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IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

FINAL REPORT FOR THE

PERIOD APRIL 1, 1995 DECEMBER 31, 1997

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MIDDLETOWN, OHIO 45042

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IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

DE-FC36-95G010085

PETER SEIFERT
AL KELLY

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IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

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PETER SEIFERT
AL KELLY

EXECUTIVE SUMMARY

TECHNICAL AND COMMERCIAL ASPECTS

Work under this two-year cooperative agreement addresses improved removal of light and sticky contaminants from waste paper. Such contaminants occur in ever-increasing amounts, resulting from glues, labels, book bindings, packaging tapes, etc., all associated with the waste paper stream. Despite various cleaning steps in the paper mill recycling systems, residual contamination remains, causing big problems with the product quality and with paper machine and converting operations. Some grades cannot be recycled at all. Stickies are truly a barrier against increased paper recycling.

Our company is a supplier of recycling machinery and systems to the pulp and paper industry. We are intimately familiar with the problem of stickies and current removal technology. Our laboratory is well equipped for development and demonstration of new technologies. Our Research and Development staff are experienced and qualified.

Investigations under this cooperative agreement extended from April 1995 through December 1997. The contribution by DOE was $1.2 million, the contribution by Black Clawson at least $1.0 million, according to the agreement. In addition, Black Clawson/ Thermo Black Clawson has absorbed significant expenses before and after the cooperative agreement for exploratory studies and for final market introduction, where needed.

The stickies problem was attacked in four project segments--three of those have yielded tangible results. One segment has been outstanding in its success; namely, the development of a centrifugal reverse cleaning system consisting of primary and secondary stages, which have unparalleled high efficiency in the removal of light and sticky contaminants. The new system is the direct result of support received under this project which permitted sufficiently broad and deep investigations to find the most efficient designs possible.

This cleaning system, consisting of primary XTREME™ and secondary XX-Clone™ units, was officially launched at the TAPPI Pulping Conference in Nashville, 1996, in the presence of a DOE representative.

Since that time, we have been able to sell fourteen installations worldwide: in the United States, Italy, Mexico, and China. Many of these orders might have been "lost" to foreign competitors had we not offered the new technology.

Another segment of this work, washing wax contaminated old corrugated wastepaper (OCC), also has resulted in the new Xtrax™ process which was released for sale. The final phase of the wax removal studies were conducted in cooperation with Inland Corporation, a major recycler of OCC.

It is conceivable that the benefits to our company and to our U.S. customers have also resulted in additional tax revenue for the U.S. Government. Perhaps, the investment by DOE has already paid for itself.

The other segments of the development also had useful results. As of this moment, they did not have as dramatic an impact yet. Field demonstrations, are still going on or are forthcoming. In one of them, the benefits are in a field different from stickies removal. There is no doubt

that several more products from this development will be released for sale soon.

The work has resulted in four patent applications and many publications and internal reports--the latter have been summarized in the main body of this report or are appended.

Personnel and Management Aspects

We are very sad to advise that Al Kelly, co-author of this report and R&D director during the cooperative agreement, has died after a brief severe illness a few days ago.

Two of our key investigators, Chris McCarthy and James Buchheit, have since left our company. They too know of the tremendous benefits of the developments and will advocate their expanded use in the industry.

At the very beginning of the cooperative agreement, we were granted a waiver by the U.S. Government, in accordance with the standard agreement to this effect. Accordingly, our company has retained all patent rights resulting from this work.

Toward the end of the agreement, our company was sold by its private owners to the public U.S. company Thermo Fibertek. Our new company name is Thermo Black Clawson, effective since May 22, 1997. DOE had been advised of this change and agreed that the developments can be continued and the project completed.

From our point of view, the cooperation with DOE's Office of Industrial Technology in Golden, Colorado and in Washington, D.C. has been very good and highly successful. We hope to have the opportunity to work together again.

The work under this cooperative agreement has helped to lower the barriers against increased wastepaper recycling. It has generated new products which are highly attractive and competitive worldwide to be manufactured in this country for domestic use and export.

Peter Seifert
Vice President R&D

Albert F. Kelly
Director New Product Dev.

Thermo Black Clawson Inc.
601 Clark Street
Middletown, OH 45042

Date: April 30, 1998

IMPROVED REMOVAL OF STICKY AND LIGHT
CONTAMINANTS FROM WASTEPAPER
DE-FC36-95GO10085

PROJECT SUMMARY

Work under this two-year cooperative agreement extended from April 1995 through December of 1997. This time period includes authorized early work, and a time extension at the end of the project. The overall budget was not changed.

The development work addresses the improved removal of light and sticky contaminants from waste paper. Such contaminants occur in ever-increasing amounts, resulting from glues, labels, book bindings, packaging tapes, etc. which are associated with the wastepaper. Despite the various cleaning steps which are available in paper mill recycling systems today, residual contamination remains, causing big problems with the product quality and with paper machine and converting operations when large amounts of lower quality recycled papers are used.

Our company is a supplier of recycling systems to the pulp and paper industry. We are intimately familiar with the problem of stickies and current removal technologies. Our laboratory is well equipped and staffed particularly for a development program of this kind (Attachment I).

The total DOE contribution was $1.2 million. The Black Clawson and Thermo Black Clawson contributed about $1.0 million, under this agreement. In addition, Black Clawson and later Thermo Black Clawson had significant expenses for the exploratory work and to complete the product development and market introduction.

As a result of the work, several new products were introduced which help the pulp and paper industry to better cope with sticky and light contaminants as follows (headings correspond to project segments). Four patents were applied for (Appendix II) and many papers were published (Appendix III).

1. New Vortex Separation Devices

A new centrifugal "reverse" cleaning system was successfully developed and introduced to the marketplace. It consists of primary and secondary stages, which together have unparalleled efficiency of light contaminant removal. These products are the direct result of the support received from DOE, which permitted our studies sufficient depth and scope to define the most efficient designs possible. The new primary cleaner is called the XTREME cleaner, the secondary is called the XX-Clone cleaner.

After conclusive trials and several customer demonstrations in the pilot plant, the product was publicly released for sale at the TAPPI Pulping Conference, Nashville, November 1996, in the presence of a DOE representative and members of the industry and the press (Appendix IV).

Since that time, we have been able to sell fourteen installations worldwide; including North America, Italy, Mexico, and China as detailed in the reference list (Appendix V).

Currently, at our own expense, we are changing the overall assembly package so that a cleaner system would require considerably less floor space and height. It will also fit into standard shipping containers facilitating export of complete cleaner assemblies from the United States.

Several papers have been published about the cleaners. One of them was written by one of our first customers, Doug Vandenberg of Green Bay Packaging, Green Bay, Wisconsin for the TAPPI Pulping Conference, October 1997, San Francisco.

Figure 1 gives a historic perspective of the developments of cleaners which remove light contaminants. It shows in a simplified way the extraordinary efficiency of the new system and its relatively low specific power requirement.

2. **Contaminant Liberation Units**

Prior to the cooperative study, a pulp kneading device had been developed by Black Clawson which was very efficient but too expensive. Under this project, we have proven that for some applications new operating conditions could be used which double the throughput capacity and still provide satisfactory treatment. In the processing of OCC (old corrugated containers, a wastepaper grade), kneading/dispersion treatment disintegrates residual contaminant particles to such a small size that they are no longer visible. This development is not fully complete, but very promising.

Dry disintegration of wastepaper was also studied. The concept was that stickies might coat themselves with paper filler clay materials so that stickies are passivated--i.e., no longer sticky. Alternatively, perhaps stickies would be disintegrated so finely that they remain attached to individual paper fibers and harmlessly pass through the process into the product where they remain invisible. These ideas did not materialize--apparently, early "dry" disintegration of stickies is not such a good idea.

3. **High Air Rate Flotation**

Stickies are normally hydrophobic in nature and thus would attach themselves to air bubbles in a deink flotation process. Unfortunately, we found a great variability of stickies removal by this method. Sometimes particles attached to the air bubbles and were removed, sometimes not. Obviously, the laws which govern removal of stickies by flotation are not sufficiently well understood. Quite possibly, the chemical nature of stickies varies so widely that efficient attachment to air bubbles only applies to few types. Here, we did not conduct a systematic study because, in the real world, a successful treatment must deal with all types of stickies.

A bench top study, where we took high speed motion pictures of free floating air bubbles as they tried to collect stickies, did not yield consistent tangible results either. The method of observation however was very simple.

A pilot-size flotation apparatus was built and tested, but stickies removal was not consistent. The unit still holds promise for deinking flotation. A first commercial unit was sold for export and will start soon. Success of this project will depend on the results of the field testing.

4. **Wax Removal by Washing**

One particular sticky contaminant which is prevalent in OCC is wax. It comes from wax coated boxes which are used for packaging vegetables and other wet materials. Such boxes today are virtually impossible to recycle. If mingled with regular (unwaxed) OCC, the waxed box content must be severely limited, otherwise the wastepaper would not be usable.

Under this project, we have conducted a literature survey and various studies of our own to learn how wax behaves in the recycling process and how it could be separated from the pulp.

The influence of wax "liberation" by kneading pretreatments was also tested. Contrary to other published results, we found this pretreatment not particularly effective, yet quite expensive.

While we were working in this area, a customer approached us with a specific suggestion for countercurrent washing removal of the wax. The idea was to use a filtering screen (TBC's Liqui-Filter) which permits water and wax to escape through very fine perforations in the screen where paper fibers are held back and leave the unit through a different outlet. Several such machines could be arranged in countercurrent treatment fashion. This concept was tested and found very satisfactory. We have now entered a cooperative agreement with Inland Container Corporation to commercialize the new process.

Accordingly, a process is now a reality for removal of wax, from old corrugated containers which will permit the recycling of wax coated OCC wastepaper--a grade which previously could not be recycled (Appendix VI). Market introduction will depend somewhat on the wastepaper supply market. However, as our customers will get ready for the next cycle of tight supply, they will consider the installation of this new process.

The main body of the report deals with the various developments in more detail. Appendices contain relevant reports and publications.

The Project Summary tells the overall story of the development work. From its tone, you will note that it was technically and commercially very successful. We are grateful for the support we received from DOE.

DETAILED REPORT

1. New Vortex Separation Devices

1.1 Principle and Background

In the pulp and paper industry, separation of light contaminants in centrifugal cleaners goes back to the 1960s and 1970s, when so-called "reverse cleaners" were patented and introduced (References 1, 2, 3). Such cleaners consisted of small-diameter cones with a tangential inlet at the base and concentric outlets at the apex (accepts flow) and near the base (rejects flow). These cleaners are shown schematically in Figure 1, left picture. The early reverse cleaners featured a very high hydraulic reject flow of 40 to 60% of the inlet flow. The reject flow was treated in a cascade system of reverse cleaners (Figure 2).

It is apparent that the pumping power for such a system would be quite high since a given flow volume is pumped several times to the cleaner inlet pressure.

In the 1970s, so-called "flow through" cleaners were introduced (see Figure 1) which featured accepts and rejects outlets near the apex of the cone. The tangential inlet was still at the base. The cleaning efficiency was lower, but acceptable at that time. The volumetric reject flow was very low. In the 1980s, flow through cleaners were arranged in series so that primary accepts would be cleaned again to overcome the problem of low efficiency in a single stage (Reference 4).

As more contaminated wastepapers were recycled, more stickies and lightweight contaminants entered the paper mill systems, requiring cleaning efficiencies which could not be provided by flow through cleaners. For that reason, Black Clawson and DOE entered into the subject cooperative agreement.

1.2 Theory

1.2.1 Radial Particle Velocity

In reverse flow cleaners, lightweight particles must travel radially inwardly; the distance of travel being approximately the radius of the base of the cone. The time available for travel is approximately the average retention time of the liquid in the cleaner calculated by cleaner volume and flow rate.

From distance and time, one can calculate the Necessary Average Radial Velocity (NARV), a critical design variable. It specifies the velocity which is necessary for a particle to reach the center of the reverse cleaner to be rejected. Low NARV values result from high residence time or larger radii (see Figure 3).

1.2.2 Cleaning Value Factor

High centripetal acceleration forces quickly increase the velocity of light particles in radial direction, other factors being equal. High acceleration combined with low NARV value provide good separate efficiency, with other factors being equal. Figure 4 defines the cleaning value factor (CVF).

1.2.3 Other Factors

Many other factors are at play which influence reverse cleaning efficiency. These can be evaluated only through experimentation. Some examples are discussed in the following paragraphs.

Consistency of the pulp slurry is a key variable as it affects the apparent viscosity of the slurry. Higher viscosity would impede separation. In addition, high fiber concentrations could also mechanically entrap light particles.

Hydraulic stability of the free vortex flow pattern may be another factor. If one would replace the conventional conical design with a constant diameter cylindrical pipe, retention time would be higher, promising higher efficiency. However, in experiments, this did not yield an improvement at all. Apparently, in conical cleaners, the hydraulic flow stability which results from the continual acceleration of the flow as it progresses from the larger diameters at the inlet to the very small diameters at the outlet is an important factor.

Other practical aspects are also important, such as size of inlets and outlets, and a pressure drop which is reasonably achievable.

1.3 Experimental

1.3.1 Background

Prior to the current study, Black Clawson had studied various cleaner configurations generally shown in Figure 5. The best performing model was a continuous cone, with 1.5° cone angle.

To improve the efficiencies even further, we applied the theoretical principles discussed previously and decided to increase retention time. This led to a quite unconventionally long cleaner which we now call the "XTREME Cleaner" (Figure 6) [patent applied for].

1.3.2 Through Flow Design for Rejects Cleaning

Review of the test data of the primary XTREME Cleaners showed that the consistency of the reject flow was very low. Conceivably, it should now be easier to remove the undesirable particles from this dilute slurry than to separate them from the higher consistency primary feed slurry.

Unfortunately, the conventional X-Clone through flow cleaner still did not match the efficiency of the primary unit. Again, we applied the theoretical principles and various trial and error test sequences to design an improved through flow unit. It is now called "XX-Clone"™ Cleaner (Figure 7).

The combination of primary XTREME Cleaner and secondary XX-Clone is illustrated in Figure 1 (right-hand picture). The reject particles have been concentrated into a very small stream which is rejected from the XX-Clone apex. The low consistency XX-Clone accepts flow is free of stickies and light contaminants and can be used upstream in the system for strategic dilution.

1.3.3 Testing and Evaluation

Contaminants

Hot melt contaminants of three different specific gravities were generated (0.95, 0.97, 0.995) for use in comparative bleached furnish test runs. The hot melt was colored using techniques developed in previous tests, and classified in two size ranges: large of 8 to 14 mesh (1.40-2.36 mm) and small of 14 to 100 mesh (0.15-1.40 mm).

Furnish

OCC furnish was seeded with wax coated boxes (waxboard) and/or clarifier skimmings from Inland Container at Maysville, Kentucky.

Bleached market pulp was used in most of the comparative testing. Other furnish types included mixed office waste (MOW) and old news papers (ONP).

Cleaner Configurations

The reverse cleaner, having a cone angle of 1.5° (1.5 NAC-R), had been selected as most efficient in previous testwork. To improve it even further, the cone angle was changed to 1° (1.0 NACR)--this unit was developed and evaluated during this phase of testing. The first 1.0° unit was manufactured without a mold by a process called stereolithography. It worked for a short time and showed the promise of the smaller angle.

Polyurethane units were subsequently made and tested.

Evaluation

For the bleached furnish test runs, visual hot melt speck counts were conducted to calculate efficiency values. Wax extraction tests were done at Miami University to compare the results of the OCC furnish samples.

The particular contaminants in this study had been used in the previous work. It had been found that in the conventional and commercially available cleaners, these contaminants were not completely removed--the efficiencies were low. This experience indicated to us that these were suitable for the current study and we concentrated on improving removal of these particular contaminants from the pulp slurry.

1.3.4 **Results**

Results are reported as excerpts from our R&D report on these matters by Chris McCarthy and Elizabeth Maze. Significant chapters and data follow. Data sheets are in Appendix VII.

Various patent applications were filed (Appendix II). Several publications have been made (Appendices VIII, IX, X).

Test Runs Before Producing Polyurethane 1.0 Degree NACR Units

Test runs similar to those reported in the 35,009.01 report were conducted comparing the 1.5 degree cone angle cleaner unit (1.5 NAC-R) to the Bauer and the X-Clone (runs 341-344). A 1.0 degree cone angle prototype cleaner was then generated by stereolithography (SLA 1.0) and compared to the 1.5 NAC-R (runs 350-364). (Later, polyurethane 1.0 degree cone angle cleaner units were made and tested.)

Cleaner testing for a secondary unit at low consistency with high contaminant levels was conducted using the Hatton unit, the X-Clone, and the clear acrylic 1.5 NAC with several orientations: long-reverse -LR (reverse mode with an extended cylindrical section - runs 372-374), reverse -R (reverse mode with no extension - runs 382-384), and through-flow design -TF (runs 378-381). In this application, the Hatton design achieved the highest efficiencies of those configurations tested.

Test Runs After Producing Polyurethane 1.0 Degree NACR Units

Many test runs were conducted using the polyurethane pour molded units (1.0 NACR #1-15). The 1.0 NACR (#15) was operated side-by-side the 1.5 NAC-R (runs 442-447). The 1.0 NACR performed slightly better than the previous best--the 1.5 NAC-R.

A competitor's cleaner unit was acquired for a short period of time to conduct further comparisons based upon performance. The Beloit Uni-Flow was compared to the 1.0 NACR, the X-Clone, and the Hatton (runs 449-500a). Several furnishes were tested: MOW seeded with hot melt particles, bleached market pulp seeded with hot melt particles, OCC with waxboard, and OCC with waxboard plus clarifier skimmings from Inland Container at Maysville, Kentucky.

Many test runs were conducted to answer operational and production design questions. The question was raised about running the 1.0 NACR cleaner with pressurized accepts and rejects in addition to the atmospheric conditions. Testing of pressurized versus atmospheric conditions was conducted in runs 550-599 and 616-620, with several different cleaner units: #1, #2, #9, #15. Test runs 581-584 were done to answer the question of orientation on banks: upside-down (accepts at the top) or right-side-up (rejects at the top). An internal gap between the tangential inlet and the reject cap was discovered. To test the effect on operation and efficiency, a modified cap was made to be flush with the inlet. The runs 581-599 and 616-620 included both pressurized and atmospheric conditions as well as the affect of the flush versus the regular cap. The flush cap actually extended into the inlet 0.125".

Results and Discussion

Testing was conducted prior to the manufacture of polyurethane units comparing the 1.5 NAC-R to the 1.0 SLA unit. The results indicated that the 1.0 degree cone angle (1.0 SLA) achieved slightly higher efficiencies than the 1.5 degree cleaner. After initial testing, the cleaner unit broke at the seams. These initial tests prompted the manufacture of the polyurethane pour molded units, 1.0 NACR (#1-15). The results in comparing the 1.0 NACR (#15) to the 1.5 NAC-R showed that the 1.0 NACR obtained the better efficiency, 91-95% (runs 442-444) compared to 89-92% (runs 445-447).

The secondary unit test results clearly concluded that the Hatton unit was the best choice for the reject tailing application. The modified vortex stabilizer held the air core very stable, and enabled the unit to achieve high efficiency in this position. All the secondary testing was performed with a consistency of 0.05% or less with elevated contaminant levels. The X-Clone, on average, achieved a hot melt count removal efficiency of 62%, the 1.5 NAC-LR - 72%, the 1.5 NAC-R - 60%, the 1.5 NAC-TF - 53%, and the Hatton cleaner achieved 87% efficiency with a hydraulic reject rate around 10%.

The Beloit Uni-Flow, the X-Clone, the Hatton, and the polyurethane 1.0 NACR #5 were comparison tested using OCC with waxboard furnish. The comparison of the 1.0 NACR #15 and the Beloit Uni-Flow was repeated using OCC furnish with waxboard and clarifier skimmings. Wax extraction tests were performed by Miami University on samples from these comparison runs. The results are given in Table 1.

Table 1: Comparison Wax Extraction Results on OCC Furnish

Sample	**% Extractives**			**% Efficiency**
	Test 1	*Test 2*	*Average (2)*	*(Fd - Acc)/Fd*100*
470-476 Feed	2.50	2.71	2.61	-
470 NACR #5 Acc	1.91	2.06	1.99	23.5
471 Beloit P1 Acc	2.43	2.48	2.45	5.8
472 Beloit P2 Acc	2.22	2.17	2.19	15.8
473 X-Clone P1 Acc	2.10	1.88	1.99	23.5
474 X-Clone P2 Acc	1.74	1.81	1.77	31.9
475 Hatton P1 Acc	1.92	2.04	1.98	23.8
476 Hatton P2 Acc	1.78	1.71	1.74	33.1
498-500a Feed	2.69	2.69	2.69	-
498 NACR #15 Acc	1.26	1.26	1.26	53.2
499 Beloit P1 Acc	1.48	1.67	1.57	41.6
500a Beloit P2 Acc	1.45	1.49	1.47	45.4

The first set of OCC with waxboard comparison runs used 1.0 NACR cleaner unit #5 which was found to have several minor manufacturing flaws which contributed to poor efficiency relative to previous performance. These minor flaws included a rough inlet surface that needed to be sanded smooth, slag material in the reject overflow orifice, and a slightly bent body, (see Table 3 for the straightness rating). This was discovered after the test run was completed and samples had been taken.

To get further comparison data, a second set of test runs were done to compare the 1.0 NACR #15 directly to the Beloit Uni-flow. The furnish was slightly different from the initial comparison runs. This second set used OCC with waxboard and clarifier skimmings from Inland Container in Maysville Kentucky. Inland Container has a Gyroclean unit; the clarifier skimmings contained wax and other contaminants that were removed from the system by the Gyroclean once already. These contaminants would then be relatively easy to remove centrifugally which would explain why there was less difference in the efficiencies of the two units, the 1.0 NACR #15 and the Beloit.

Hot melt speck counts were conducted on the seeded Mixed Office Waste (MOW) and comparison bleached market pulp runs. The results have been compiled in the following Table 2. The same 1.0 NACR #5 minor flaws described above existed during runs 449-488. Runs 489-491 show the good polyurethane unit, 1.0 NACR #15, compared to the Beloit pass 1 (P1) and Beloit pass 2 (P2).

It is clear to see that the #15 polyurethane unit performed with a more striking difference in efficiency performance than did the #5 unit. The #15 unit was the first unit off the mold and was given much more care in creating the tangential inlet and removing the slag in the reject orifice. This unit is also visibly straighter than the #5 unit. After finding that the #5 unit did not perform as well as the #15, all of the units were checked over for these minor flaws. The more minor flaws were corrected, but it was found that not all of the polyurethane units were perfectly straight. Furthermore, it was concluded that the straightness of the unit makes a considerable difference in the operation of the cleaner. See Table 3 for cleaner straightness rating.

Table 2: Comparison Efficiency Results

Sample	% Efficiency = (Feed count - Accept count)/Feed count * 100						
	Lg. 0.95	*Lg. 0.97*	*Lg. 0.995*	*Sm. 0.95*	*Sm. 0.97*	*Sm. 0.995*	*Overall*
1.02% cons.	*MOW w/ hot melt; 120 degrees F; 0.52% contaminant by weight*						
450 NACR #5 Acc	100	100	94	80	93	63	88
449 Beloit P1 Acc	75	83	50	48	56	34	58
451 Beloit P2 Acc	100	100	72	83	87	55	83
1.03% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.50% contaminant by weight*						
452 NACR #5 Acc	100	100	94	90	78	29	82
453 Beloit P1 Acc	100	100	69	55	48	9	64
454 Beloit P2 Acc	100	100	88	90	67	29	79
0.80% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.63% contaminant by weight*						
455 NACR #5 Acc	100	100	25	96	78	39	73
456 Beloit P1 Acc	100	75	0	68	42	13	50
457 Beloit P2 Acc	100	92	33	82	55	22	64
0.90% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.48% contaminant by weight*						
458 X-Clone P1 Acc	100	80	44	69	53	48	66
459 X-Clone P2 Acc	100	100	67	95	77	53	82
0.76% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.64% contaminant by weight*						
460 Hatton P1 Acc	100	67	50	88	69	14	65
461 Hatton P2 Acc	100	100	71	97	81	9	76
0.85% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.49% contaminant by weight*						
489 NACR #15 Acc	100	100	86	93	85	43	85
490 Beloit P1 Acc	73	7	0	37	58	20	33
491 Beloit P2 Acc	64	100	29	30	65	6	49

To be fair, an average of the four comparison runs (449-451, 452-454, 455-457, 489-491) was calculated. The average of the 1.0 NACR (#5 & #15) single pass efficiency is 82%. The average for the Beloit single pass is 51%, and the average of the four Beloit double pass efficiencies is 69%. This says that the single pass 1.0 NACR, even when not operating at its best, still is able to remove nearly three times more residual contaminant than the Beloit with one pass, and nearly twice as much contaminant as the Beloit Uni-Flow with two passes.

