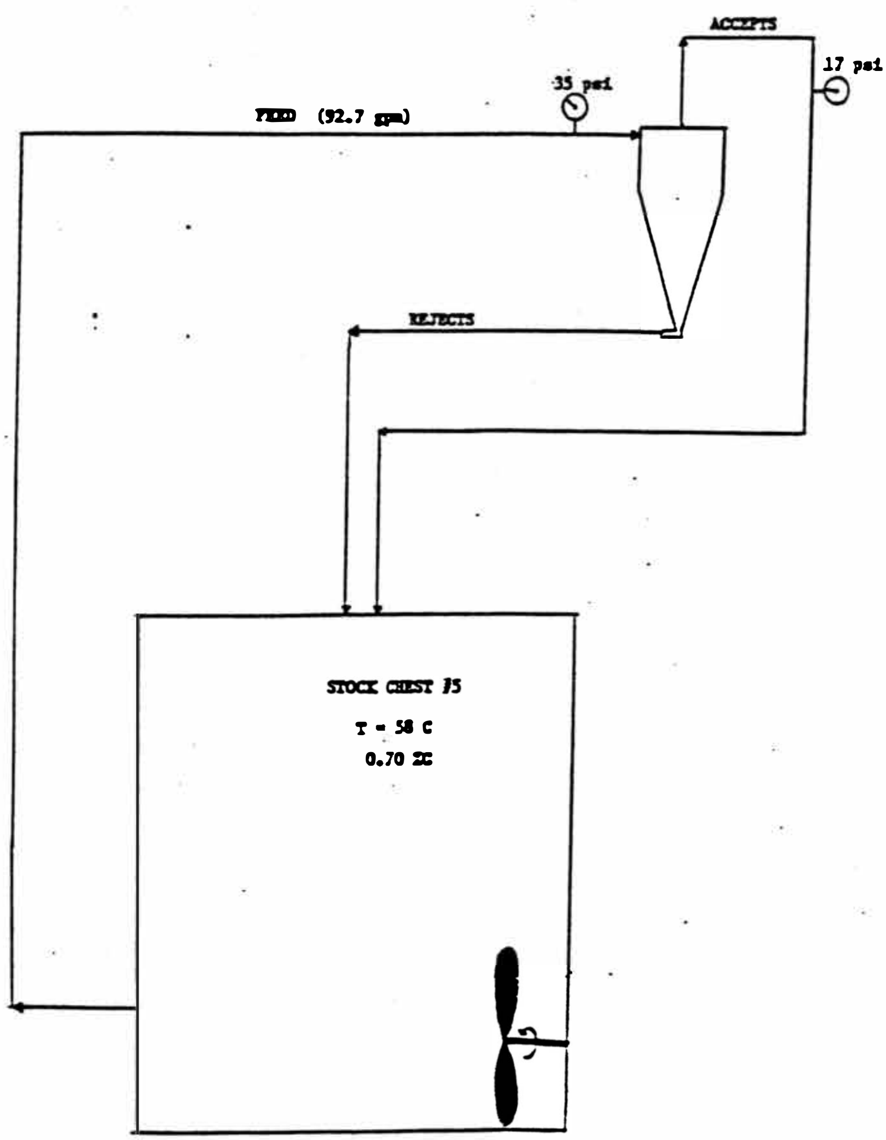
This device operates by pumping stock up to a 43 um screen where the fines could go through, and subsequently rejecting the longer fibers which fell off the screen and were pumped back to the stock chest. The side of the screen which received the fines used a vacuum to pull them into a separate stock chest.

A batch of OCC was pulped and diluted to the required consistency in order to be fractionated by the float wash. The rejected long fiber stock was used as the base furnish stock for one of the runs. The fines obtained from the float wash were added to a separate batch of OCC to result in a base furnish stock which was high in fines content; this was used for another test run. The last base stock was obtained by simply hydropulping the OCC and using it as is, which resulted in a test run with a medium fines content level. To each of these three base stocks was added 0, 15, and 30% filler. Preliminary tests showed that the OCC already contained 1.5% filler. This was determined by following Tappi Standard T413 om-83 Testing Procedure. The table below illustrates the series of furnishes which were run through the centricleaner.

				FILLER	
			A	B	C
	Run #1	5% ---	1.5%	16.5%	31.5%
FINES	Run #2	13% ---	1.5%	16.5%	31.5%
	Run #3	21% ---	1.5%	16.5%	31.5%

As each of these runs were being tested, there were several parameters which needed to be regulated. The design parameters were kept constant by simply using only one centricleaner. The operating parameters were kept constant by monitoring the temperature, differential pressure, feed consistency, and reject rate of every run. The stock being tested was sent through the centricleaner with the subsequent accepts and rejects being pumped back into the stock chest. This resulted in uniform characteristics for every run, excluding the clay and filler content which was increased at set intervals. The process parameters are summarized below.