Table 3: Straightness Rating

NACR Unit #	Grade Rating	Description	NACR Unit #	Grade Rating	Description
1	B-	slightly bent	9	A	good
2	D-	badly bowed	10	A-	ok
3	B+	slightly bent	11	C	bottom bowed
4	A-	ok	12	A	good
5	B	slightly bent	13	A	good
6	A	good	14	A	good
7	A-	ok	15	A	good
8	F-	badly bowed			

Conclusions

The 1.5 and 1.0 degree NACR units perform much better than the current X-Clone on difficult to remove contaminants (those above 0.95 specific gravity and below 1.0). The results in comparing the 1.0 NACR to the 1.5 NAC-R showed that the 1.0 NACR (#15) obtained better overall efficiency, 91-95% (runs 442-444) compared to 89-92% (runs 445-447). The 1.0 NACR can achieve excellent efficiency with 0.95 and 0.97 specific gravity contaminants large and small (average of 97% efficiency) and large 0.995 specific gravity contaminants (91%), but lower efficiency with small 0.995 specific gravity particles (~70%) (runs 442-444, 489). Overall, during the comparison testing, even the 1.0 NACR #5 single-pass did better than double-pass Beloit, X-Clone and Hatton in comparison tests (runs 452-454, 458-461). Note that the #5 did not perform quite as well as the #15 unit due to the described minor flaws. The Beliot Uni-Flow, the X-Clone and the Hatton performed with approximately the same efficiency in the bleached market pulp with hot melt comparison trials. Both the X-Clone and the Hatton achieved better efficiencies (24% first pass and 33% second pass) than the Uni-Flow (6% first pass and 16% second pass) on the OCC furnish, based on wax extraction results.

The secondary unit test results clearly concluded that the Hatton unit was the best choice for the application. The modified vortex stabilizer held the air core very stable, and enabled the unit to achieve high efficiency in this position. The Hatton achieved up to an 89% overall efficiency on all three hot melts and both size ranges. The next best unit was the modified 1.5 NAC-LR (reverse mode with a cylindrical extension) with a 76% overall efficiency. The X-Clone brought up the lowest of a 63% overall efficiency; this was mainly due to the inability of the X-Clone to remove 0.995 specific gravity particles. In comparison, the Hatton removed the 0.995 particles very well, with a high of 84% in this category.

The 1.0 NACR can operate effectively at pressurized conditions without sacrificing efficiency, provided that the hydraulic reject rate be held constant at approximately 42% (runs 550-560, 574-580, 585-594, 595-599, 616-620). The NACR unit should be placed right-side-up on banks, with rejects coming off the top at the cone base, as a result of runs 581-584. The testing of the flush and regular caps does not show a decrease in efficiency with the regular cap making a half inch gap above the tangential inlet. Conversely, use of the flush cap does not increase the efficiency, in fact, to a small degree the opposite was seen (refer to runs 581-584, 585-594, 595-599, 616-620).

2. Contaminant Liberation Units

During this investigation, work concentrated on two different approaches. First, we looked at an enhanced kneading device which would treat pulp at high consistency. The other approach was a "dry" pulper in which pulping and dispersion would take place simultaneously. Since wastepaper is fed virtually dry, the thickening step normally required ahead of dispersion could be avoided.

The two approaches are reported separately as follows.

2.1 Kneader Principle and Background

Light and sticky contaminants, when of large size, can be removed from pulp slurries by screening (Reference 5). Gentle pulping conditions at low temperature (100°F to 120°F) favor this approach. Unfortunately, the offensive materials are often quite weak so that they break into very small fragments which cannot be efficiently rejected by screens. Often, small stickies are also bonded to pieces of paper or individual fibers, a fact which makes their separation from the slurry even more difficult.

In centrifugal cleaners, flow-through or reverse type, light particles with paper fibers attached could easily be accepted (see Item 1).

Likewise, in flotation machines, removal efficiency suffers severely if the particles are sticking to paper fibers (see Item 3).

The conventional remedy to the problem is to thicken the pulp to 25 to 30% consistency and then kneading the pulp in a low speed kneading machine.

Our hypothesis was that the kneading treatment would have the following effects:

- -- Stickies are made smaller, fewer fibers are attached--flotation separation is improved.
- -- Very small stickies (under 50 micron) could be washed out.
- -- Intermediate size stickies (50 to 250 micron) would be free of adhering fibers and could be cleaned in reverse or through flow cleaners.
- -- Stickies may become so small that they are not a detriment in the product.

In previous work, Black Clawson had developed a kneader with two parallel shafts similar to state-of-the-art units (Lamort Tritorateur, Shinhama, Maule). The first two commercial units of this style have operated satisfactorily at First Urban Fiber in Hagerstown, PA. Operation of conventional units can be specified as follows:

- -- Feed consistency: 25 to 35%
- -- Specific power input: 3 to 5 HPD/T
- -- Shaft speed of rotation: 100 to 120 rpm
- -- Retention time: 3 minutes

Kneaders are quite expensive and as a result, the paper industry often uses a lower cost high speed disperser. This approach has a number of disadvantages and is not considered optimal.

With this background, the present study was aimed at increasing the capacity of machines which operate on a kneader principle, as described below.

2.2 Enhanced Kneader Theory

In the consistency range of 20 to 35%, pulp appears virtually dry and behaves almost like a dry material. As a result, the mechanism of introduction of shear to disperse particles in the pulp is based on mechanical friction, not on hydrodynamic turbulence. Friction forces, however, are independent of speed of rotation or, in other words, the rate of shear. For example, if one doubled the speed, the power input would also be doubled.

The conveying mechanism inside a kneader is also proportional to speed since the kneader paddles act like parts of a conveying screw. Again, doubling the speed would double the conveying action and therefore the throughput rate.

If these relationships hold true, kneader capacity would be increased proportional to speed and power input, i.e., it could be doubled by doubling speed and drive power. Drive torque would them stay the same, just as the specific power input--the main factor which affects dispersion. Retention time would be less. Therefore, it was the aim of the study to verify that

(a) Capacity and power do indeed increase proportional to the speed.

(b) The effectiveness of the kneading does indeed stay the same, even if the retention time is reduced and the rate of shear increased while the specific power input stays the same.

2.3 Enhanced Kneader, Experimental

The existing small commercial size kneader which had been built prior to the present study is shown in Figure 8. To verify the previously stated hypothesis, we increased the speed and drive power by factor of 2 and planned to test various furnishes according to the outline presented in the following table.

	Conventional	Enhanced
Speed (RPM)	100	200
Power (HP)	150	300
Throughput (T/D)	30	60
Spec. Power (HPD/T)	5	5
Consistency (%)	35	35
Disp. Efficiency (%)	90±	?

We found that the machine could indeed operate at greatly increased throughput rate and power input as envisioned. Unfortunately, we could not continue with experimental comparisons because of a logistical problem: The feed rate was now so great that it was impractical to operate this machine under pilot plant conditions. Too much pulp and additional feeding equipment would be needed for a valid comparison. Nevertheless, the exploratory tests encouraged us to pursue this approach further and to build a smaller machine for this purpose.

2.4 Smaller Pilot Kneader

A smaller pilot kneader was designed and built which would have a nominal capacity of only 7 T/D in conventional operation. At higher speeds, power and capacity would increase, as envisioned in the following table.

	Conventional	Enhanced		
Speed (RPM)	100	200	300	400
Power (HP)	35	70	105	140
Capacity (T/D	7	14	21	28
Spec. Power (HPD/T)	5	5	5	5
Retention Time (min)	3.0	1.5	1.0	0.7
Disp. Efficiency	Standard	-----Equal-----		

The kneader was built, as shown in Figure 9.

At this time, the evaluation of the enhanced kneader is not yet complete. Since the contract budget has been reached, we are now fitting the final evaluation work into our normal schedule of priorities. When the results are available, they will be submitted as an addendum to this report.

2.5 Dry Pulper

Based on the discussions of background and theory of liberation of stickies, dry disintegration of wastepaper was also studied. The concept was that stickies might coat themselves with paper filler clay so that their surfaces are passivated--i.e., no longer sticky. Alternatively, perhaps stickies would be so finely disintegrated that they could remain suspended in the

pulp slurry and harmlessly pass through the process into the product.

Possibly, stickies might be so small and free of adhering fibers that subsequent flotation would be effective (see Item 3).

2.6 Dry Pulper, Experimental

A new pulper was designed and built suitable for dry disintegration of wastepaper. The machine is basically a rectangular tank with a "live bottom" surface. Two parallel shafts cooperate with the bottom of the tank and with each other acting to mechanically disintegrate paper.

Similar machines which process dry goods include the following:

- -- Banbury for rubber disintegration, in the manufacture of tires.
- -- Dry mixers, in the paint industry.
- -- Komar shredder for very coarse debris shredding.
- -- Saturn and Shredpack shredders

The experimental machine is shown in Figure 10. Its tank size is 4'x 4', sufficiently large to accept parts of bales of wastepaper.

The shafts are specially shaped screws with teeth at their periphery. The tub bottom has ribs which cooperate with the screws to tear and shred the paper. Each shaft is driven by a variable speed hydraulic drive, permitting optimizing shaft operating speed. At conditions of torque overload, the shaft direction of rotation could be automatically reversed.

After a mechanical review, tests were made feeding various grades of dry paper into the pulper and adding small amounts of water to keep the consistency in the range of 30 to 70%. Under these conditions, the pulp in the pulper appears virtually dry.

Not surprisingly, contaminants, and particularly stickies, were also disintegrated to a relatively small size. The passivation of the sticky surfaces, which we had hoped for, did not occur. Apparently, in the process of forming the observation sheets, ash and fine particles must have been washed away from the sticky surfaces, leaving them sticky.

Accordingly, we have not found that the dry pulping technique is an effective tool for improved removal of stickies. For R&D report, excerpts, see Appendix XI.

Our company is continuing the development work with its own funding to explore other subsequent process steps or sequences to improve stickies removal. The dry pulper also has applications besides removal of sticky contaminants. We are working with a number of customers on other applications not related to the removal of stickies.

2.7 Patent Applications

Patent applications were filed as listed in Appendix II.

3. High Air Rate Flotation

3.1 Background and Theory

It is known that conventional deinking flotation can remove a percentage of stickies, however the results and experiences are quite variable.

We had theorized that the unpredictable results might be due to the relatively large size of the sticky particles or that so many paper fibers protrude from the sticky particle surface that the conglomerate acts like having a hydrophylic surface vis-a-vis an air bubble. As such, it would not attach to the bubble and therefore could not be removed by flotation.

Based on this hypothesis, an efficient kneading step, or dry pulping (see Item 2) would improve this situation. In addition, a flotation cell with separate in-line air mixing and a quiescent tank might also favor the removal of larger particles, by leaving bubble/ particle connections intact. Consequently, work in this study aimed at testing process sequence with dispersion or dry pulping prior to flotation and at the design of a more beneficial flotation cell.

3.2 Experimental

A pilot flotation cell was designed, built, and tested, as described in R&D Report 37,006 of September 1996 (Appendix XII).

It can be seen that in pilot flotation runs, EVA sticky particles (ethylene vinyl acetate, a basic sticky material) were removed effectively when the operating conditions were optimal and pH near neutral.

Unfortunately, the results were not consistently repeatable in the pilot conditions, nor in subsequent field trials with a first small commercial size in-line air mixer.

The sequence of kneading/dispersing and then flotating small, fiber-free stickies was investigated in a large deinking plant which processed mixed office waste. State-of-the-art kneaders (Item 2) did, in fact, reduce the size of the stickies. Subsequent flotation, however, did not consistently produce high sticky removal efficiency.

3.3 Bench Top Tests

To shed light on the causes for the variability of the results, a small test loop was built which permitted the observation of individual air bubbles as they floated freely in a stream of water or pulp. Particles could be introduced and video recordings made, showing how such particles attach themselves to air bubbles. Sometimes, the attachment was very strong. For example, small polyethylene particles bonded strongly to air bubbles, under pH conditions slightly below neutral. Sometimes, many bubbles formed a strong group around a particle and floated it away. Again, the results were not consistent. We feel that the reason for the inconsistency lies in various factors.

- -- Great variability of the chemistry of the sticky particles.
- -- Variability of the surface properties of the stickies, depending on prior treatments.
- -- Amount and nature of the dissolved substances in the process water.

In this study, a systematic analysis of the chemistry of both particles and the water was not undertaken, as it was not part of our original plan and lied outside of the special expertise of our laboratory. Nevertheless, such an investigation, perhaps with the use of bench test loop, would be a valuable undertaking in the future.

3.4 Results

While the attached R&D Report portrays a positive outcome of the study, we found in subsequent work that the results were not repeatable in the pilot plant or in the field. Obviously, our work did not advance the art of removal of sticky particles from pulp slurries by means of flotation.

The flotation cell itself, however, is useful for deinking flotation. A full size commercial system has been sold and manufactured for export.

The bench test loop, for visual observations, was very useful and lends itself for simple laboratory and also field study. Our experiences with this loop were published at the CPPA Annual Meeting, January 1998, in Montreal (Appendix XIII).

4. Wax Removal by Washing

Wax contamination of wastepaper is not widespread. Old corrugated containers are sometimes wax treated to make them suitable for transportation of wet goods, like vegetables, fish, etc. Also, paper cups, for cold drinks, are waterproofed with wax. The major wastepaper stream is waxed OCC--it represents about 5 to 8% of the total OCC stream. Such paper is collected separately because it drastically lowers the quality of regular OCC. High wax content causes

-- weak, unsightly paper product;

-- slippery paper surface;

-- landfill costs.

4.1 Theory and Background

The relationships of wax usage, waxed OCC production, and the total OCC stream are shown in Figure 11. Approximately half a million tons of this material is available per year in form of converting trim and collectable post-consumer waxed OCC.

Generally, up to 5% of waxed boxes can be tolerated in the regular OCC material, resulting in a residual wax content of around 1%, after conventional wastepaper processing (Figure 12). Waxed OCC alone is not being processed today on a commercial scale.

Excessive residual wax content affects the properties of new paperboard made. Slide angle is reduced, strength properties are lower, water absorption time is increased, and appearance is poor (Figure 13).

Based on the literature (Reference 8) and on our own work, various means are available to process 100% of the waxed OCC, including:

-- elevated temperature

-- use of dispersable wax

-- kneading or dispersion

-- high speed belt washing

-- DAF clarification of washer filtrate

-- post refining

Under this project, we have studied the relative importance of the above measures in pilot plant work.

4.2 Experimental

According to the discussion, we processed waxed OCC on a pilot plant scale, in small batches, including the following process steps.

-- repulping at 160°F and above;

-- coarse cleaning, and screening;

-- washing under high turbulence conditions, using a high speed belt washer.

High temperature is maintained throughout the process to prevent wax from coating cooler surfaces, such as inside equipment and pipes. At high temperature, the wax is dispersed in the liquid phase in the form of emulsion. As a result, it can be separated from the pulp in the high turbulence washer, leaving with the filtrate. For removal from the system, the washer filtrate is clarified in a DAF unit, so that it can be recycled. Wax is discharged from the DAF unit as sludge.

Note that there is a noticeable yield loss as the wax is removed with some pulp fines.

The resulting final pulp is relatively high in freeness, refinable, and very strong.

We also found that it is not necessary to use water dispersible wax.

Our work also showed that kneading or dispersion prior to high speed washing was not necessary. At elevated temperature, wax removal efficiency was sufficiently high without it.

Details of this work are contained in Appendix XIV.

4.3 The Xtrax™ Result

During our experimental work, we were approached by Inland Corporation, a major user of Old Corrugated Containers for making new paperboard, with a suggestion to effect the wax separation in a different washer. Inland proposed to use pressurized pulp screen with very fine holes, through which only water, dispersed colloidal wax and paper fines could pass. The paper fibers would stay on the inlet side of the screen and discharge from a separate outlet. The commercial machine by Thermo Black Clawson for such a process is called Liqui-Filter™.

The Inland Corporation further suggested that the pulp be washed several times in sequence with counter-current flow of the wash water (Figures 14, 15). This system was successfully demonstrated and subsequently released for sale (Appendix VI).

A patent application which covers the significant aspects of the process was filed jointly by Thermo Black Clawson and the Inland Corporation.

IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

DE-FC36-95G010085

LIST OF REFERENCES

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2. BLISS, "Reverse Cleaning for Removing Light and Sticky Contaminants"; TAPPI Journal, Vol. 63, No. 6, 1980

3. SEIFERT, HATTON, BLISS, U.S. Patent 4,155,839, 1997

4. BLISS, et al, "An Overview of American Old Corrugated Containers Recycling Technology"; Asia Pacific Pulp and Paper Conference, Singapore, 1991

5. FERGUSON, "Union Camp Sets Deinking Standard with Modern Franklin Pulp Facility"; Pulp & Paper, Vol. 69, No. 5, 1995

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8. BACK, Ernst, "Effect of Dispersion Variables on the Papermaking Properties of OCC"; Progress in Paper Recycling, August 1995

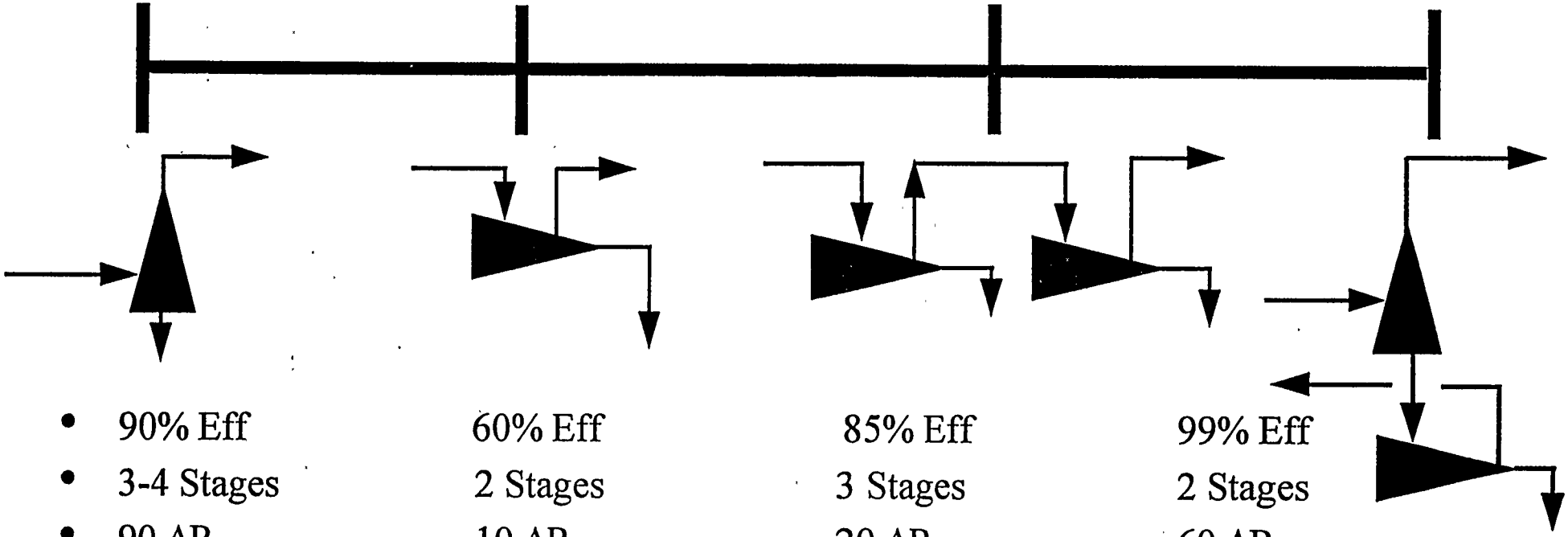
IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

DE-FC36-95G010085

FIGURES

1. LIGHTWEIGHT CLEANER DEVELOPMENT, HISTORY
2. REVERSE CLEANING SYSTEM
3. REVERSE CLEANER DESIGN - NARV VALUE
4. REVERSE CLEANER DESIGN - CVF VALUE
5. REVERSE CLEANERS - VARIOUS SHAPES TESTED
6. COMMERCIAL XTREME CLEANER
7. COMMERCIAL XX-CLONES
8. ULTRA TWIN-FLYTE KNEADER, SMALL COMMERCIAL SIZE
9. ULTRA TWIN-FLYTE KNEADER, PILOT UNIT
10. PILOT DRY PULPER, SCHEMATIC
11. WAXED OCC USAGE AND RECOVERY
12. WAXED OCC USAGE
13. WAX CAUSES UNDESIRABLE PROPERTIES
14. PROCESS STEPS TO SEPARATE WAX, FLOW SCHEMATIC
15. THERMO BLACK CLAWSON LIQUI-FILTER, IN XTRAX SYSTEM

Lightweight Cleaner Development



1960's Multi-Stage Reverse	1970's Single Pass Through-Flow	1980's Series Through-Flow	1990's New Reverse w/ Through-Flow
• 90% Eff	60% Eff	85% Eff	99% Eff
• 3-4 Stages	2 Stages	3 Stages	2 Stages
• 90 ΔP	10 ΔP	20 ΔP	60 ΔP
• 4.0 HPD/T	0.70 HPD/T	2.1 HPT/D	2.0 HPT/D
• High Losses	Low Losses	Increased Losses	Low Losses

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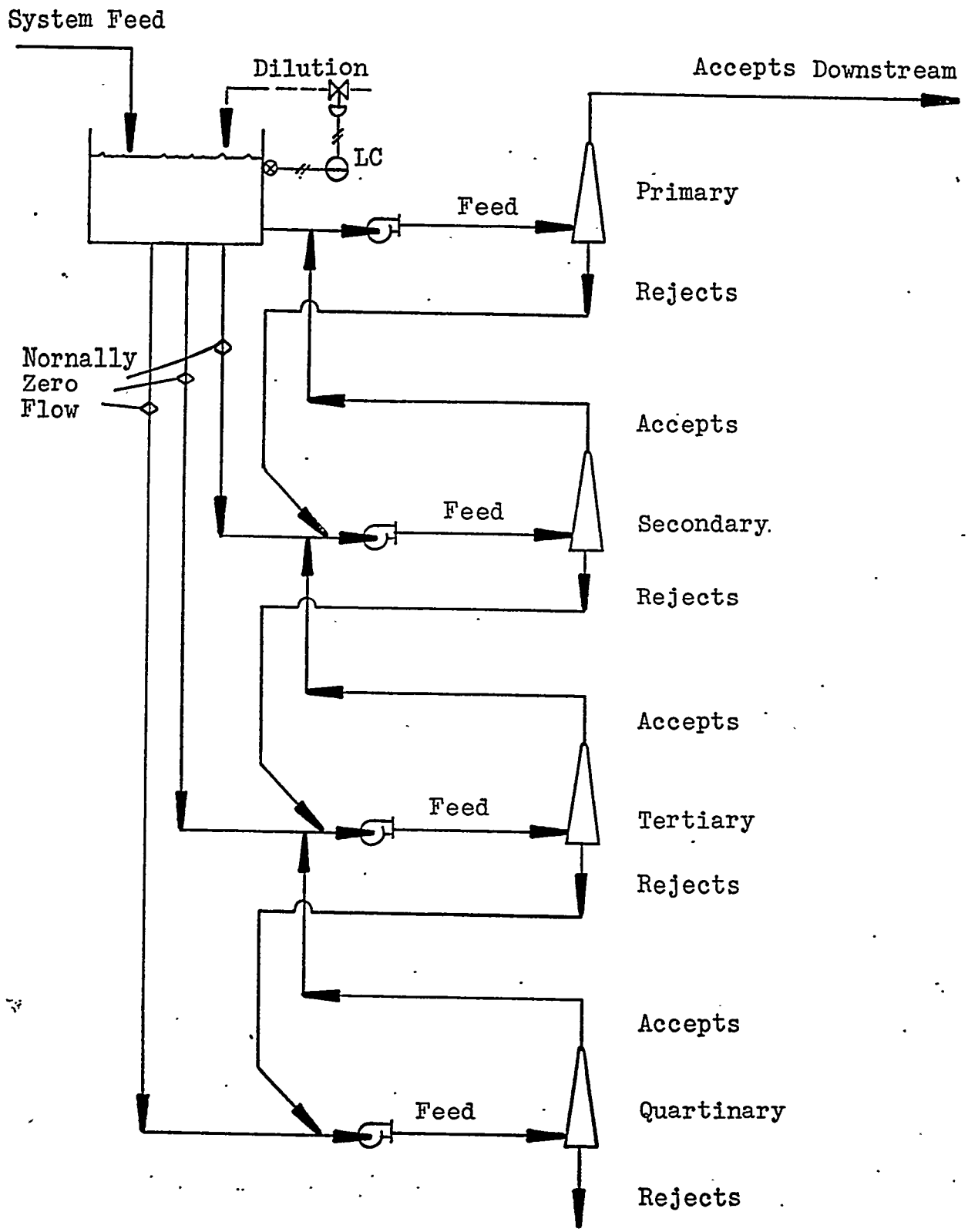
FIGURE 1

FIGURE 2

Classical Cascade System



Necessary Average Radial Velocity

$$\text{NARV(Ft/Sec)} = \frac{\text{Radial Distance At Inlet}}{\text{Retention Time in Cleaner}}$$

The Average Velocity The Particle Must Travel To Reach The Air Core Of The Cleaner

FIGURE 3

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Cleaner Value Factor

$$\text{CVF } (\text{Sec}^{-1}) = \frac{\left[\dfrac{\text{Tangential Velocity}^2}{\text{Radius}}\right]}{\text{NARV}}$$

A Measurement Of The Centripetal Acceleration On The Particle vs. The Average Velocity Necessary To Reach The Air Core.

FIGURE 4

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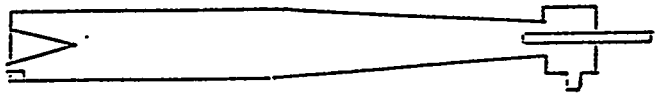
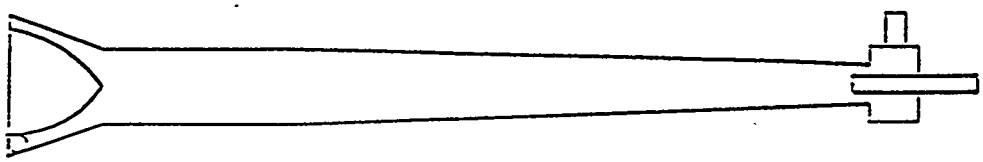
FIGURE 5

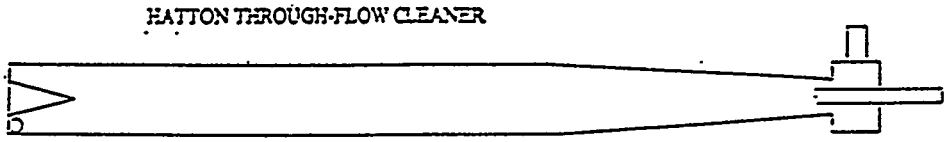
Cleaner Configurations Used in Cleaner Comparison Testwork



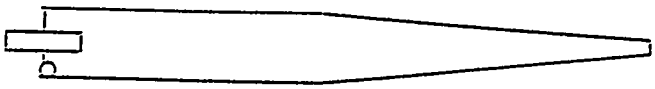
STANDARD X-CLONE THROUGH-FLOW CLEANER



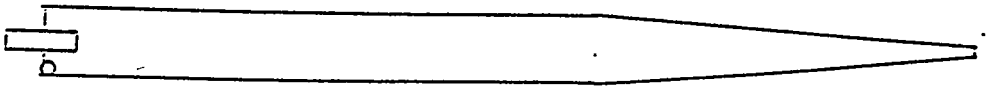
HATTON THROUGH-FLOW CLEANER



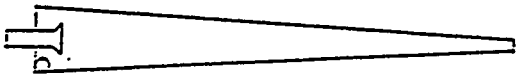
EXTENDED CYLINDER X-CLONE THROUGH-FLOW CLEANER



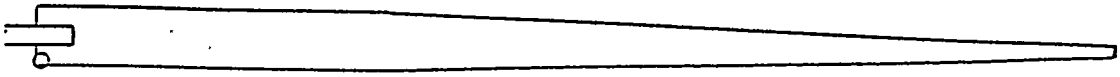
STANDARD ULTRA-CLONE REVERSE CLEANER WITH INSERTS



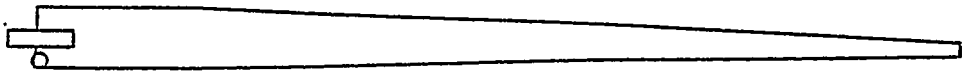
EXTENDED CYLINDER ULTRA-CLONE REVERSE CLEANER WITH INSERTS



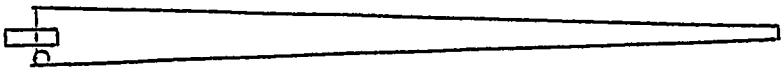
BAUER REVERSE CLEANER



DPR REVERSE CLEANER



DPN REVERSE CLEANER



NAC-R CLEANER

FIGURE 6

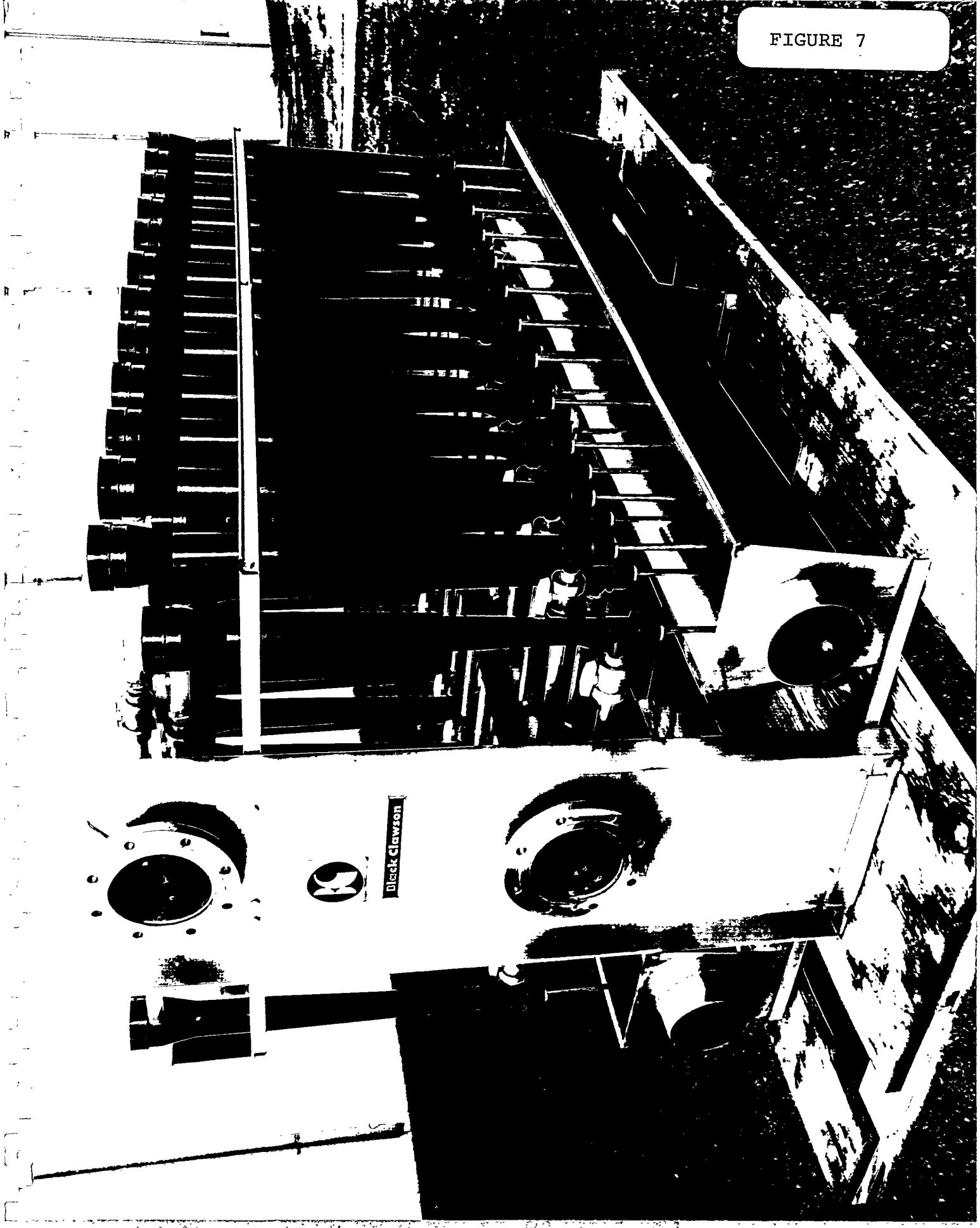
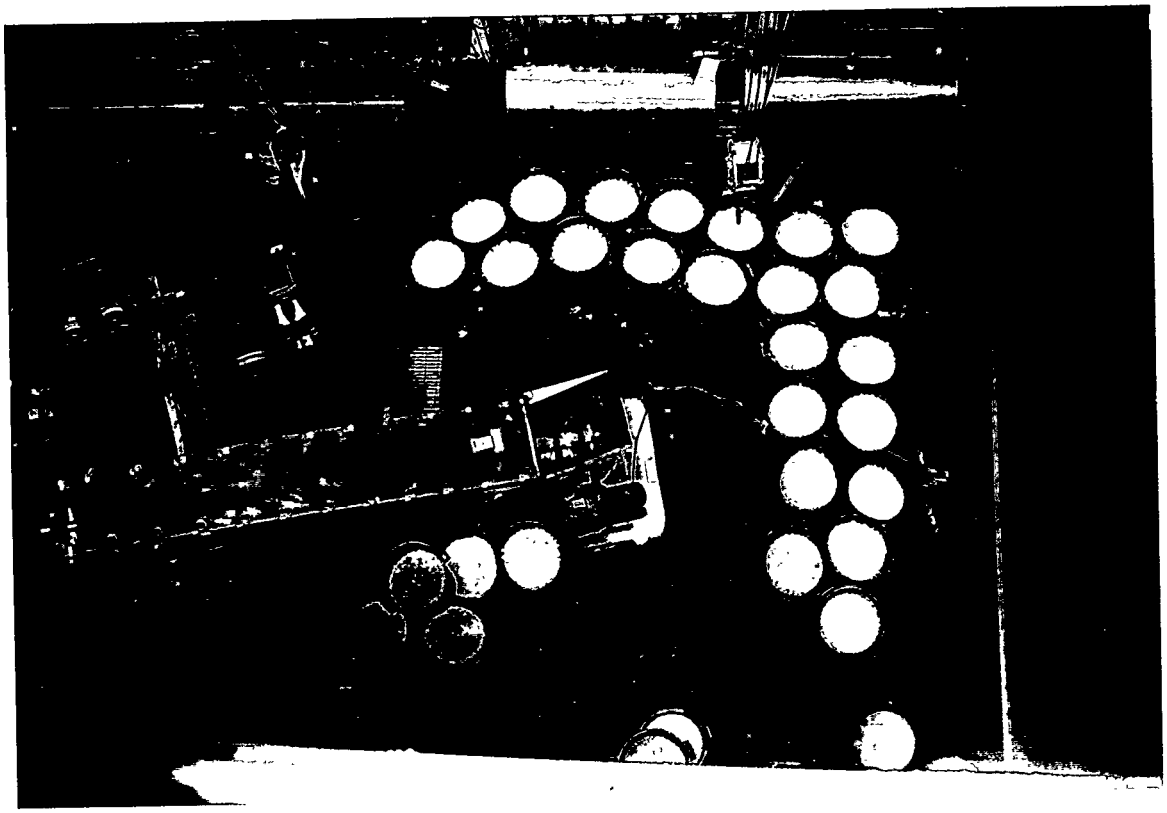


FIGURE 7

FIGURE 8



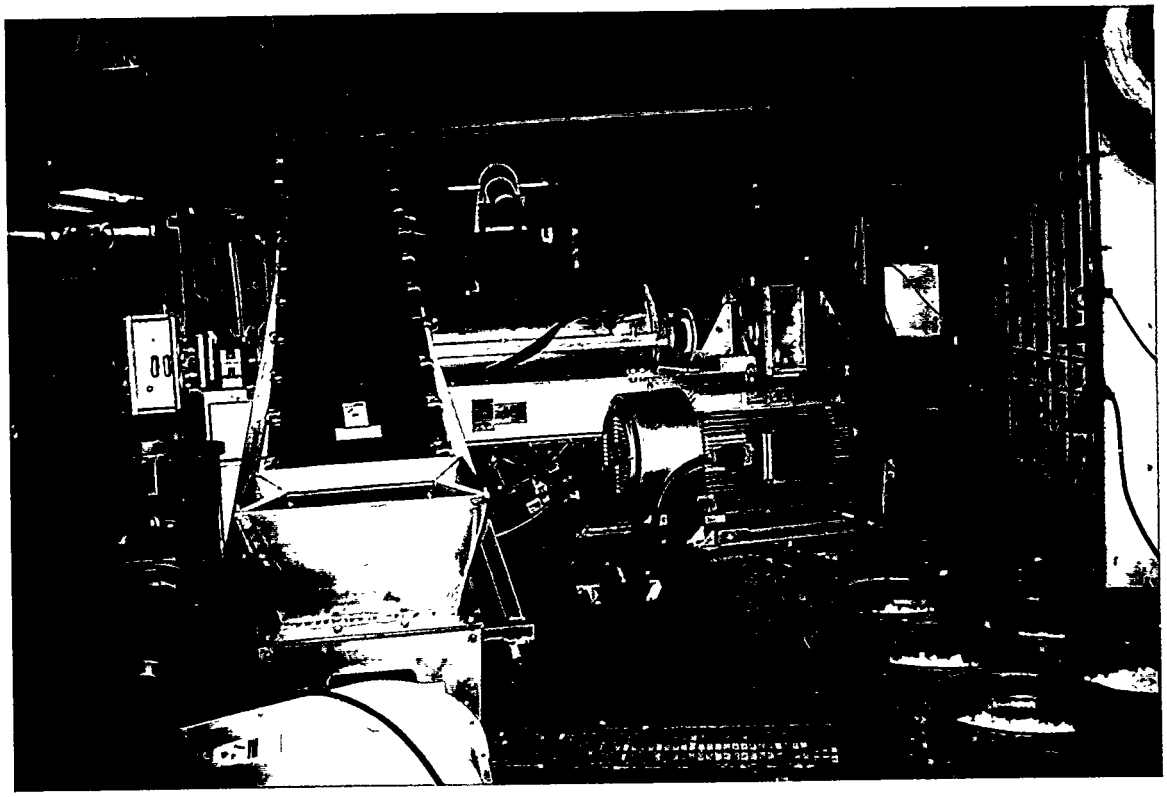


FIGURE 9

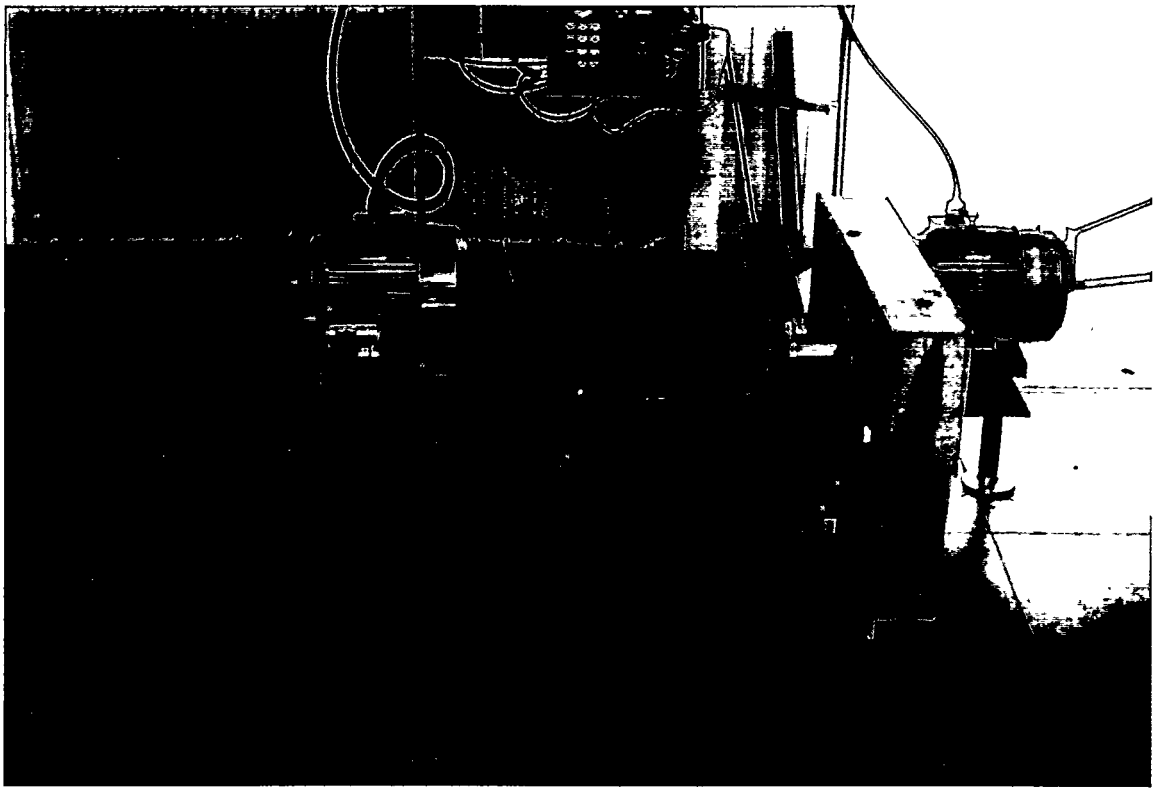
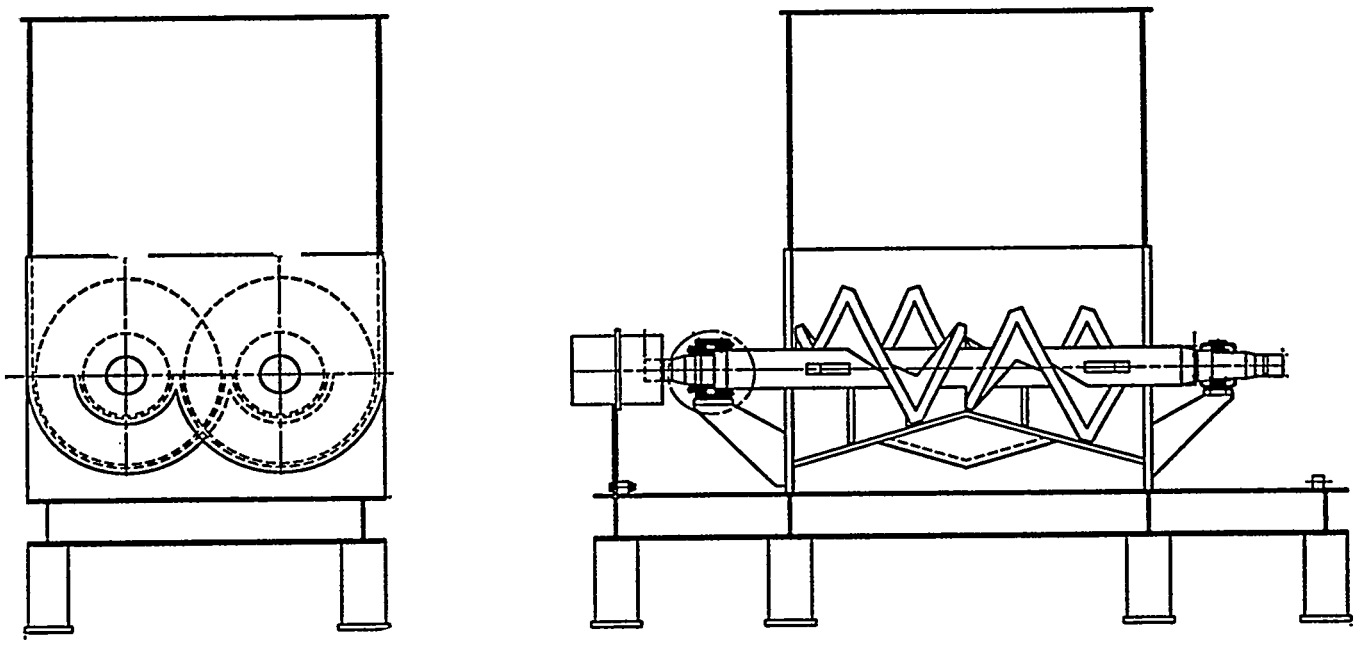


FIGURE 10



WAXED OCC

ESTIMATES, U.S.

	1000 T/YR
OCC Recovered	11,000
Wax on Corrugated	170
Application Rate	20% (10-30)
Waxed Cartons Produced	860
Trim (15%)	130
Collected (50%)	430

FIGURE 11

WAXED OCC

- Tolerated in OCC 5%, Max
- Wax Content in Final Pulp 1%, Max
- Waxed OCC Alone Not Processed on Commercial Scale Today
- Literature Confirms the Problem and Suggests Solutions
  - ★ Back
  - ★ Wilken
  - ★ Galland
  - ★ McDonnell

FIGURE 12

RESIDUAL EXCESSIVE WAX CONTENT

AFFECTS PROPERTIES

Slide Angle	Reduced
Strength Properties	Reduced
6.5% Residual Wax	Burst 10 to 40% Crush 5 to 25%
Absorption Time	Increased
Appearance	Spots

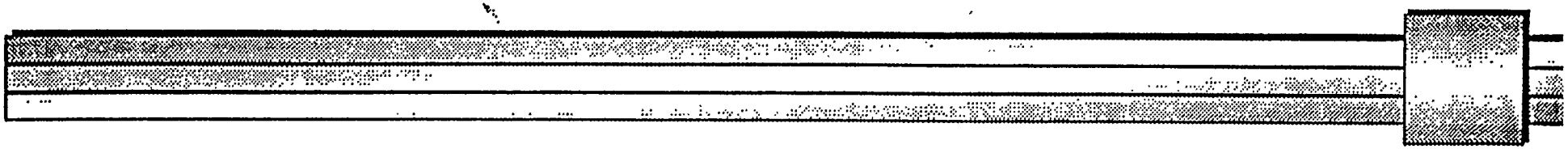


FIGURE 13

Xtrax™
Impurities Extraction System

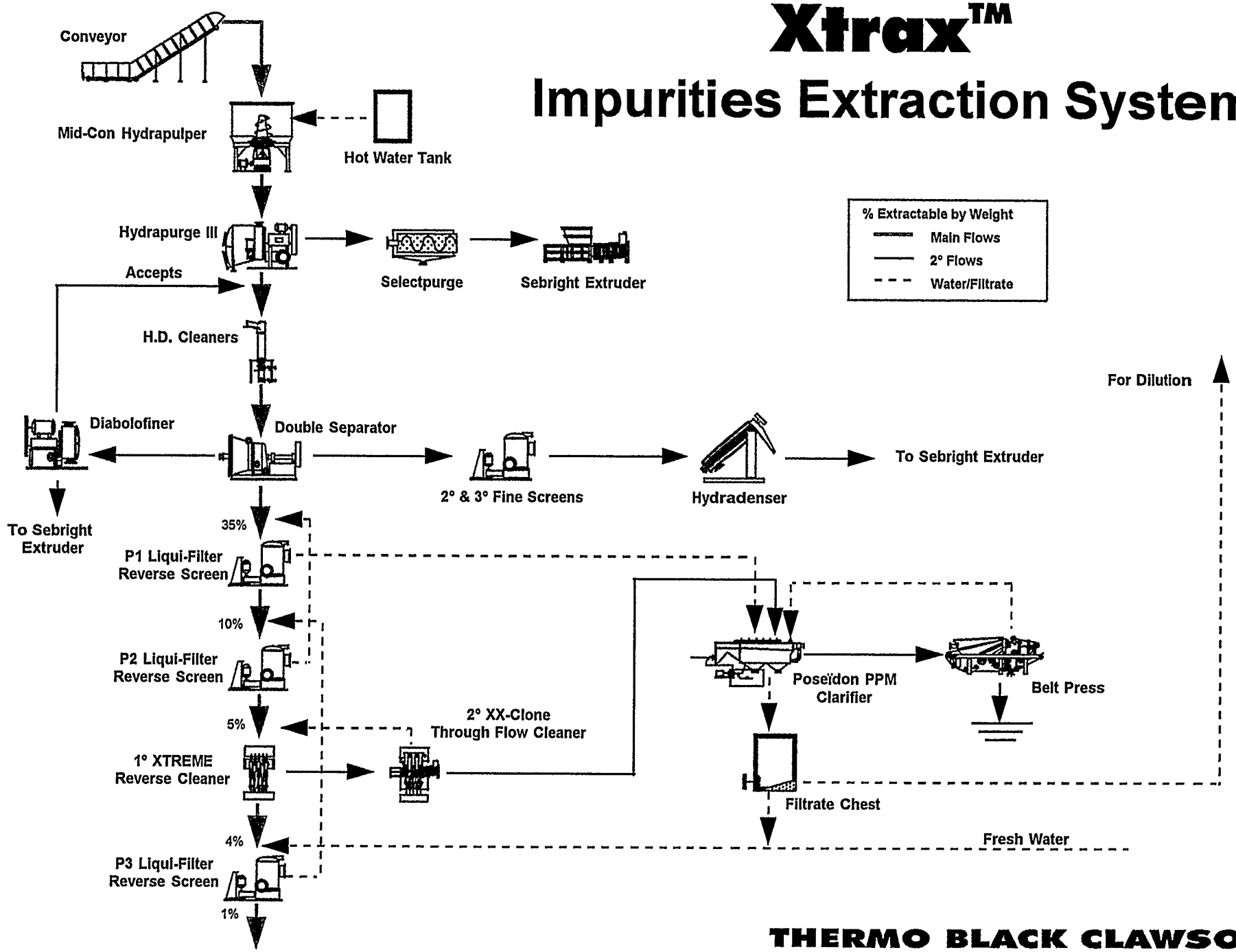


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FIGURE 14

THE REVERSE SCREENING™ PRINCIPLE

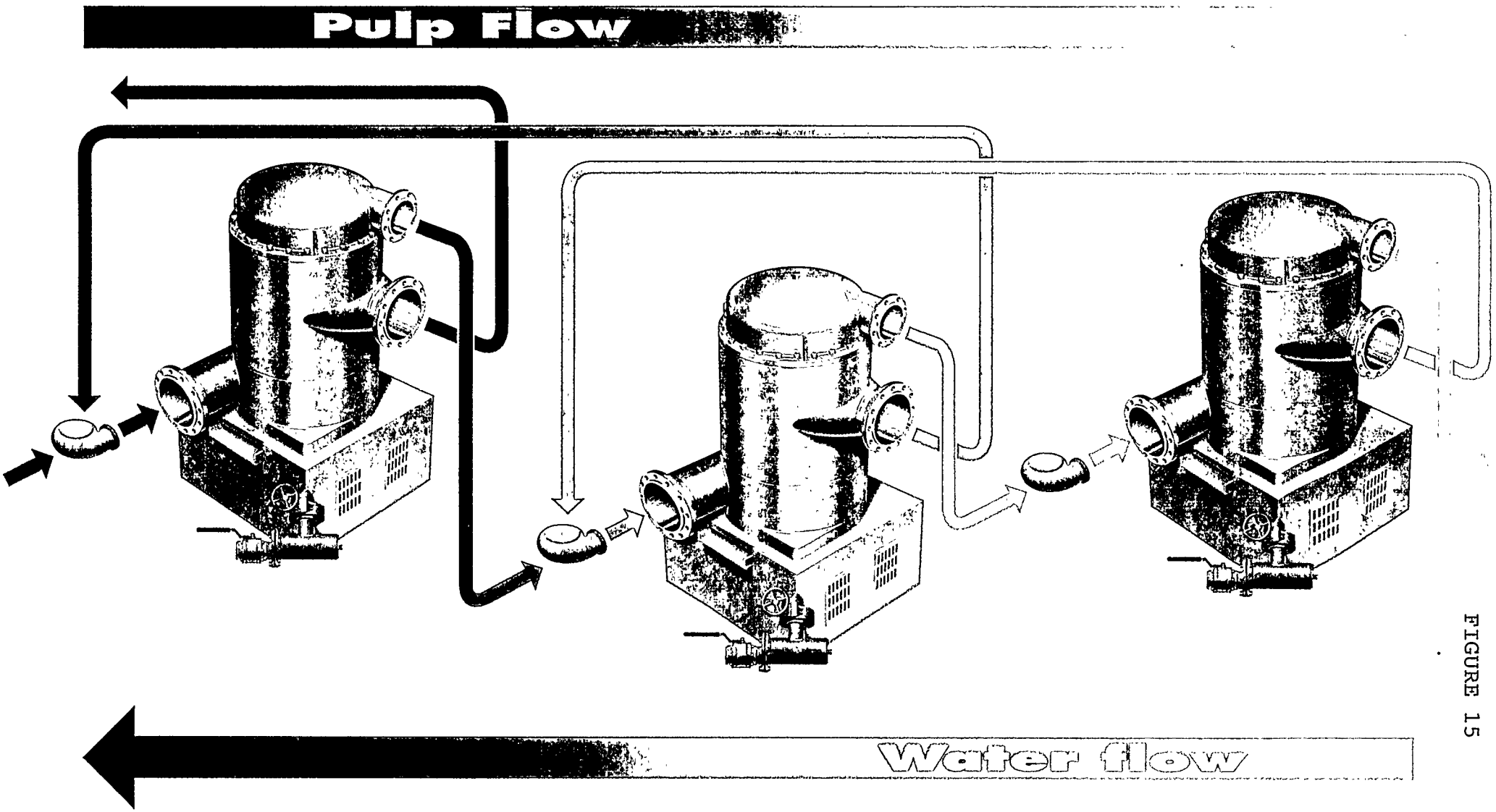


FIGURE 15

THERMO BLACKCLAWSON INC.