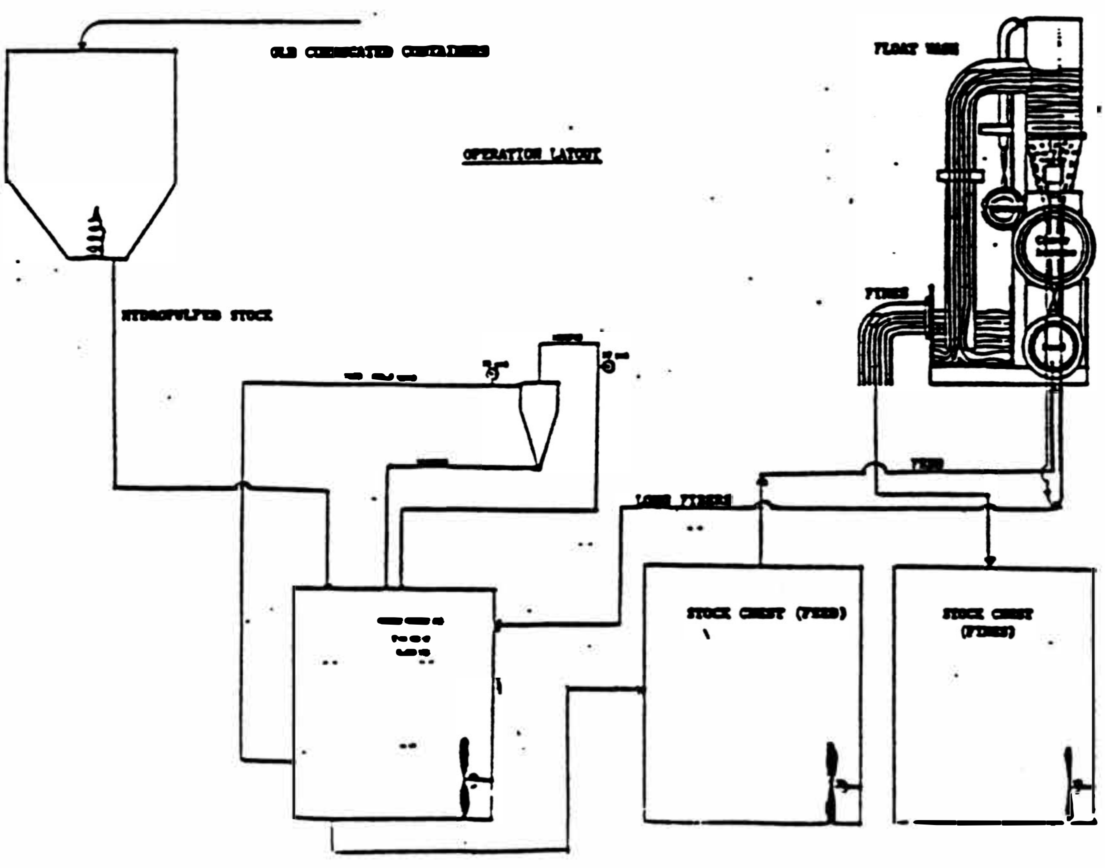
FORWARD CENTRICLEANER SYSTEM



Samples of stock were obtained from the feed, accepts, and rejects of each run. These samples were tested for consistency, fines content, and Canadian Standard Freeness. Contaminant removal efficiency was calculated by using the following equation. (9)

$$\text{Efficiency} = \frac{\text{contaminants in feed} - \text{contaminants in accepts}}{\text{contaminants in feed}} \times 100$$

The amount of contaminants contained in each line were determined by a 0.006 inch vibrating slotted screen. The acceptable fiber passed through the slots, while the reject material stayed on the screen which were then removed and allowed to air dry. The air dried contaminants were then weighed to determine their respectful quantities. The diagram below illustrates the entire system utilized in this thesis.



RESULTS AND DISCUSSION:

The outcome of this experiment yielded some rather interesting results. As was stated at the beginning of this paper, the paper industry has assumed that the amount of fines and filler in the stock leading to the centricleaners had no effect on contaminant removal efficiency. The work performed in this thesis shows definite trends between fines and filler content and the resulting contaminant removal efficiency.

The following table portrays the effect of the fines content on contaminant removal efficiency.