A Thermo Fibertek company

IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

DE-FC36-95GO10085

APPENDICES

I. THERMO BLACK CLAWSON, R&D CENTER BROCHURE

II. PATENT APPLICATIONS, LIST

III. PUBLICATIONS, LIST

IV. NOTICE OF PRODUCT RELEASE, XTREME AND XX CLEANERS

V. REFERENCE LIST, XTREME AND XX CLEANER SALES

VI. NOTICE OF NEW PRODUCT RELEASE, XTRAX PROCESS

VII. DATA SHEETS, CLEANER EVALUATION

VIII. PUBLICATION, NEW CLEANER DEVELOPMENT FOR LIGHTWEIGHT CONTAMINANT REMOVAL (MAZE, MCCARTHY)

IX. PUBLICATION, CLEANING UPGRADE IMPROVES SHEET QUALITY AT GREEN BAY PACKAGING (SHAW)

X. XTREME AND XX CLEANERS AT GREEY BAY PACKAGING (VANDENBERG)

XI. R&D REPORT, EXERPTS, DRY PULPER

XII. R&D REPORT, FLOTATION, HARA-T EXERPTS

XIII. PUBLICATION, FLOTATION DEINKING BUBBLES (SEIFERT, ET AL)

XIV. R&D REPORT, WAX WASHING (EXCERPTS)

THERMO BLACK CLAWSON INC.

A Thermo Fibertek company

Recycled Fiber • Chemical Pulping • Stock Preparation

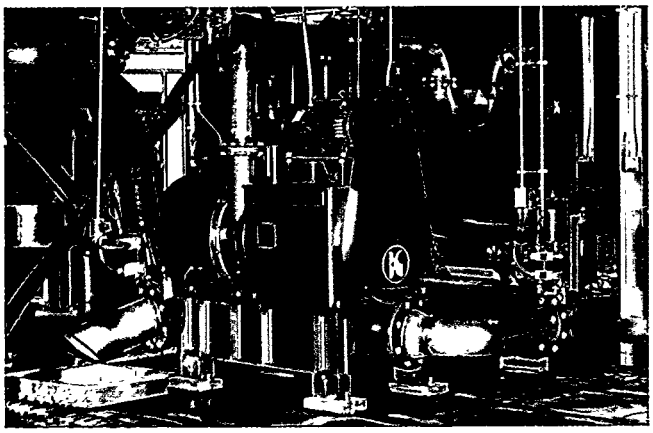
605 Clark Street, Middletown, OH 45042-2117 USA +1 513.424.7400 Fax +1 513.424.1168 www.blackclawson.com

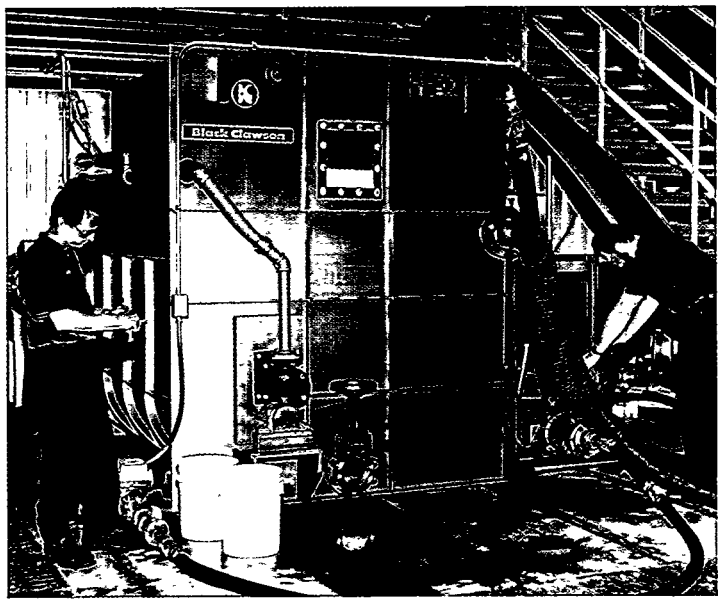
APPENDIX I

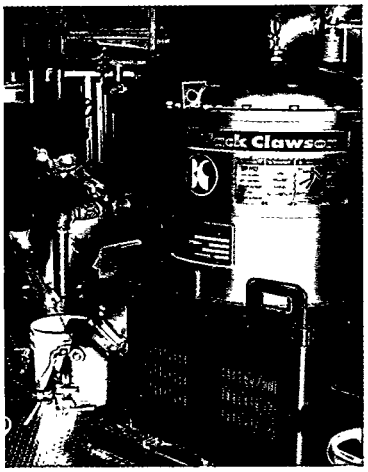
Excellence In The Advancement of Fiber Processing Systems

Black Clawson Technology Center
- Recycling Center
- Product Improvement Center
- Product Development Center

Black Clawson Technology Center
Dedicated to Serving Customers Worldwide







The Technology Center is a client oriented facility, providing access to advanced fiber processing equipment. Projects, tailored to a mill's individual needs, can be run on full scale, mill-sized equipment. Mill operating conditions are simulated in a pilot plant environment to help clients produce a higher quality pulp, more economically.

Trials and system evaluations are conducted at the Technology Center for clients all over the world.

All trial work is performed by staff engineers, technicians and mechanics who are technical professionals with years of experience in the pulp and paper industry.

Tapping this wealth of knowledge and ideas, every client is assured of the most reliable and dependable trial results, whatever the application. These results are evaluated in fully equipped wet labs that include the latest analytical and test instrumentation.

THERMO BLACK CLAWSON INC.

TECHNOLOGY CENTER

- Develop New Technology For Stock Preparation, Recycling, Pulp Mill.
  - -In House
  - -Contract With Customers
- Training For Operating Crews
- Demonstrations With Customers' Pulp Furnishes
- Location

  Middletown, Ohio
  (513) 424-7400

THERMO BLACK CLAWSON INC.

TECHNOLOGY CENTER

Engineers/Scientist	8
Person, Total	16
Area (M^2)	2500

Small Commercial Equipment

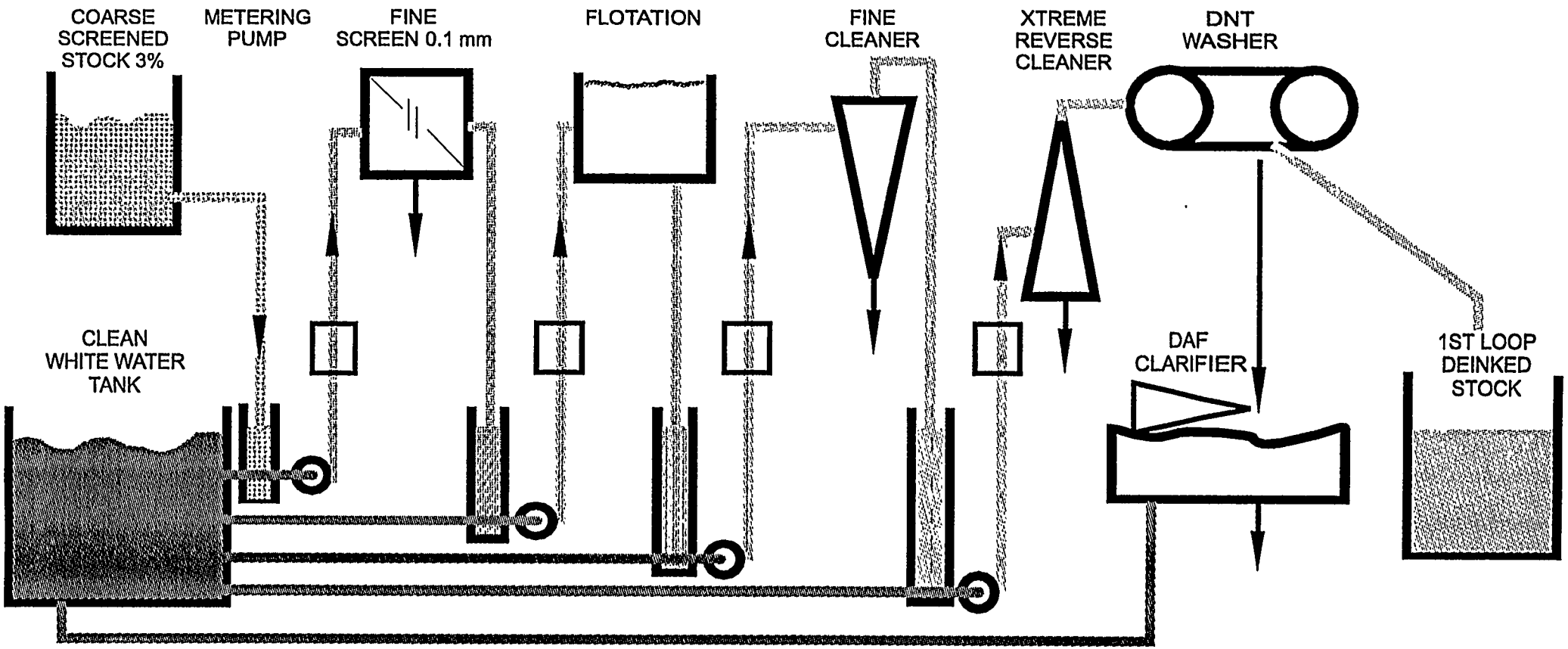
Hydrapulpers	Screens
DNT Washer	Kneaders
Flotation Cells	Sets Cleaners

- IIM Flotator
- MAC
- Ultra-Clone
- Xtreme, XX

DAF Clarifier

THERMO BLACK CLAWSON TECHNOLOGY CENTER

CONTINUOUS STOCK PREP LOOP



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A Description of Black Clawson's Pilot Plant Facilities in Middletown

Terry Bliss

ABSTRACT

Pilot plants can be used to evaluate process equipment, furnish, and chemistry variables in a controlled, low-cost atmosphere with none of the risks intrinsic to a mill trial (off-specification product, production downtime, etc.) There are a large number of pilot plants of various sizes and capabilities, but access policies vary. These pilot plants can operate with bench scale or mill-scale equipment and in batch or continuous mode. Advantages and disadvantages are given for each scale and mode. Black Clawson operates a complex of three pilot plants in Middletown, Ohio; all operate with mill-scale equipment and in a batch processing mode. Their capabilities are described.

KEYWORDS

Batch process, Continuous process, Pilot plants, Reclaimed fibers, Stock preparation.

INTRODUCTION

The U.S. paper industry plans to substantially increase the amount of secondary fiber recovered to 38.5% by 1995. Utilization is expected to grow from 23% of production in 1988 to 31% by 2001, a 35% increase. Given the enormous size of the U.S. paper industry, even small increases in the U.S. recovery and utilization rates, which are modest by world standards, represent huge increases in the total tons of secondary fiber recovered and utilized. The U.S. already utilizes approximately 25 million tons per year of secondary fiber, more than the next three countries combined, and it is also the largest exporter of recovered fiber by far (1).

Many years ago, stock preparation and secondary fiber pilot plants were not readily accessible. Pilot plant trial results did not play a major role in the decision-making process for expansions and new installations. Over the years, process technology has improved, mill systems have become more complex, and raw material quality has deteriorated. Today, pilot plants are much more accessible, and trial results have become an important part of the decision-making process for mill quality and capacity upgrade projects. In North America, there are no less than 29 pilot plants which have some secondary fiber or stock preparation capability. It is not unusual for as much as 0.5-1.0% of the total process equipment costs of a typical quality or capacity upgrade project to be spent in the pilot plant to better define the anticipated results of the project. In addition, many equipment and chemical suppliers spend about 2-3% of their gross sales for the pilot plant portion of their new product development programs. Pilot plant trials do not eliminate the need for in-mill trials but they do reduce the frequency and risk of in-mill trials.

PILOT PLANT BASICS

Pilot Plant Locations

Universities and government-sponsored research organizations operate the majority of the pilot plants found in the U.S. They use them primarily for publicly funded research, for teaching purposes, and, to a limited extent, for privately funded contract research.

Process chemical and equipment suppliers also operate a significant number of pilot plants. They use them for new product development, product technical support, sales promotion demonstrations, and privately funded contract research. Access policies vary.

A modified version of this article was presented at the Pira Internatioal Conference on Developments in Wastepaper Technology., March 24-25, 1993.

The author is Director, Research & Development, Shartle Division, Black Clawson Company, 605 Clark Street, P. O. Box 160, Middletown, OH 45042, USA.

There are a few independent or contract research facilities, either privately funded by industry groups or by government grants. A few very large paper companies also maintain pilot plants. Most only do work for their own purposes and will not accept contract research work.

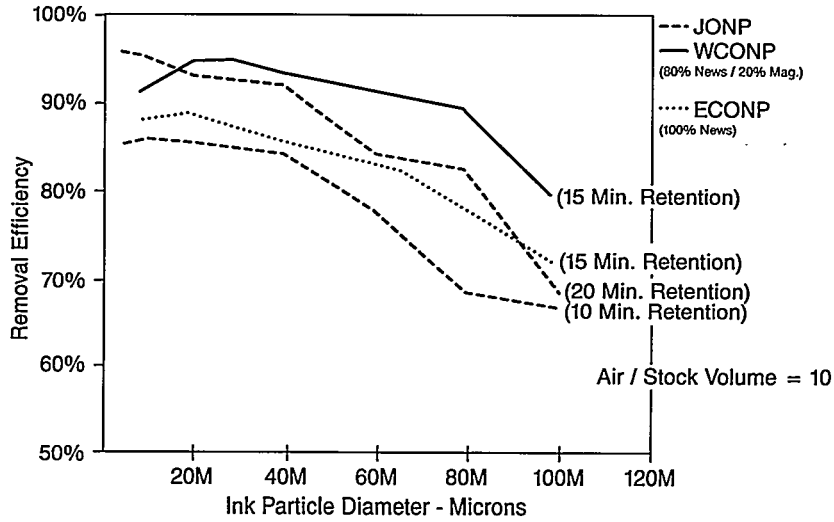
Table 1 summarizes the sponsorship of 29 U.S. stock preparation and secondary fiber pilot plants (2).

Scale of Pilot Plants

Mill-scale pilot plants can be conveniently described as containing only equipment which is capable of commercial production rates, in the range of 20-50 t/d minimum or, if operated in batch mode, with batch sizes of 0.5-1.0 tons minimum. Ideally, in such a facility, only production equipment would be used and results would very closely match expected results in a mill environment.

Near-mill-scale could be described as capable of 5-20 t/d operating rates or batch sizes of 0.1-1.0 tons minimum, generally containing equipment with all critical dimensions within the range of commercial-size machines. For example, a near-mill-scale decker would be of normal diameter and would operate at normal rotation speeds but could be built in a very narrow size to limit its production rate to 5-20 t/d. In this case, the same operating conditions could be expected to produce the same results as true mill-scale equipment but at reduced production rates.

FIGURE 1: **Ink removal efficiency by flotation for three different ONP: (J) Japanese, (WC) West Coast, and (EC) East Coast. Results were obtained in a flotation cell, shown in Fig. 4. Ink removal efficiencies were calculated from inage analysis data for a known particle-size range. Results show that flotation efficiency depends on ink particle size, origin of ONP, and the amount of OMG.**



Bench-scale pilot plants typically contain equipment with critical dimensions much smaller than commercial-size machines. They typically operate at production rates of 0.1-5 t/d or with batch sizes of 0.001-0.1 tons. The range of operating conditions for bench-scale equipment is not necessarily the same as for mill-scale equipment, and bench-scale equipment often does not produce results identical to those expected from commercial-size equipment. Bench-scale equipment is useful for comparative work and for obtaining limited information very quickly at very low cost and with very little pulp.

These descriptions are very general. Some equipment scales up directly from bench-scale. For example, a single, small-diameter centrifugal cleaner scales up perfectly by using multiple identical units. Other equipment requires considerable experience for scale-up. These descriptions correspond to the generally accepted definitions of pilot and scale paper machines. A pilot paper machine has mill-size dimensions for everything except width, resulting in a close approximation to mill operation; a scale paper machine is smaller in all dimensions and results from it are less likely to correspond to mill operation.

Table 1. Sponsorship of U.S. Stock Preparation and Secondary Fiber Pilot Plants.

Sponsorship	Number of Pilot Plants
Unversities & government	13
Chemical & equipment suppliers	9
Independent, private & consortium	2
Paper producing companies	6

Modes of Operation

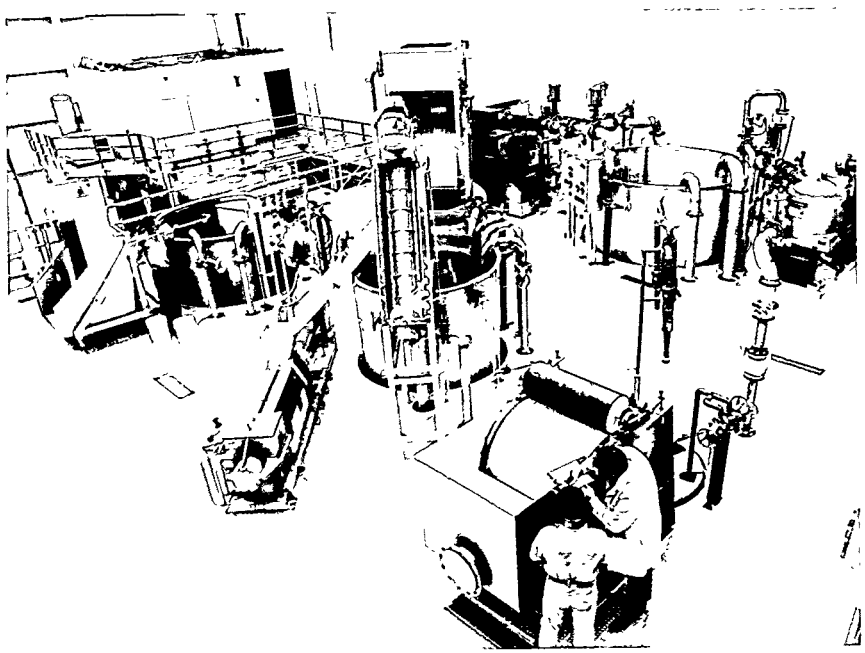
Continuous pilot plants - advantages and disadvantages.

Given equal-scale equipment, continuous pilot plants typically out-

put 5-10 times more stock per day than batch pilot plants. Continuous pilot plants also have negligible tank and line losses. This makes their yield typically much higher than batch pilot plants and makes them much more cost-effective for producing large quantities of stock for pilot or in-mill paper machine trials. It is also much easier to operate realistic secondary or tailing loops and water clarification or recirculation loops in a continuous pilot plant. Many tailing or recirculation loops require a considerable amount of time or number of cycles to come to equilibrium. This makes anything more than a "first pass" simulation impossible in a batch pilot plant and time-consuming in a continuous pilot plant. Continuous pilot plants tend to require fairly elaborate instrumentation and controls which makes automated data collection more feasible. Since the system is in continuous operation for a length of time, the equipment, tanks, and pipes tend to stay flushed out and there is less likelihood of picking up casual contamination left in dead corners from a previous run. In summary, continuous pilot plants operate more like mill operations in virtually every way.

Continuous pilot plants also have several distinct disadvantages, most of which tend to affect the cost of operation. Since all the equipment is in operation at once, considerable more equipment is required. For example, four pressure screens would be required to simulate coarse screening, fine screening, and secondary screening in both positions. In a batch pilot plant, the same screen body could be used for all of these applications, just be changing the rotor and/or the screen cylinder. Likewise, in a batch pilot plant, a single flotation cell might be used to simulate multiple stages of flotation in the pre- and post-flotation position while, in a continuous pilot plant, 8-16 cells may be required for the same simulation. Continuous pilot plants require much large quantities of stock to start up and operate, and generally more operators, even when only small quantities of output stock are required. The plant must operate for a substantial length of time, sometimes 24 hours or more, to come to equilibrium with the tailing systems and water recirculation systems. All of these factors contribute to the daily operating rate and the total cost to obtain results.

FIGURE 2: **Overall view of Black Clawson Recycling Center. View from mezzanine level shows operating floor and equipment, including the 8-ft-diameter HI-CON™ Pulper, the Model 100 DNT™ Washer, the Model 100 Ultra-V™ Pressure Screen, the cleaner test stand, the Free-Flo™ Thickener, the Model 1-B-9 Hydradenser™ Inclined Screw Thickener, the VS-1 Vertiscreen™ Inclined Stock Screen, and the French Oil Press.**



Continuous pilot plants also tend to lack versatility since it is usually much more difficult to reconfigure the equipment arrangement. Individual pieces of process equipment often operate at unrealistically low rates, due to the capacity of other equipment in the system. This is particularly true of pressure screens and tailing systems in general. For example, the smallest mill-size pressure screen may have a capacity of 200 t/d or more as a coarse screen and 50-100 t/d as a fine screen but, in a continuous pilot plant, they both may operate at a 20 t/d rate because of capacity restrictions elsewhere in the system. The operating rate for a secondary or tailing screen may be even more unrealistically low, perhaps 5 t/d or less.

Batch pilot plants - advantages and disadvantages.

By comparison, most batch systems are much smaller and simpler. Many times, a single piece of equipment can be used several times, thus reducing capital cost. Control requirements are less critical because batch systems are usually operated manually. Batch pilot plants typically operate with much smaller quantities of furnish (0.2-2.0 tons is common), and they typically operate only one shift per day. These factors tend to keep the overall cost low.

FIGURE 3: **The Recoupe™ Steam Explosion Process is demonstrated in the Technology Center. Thicknened pulp is fed into the system from the floor above. The reciprocating plug feeder discharges stock into the retention tube, shown in the foreground. After completing the required residence time, the pulp is discharged through a blow line to a blow cyclone on the floor above. This 6 t/d reactor is the only Recoupe unit in the world available, along with the necessary screening, cleaning, and washing equipment, to simulate a complete secondary fiber system.**

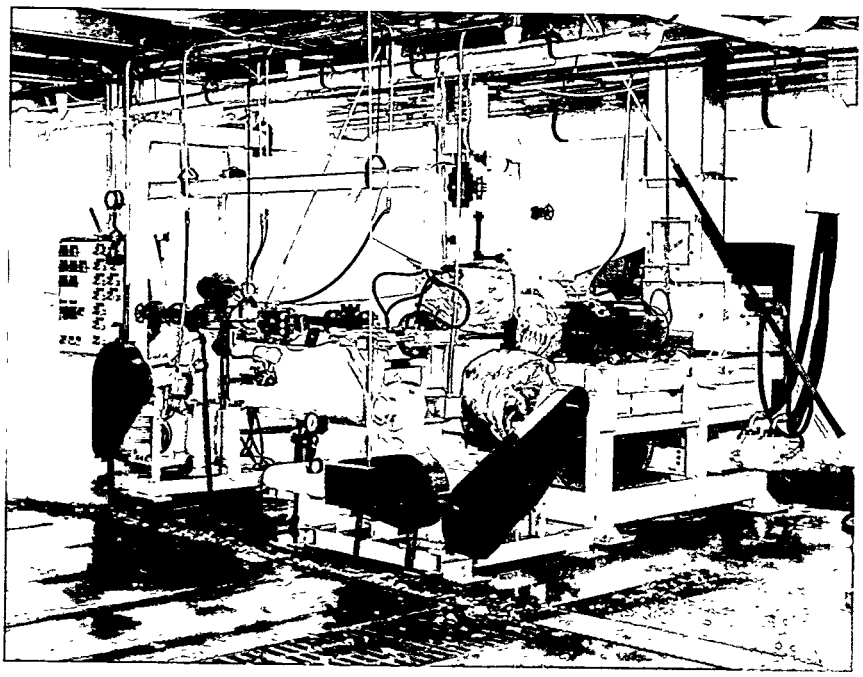
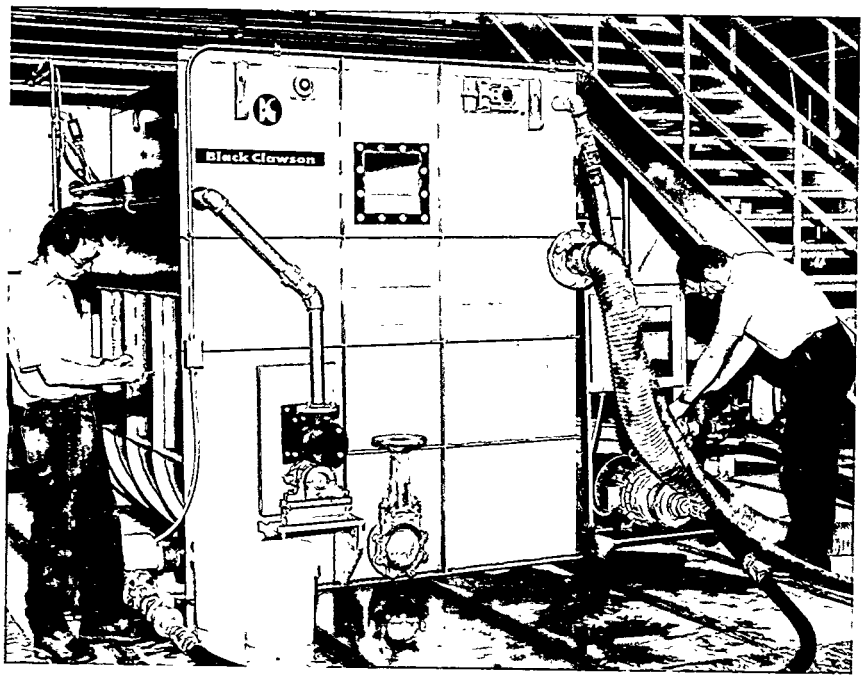


FIGURE 4: **The IIM/BC Flotator™ Deinking Cell aerates the stock many times as it passes through the cell in a spiral flow path, such that a single stage often increases brightness or reduces specks more than an equivalent six to eight passes through a conventional cell. The Technology Center's 5 m³ unit, shown here, is sometimes used as a secondary unit in mill applications.**



Batch pilot plants often can operate a single piece of equipment in recirculation; for example, screen or cleaner accepts and rejects return to the feed tank while operating conditions are adjusted. Recirculation makes it easy to obtain small samples at a variety of operating conditions, using very small quantities of stock. Since each piece of equipment operates independently, all can be operated at their normal throughput rates, independent of downstream equipment capacity.

Batch pilot plants also have several disadvantages. Their total pulp output per day may be quite low because of substantial losses in the bottom of tanks, the usual process equipment reject rates, and because only one process step is run at a time. Sometimes, there are delays while screen cylinders are changed, etc. Consequently, batch pilot plants are usually not the best choice for producing sufficient quantities of stock for pilot or in-mill paper machine runs. It is more difficult to evaluate tailing streams because often there isn't much stock produced in those circuits. Finally, recirculation or water treatment loops are at best poorly simulated due to "first pass only" process simulation.

In most cases, only comparative information or magnitude of improvement information is needed. Consequently, the great majority of stock preparation and secondary fiber pilot plants operate in a batch mode.

Effects of Casual Contamination in Pilot Plants

Typically, pilot plants do not operate on the same furnish at all times. This means contamination may be possible from one run to the next due to difficulties in thoroughly cleaning each piece of equipment,

Table 2. A Partial List of Equipment Contained in Black Clawson's Middletown, OH Pilot Plants.

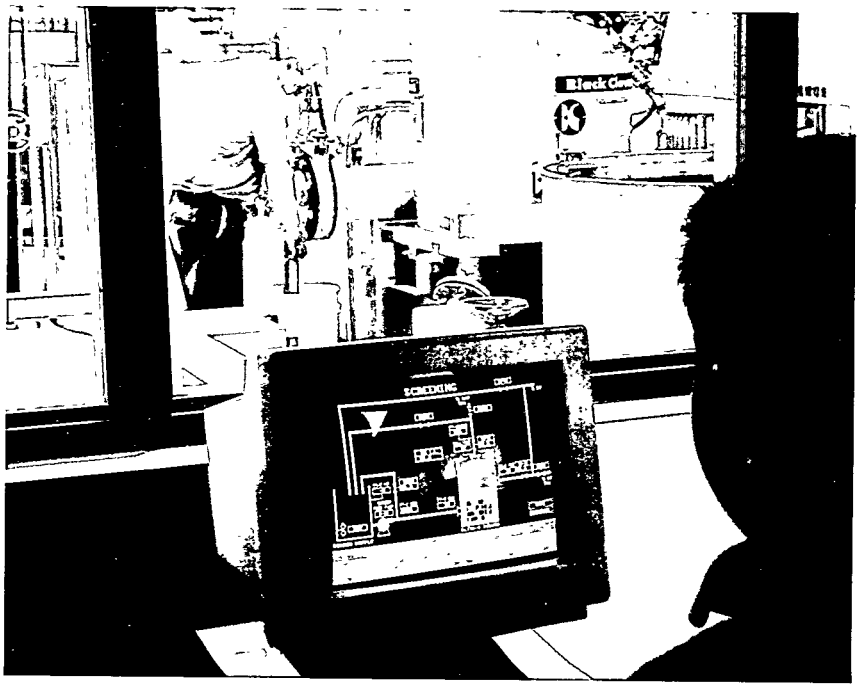
Equipment Type	Quantity	Size(s) or Capacities	Options
Pulpers	4	0.6-2.5 m diameter; 3-700 kg batch capacity	7 rotor choices; extraction holes from 3-50 mm diameter; variable speed
Pulper Detrashing System	1	For 2.5 m continuous or batch pulper	2 rotor choices; extraction holes from 6-12 mm diameter; Batch or continuous pulper configuration
Pressure Screens	3	50-300 t/d	Rotor choices; 70-screen cylinders; variable speed
High Speed Deink Washers	2	50-150 t/d	Interchangeable fabrics; variable speed
Deink Flotation Cells	4 cells, 3 designs	3-liter batch to 15 t/d continuous	Single or multiple pass capability
Centrifugal Cleaners	25 cleaners, 5 types	Single units and banks with capacities to 2000 l/m	Reject tip size
Dispersers	2	10-50 t/d	
Deckers	1	10-20 t/d	Rotating speed
Screw Thickeners	1	10-20 t/d	
Screw Presses	1	2-8 t/d	
Cone Presses	2	10-50 t/d	
Deflakers	1	50 t/d	Adjustable tackle clearance
Refiners	2	31 cm and 41 cm	Adjustable speed; multiple plate patterns
Steam Explosion Pulping System	1	6 t/d	Variable throughput, retention, blow rate, discharge options; pressure to 2000 kPa

tank, and pipe run. Infrequently used sections of pipe cause the most problems; the extra tees which contribute so much to versatility of operation tend to create dead spots where stock can collect and dewater across a valve. In general, there is no substitute for a thorough flushing with the same type of stock which will be run next. The necessity of flushing is illustrated by the very small quantities of some contaminants in white pulp which are visible to the naked eye. For example, unbleached or heavily dyed fibers can be detected visually at concentrations as low as 0.1%, and the brightness of bleached pulp can be reduced by 3-4 points with as little as 2% unbleached or heavily dyed fibers.

Some contaminants, such as rust flakes or carbon paper specks, can

be detected at concentrations of only a few ppm. Even "all stainless" process equipment sometimes has nonstainless shafts. It is practically impossible to obtain rust-free water from municipal water systems since they usually use cast iron pump casing and water mains. Rust from incoming water supply pipes is a particular problem in pilot plants since the incoming pipes often are idle for days at a time and may be difficult to flush out. Rust problems can also be caused by steam lines. Pilot plants rarely use stainless steel steam lines and they too are used only sporadically.

FIGURE 5: **A technician draws a sample from the Ultra-V Pressure Screen. The Technology Center maintains three pressure screens, and more than 70 screen cylinders to support active R&D and client contract research programs.**



BLACK CLAWSON'S TECHNOLOGY CENTER - AN OVERVIEW

A Brief History

Black Clawson acquired a 1935-era pilot plant when it bought the Dilts Division in Fulton, NY, in 1940. In 1946, the stock preparation and secondary fiber product lines were consolidated at the Shartle Division in Middletown, OH. The Shartle Division constructed a greenfield pilot plant in 1959, adjacent to their existing offices and shop; some of the now 60-year-old pumps from the original Dilts pilot plant are still in service there. Noteworthy products and processes developed in the Fulton, NY and Middletown, OH facilities include the Hydrapulper® pulping machine, numerous pulper improvements, the Verti-Former® vertical twin-wire former, the Fiberclaim™ and Hydrasposal™ processes, the DNT™ washer, the Sectifier® pressure screen, and several generations of high-speed beater room pressure screens, pressure screen cylinders, flotation cells, and centrifugal cleaners.

In 1976, a five-story addition was constructed to house a 5 t/d continuous Pandia digester pilot plant. This facility was operated until 1989, when the Pandia product line was sold and the equipment relocated. This facility was then converted to a new product development facility, its present use.

During the 1970's and 1980's, interest in secondary fiber processing grew quite rapidly in North America; the demand for access to the Technology Center by Black Clawson customers grew with it. Another expansion was initiated in 1991 and completed in mid-1992. With the most recent addition, the complex now occupies a total of 2400 sq m and is the largest facility in North America dedicated strictly to secondary fiber and stock preparation process technology.

Three Independent Pilot Plants Under One Roof

The Technology Center is still operated as three independent pilot plants. They are all under one roof, can share some portable equipment, and stock can be transferred from one to another. Internal walls divide them, and they each have their own entrance, office area, and wet labs. This allows privacy to visiting clients and also allows the sample buckets to be isolated for more convenient processing.

The Product Development Center is used only by Black Clawson for new product development and is closed to visitors. Details of this facility are not released.

The Product Improvement Center is used by Black Clawson for developing technical information on products which have already been commercially released and for client work involving a limited number of process steps. It operates primarily in the batch mode, with batch sizes between 0.1-0.2 tons. However, the majority of the equipment is capable of operating at rates of 25 t/d or greater.

The Recycling Center is used primarily for client contract work. It also operates primarily in the batch mode, although simple continuous systems can also be simulated. Its typical batch size is 0.4-0.8 tons, but the majority of the equipment is capable of operating rates of 25 t/d or greater.

All these pilot plants use mill-scale or near-mill-scale equipment with instantaneous operating rates as high as 350 t/d. However, corresponding bench-scale equipment is also available in most cases. Chests are as large as 30,000 l, and pumps are as large as 15,000 l/m.

A Partial List of Equipment

It is difficult to produce an up-to-date list of equipment because, on average, a new piece of equipment is installed and removed each month in one of the pilot plants. In addition, equipment which is still under development or not yet commercially released is usually kept confidential. Table 2 gives the equipment and general capabilities of the three pilot plants. In most cases, extensive spare or alternate interchangeable parts and variable speed drives are available to assist in changing the individual machines' configurations to match the desired configurations.

The piping is extensively branched and interconnected to allow for versatility of operation. It also has many locations for sampling and stock transfer. Each run is custom planned (and repiped if necessary) and executed to accomplish the goals of that particular program.

Utilization

About 50% of the operating days in the complex are consumed by Black Clawson, typically for new product development, product improvement, and generating technical information. The remainder are used for client contract research which could include furnish evaluations, furnish upgrading, evaluation of new process equipment and technology, evaluation of chemistry alternatives, repulpability studies, refiner studies, operator training for new production facilities, and occasional production of stock for pilot paper machine trials.

SUMMARY

Stock preparation and secondary fiber pilot plants are used to reduce the cost and risk of exploratory work prior to system modifications, in-mill trials, or greenfield installations. Pilot plant trials consume only a tiny percentage of the total installed cost of a new or upgraded system, but they are instrumental in providing the data for key decisions.

Pilot plants can be small (bench-scale simulators) or large (mill-scale or near-mill-scale equipment). In general, a better simulation of the mill environment can be made with a mill-scale, continuous operation pilot plant but at a much greater expense than a smaller, simpler system. Continuous pilot plants generally are better for producing large quantities of output stock (five tons or more) and for simulating tailing, recirculation , and water treatment loops. Batch pilot plants generally are much more cost effective and perhaps better suited for examining unit operation variables by allowing each piece of process equipment to operate at its normal throughput rate, independent of the capacity of the rest of the system.

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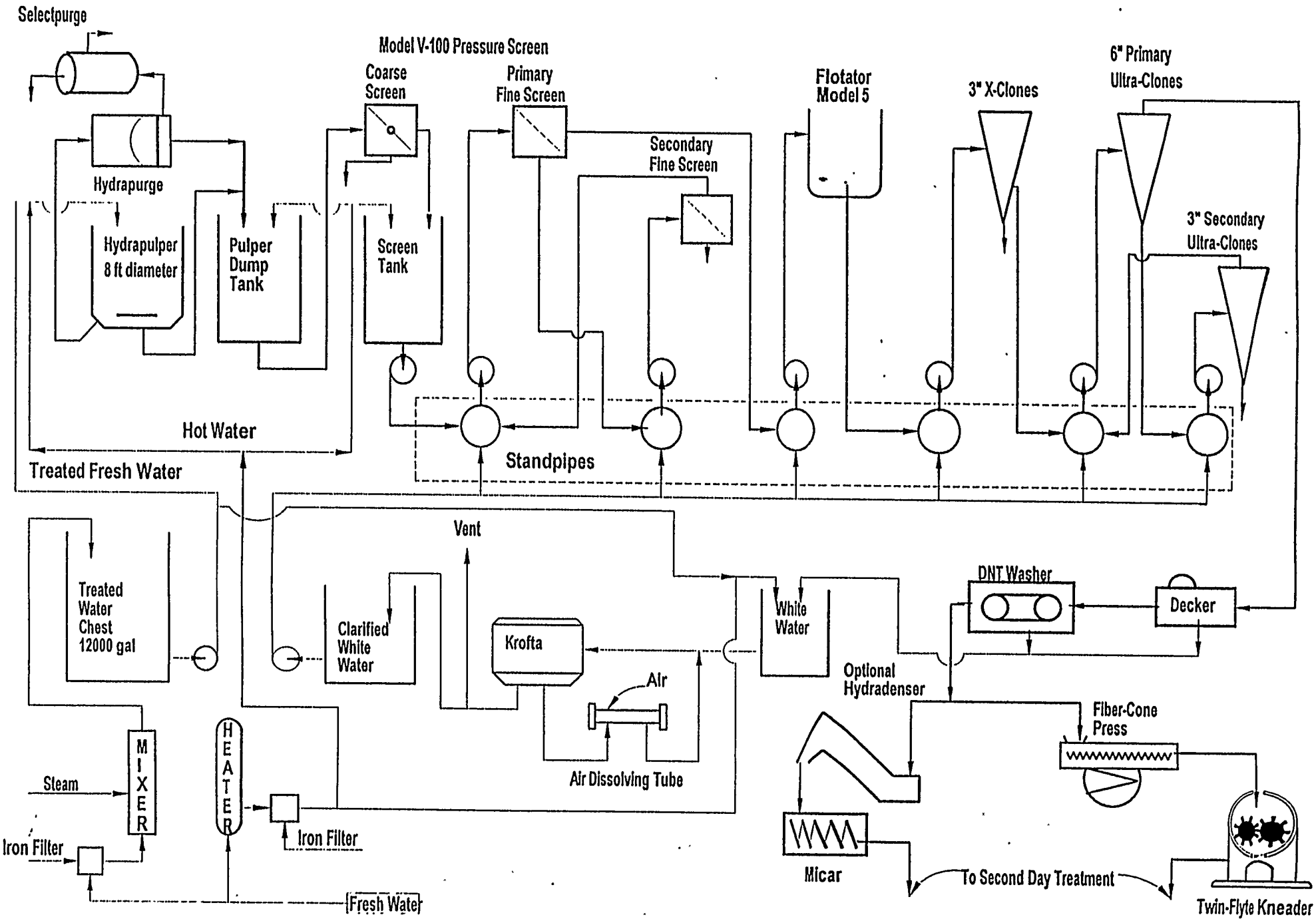
1. Garcia, D.A. Recycling capacity to increase at record rates as laws proliferate. Pulp Paper 64, no. 5: S1-S29 (May 1990).

2. Anon. Catalog of Stock Prep Pilot Plants. TAPPI (1987). ■

Notes

A SECONDARY FIBER TREATMENT PROCESS (One of Several Possible Configurations)



APPENDIX II

IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

DE-FC36-95GO10085

LIST OF PATENT APPLICATIONS BY THERMO BLACK CLAWSON

Chris McCarthy, el al, "Reverse Cleaner with Elongated Conical Body, With Length to Diameter Ratio of at Least 20 to 1."

Chris McCarthy, et al, "Cleaning System Consisting of a Reverse Primary Cleaner and a Second-Stage Through Flow Cleaner."

Chris McCarthy, et al, "Through Flow Hydro-Cyclone Cleaner With Improved Inlet Section"

Dave Chupka, et al, "Method of Simultaneously Pulping and Dispersing Wastepaper Having a Solids Content of Greater Than 20%."

IMPROVED REMOVAL OF STICKY AND LIGHT CONTAMINANTS FROM WASTEPAPER

DE-FC36-95G010085

LIST OF PUBLICATIONS BY THERMO BLACK CLAWSON

Maze, Elizabeth, McCarthy, Chris, "New Cleaner Development for Lightweight Contaminant Removal", Progress and Paper Recycling, 1996

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Peter Seifert, "Deinking Technology Basics", Paper Recycling Challenge, Volume II--Deinking and Bleaching, 1997

Chris Vitori, "Xtrax Wax Box Recycling System", TAPPI, Gulf States Local Session, 1998

Chris Vitori, "Xtrax Wax Box Recycling System", Southeast Recycler's Conference, Perdido Beach, 1998

Chris Vitori, "Deinking Technology and Reverse Cleaners", ABTCP Annual Meeting, Sao Paulo, Brazil

Black Clawson

NEWS RELEASE

Contact: Stephen T. Temple
(513) 424-7400

BLACK CLAWSON UNVEILS REVOLUTIONARY NEW CLEANING TECHNOLOGY

NASHVILLE, TN, October 28, 1996...Today, William J. Fondow, President and General Manager, Shartle Division, Black Clawson Company, announced the introduction of the XTREME™ reverse and the XX-Clone™ through-flow cleaning system. "These new cleaners are the most efficient now available on the market, especially in their ability to remove lightweight contaminants, including stickies," Fondow said at a press conference held for the pulp and paper industry trade press at the Opryland Hotel. "Data developed in testing these cleaners at our Technology Center in Middletown, Ohio, confirms removal rates higher than have ever before been attained," he said. "To date, we have already obtained five orders from some of the best known paper companies in the world."

Developed by Black Clawson with joint funding from a U. S. Department of Energy grant, the XTREME cleaner employs the latest technology to remove lightweight contaminants in all types of pulp slurries. Coupled with the advanced design of the XX-Clone cleaner in the tailing position, only two stages are required to minimize fiber loss and maximize removal efficiency.

(Continued)

Black Clawson Company
Shartle Division
605 Clark Street, P.O. Box 160, Middletown, Ohio 45042
Phone: (513) 424-7400 Fax: (513) 424-1168

Printed on Recycled Paper

The XTREME cleaner uses long residence times in a small diameter cleaner to extract very small contaminants that approach the specific gravity of the fiber itself. The XX-Clone is designed to be operated as a secondary cleaner in a system incorporating XTREME cleaners under very low consistency conditions. With these radical new cleaners, even the largest systems require only two cleaning stages, minimizing installation and operating costs. The entire system uses no more power than conventional through-flow or centrifuge systems, yet still removes more wax, lightweight hot melt adhesives and stickies.

"The significant new technology represented by these cleaners will enable papermakers to use even lower grades of furnish without compromising high end product quality. The XTREME and XX-Clone cleaners are a true breakthrough in cleaning technology," Fondow concluded. "They will change the way in which paper fibers are processed."

Green Bay Packaging Inc.

®

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P.O. BOX 19017
GREEN BAY, WISCONSIN 54307-9017
(414) 433-5111

FOR IMMEDIATE RELEASE

For More Information Contact:

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414-433-5307; FAX: 414-433-5150

- OR -

Mr. Ron Chase
GREEN BAY PACKAGING INC. -- CORPORATE OFFICES
414-433-5225

GREEN BAY PACKAGING MILL DIVISION PURCHASES STATE-OF-THE-ART CLEANERS FROM BLACK-CLAWSON

GREEN BAY, Wisconsin--September 9, 1996--Green Bay Packaging's Mill Division announced today the purchase of several cleaning systems-all designed to improve the quality of the linerboard sheet they produce.

This major capital expenditure, totaling nearly $4,000,000, is part of a three-Phase program in which fine slotted screens, reverse cleaners, and forward cleaners will be installed-resulting in a cleaner appearing, more consistent, uniformly colored sheet. With more contaminants removed, sheet strength, reportedly will be improved as well.

- MORE -

The new Black-Clawson XTREME™ reverse cleaners, part of Green Bay Packaging's "Phase II", were selected based on the quality of the sheet they were capable of producing. Reverse cleaners are noted for rejecting lightweight contaminants, such as "stickies", etc. whereas 6" Ultra-Clone™ forward cleaners (part of Phase III) remove small, heavy contaminants.

Developed by Black Clawson with joint funding from a US Department of Energy grant, the XTREME cleaners are significantly more efficient than anything else on the market. The installation at Green Bay Packaging will be the first start-up of these cleaners in North America.

"We've spent over six months of testing and evaluation", states Jeff Walch, Green Bay Mill Division vice-president, General Manager. "With the installation of the reverse and forward cleaners in January, we'll be up and running in February, 1997."

At the conclusion of the project, the new cleaning systems will allow the Mill to run 100% OCC post-consumer material exclusively.

Green Bay Packaging Inc. is a vertically integrated international corporation with more than 27 divisions operating in 11 states.

Black Clawson Company
Shartle Division
605 Clark Street, P.O. Box 160, Middletown, Ohio 45042
Phone: (513) 424-7400 Fax: (513) 424-1168

Case Study

Green Bay Packaging Installs Black Clawson Cleaners For Significant Improvement in Linerboard Quality

The Green Bay Packaging linerboard mill, Green Bay, WI, has increased its linerboard sales and profits by raising its product quality. Black Clawson screens and cleaners were key elements in the success of Green Bay's quality improvement program.

When Jeff Walch, general manager of the mill, saw an opportunity to increase linerboard sales in a highly competitive market by offering a higher quality product, he launched a search for the necessary quality improvement technology. A quality improvement objective was set and was used as a performance benchmark in the evaluation of all proposed new equipment.

Three principal quality criteria were set for the project. The first requirement was a measurable drop in sheet blemishes, even with declining quality in incoming recovered fiber. Second, there had to be little effect on overall fiber balance and, third, the system would have to maintain white water quality in a closed water system. The proposal submitted by Black Clawson outlined a three-phase project that would achieve all three of these success factors.

Phase One: Reverse Screening

The Black Clawson plan began with the installation of Black Clawson's Liqui-Filter™ reverse screen, which thickens pulp in-line. This permitted the shutdown of a problematic twin-wire press. The quality of the white water produced by this thickener was good enough to allow for better consistency control in the system and still result in the desired consistency in the high-density storage chest. After some initial adjustments to the machine components, the performance of the thickener continues to exceed the mill's target goals.

Phases Two and Three: Pressure Screens and Cleaners

Phases two and three have been combined and are scheduled for startup in January 1997. The mill will install Black Clawson's 6" Ultra-Clone™ forward cleaning system for the removal of small heavyweight debris. Fine slotted Ultra-V™ pressure screens will be installed to improve

removal of stickies and small debris, and Black Clawson's revolutionary new XTREME™ reverse cleaners will be installed to remove fine lightweight debris.

The XTREME cleaner is a totally new concept in lightweight debris removal systems. It incorporates an ultra-high efficiency cleaner design in a new bank array that saves considerable mill floor space. Tailed by Black Clawson's new XX-Clone™ through-flow cleaner, this system achieves record removal efficiencies for all types of lightweight debris.

Tried and Tested System

Green Bay Packaging performed extensive pilot trials and in-mill tests before selecting Black Clawson equipment for its quality upgrade project. Only after the new cleaning technology clearly demonstrated that it could deliver results that were unavailable with other equipment did the mill commit to using Black Clawson's equipment. Testing was done in both the mill and in Black Clawson's Research and Technology Center in Middletown, Ohio.

In the Green Bay Packaging mill and in three other mills where the new XTREME cleaning systems will be installed, testing has demonstrated removal efficiencies greater than 95% for all lightweight debris less than or equal to 0.995 specific gravity.

As secondary fiber contaminant problems grow more complex, the processing equipment required to remove contaminants grows more sophisticated, and removal efficiency demand becomes more critical. With Black Clawson's new cleaning technology, Green Bay Packaging can effectively and profitably deliver the quality the market demands.

May 1, 1996

Black Clawson

NEWS RELEASE

FOR IMMEDIATE RELEASE

JEFFERSON SMURFIT UPGRADES WITH BLACK CLAWSON

Jefferson Smurfit has embarked on a program to improve quality at their mill in Wabash, Indiana. Black Clawson equipment is an integral part of the new system which processes mill mixed waste into coated and uncoated boxboard. The installation consists of a Hydrapulper® pulping machine conversion, Liquid Cyclone™ high density cleaners, Ultra-V™ coarse and fine pressure screens.

New Black Clawson XTREME™ Cleaners for Stickies Removal

The primary objective of the upgrade is to improve stickies removal. For this application, Smurfit chose the new Black Clawson XTREME cleaner. This revolutionary new high-efficiency cleaner is designed to remove lightweight debris from all types of pulp.