Fines Content	Average Efficiency (%)
5%	46.7
13%	53.5
21%	62.6

This data shows a definite trend towards an increase in contaminant removal efficiency as the fines level is increased. One explanation for this is that the excess amount of fines acts to flush out the contaminants. If the size of the contaminants is similar to that of the fines, a good posibility exists for the fines to be thrown towards the outside wall of the centricleaner along with the contaminants. This is a realistic assumption since the centricleaner separates by specific gravity and size. Smaller objects can migrate outward with less interference than longer fibers. Thus, as the fines level is increased, there is a greater amount of smaller particles in the feed. Therefore, the

increase in fines would aid in the removal of contaminants. This hypothesis is supported by a fines analysis of the reject stream which indicated that the relative amount of fines had doubled from that of the feed stream. This strengthens the aforementioned hypothesis since it indicates that the extra fines are being washed out in the reject stream.

The next table illustrates the effect that the filler content had on contaminant removal efficiency.

Filler (%)	Average Efficiency (%)
1.5	60.7
16.5	51.6
30.5	50.5

The effect of filler indicates a decrease in efficiency as the filler is increased. The reasoning behind this is not as clear as would be desired. In order to understand this relationship completly, one would require a knowledge of the separation phenomenon taking place inside the cleaner.

When analyzing the fines and filler results separately, there has been a noticeable change in contaminant removal efficiency. However, a complete evaluation of the data obtained must include a study of the interaction between the fines, filler, and fibers simultaneously. It was originally proposed that there may be a possible effect on contaminant removal efficiency caused by fines and filler when acting together on the contaminants.

The following table portrays the results of both the fines and filler content on contaminant removal efficiency obtained from this thesis.

Fines \ Filler	1.5%	16.5%	31.5%
5%	43.5%	49.5%	47.2%
13%	63.6%	52.7%	44.2%
21%	75.1%	52.6%	60.0%
21%	53.9%	47.8%	56.4%

This shows that at 1.5% filler, the effect of fines is drastic compared to the effect at 31.5% filler. The data indicates the effect of fines on contaminant removal efficiency is canceled out with the addition of filler.

After the data was analyzed, it was determined that one run should be duplicated in order to compute the variance of the test. With this information, a two way analysis of variance was performed. The results of this test did not show significance at a 95% confidence interval. The reason being that the duplicated run was not run at the same inlet consistency as the run to which it was being compared. This mistake explains the results of this

analysis. Another statistical analysis was performed on all the results in order to determine if the data fit the following equation. This included a regression of the fines and filler contaminant removal efficiencies with the aid of the "Minitab" statistical analysis program. The following equation fits the results within a 95% confidence interval.

$$\text{EFFICIENCY} = 41.4 - (0.0289 * A * B) + (1.47 * B)$$

$$A = \text{Filler } (\%)$$

$$B = \text{Fines } (\%)$$

This shows two things: first, the negative sign in front of the "A" variable indicates that the efficiency will decrease as the "A" variable is increased. Second, the positive sign in front of the "B" variable tells us that an increase in fines percentage will result in an increase in efficiency.

CONCLUSIONS:

The original assumption that contaminant removal efficiency is not effected by fines and filler content is false. Both the fines and filler do have a definite impact. However, their combined effect on contaminant removal efficiency is small because they tend to cancel each other out. As the amount of fines is increased, the resulting contaminant removal efficiency is increased. The average efficiency increased from 46.7% to 62.6% when the fines level was increased from 5% to 21%. Alternately, the filler content hindered the average efficiency; it decreased from 60.7% to 50.5% when the filler was increased from 1.5% to 31.5%.

The end result is a forward centricleaner does not appear to operate much differently when the fines and filler levels are increased or decreased simultaneouely. However, if only one of these variables changes, the effect on contaminant removal efficiency will be obvious.

This probably is not the biggest news ever presented to people such as papermakers; however, it is always pleasant to hear something optimistic.

Since secondary fiber utilization is becoming increasingly popular in the paper industry, the operation of cleaners in the paper mill will become more important. More specific, the operation of centricleaners will be less neglected. The more that is known about the operation of the centricleaners, the more the process will be able to be fine tuned in order to produce an

optimum product. The results of this thesis will help the understanding of centricleaner operation.

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APPENDIX:

Technical specification

Pressure drop m w. g.	Feed capacity l/min	Pressure drop psi.	Feed capacity USgpm
10	365	14	96
12	400	17	106
15	450	21	118

Minimum accept counter pressure requested:
3.5 m w. g.

Minimum accept counter pressure requested:
5 psi.

Maximum feed pressure allowed:
1-stage canister – 30 m w. g.
2-stage canister – 25 m w. g.
Bank type – 42 m w. g.