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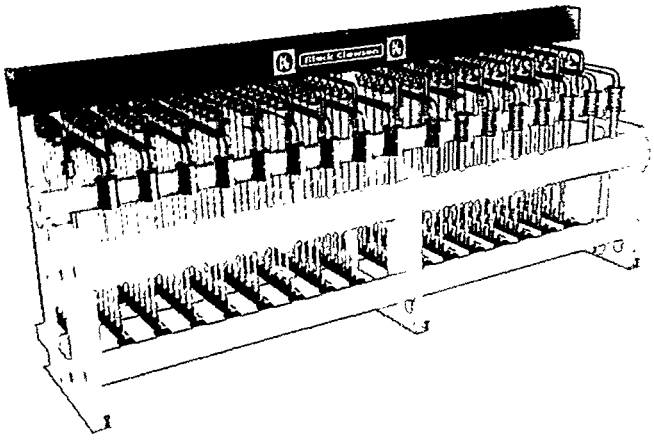
Black Clawson

NEW

XTREME™ Cleaners



SIMPLE SYSTEM DESIGN

Design simplicity is the result of primary XTREME Cleaners tailed by the new XX-Clone™ Through-Flow Cleaners in the secondary stage. With the lean rejects obtained from the XTREME Cleaner, the XX-Clone attains maximum removal efficiency with minimum pressure drop and fiber loss.

Even the largest system requires only two cleaning stages, minimizing system installation and operating costs. The entire system requires no more power than conventional through–flow or centrifuge-type systems, yet efficiently removes more wax, lightweight hot melts and stickies.

HIGHEST EFFICIENCY

The Black Clawson XTREME Cleaner employs the latest technology to remove lightweight debris in all types of pulp slurries. It uses long residence times in a small diameter cleaner to maximize the separation of very small contaminants that are close to the specific gravity of the fiber itself. Coupled with an advanced design through-flow cleaner in the tailing position, only two stages are needed to minimize fiber loss and maximize removal efficiency.

HIGH CONSISTENCY

High consistency accepts result from thickening from the XTREME Cleaner's reverse flow patterns. Able to be installed prior to conventional thickeners, the XTREME Cleaners increase thickener capacity. At 0.9 - 1.8% accepts consistency, the XTREME Cleaner is ideal for positioning before either fine slotted screening or thickening. Feed consistencies are the same as in more conventional lightweight cleaning systems.

FEATURES

- Highest possible efficiency
- High accept stock consistency
- High system yield
- No power penalty
- Low installation and operating costs
- Significant new technology

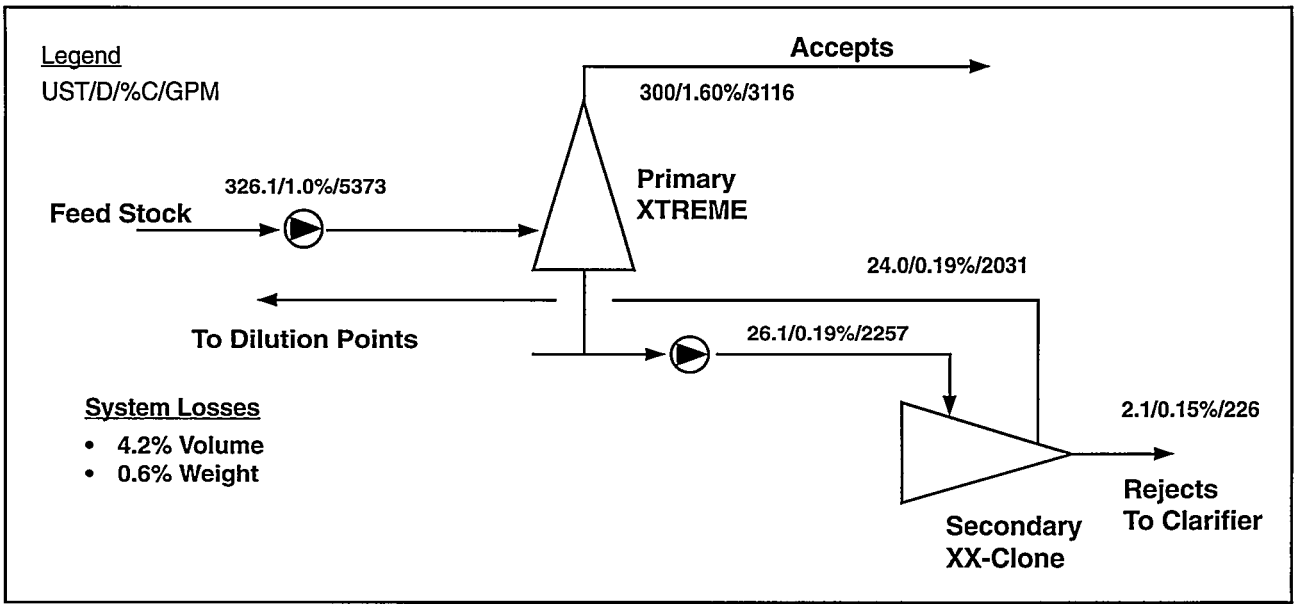
BENEFITS

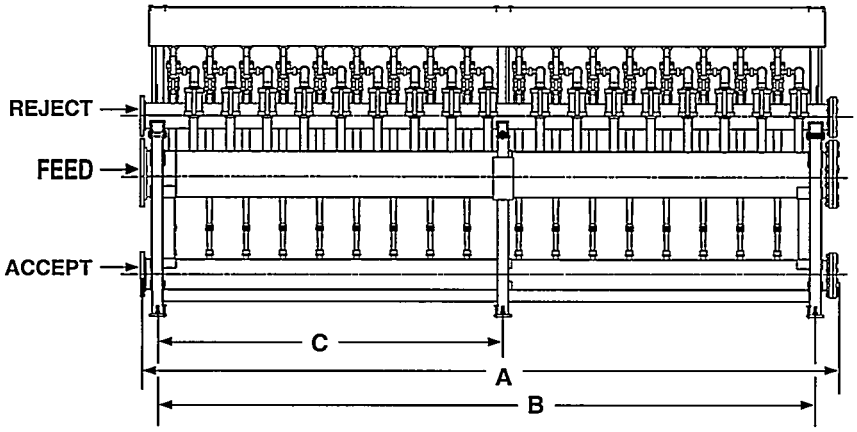
- Improve end product quality using existing furnish of declining grade
- Use even lower grades of furnish without compromising high end product quality.
- Reduce system losses to maximize fiber use, reduce sludge disposal costs
- Expanded capacity of existing thickeners
- Optimize system design using XTREME process flexibility

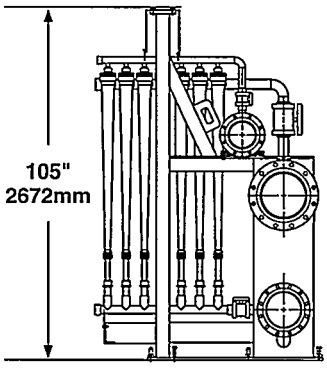
Black Clawson Company

Bulletin No. MB-352

XTREME™ Cleaners







GUARDS OMITTED FOR CLARITY

GENERAL DIMENSIONS – NOT CERTIFIED FOR CONSTRUCTION OR INSTALLATION

Unit Size	Dimensions		
mm (in.)	A	B	C
119	6200 (244)	5890 (232)	3100 (122)
126	6530 (257)	6220 (245)	3100 (122)
133	6860 (270)	6550 (258)	3430 (135)
140	7190 (283)	6880 (271)	3430 (135)
147	7520 (296)	7210 (284)	3760 (148)
154	7850 (309)	7540 (297)	3760 (148)
161	8180 (322)	7870 (310)	4090 (161)

Black Clawson Company

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2M 7/96 AP

Black Clawson

NEW

XX-CLONE™ CLEANER

The XX-Clone cleaner is designed to operate as a secondary cleaner in a system incorporating XTREME™ reverse cleaners. Under very low consistency conditions, the XX-Clone through-flow cleaner removes wax, styrofoam, hot melt adhesives and other material with a specific gravity less than water. The cleaner employs centrifugal force to concentrate light contaminants. There are no moving parts or energy source in the cleaner body. The efficiency of the contaminant removal is influenced by the cleaner's geometry and flow properties of the pulp slurry — particularly temperature, consistency and contaminant level.

A patented inlet maintains rotational stability in the air core for optimum separation. Pressure generated at the inlet port, coupled with the short distance individual particles travel and long dwell times in the cleaner body, assure high centrifugal forces and maximum contaminant removal. These characteristics, combined with a highly stable flow and low inlet consistency, result in excellent contaminant concentration. In situations with high contaminant loading, hydraulic reject rates can be increased to accommodate the larger concentration of debris.

Operating efficiency depends on a stable rotation pressure and a minimum of disruption of internal flow which the XX-Clone provides. The 30 psi (nominal) pressure drop from the feed to the accept port determines the capacity and the unit's internal velocity.

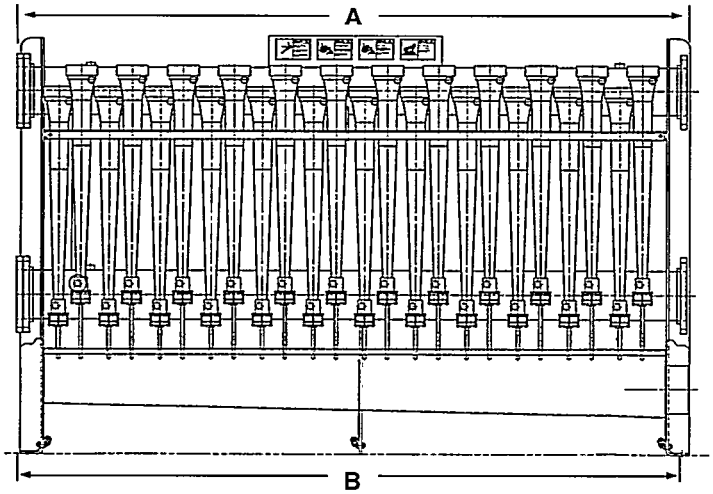
FEATURES/BENEFITS

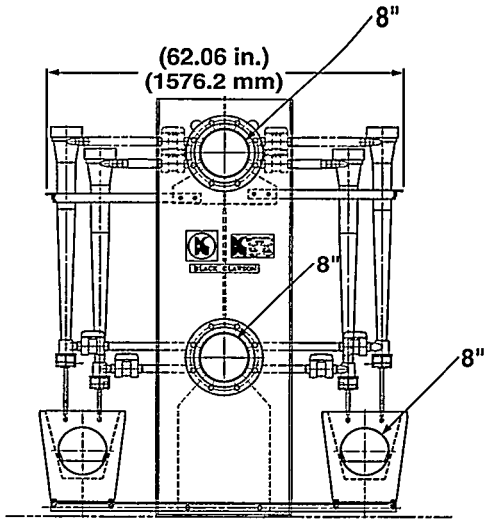
- Improved through-flow design maximizes contaminant removal efficiency
- Patented inlet design prohibits mixing at the inlet, and assures stable rotation of the fluid
- Excellent concentration of large reject volumes saves operating costs
- Low percentage reject rate by weight leads to higher system yield and a smaller capital investment for the reject handling system
- Low percentage reject rate by volume allows installation of a smaller clarifier resulting in capital savings
- Low feed consistencies lessen resistance to movement of contaminants traveling to the axial center of the cleaner improving efficiency
- Unit can be retrofitted to existing X-Clone manifolds reducing capital expenditures

Black Clawson Company

Bulletin No. MB-357

XX-CLONE CLEANERS





Unit Size	A in./mm	B in./mm	Weight lb/kg	
			Shipping	Operating
40	**98.8** 2510	**96.1** 2440	**1740** 790	**2320** 1050
44	**107.6** 2735	**104.9** 2665	**1830** 830	**2470** 1120
48	**116.5** 2960	**113.8** 2890	**1920** 870	**2610** 1185
52	**125.3** 3185	**122.6** 3115	**2010** 910	**2750** 1250
56	**134.2** 3410	**131.5** 3340	**2100** 950	**2900** 1315
60	**143.1** 3635	**140.4** 3565	**2190** 995	**3040** 1380
64	**151.9** 3860	**149.2** 3790	**2280** 1035	**3190** 1450
68	**160.8** 4085	**158.1** 4015	**2370** 1075	**3330** 1510
72	**169.6** 4310	**166.9** 4240	**2460** 1115	**3480** 1580
76	**178.5** 4535	**175.8** 4465	**2550** 1155	**3620** 1640

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2.5M 10/96 AP

XTREME / XX-Clone Systems Sold

- Jefferson Smurfit Corp. - Wabash, IN
  - (2) 300 T/D Systems
- Cadidavid Paper - Milan, Italy
- Sonoco Products - China
- Green Bay Packaging - Green Bay, WI
- Nine Dragons Paper - Dong Guan, China
- COTESA - Orizaba, Mexico
- Sun Paper - China
- Jiangxi Paper Co - China
- U.S. Gypsum - Clark, NJ
- U.S. Gypsum - Southgate, CA
- U.S. Gypsum - Gypsum, OH
- Maanshan Shanying Paper - China
- Rock-Tenn Co. - St. Paul, MN

THERMO BLACK CLAWSON

APPENDIX V

THERMO BLACK CLAWSON INC.
A Thermo Fibertek company

News Release

Contact: Jonathan C. Kerr
Phone: 513.420.8315
Fax: 513.424.1168
e-mail: jkerr@blackclawson.com

THERMO BLACK CLAWSON INC. AND INLAND PAPERBOARD AND PACKAGING INC. JOINTLY DEVELOP NEW PROCESS

MIDDLETOWN, OH, March 9, 1998--Inland Paperboard and Packaging Inc., Indianapolis, Indiana, and Thermo Black Clawson Inc., Middletown, Ohio, have jointly announced the introduction of Xtrax™, a new patented recycling process that recovers waxed boxes. Not previously recoverable because of the wax coating, meat and vegetable boxes have up to now been landfilled instead of put back into the fiber stream and recycled.

With over 3000T/D of brown fiber dedicated to the production of such boxes, Inland and TBC were deeply concerned about the future of the industry should the waxed box products succumb to the threat of being replaced by plastics. Plastic boxes are replacing some waxed fiber boxes in both Europe and Canada, and if the trend continues into the United States, significant collapse of the brown fiber processing market could occur.

The key to the plastic versus paper decision for most meat and vegetable packers is cost and recyclability or reusability of the package. Inland Paperboard and Packaging approached Thermo Black Clawson with the problem, and together the companies worked out a technical and commercial solution. Inland's Alternative Fiber Task Force identified the issue and proposed a number of solutions. Each solution was tested in Thermo Black Clawson's research and technology center in Middletown, OH, where a wide selection of commercially sized process equipment is available.

Tests concluded that it is possible to repulp the waxed cartons under medium consistency conditions, then screen and clean to remove non-fibrous contaminants. The cleaned pulp is then processed through a series of Reverse Screens™ to remove the wax and other extractable components from the furnish. Thus cleaned, the final pulp was found to have less than 1% extractables remaining, well below the average extractables for standard OCC pulps, and was significantly stronger than other recycled furnishes. The process can also be used for deinking plants that desire to use lower cost curbside waste that inherently has a high content of ash and wax that must be removed.

Xtrax is designed to be a side stream process whereby a paper mill that is currently using recovered paper as a furnish component can install the system and use the pulp to supplement the existing capacity. Used as a displacement pulp, the clean, strong furnish from the Xtrax system can lower overall costs of paper production and improve papermachine performance.

The Xtrax process will be commercially developed and marketed solely by Thermo Black Clawson, its sister companies Thermo Black Clawson Canada Ltd., St. Laurent, Quebec (Canada) and Thermo Black Clawson China, Guangzhou (China) and its affiliated companies, E. & M. Lamort, Vitry-le-François (France) and Thermo Black Clawson Ltd., Newport, Wales (UK).

Thermo Black Clawson Inc. is a complete fiber line process equipment supplier based in Middletown, Ohio and leads the industry in the design and manufacture of equipment used in paper recycling, chemical pulp and papermachine approach flow systems. The multi-national company was recently acquired by Thermo Fibertek Inc. (ASE:TFT), a public subsidiary of Thermo Electron Corporation (NYSE:TMO).

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Inland Paperboard and Packaging, Inc.
4030 Vincennes Road
Indianapolis, IN 46268-0937

news

For Release: Immediate

INLAND
A Temple-Inland Company

Contact: Donna Reynolds
Tel: 317-879-4328
Fax: 317-337-8856
email: dreynol2@iccnet.com

Wax Coated Boxes Saved From Extinction -- Now Recyclable With Patented Process

Inland Paperboard and Packaging and Thermo Black Clawson Joint Patent Holders of New Xtrax™ Impurities Extraction Process

INDIANAPOLIS, IN, March 9, 1998--Up to now, recycling systems couldn't handle a lot of waxed boxes, so thousands of tons of vegetable and meat boxes ended up in the landfill because they were labled "non-recyclable". Inland Paperboard and Packaging has changed all that with Xtrax™, a new patented process.

"The threat of reusable plastic crates replacing non-recyclable waxed containerboard should concern every linerboard and medium producer as well as each and every corrugated sheet plant converter," says William B. Howes, chairman and chief executive officer of Inland Paperboard and Packaging, Inc. Inland has taken charge of the problem of paper versus plastic by teaming with Thermo Black Clawson, a leading supplier to the paper recycling industry, to develop a method by which wax coated boxes are 100% recyclable. The new impurities extraction process, fully patented and trademarked Xtrax, takes advantage of the newest fiber cleaning technique of Reverse Screening™, a concept developed by Inland's alternative fiber task force.

Wax coated boxes currently used for the packaging of high moisture products like produce or meats have been coming under attack recently from the plastics industry, reminiscent of the

grocery store battle over the bags used at the checkout counter. Claims of non-recyclability adversely affected the popularity of the waxed corrugated paper box, in spite of its obvious price and flexibility of use advantages. Unlike the plastic crates that are already replacing paper boxes in Europe and Canada, the waxed corrugated container can now be recycled successfully in the Xtrax side stream process, which can be installed in any brown grade paper mill in the country that currently uses old corrugated containers (OCC) as a component of their furnish.

The Xtrax process is designed to provide supplemental fiber for the mill that is higher quality than current OCC, but from a fiber source that is largely landfilled today. The process starts with waxed boxes that contain over 30% wax by weight, and reduces the wax in the end furnish to less than 1%. Average OCC producers have about 3% wax in their current systems, which is acceptable for most grades, but they cannot afford to add waxed boxes without severely impacting the quality of their end product.

Papermakers tend to avoid wax boxes now because the wax is persistent and causes dark blemishes in the finished product that are unattractive and reduce the performance of the recycled end product. Other, less successful, approaches to the problem have centered on modifying the waxes used to improve dispersability, but the Xtrax process is equally effective on standard, unmodified paraffin based waxes.

William J. Fondow, president of Thermo Black Clawson Inc., was quick to endorse the development and provided the necessary laboratory resources needed to fully develop and commercialize the process. "We are providing a vital service to the paper industry by teaming up with Inland in this development. We now have a process by which used waxed containers can be fully utilized to produce high grade recycled linerboard. This not only saves jobs in the mills that now produce paper used to make waxed boxes, but also provides a lower cost, high quality fiber back to the paper mills that doesn't end up in our nation's landfills," he said in a recent interview. Fondow termed the teaming up of Inland and Thermo Black Clawson as a "perfect opportunity" to get the most of our resources for the good of the industry.

The Xtrax process starts with medium consistency pulping in a Thermo Black Clawson Mid-Con™ pulper and is followed by coarse and fine screening and cleaning. This basic process is then followed with a series of Thermo Black Clawson Reverse Screens™ that are arranged in such a way as to concentrate the wax away from the now useable fiber. As a result, the strength of the cleaned pulp is significantly higher than other, more common pulps such as OCC or Double Lined Kraft (DLK), a pre-consumer waste paper. Collection of the waxed boxes is not expected to pose a problem, as they are now segregated at the grocery stores and separately landfilled. This waste stream now becomes a low cost fiber alternative to mills that install the Xtrax process.

Inland Paperboard and Packaging, Inc., is an international manufacturer of paperboard and packaging products, with 47 converting facilities in the United States, Latin America and Puerto Rico. It owns seven paper mills and manages a bleached paperboard mill owned by an affiliate of Inland in the U.S. Based in Indianapolis, Indiana, the company is a wholly owned subsidiary of Temple-Inland Inc. (NYSE and PacExchg:TIN), headquartered in Diboll, Texas.

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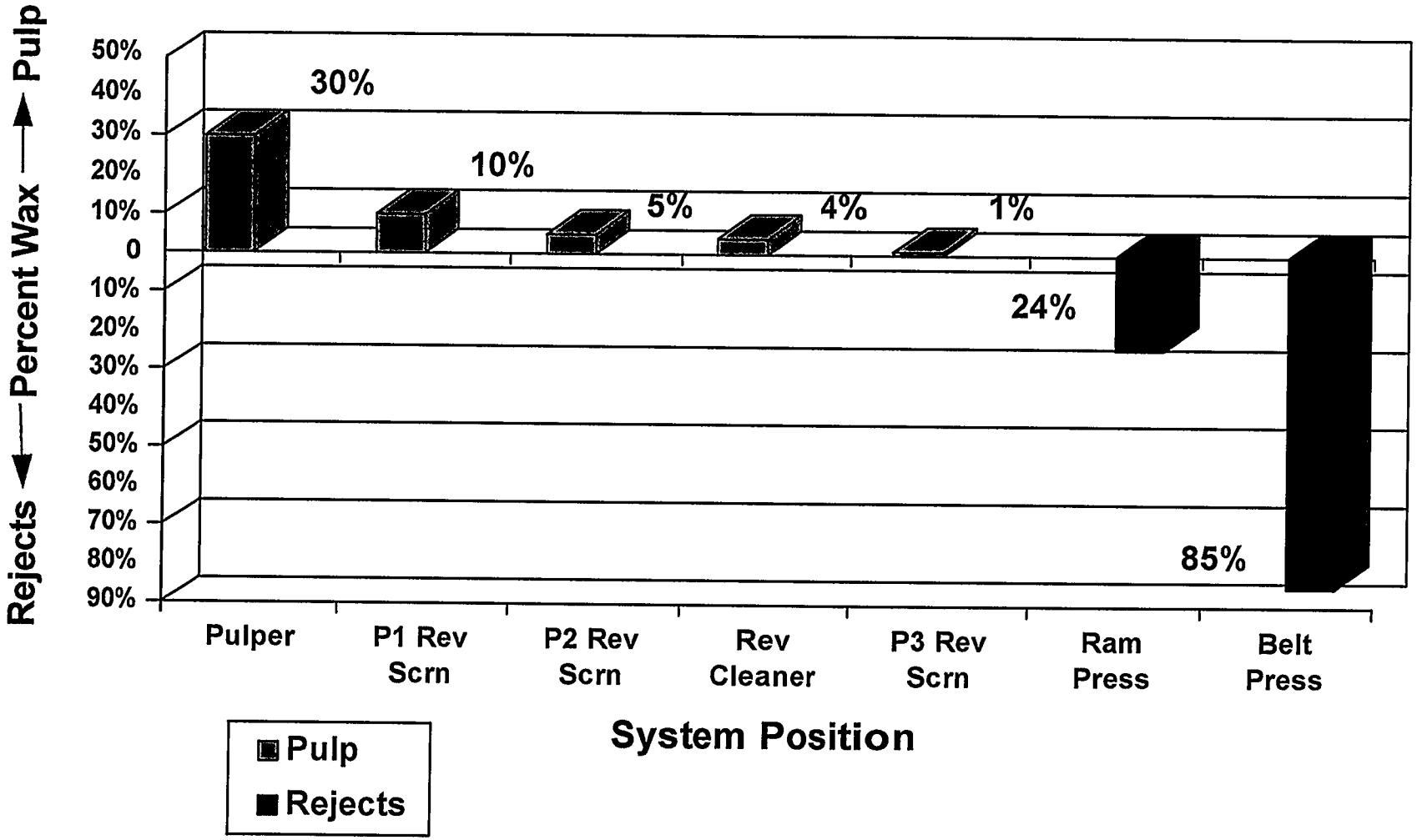
™Xtrax, Reverse Screen and Reverse Screening are trademarks of Thermo Black Clawson Inc.