Maximum feed pressure allowed:
1-stage canister – 42 psi.
2-stage canister – 35 psi.
Bank type – 60 psi.

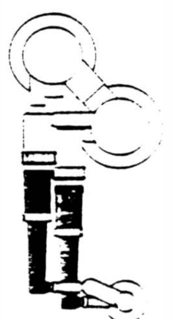
Material
All cleaner units including seals are made of wear resistant synthetic material. Max temperature: 85°C (185°F). Contact Celleco when higher temperature.

Canister and banks are made with all wetted parts of stainless steel. SS 2343 – AISI 316. Bank structures are made of painted mild steel.

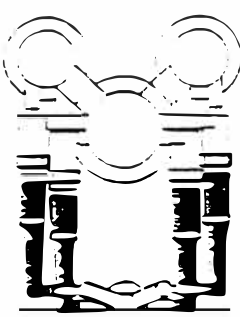
Patents
The design is protected by series of patents and patent applications.

Assembly alternatives

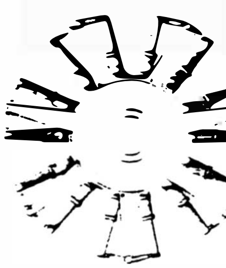
Type 1



Type 2



Type 4



Canister

Number of units	FEED CAPACITY l/min, Pressure drop m w. g. 10	12	15	USgpm, Pressure drop psi. 14	17	21	BANK Horizontal Type 1	2	4	Vertical Type 1	2	4	CANISTER One-stage	Two-stage 3/1	3,3/1
6	2190	2400	2700	576	636	708	●	[illegible]	[illegible]	●			[illegible]		
8	2920	3200	3600	[illegible]	848	944	[illegible]	[illegible]	[illegible]	●			[illegible]		
10	3650	4000	4500	960	1060	1180	[illegible]	[illegible]	[illegible]	●			[illegible]		
12	4380	4800	5400	[illegible]	1272	1416		[illegible]	[illegible]	●	●		[illegible]		
16	5840	6400	7200	[illegible]	1696	1888		●	[illegible]		●				
20	7300	8000	9000	1920	2120	2360	[illegible]	●	[illegible]		●		[illegible]		
24	8760	9600	10800	2304	2544	2832	[illegible]	●	●		●	●	[illegible]		
28	10220	11200	12600	2688	2968	3304		●			●				
32	11680	12800	14400	3072	3392	3776		●	●		●	●			
36	13140	14400	16200	3456	3816	4248		●							
40	14600	16000	18000	3840	4240	4720		●	●			●			
44	16060	17600	19800	4224	4664	5192		●							
48	17520	19200	21600	4608	5088	5664		●	●			●		36/12	
52	18980	20800	23400	4992	5512	6136									40/12
56	20440	22400	25200	5376	5936	6608			●			●	●		
60	21900	24000	27000	5760	6360	7080								45/15	
64	23360	25600	28800	6144	6784	7552			●			●			
65	23725	26000	29250	6240	6890	7670									50/15
70	25550	28000	31500	6720	7420	8260							●		
72	26280	28800	32400	6912	7632	8496			●					54/18	
78	28470	31200	35100	7488	8268	9204									60/18
80	29200	32000	36000	7680	8480	9440			●						
84	30660	33600	37800	8064	8904	9912							●	63/21	
88	32120	35200	39600	8448	9328	10384			●						
89	32485	35600	40050	8544	9434	10502									68/2[illegible]
94	34310	37600	42300	9024	9964	11092								70/24	
96	35040	38400	43200	9216	10176	11328			●						
98	35770	39200	44100	9408	10388	11564							●		
100	36500	40000	45000	9600	10600	11800									76/24
104	37960	41600	46800	9984	11024	12272			●						
106	38690	42400	47700	10176	11236	12508								79/27	
109	39785	43600	49050	10464	11554	12862							●		
112	40880	44800	50400	10752	11872	13216			●						85/27
115	41975	46000	51750	11040	12190	13570							●		
118	43070	47200	53100	11328	12508	13924								88/30	
120	43800	48000	54000	11520	12720	14160			●						
125	45625	50000	56250	12000	13250	14750									95/30
129	47085	51600	58050	12384	13674	15222							●		
130	47450	52000	58500	12480	13780	15340								97/33	
133	50370	55200	62100	13248	14628	16254									[illegible]
143	52195	57200	64350	13728	15158	16874							●		
157	57305	62800	70650	15072	16642	18526							●		
171	62415	68400	76950	16416	18126	20178							●		
185	67525	74000	83250	17760	19610	21830							●		
199	72635	79600	89550	19104	21094	23482							●		