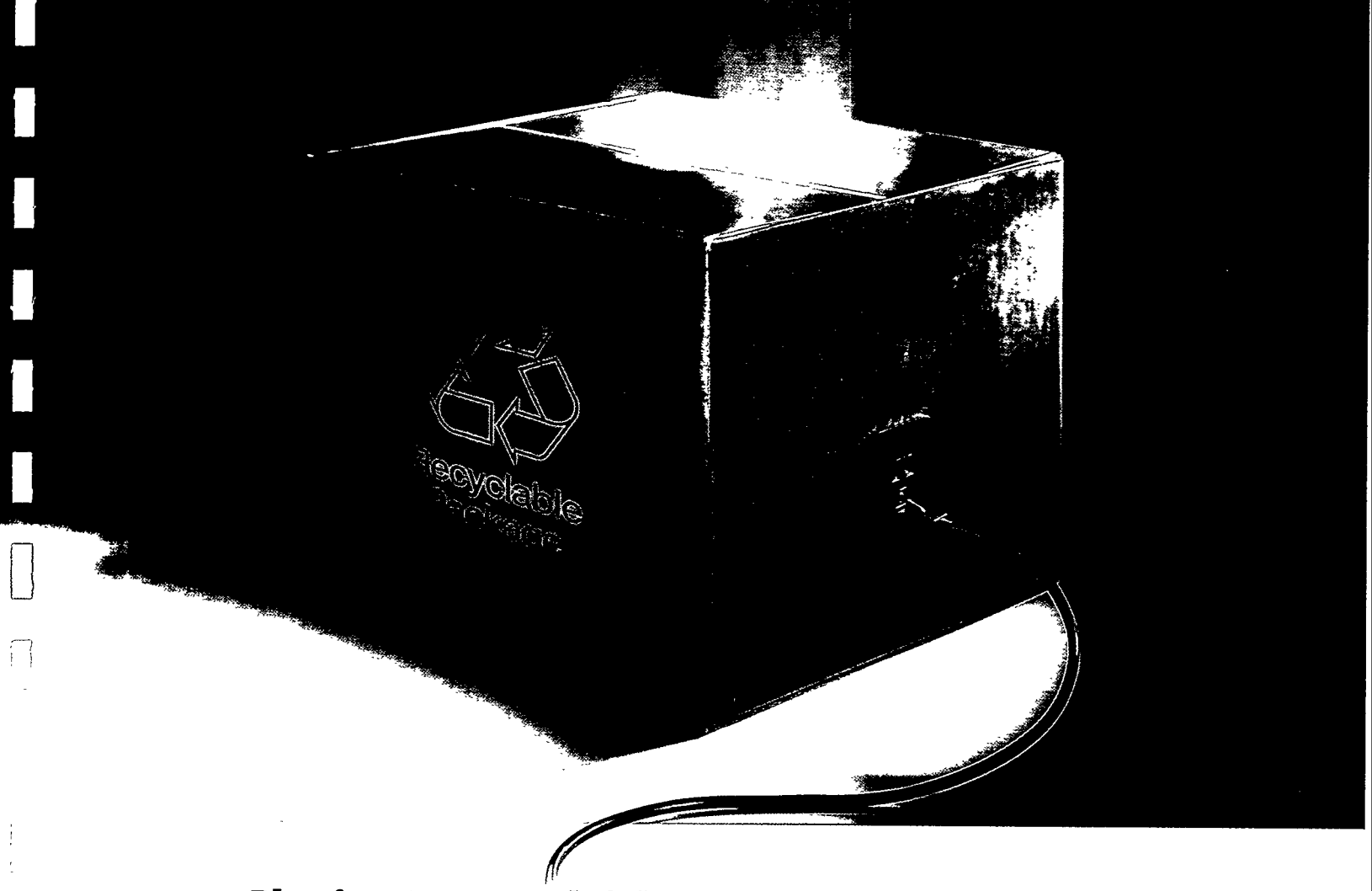
Xtrax™

Waxed Box Recycling



THERMO BLACK CLAWSON

Waxed corrugated cartons are now recyclable.



Plug into Xtrax™. A bright new recycling technology.

From the minds of **Inland Paperboard and Packaging** and the labs of **Thermo Black Clawson** comes a breakthrough recycling technology. The patented Xtrax™ Impurities Extraction System makes wax coated boxes 100% recyclable. Papermakers now have a new source of high performance fiber at a much lower cost.

The new impurities extraction system uses Reverse Screening™ to remove wax and other contaminants from recovered paper in a sidestream process. The system can be easily installed in any mill that now uses recycled furnish. The process reduces the extractables content to less than 1%. The finished pulp of the Xtrax System is not only cleaner, but significantly stronger than conventionally recycled pulp.

No other system can hold a candle to the Xtrax process for removing wax. Plug into Thermo Black Clawson today for complete details.

Recycled Fiber • Chemical Pulping • Stock Preparation

THERMO BLACK CLAWSON INC.
A Thermo Fibertek company

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Thermo Black Clawson China • Thermo Black Clawson Canada Ltd. • Thermo Black Clawson S.A. • Thermo Black Clawson Ltd. (UK)

APPENDIX VII

The Black Clawson Company
Shartle Division - Technology Center
Middletown, Ohio

September 29, 1995

Report Number: 36,009.01

Addendum to The New Reverse Cleaner R&D Report #35,009.01

For

The Black Clawson Company
Shartle Division
Technology Center
Middletown, Ohio

By:

Elizabeth L. Maze

Black Clawson Distribution

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D. P. Churchill

Test Runs before producing Polyurethane 1.0 degree NACR units

Test runs similar to those reported in the 35,009.01 report were conducted comparing the 1.5 degree cone angle cleaner unit (1.5 NAC-R) to the Bauer and the X-Clone (runs 341-344). A 1.0 degree cone angle prototype cleaner was then generated by stereolithography (SLA 1.0) and compared to the 1.5 NAC-R (runs 350-364). (Later, polyurethane 1.0 degree cone angle cleaner units were made and tested.)

Cleaner testing for a secondary unit at low consistency with high contaminant levels was conducted using the Hatton unit, the X-Clone, and the clear acrylic 1.5 NAC with several orientations: long-reverse -LR (reverse mode with an extended cylindrical section - runs 372-374), reverse -R (reverse mode with no extension - runs 382-384), and through-flow design -TF (runs 378-381). In this application, the Hatton design achieved the highest efficiencies of those configurations tested.

Test Runs after producing Polyurethane 1.0 degree NACR units

Many test runs were conducted using the polyurethane pour molded units (1.0 NACR #1-15). The 1.0 NACR (#15) was operated side-by-side the 1.5 NAC-R (runs 442-447). The 1.0 NACR performed slightly better than the previous best -- the 1.5 NAC-R.

A competitor's cleaner unit was acquired for a short period of time to conduct further comparisons based upon performance. The Beloit Uni-Flow was compared to the 1.0 NACR, the X-Clone, and the Hatton (runs 449-500a). Several furnishes were tested: MOW seeded with hot melt particles, bleached market pulp seeded with hot melt particles, OCC with waxboard, and OCC with waxboard plus clarifier skimmings from Inland Container at Maysville, Kentucky.

Many test runs were conducted to answer operational and production design questions. The question was raised about running the 1.0 NACR cleaner with pressurized accepts and rejects in addition to the atmospheric conditions. Testing of pressurized versus atmospheric conditions was conducted in runs 550-599 and 616-620, with several different cleaner units: #1, #2, #9, #15. Test runs 581-584 were done to answer the question of orientation on banks: upside-down (accepts at the top) or right-side-up (rejects at the top). An internal gap between the tangential inlet and the reject cap was discovered. To test the effect on operation and efficiency, a modified cap was made to be flush with the inlet. The runs 581-599 and 616-620 included both pressurized and atmospheric conditions as well as the affect of the flush versus the regular cap. The flush cap actually extended into the inlet 0.125".

Results and Discussion

Testing was conducted prior to the manufacture of polyurethane units comparing the 1.5 NAC-R to the 1.0 SLA unit. The results indicated that the 1.0 degree cone angle (1.0 SLA) achieved slightly higher efficiencies than the 1.5 degree cleaner. After initial testing, the cleaner unit broke at the seams. These initial tests prompted the manufacture of the polyurethane pour molded units, 1.0 NACR (#1-15). The results in comparing the 1.0 NACR (#15) to the 1.5 NAC-R showed that the 1.0 NACR obtained the better efficiency, 91-95% (runs 442-444) compared to 89-92% (runs 445-447).

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The secondary unit test results clearly concluded that the Hatton unit was the best choice for the reject tailing application. The modified vortex stabilizer held the air core very stable, and enabled the unit to achieve high efficiency in this position. All the secondary testing was performed with a consistency of 0.05% or less with elevated contaminant levels. The X-Clone, on average, achieved a hot melt count removal efficiency of 62%, the 1.5 NAC-LR - 72%, the 1.5 NAC-R - 60%, the 1.5 NAC-TF - 53%, and the Hatton cleaner achieved 87% efficiency with a hydraulic reject rate around 10%.

The Beloit Uni-Flow, the X-Clone, the Hatton, and the polyurethane 1.0 NACR #5 were comparison tested using OCC with waxboard furnish. The comparison of the 1.0 NACR #15 and the Beloit Uni-Flow was repeated using OCC furnish with waxboard and clarifier skimmings. Wax extraction tests were performed by Miami University on samples from these comparison runs. The results are given in Table 1.

Table 1: Comparison Wax Extraction Results on OCC Furnish

Sample	% Extractives			% Efficiency
	Test 1	*Test 2*	*Average (2)*	*(Fd - Acc)/Fd*100*
470-476 Feed	2.50	2.71	2.61	-
470 NACR #5 Acc	1.91	2.06	1.99	23.5
471 Beloit P1 Acc	2.43	2.48	2.45	5.8
472 Beloit P2 Acc	2.22	2.17	2.19	15.8
473 X-Clone P1 Acc	2.10	1.88	1.99	23.5
474 X-Clone P2 Acc	1.74	1.81	1.77	31.9
475 Hatton P1 Acc	1.92	2.04	1.98	23.8
476 Hatton P2 Acc	1.78	1.71	1.74	33.1
498-500a Feed	2.69	2.69	2.69	-
498 NACR #15 Acc	1.26	1.26	1.26	53.2
499 Beloit P1 Acc	1.48	1.67	1.57	41.6
500a Beloit P2 Acc	1.45	1.49	1.47	45.4

The first set of OCC with waxboard comparison runs used 1.0 NACR cleaner unit #5 which was found to have several minor manufacturing flaws which contributed to poor efficiency relative to previous performance. These minor flaws included a rough inlet surface that needed to be sanded smooth, slag material in the reject overflow orifice, and a slightly bent body, (see Table 3 for the straightness rating). This was discovered after the test run was completed and samples had been taken.

In order to get further comparison data, a second set of test runs were done to compare the 1.0 NACR #15 directly to the Beloit Uni-flow. The furnish was slightly different from the initial comparison runs. This second set used OCC with waxboard and clarifier skimmings from Inland Container in Maysville Kentucky. Inland Container has a Gyroclean unit; the clarifier skimmings contained wax and other contaminants that were removed from the system by the Gyroclean once already. These contaminants would then be relatively easy to remove centrifugally which would explain why there was less difference in the efficiencies of the two units, the 1.0 NACR #15 and the Beloit.

Hot melt speck counts were conducted on the seeded Mixed Office Waste (MOW) and comparison bleached market pulp runs. The results have been compiled in the following Table 2. The same 1.0 NACR #5 minor flaws described above existed during runs 449-488. Runs 489-491 show the good polyurethane unit, 1.0 NACR #15, compared to the Beloit pass 1 (P1) and Beloit pass 2 (P2).

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Table 2: Comparison Efficiency Results

Sample	% Efficiency = (Feed count - Accept count)/Feed count * 100						
	Lg. 0.95	*Lg. 0.95*	*Lg. 0.95*	*Sm. 0.95*	*Sm. 0.97*	*Sm. 0.995*	*Overall*
1.02% cons.	*MOW w/ hot melt; 120 degrees F; 0.52% contaminant by weight*						
450 NACR #5 Acc	100	100	94	80	93	63	88
449 Beloit P1 Acc	75	83	50	48	56	34	58
451 Beloit P2 Acc	100	100	72	83	87	55	83
1.03% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.50% contaminant by weight*						
452 NACR #5 Acc	100	100	94	90	78	29	82
453 Beloit P1 Acc	100	100	69	55	48	9	64
454 Beloit P2 Acc	100	100	88	90	67	29	79
0.80% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.63% contaminant by weight*						
455 NACR #5 Acc	100	100	25	96	78	39	73
456 Beloit P1 Acc	100	75	0	68	42	13	50
457 Beloit P2 Acc	100	92	33	82	55	22	64
0.90% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.48% contaminant by weight*						
458 X-Clone P1 Acc	100	80	44	69	53	48	66
459 X-Clone P2 Acc	100	100	67	95	77	53	82
0.76% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.64% contaminant by weight*						
460 Hatton P1 Acc	100	67	50	88	69	14	65
461 Hatton P2 Acc	100	100	71	97	81	9	76
0.85% cons.	*Bleached market pulp w/ hot melt; 120 degrees F; 0.49% contaminant by weight*						
489 NACR #15 Acc	100	100	86	93	85	43	85
490 Beloit P1 Acc	73	7	0	37	58	20	33
491 Beloit P2 Acc	64	100	29	30	65	6	49

It is clear to see that the #15 polyurethane unit performed with a more striking difference in efficiency performance than did the #5 unit. The # 15 unit was the first unit off the mold and was given much more care in creating the tangential inlet and removing the slag in the reject orifice. This unit is also visibly straighter than the #5 unit. After finding that the #5 unit did not perform as well as the #15, all of the units were checked over for these minor flaws. The more minor flaws were corrected, but it was found that not all of the polyurethane units were perfectly straight. Furthermore, it was concluded that the straightness of the unit makes a considerable difference in the operation of the cleaner. See Table 3 for cleaner straightness rating.

To be fair. an average of the four comparison runs (449-451, 452-454, 455-457, 489-491) was calculated. The average of the 1.0 NACR (#5 & #15) single pass efficiency is 82%. The average for the Beloit single pass is 51%, and the average of the four Beloit double pass efficiencies is 69%. This says that the single pass 1.0 NACR, even when not operating at its best, still is able to remove nearly three times more residual contaminant than the Beloit with one pass, and nearly twice as much contaminant as the Beloit Uni-Flow with two passes.

Table 3: Straightness Rating

NACR Unit #	Grade Rating	Description	NACR Unit #	Grade Rating	Description
1	B-	slightly bent	9	A	good
2	D-	badly bowed	10	A-	ok
3	B+	slightly bent	11	C	bottom bowed
4	A-	ok	12	A	good
5	B	slightly bent	13	A	good
6	A	good	14	A	good
7	A-	ok	15	A	good
8	F-	badly bowed			

Conclusions

The 1.5 and 1.0 degree NACR units perform much better than the current X-Clone on difficult to remove contaminants (those above 0.95 specific gravity and below 1.0). The results in comparing the 1.0 NACR to the 1.5 NAC-R showed that the 1.0 NACR (#15) obtained better overall efficiency, 91-95% (runs 442-444) compared to 89-92% (runs 445-447). The 1.0 NACR can achieve excellent efficiency with 0.95 and 0.97 specific gravity contaminants large and small (average of 97% efficiency) and large 0.995 specific gravity contaminants (91%), but lower efficiency with small 0.995 specific gravity particles (~70%) (runs 442-444, 489). Overall, during the comparison testing, even the 1.0 NACR #5 single-pass did better than double-pass Beloit, X-Clone and Hatton in comparison tests (runs 452-454, 458-461). Note that the #5 did not perform quite as well as the #15 unit due to the described minor flaws. The Beliot Uni-Flow, the X-Clone and the Hatton performed with approximately the same efficiency in the bleached market pulp with hot melt comparison trials. Both the X-Clone and the Hatton achieved better efficiencies (24% first pass and 33% second pass) than the Uni-Flow (6% first pass and 16% second pass) on the OCC furnish, based on wax extraction results.

The secondary unit test results clearly concluded that the Hatton unit was the best choice for the application. The modified vortex stabilizer held the air core very stable, and enabled the unit to achieve high efficiency in this position. The Hatton achieved up to an 89% overall efficiency on all three hot melts and both size ranges. The next best unit was the modified 1.5 NAC-LR (reverse mode with a cylindrical extension) with a 76% overall efficiency. The X-Clone brought up the lowest of a 63% overall efficiency; this was mainly due to the inability of the X-Clone to remove 0.995 specific gravity particles. In comparison, the Hatton removed the 0.995 particles very well, with a high of 84% in this category.

The 1.0 NACR can operate effectively at pressurized conditions without sacrificing efficiency, provided that the hydraulic reject rate be held constant at approximately 42% (runs 550-560, 574-580, 585-594, 595-599, 616-620). The NACR unit should be placed right-side-up on banks, with rejects coming off the top at the cone base, as a result of runs 581-584. The testing of the flush and regular caps does not show a decrease in efficiency with the regular cap making a half inch gap above the tangential inlet. Conversely, use of the flush cap does not increase the efficiency, in fact, to a small degree the opposite was seen (refer to runs 581-584, 585-594, 595-599, 616-620).

The Black Clawson Company
Shartle Division - Technology Center
Middletown, Ohio

Report Number: 36,009.01 Date: September 29, 1995

Addendum to The New Reverse Cleaner R&D Report #35,009.01

APPENDIX A:

CLEANER DATA

Black Clawson Company - Shartle Division - Technology Center

Run #	324	325	326	327	328	329	330	331	332	333	334	335
Date	3/22/95	3/23/95						4/4/95	4/4/95	4/4/95	4/4/95	4/4/95
Furnish	MOW w/	MOW w/						OCC w/	OCC w/	OCC w/	OCC w/	OCC w/
	clar. sludge	clar. sludge						carrier brd.	carrier brd.	carrier brd.	carrier brd.	carrier brd.
Stock Temp, F	120	120						114	114	114	114	114
Cleaner	1.5 NAC-R (P1)	Bauer (P1)						Ultra-Clone	Ultra-Clone	Ultra-Clone	Ultra-Clone	Ultra-Clone
	2.75" diam.	2.75" diam.						6" diam.	6" diam.	6" diam.	6" diam.	6" diam.
Ave. Fd cons.	0.701	0.661						1.194	1.194	1.194	1.194	1.194
Cons.:Fd	0.701	0.661						1.194	1.194	1.194	1.194	1.194
Cons.:Acc	1.016	1.002						0.99	1.01	1.06	0.979	1.049
Cons.:Rej	0.213	0.156						2.76	3.52	3.66	3.372	2.668
Flow: (bal. Fd)	24	21						111	132	126	126	113
Flow: Fd	26	24						113	127	121	129	116
gpm Acc	13.9	12.3						101.6	115.3	112.6	118.9	107.9
Rej	12.1	11.7						11.45	11.72	8.39	10.08	8.11
Pulp Flow: Fd	1.00	0.85						7.95	9.49	9.03	9.05	8.11
t/d Acc	0.85	0.74						6.05	7.01	7.18	7.00	6.81
Rej.	0.16	0.11						1.90	2.48	1.85	2.05	1.30
Press.: Fd	50	60						25	31	30	39	27
Press.: Acc	0	0						5	6	10	14	7
Press.: Rej	0	0						0	0	0	0	0
Pressure drop	50	60						20	25	20	25	20
%Hyd.R.R.	46.7	48.9						10.1	9.2	6.9	7.8	7.0
% R.R. B.O.P.	14.2	11.5						23.4	27.2	21.3	22.1	15.6
Thick. Factor	1.45	1.52						0.83	0.85	0.89	0.82	0.88
% Eff. Lg.: Blue												
Red												
Orange												
Yellow												
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												
								3/8" square tip		1/2" diam. tip		1/4" sq. tip

Run #	335 a	335 b	336	337	338	339	340	341	342	343	344	345
Date	4/4/95	4/4/95	4/4/95	4/6/95	4/6/95	4/6/95	4/6/95	4/18/95	4/18/95	4/18/95	4/18/95	
Furnish	OCC w/	OCC w/	OCC w/	C.C.C. w/	C.C.C. w/	C.C.C. w/	C.C.C. w/	Virgin SW	Virgin SW	Virgin SW	Virgin SW	
	carrier brd.	carrier brd.	carrier brd.	carrier brd.	carrier brd.	carrier brd.	carrier brd.	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	
Stock Temp, F	114	114	114	120	120	120	120	120	120	120	120	
Cleaner	Ultra-Clone	Ultra-Clone	Ultra-Clone	Ultra-Clone	Ultra-Clone	Ultra-Clone	Ultra-Clone	Bauer	1.5 NAC-R	1.5 NAC-R	X-Clone	
	6" diam.	6" diam.	6" diam.	3" diam.	3" diam.	3" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	3" diam.	
Ave. Fd cons.	-	-	1.194	1.270	1.270	1.270	1.270	0.935	0.935	0.935	0.200	
Cons.:Fd	-	-	1.194	1.270	1.270	1.270	1.270	0.950		0.920	0.200	
Cons.:Acc	-	-	1.003	0.680	0.750	0.890	0.800	1.650	1.420	1.390	0.203	
Cons.:Rej	-	-	3.004	4.340	4.330	3.270	4.240	0.044	0.210	0.194	0.052	
Flow: (bal. Fd)	-	-	130	38	35	32	48	23	27	28	46	
Flow: Fd	145	118	134	39	36	32	50	23	27	27	49	
gpm Acc	140.0	111.6	123.4	33.0	31.0	27.0	44.0	12.7	16.5	17.3	44.3	
Rej	5.0	6.4	10.6	6.0	5.0	5.0	6.0	10.34	10.53	9.66	4.72	
Pulp Flow: Fd	-	-	9.37	2.92	2.70	2.43	3.65	1.28	1.54	1.56	0.56	
t/d Acc	-	-	7.45	1.35	1.40	1.45	2.12	1.26	1.41	1.45	0.54	
Rej.	-	-	1.92	1.57	1.30	0.98	1.53	0.03	0.13	0.11	0.01	
Press.: Fd	33	25	37	60	50	40	50	60	60	60	25	
Press.: Acc	0	2	12	7	6	5	12	0	0	0	10	
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	
Pressure drop	33	23	25	53	44	35	38	60	60	60	15	
%Hyd.R.R.	3.5	5.4	7.9	15.4	13.9	15.6	12.0	45.0	39.0	35.8	9.6	
% R.R. B.O.P.	-	-	20.0	52.6	47.4	40.2	40.1	2.1	8.8	7.4	2.5	
Thick. Factor	-	-	0.84	0.54	0.59	0.70	0.63	1.76	1.52	1.49	1.02	
% Eff. Lg.: Blue								100	100	100	97	
Red								100	100	96	38	
Orange								64	79	95	0	
Yellow								-	-	-	-	
% Eff. Sm.: Blue								94	96	98	82	
Red								89	90	92	55	
Y/O								60	48	73	1	
Overall % Eff.								85	86	92	46	
	1/4" square tip		1/4" sq. tip	0.25 sq. in. Inlet Insert Open Area			0.50 sq. in. O. A.	0.6% prim. debris level: 0.95, 0.907, 0.995 sp. gr. (-14,+100) mesh				

Run #	346	347	348	349	350	351	352	353	354	355	356	357
Date					5/4/95	5/4/95	5/4/95	5/4/95	5/4/95	5/4/95	5/4/95	5/4/95
Furnish					Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin
					w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt
Stock Temp, F					92			98			90	
Cleaner					SLA 1.0	SLA 1.0	SLA 1.0	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R
					2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.
Ave. Fd cons.					0.700	0.700	0.700	0.700	0.700	0.700	0.340	0.340
Cons.:Fd					0.690			0.700			0.341	
Cons.:Acc					1.070	1.090	1.090	1.080	1.190	1.050	0.525	0.558
Cons.:Rej					0.140	0.140	0.120	0.010	0.030	0.020	0.036	0.025
Flow: (bal. Fd)					27	31	32	23	26	25	24	27
Flow: Fd					28	31	33	26	28	30	26	28
gpm Acc					16.0	18.0	19.0	15.0	15.0	16.6	15.0	16.0
Rej					12.0	13.0	14.0	11.0	13.0	13.4	11.0	12.0
Pulp Flow: Fd					1.13	1.29	1.35	0.98	1.10	1.06	0.50	0.56
t/d Acc					1.03	1.18	1.25	0.97	1.07	1.05	0.47	0.54
Rej.					0.10	0.11	0.10	0.01	0.02	0.02	0.02	0.02
Press.: Fd					50	60	70	50	60	70	50	60
Press.: Acc					0	0	0	0	0	0	0	0
Press.: Rej					0	0	0	0	0	0	0	0
Pressure drop					50	60	70	50	60	70	50	60
%Hyd.R.R.					42.9	41.9	42.4	42.3	46.4	44.7	42.3	42.9
% R.R. B.O.P.					8.6	8.4	7.3	0.6	2.0	1.3	4.5	3.2
Thick. Factor					1.53	1.56	1.56	1.54	1.70	1.50	1.54	1.64
% Eff. Lg.: Blue					100	92	100	100	100	100	100	100
Red					100	100	89	100	100	100	94	100
Orange					31	79	52	38	66	93	60	80
Yellow					-	-	-	-	-	-	-	-
% Eff. Sm.: Blue					85	89	91	94	96	100	92	98
Red					60	77	73	79	85	92	82	97
Y/O					21	26	42	37	54	45	85	41
Overall % Eff.					66	77	75	75	84	88	86	86
	1/4" square tip		1/4" sq. tip									

Run #	358	359	360	361	362	363	364	365	366	367	368	369
Date	5/4/95	5/4/95	5/4/95	5/4/95	5/5/95	5/5/95	5/5/95	5/8/95	5/8/95	5/8/95	5/8/95	5/8/95
Furnish	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin
	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt
Stock Temp, F		91			120			122	123	124	125	126
Cleaner	1.5 NAC-R	SLA 1.0	SLA 1.0	SLA 1.0	SLA 1.0	SLA 1.0	1.5 NAC-R	REX	REX	REX	REX	REX
	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	12" diam.	12" diam.	12" diam.	12" diam.	12" diam.
Ave. Fd cons.	0.340	0.340	0.340	0.340	0.340	0.340	0.340	1.07	1.07	1.07	1.07	1.07
Cons.:Fd	0.341	0.343			0.328		0.342	1.07				
Cons.:Acc	0.563	0.525	0.522	0.551	0.524	0.568	0.548	1.16	1.22	1.06	1.07	1.11
Cons.:Rej	0.021	0.074	0.067	0.071	0.048	0.022	0.016	0.72	0.67	0.81	0.69	0.67
Flow: (bal. Fd)	29	29	30	34	26	31	24	257	235	260	253	268
Flow: Fd	30	28	31	33	28	31	26	280	280	280	280	280
gpm Acc	17.0	17.0	18.0	19.0	15.4	18.0	14.8	166.0	116.0	205.0	205.0	225.0
Rej	13.0	11.0	13	14	12.6	13	11.2	114	164	75	75	55
Pulp Flow: Fd	0.59	0.59	0.62	0.69	0.52	0.63	0.50	16.52	15.13	16.73	16.31	17.24
t/d Acc	0.58	0.54	0.57	0.63	0.49	0.62	0.49	11.59	8.52	13.07	13.20	15.03
Rej.	0.02	0.05	0.05	0.06	0.04	0.02	0.01	4.94	6.61	3.66	3.11	2.22
Press.: Fd	50	50	60	70	50	60	50	65	65	65	65	65
Press.: Acc	0	0	0	0	0	0	0	10	15	5	5	2
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	50	50	60	70	50	60	50	55	50	60	60	63
%Hyd.R.R.	43.3	39.3	41.9	42.4	45.0	41.9	43.1	40.7	58.6	26.8	26.8	19.6
% R.R. B.O.P.	2.7	8.6	8.3	8.9	6.4	2.7	2.0	27.4	36.7	20.3	17.3	12.3
Thick. Factor	1.66	1.54	1.54	1.62	1.54	1.67	1.61	1.08	1.14	0.99	1.00	1.04
% Eff. Lg.: Blue	100	100	100	100	100	100	100	100	100	80	100	80
Red	100	94	100	100	100	100	100	100	0	0	100	100
Orange	80	100	81	43	81	100	81	71	29	86	57	86
Yellow	-	-	-	-	-	-	-	-	-	-	-	-
% Eff. Sm.: Blue	100	98	98	91	100	100	98	100	0	0	0	0
Red	93	95	87	86	91	93	95	100	0	0	0	100
Y/O	19	66	25	50	87	69	66	100	0	0	100	100
Overall % Eff.	82	92	82	78	93	94	90	95	22	28	60	78
						seam broke						

Run #	370	371	372	373	374	375	376	377	378	379	380	381
Date	5/11/95	5/11/95	5/15/95	5/15/95	5/15/95	5/15/95	5/15/95	5/15/95	5/15/95	5/15/95	5/15/95	5/15/95
Furnish	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin
	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt
Stock Temp, F	125	125	118	118	118	118	117	117	116	116	116	116
Cleaner	1.5 NAC-R	1.5 NAC-R	1.5 NAC-LR	1.5 NAC-LR	1.5 NAC-LR	X-Clone	X-Clone	X-Clone	1.5 NAC-TF	1.5 NAC-TF	1.5 NAC-TF	1.5 NAC-TF
	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.
Ave. Fd cons.	1.19	1.19	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Cons.:Fd	1.17	1.20	0.052			0.051			0.050			
Cons.:Acc	1.93	1.90	0.042	0.050	0.045	0.047	0.049	0.047	0.047	0.045	0.054	0.049
Cons.:Rej	0.06	0.06	0.080	0.072	0.052	0.062	0.052	0.065	0.052	0.053	0.067	0.034
Flow: (bal. Fd)	27	30	21	26	26	45	38	51	31	33	44	34
Flow: Fd	28	30	23	25	28	46	38	52	33	36	40	36
gpm Acc	16.0	18.3	21.1	23.0	25.8	41.3	32.2	47.2	29.4	32.9	37.5	31.3
Rej	12.0	11.7	1.88	2.01	2.2	4.75	5.81	4.85	3.56	3.12	2.47	4.71
Pulp Flow: Fd	1.90	2.13	0.06	0.08	0.08	0.13	0.11	0.15	0.09	0.10	0.13	0.10
t/d Acc	1.86	2.09	0.05	0.07	0.07	0.12	0.09	0.13	0.08	0.09	0.12	0.09
Rej.	0.04	0.04	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Press.: Fd	60	65	50	60	70	25	20	30	50	60	70	60
Press.: Acc	0	0	0	0	0	10	10	10	10	10	10	15
Press.: Rej	5	8	2	2	5	0	0	0	0	0	0	0
Pressure drop	60	65	50	60	70	15	10	20	40	50	60	45
%Hyd.R.R.	42.9	39.0	8.2	8.0	7.9	10.3	15.3	9.3	10.8	8.7	6.2	13.1
% R.R. B.O.P.	2.2	2.0	13.1	11.6	8.2	12.8	15.9	12.1	11.2	9.2	8.3	8.9
Thick. Factor	1.63	1.60	0.84	1.00	0.90	0.94	0.98	0.94	0.94	0.90	1.08	0.98
% Eff. Lg.: Blue	100	82	100	100	96	100	100	100	100	100	0	100
Red	100	100	100	78	96	100	78	91	74	91	0	100
Orange	100	20	45	24	62	17	31	17	0	59	0	28
Yellow	-	-	-	-	-	-	-	-	-	-	-	-
% Eff. Sm.: Blue	91	95	97	93	92	85	90	87	95	97	37	98
Red	82	93	82	71	78	66	68	61	76	63	28	86
Y/O	63	6	34	24	33	9	0	14	0	16	0	19
Overall % Eff.	89	66	76	65	76	63	61	62	58	71	11	72
	0.1% lg. debris & 0.2% sm. debris		secondary cleaner work									

Run #	382	383	384	385	386	387	388	389	390	391	392	393
Date	5/15/95	5/15/95	5/15/95	5/31/95	5/31/95	5/31/95	5/31/95	5/31/95	5/23/95	5/23/95	5/23/95	5/23/95
Furnish	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/
	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	PIRA E1 hm	PIRA E1 hm	PIRA E1 hm	PIRA E1 hm
Stock Temp, F	116	116	116	120	120	120	120	120	98	98	98	99
Cleaner	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	Hatton	Hatton	Hatton	Hatton	Hatton	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone
	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.
Ave. Fd cons.	0.050	0.050	0.050	0.038	0.038	0.038	0.038	0.038	0.879	0.879	0.879	0.879
Cons.:Fd	0.047			0.038					0.856			0.927
Cons.:Acc	0.048	0.052	0.049	0.038	0.036	0.036	0.038	0.037	1.419	1.454	1.374	1.013
Cons.:Rej	0.050	0.044	0.063	0.046	0.059	0.069	0.046	0.070	0.127	0.128	0.119	0.127
Flow: (bal. Fd)	28	24	26	25	26	30	34	39	28	29	27	46
Flow: Fd	29	24	26	24	26	29	33	37	28	29	30	45
gpm Acc	24.9	19.0	23.6	20.0	23.0	26.0	30.0	34.0	16.5	16.3	15.8	39.4
Rej	4.1	5.0	2.4	4.0	3.0	3.0	3.0	3	11.49	12.73	14.23	5.61
Pulp Flow: Fd	0.08	0.07	0.08	0.06	0.06	0.07	0.08	0.09	1.50	1.52	1.41	2.44
t/d Acc	0.07	0.06	0.07	0.05	0.05	0.06	0.07	0.08	1.41	1.42	1.30	2.40
Rej.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0.10	0.10	0.04
Press.: Fd	40	30	30	25	30	35	45	55	50	60	70	25
Press.: Acc	10	10	5	10	10	10	15	15	0	0	0	10
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	30	20	25	15	20	25	30	40	50	60	70	15
%Hyd.R.R.	14.1	20.9	9.3	16.7	11.5	10.3	9.1	8.1	41.0	43.9	47.4	12.5
% R.R. B.O.P.	14.1	18.4	11.7	20.2	17.9	18.8	11.0	14.9	5.9	6.4	6.4	1.8
Thick. Factor	0.96	1.04	0.98	1.00	0.95	0.95	1.00	0.97	1.61	1.65	1.56	1.15
% Eff. Lg.: Blue	100	100	89	100	100	100	100	100				
Red	96	78	74	98	92	96	93	97				
Orange	3	0	0	50	57	59	64	63				
Yellow	-	-	-	-	-	-	-	-	Efficiencies were calculated.			
% Eff. Sm.: Blue	98	96	87	98	97	98	99	97	Data is under different format.			
Red	82	87	49	93	92	93	94	94				
Y/O	13	19	4	57	73	79	84	83				
Overall % Eff.	65	63	51	83	85	88	89	89				
	secondary cleaner work			secondary cleaner work					PIRA hot melt trials: 390-399 - hot melt E1			

Black Clawson Company - Shartle Division - Technology Center

Run #	394	395	396	397	398	399	400	401	402	403	404	405
Date	5/23/95	5/23/95	5/23/95	5/23/95	5/23/95	5/23/95	5/23/95	5/24/95	5/24/95	5/24/95	5/24/95	5/24/95
Furnish	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/
	PIRA E1 hm	PIRA E1 hm	PIRA E1 hm	PIRA E1 hm	PIRA E1 hm	PIRA E1 hm	PIRA E2 hm	PIRA E2 hm	PIRA E2 hm	PIRA E2 hm	PIRA E2 hm	PIRA E2 hm
Stock Temp, F	99	130	130	130	130	130	100	100	100	100	100	130
Cleaner	X-Clone	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone	1.5 NAC-R
	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.	2.75" diam.
Ave. Fd cons.	0.879	0.879	0.879	0.879	0.879	0.879	0.923	0.923	0.923	0.923	0.923	0.923
Cons.:Fd		0.795			0.936		0.946			0.925		0.882
Cons.:Acc	1.078	1.452	1.486	1.316	1.027	1.065	1.476	1.555	1.530	1.106	1.109	1.428
Cons.:Rej	0.114	0.120	0.117	0.112	0.119	0.105	0.110	0.106	0.112	0.091	0.088	0.102
Flow: (bal. Fd)	48	26	28	28	47	47	24	29	30	47	48	24
Flow: Fd	46	26	28	30	45	46	26	29	31	45	47	26
gpm Acc	38.5	14.9	15.7	17.5	39.3	38.4	14.1	16.5	17.0	38.8	39.5	14.8
Rej	7.5	11.2	12.27	12.5	5.71	7.61	11.9	12.51	13.99	6.25	7.51	11.19
Pulp Flow: Fd	2.55	1.38	1.49	1.47	2.47	2.51	1.33	1.62	1.66	2.61	2.67	1.34
t/d Acc	2.50	1.30	1.41	1.39	2.43	2.46	1.25	1.54	1.57	2.58	2.64	1.27
Rej.	0.05	0.08	0.09	0.08	0.04	0.05	0.08	0.08	0.09	0.03	0.04	0.07
Press.: Fd	30	50	60	70	25	30	50	60	70	25	30	50
Press.: Acc	15	0	0	0	10	15	0	0	0	10	15	0
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	15	50	60	70	15	15	50	60	70	15	15	50
%Hyd.R.R.	16.4	42.9	43.8	41.7	12.7	16.5	45.8	43.1	45.1	13.9	16.0	43.0
% R.R. B.O.P.	2.1	5.9	5.8	5.3	1.7	2.0	5.5	5.0	5.5	1.4	1.5	4.8
Thick. Factor	1.23	1.65	1.69	1.50	1.17	1.21	1.60	1.68	1.66	1.20	1.20	1.55
% Eff. Lg.: Blue												
Red												
Orange	Efficiencies were calculated.						Efficiencies were calculated.					
Yellow	Data is under different format.						Data is under different format.					
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												
	PIRA hot melt trials: 390-399 - hot melt E1						PIRA hot melt trials: 400-409 - hot melt E2					

Run #	406	407	408	409	410	411	412	413	414	415	416	417
Date	5/24/95	5/24/95	5/24/95	5/24/95	5/25/95	5/25/95	5/25/95	5/25/95	5/25/95	5/25/95	5/25/95	5/25/95
Furnish	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/
	PIRA E2 hm	PIRA E2 hm	PIRA E2 hm	PIRA E2 hm	PIRA E3 hm	PIRA E3 hm	PIRA E3 hm	PIRA E3 hm	PIRA E3 hm	PIRA E3 hm	PIRA E3 hm	PIRA E3 hm
Stock Temp, F	130	130	130	130	98	98	98	98	98	130	130	130
Cleaner	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R
	2.75" diam.	2.75" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.
Ave. Fd cons.	0.923	0.923	0.923	0.923	1.035	1.035	1.035	1.034	1.035	1.035	1.035	1.035
Cons.:Fd			0.938		1.011			1.044		1.076		
Cons.:Acc	1.577	1.352	1.071	1.053	1.752	1.720	1.783	1.258	1.272	1.654	1.724	1.586
Cons.:Rej	0.095	0.102	0.099	0.085	0.211	0.122	0.112	0.173	0.150	0.110	0.107	0.105
Flow: (bal. Fd)	28	27	45	46	27	29	32	46	46	24	27	28
Flow: Fd	28	30	44	47	27	29	31	44	46	26	28	30
gpm Acc	15.4	17.3	38.4	40.1	14.2	16.9	17.8	37.1	36.6	14.6	15.6	17.1
Rej	12.6	12.7	5.64	6.89	12.81	12.15	13.16	6.88	9.37	11.43	12.36	12.89
Pulp Flow: Fd	1.53	1.49	2.51	2.58	1.66	1.83	2.00	2.88	2.89	1.53	1.70	1.71
t/d Acc	1.46	1.41	2.47	2.54	1.50	1.74	1.91	2.81	2.80	1.45	1.62	1.63
Rej.	0.07	0.08	0.03	0.04	0.16	0.09	0.09	0.07	0.08	0.08	0.08	0.08
Press.: Fd	60	70	25	30	50	60	70	25	30	50	60	70
Press.: Acc	0	0	10	15	0	0	0	10	15	0	0	0
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	60	70	15	15	50	60	70	15	15	50	60	70
%Hyd.R.R.	45.1	42.3	12.8	14.7	47.4	41.9	42.5	15.6	20.4	44.0	44.1	43.0
% R.R. B.O.P.	4.6	4.7	1.4	1.4	9.7	4.9	4.6	2.6	3.0	4.7	4.6	4.4
Thick. Factor	1.71	1.46	1.16	1.14	1.69	1.66	1.72	1.22	1.23	1.60	1.67	1.53
% Eff. Lg.: Blue												
Red												
Orange	Efficiencies were calculated.				Efficiencies were calculated.							
Yellow	Data is under different format.				Data is under different format.							
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												
	PIRA hot melt trials: 400-409 - hot melt E2				PIRA hot melt trials: 410-419 - hot melt E3							

Run #	418	419	420	421	422	423	424	425	426	427	428	429
Date	5/25/95	5/25/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95
Furnish	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/
	PIRA E3 hm	PIRA E3 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm	PIRA E4 hm
Stock Temp, F	130	130	98	98	98	98	98	130	130	130	130	130
Cleaner	X-Clone	X-Clone	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone
	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.
Ave. Fd cons.	0.923	0.923	0.869	0.869	0.869	0.869	0.869	0.869	0.869	0.869	0.869	0.869
Cons.:Fd	1.009		0.857			0.847		0.878			0.892	
Cons.:Acc	1.174	1.138	1.401	1.414	1.325	0.955	1.035	1.354	1.366	1.437	1.006	1.018
Cons.:Rej	0.206	0.221	0.107	0.099	0.090	0.091	0.089	0.096	0.098	0.090	0.081	0.075
Flow: (bal. Fd)	44	47	25	28	29	38	42	24	26	30	40	41
Flow: Fd	45	48	27	29	31	46	47	27	28	30	46	47
gpm Acc	32.4	35.3	14.4	16.3	18.4	33.3	34.4	14.3	15.4	17.3	33.4	34.3
Rej	12.6	12.7	12.6	12.7	12.6	12.7	12.6	12.7	12.6	12.7	12.6	12.7
Pulp Flow: Fd	2.44	2.59	1.29	1.46	1.53	1.98	2.21	1.24	1.34	1.56	2.08	2.16
t/d Acc	2.29	2.42	1.21	1.39	1.46	1.91	2.14	1.16	1.26	1.50	2.02	2.10
Rej.	0.16	0.17	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06
Press.: Fd	25	30	50	60	70	25	30	50	60	70	25	30
Press.: Acc	10	15	0	0	0	10	15	0	0	0	10	15
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	15	15	50	60	70	15	15	50	60	70	15	15
%Hyd.R.R.	28.1	26.5	46.8	43.8	40.8	27.6	26.9	47.0	45.1	42.3	27.5	27.0
% R.R. B.O.P.	6.3	6.3	5.8	5.0	4.2	2.9	2.8	5.2	5.1	4.4	2.6	2.3
Thick. Factor	1.27	1.23	1.61	1.63	1.52	1.10	1.19	1.56	1.57	1.65	1.16	1.17
% Eff. Lg.: Blue												
Red												
Orange			Efficiencies were calculated.									
Yellow			Data is under different format.									
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												
	410-419 - hot melt E3		PIRA hot melt trials: 420-429 - hot melt E4									

Black Clawson Company - Shartle Division - Technology Center

Run #	430	431	432	433	434	435	436	437	438	439	440	441
Date	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/26/95	5/31/95	5/31/95
Furnish	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. V. w/	Bl. Virgin	Bl. Virgin
	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	PIRA S18 hm	w/ hot melt	w/ hot melt
Stock Temp, F	100	100	100	100	100	130	130	130	130	130	120	120
Cleaner	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	X-Clone	X-Clone	1.5 NAC-R	1.5 NAC-R
	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.
Ave. Fd cons.	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.037	0.037
Cons.:Fd	0.771			0.811		0.806			0.821		0.037	
Cons.:Acc	1.255	1.323	1.180	0.931	0.959	1.343	1.288	1.24	0.954	0.973	0.046	0.048
Cons.:Rej	0.097	0.092	0.084	0.062	0.077	0.091	0.087	0.074	0.066	0.07	0.027	0.027
Flow: (bal. Fd)	24	29	28	47	49	27	26	28	49	50	27	30
Flow: Fd	26	29	31	46	48	26	28	30	46	48	26	28
gpm Acc	14.5	16.9	17.8	40.2	40.3	15.3	15.6	17.0	40.8	40.9	15.0	16.0
Rej	11.5	12.2	13.2	5.8	7.74	10.75	12.41	12.97	5.23	7.12	11	12
Pulp Flow: Fd	1.16	1.41	1.33	2.28	2.36	1.29	1.27	1.33	2.36	2.42	0.06	0.07
t/d Acc	1.10	1.34	1.26	2.25	2.32	1.23	1.21	1.27	2.34	2.39	0.04	0.05
Rej.	0.07	0.07	0.07	0.02	0.04	0.06	0.06	0.06	0.02	0.03	0.02	0.02
Press.: Fd	50	60	70	25	30	50	60	70	25	30	50	60
Press.: Acc	0	0	0	10	15	0	0	0	10	15	0	0
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	50	60	70	15	15	50	60	70	15	15	50	60
%Hyd.R.R.	44.1	41.9	42.5	12.5	16.1	41.3	44.3	43.2	11.4	14.8	42.3	42.9
% R.R. B.O.P.	5.3	4.8	4.5	1.0	1.5	4.7	4.8	4.0	0.9	1.3	30.9	31.3
Thick. Factor	1.56	1.65	1.47	1.16	1.20	1.67	1.61	1.55	1.19	1.21	1.24	1.30
% Eff. Lg.: Blue											100	100
Red											99	100
Orange	Efficiencies were calculated.										68	65
Yellow	Data is under different format.										-	-
% Eff. Sm.: Blue											100	99
Red											97	97
Y/O											78	89
Overall % Eff.											90	92
	PIRA hot melt trials: 430-439 - hot melt S18										secondary cleaner work	

Run #	442	443	444	445	446	447	448	449	450	451	452	453
Date	6/2/95	6/2/95	6/2/95	6/2/95	6/2/95	6/2/95		6/23/95	6/23/95	6/23/95	6/26/95	6/26/95
Furnish	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin		MOW w/	MOW w/	449	Bl. V. w/	Bl. V. w/
	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt	w/hot melt		hot melt	hot melt	Acc	hot melt	hot melt
Stock Temp, F	118	118	118	118	118	118	note: for	120	120	115	120	120
Cleaner	1.0 NACR#15	1.0 NACR#15	1.0 NACR#15	1.5 NAC-R	1.5 NAC-R	1.5 NAC-R	the next	Beloit P1	1.0 NACR#5	Beloit P2	1.0 NACR#5	Beloit P1
	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	comparative	4" diam.	2.75" diam.	4" diam.	2.75" diam.	4" diam.
Ave. Fd cons.	0.820	0.820	0.820	0.890	0.890	0.890	runs, a	1.015	1.015	1.101	1.000	1.000
Cons.:Fd	0.820			0.890			different	1.015		1.101	1.030	
Cons.:Acc	1.330	1.350	1.360	1.380	1.470	1.370	1.0 NACR	1.101	1.550	1.039	1.705	1.095
Cons.:Rej	0.078	0.072	0.072	0.077	0.071	0.073	cleaner	0.155	0.146	0.064	0.083	0.105
Flow: (bal. Fd)	27	29	31	24	26	27	unit was	42	27	37	30	43
Flow: Fd	26	28	30	26	28	30	used.	41	28	41	29	41
gpm Acc	16.0	17.0	18.0	15.0	15.0	17.0	It will be	38.9	16.8	39.2	16.9	38.9
Rej	10.0	11.0	12.0	11.0	13.0	13.0	denoted as	2.2	11.2	1.8	12.1	2.1
Pulp Flow: Fd	1.33	1.43	1.52	1.30	1.38	1.46	NACR#5.	2.59	1.67	2.46	1.79	2.58
t/d Acc	1.28	1.38	1.47	1.25	1.33	1.40		2.57	1.57	2.45	1.73	2.56
Rej.	0.05	0.05	0.05	0.05	0.06	0.06		0.02	0.10	0.01	0.06	0.01
Press.: Fd	50	60	70	50	60	70		28	60	28	60	28
Press.: Acc	0	0	0	0	0	0		8	0	8	0	8
Press.: Rej	0	0	0	0	0	0		0	0	0	0	0
Pressure drop	50	60	70	50	60	70		20	60	20	60	20
%Hyd.R.R.	38.5	39.3	40.0	42.3	46.4	43.3		5.2	40.0	4.3	41.7	5.1
% R.R. B.O.P.	3.7	3.4	3.5	3.7	3.7	3.6		0.8	5.8	0.3	3.5	0.5
Thick. Factor	1.62	1.65	1.66	1.55	1.65	1.54		1.08	1.53	0.94	1.71	1.10
% Eff. Lg.: Blue	100	100	100	100	100	100		75	100	100	100	100
Red	100	100	100	100	100	100		83	100	100	100	100
Orange	82	100	94	92	75	83		50	94	72	94	69
Yellow	-	-	-	-	-	-		-	-	-	-	-
% Eff. Sm.: Blue	93	98	94	93	94	92		48	80	83	90	55
Red	91	94	92	92	90	90		56	93	87	78	48
Y/O	82	76	82	73	73	69		34	63	55	29	9
Overall % Eff.	91	95	94	92	89	89		58	88	83	82	64
	Runs 442-444: Parkway Products 1.0 deg. NAC-R			Runs 445-447: Clear Acrylic 1.5 deg. NAC-R				Runs 449-450: 0.52% contaminant			Runs 452-453: 0.50% debris	

Run #	454	455	456	457	458	459	460	461	462	463	464	465
Date	6/26/95	6/27/95	6/27/95	6/27/95	6/27/95	6/27/95	6/27/95	6/27/95	6/28/95	6/28/95	6/28/95	6/29/95
Furnish	453	Bl. Virgin	Bl. Virgin	456	Bl. Virgin	458	Bl. Virgin	460	Bl. Virgin	Bl. Virgin	463	OCC w/
	Accepts	w/hot melt	w/hot melt	Accepts	w/hot melt	Accepts	w/hot melt	Accepts	w/hot melt	w/hot melt	Accepts	waxboard
Stock Temp, F	120	120	120	120	118	118	124	124	93	93	93	108
Cleaner	Beloit P2	1.0 NACR#5	Beloit P1	Beloit P2	X-Clone P1	X-Clone P2	Hatton P1	Hatton P2	1.0 NACR#5	Beloit P1	Beloit P2	Ultra-Clone
	4" diam.	2.75" diam.	4" diam.	4" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	2.75" diam.	4" diam.	4" diam.	6" diam.
Ave. Fd cons.	1.000	0.801	0.820	0.863	0.901	0.600	0.757	0.793	0.911	0.911	0.911	1.083
Cons.:Fd		0.801		0.863	0.901		0.757		0.911			1.083
Cons.:Acc	1.066	1.227	0.872	0.955	1.008	0.692	0.793	0.871	1.273	0.908	0.755	0.979
Cons.:Rej	0.061	0.052	0.082	0.035	0.035	0.010	0.179	0.115	0.123	0.072	0.020	2.463
Flow: (bal. Fd)	44	25	43	45	51	50	33	35	27	41	34	
Flow: Fd	43	28	42	42	51	49	33	33	28	43	43	120
gpm Acc	40.9	15.8	40.1	40.2	45.3	43.6	31.3	31.3	18.4	41.0	41.0	
Rej	2.14	12.2	1.9	1.8	5.7	5.4	1.7	1.7	9.6	2.0	2.1	-
Pulp Flow: Fd	2.63	1.20	2.11	2.31	2.76	1.82	1.51	1.65	1.48	2.25	1.86	
t/d Acc	2.62	1.17	2.10	2.31	2.75	1.81	1.49	1.64	1.41	2.24	1.86	
Rej.	0.01	0.04	0.01	0.00	0.01	0.00	0.02	0.01	0.07	0.01	0.00	
Press.: Fd	28	65	30	30	30	30	45	45	60	30	30	50
Press.: Acc	8	0	10	10	10	10	10	10	0	10	10	25
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	20	65	20	20	20	20	35	35	60	20	20	25
%Hyd.R.R.	5.0	43.6	4.5	4.4	11.2	11.1	5.2	5.3	34.3	4.7	4.8	
% R.R. B.O.P.	0.3	2.8	0.5	0.2	0.4	0.2	1.2	0.8	4.6	0.4	0.1	
Thick. Factor	1.07	1.53	1.06	1.11	1.12	1.15	1.05	1.10	1.40	1.00	0.83	0.90
% Eff. Lg.: Blue	100	100	100	100	100	100	100	100	100	70	100	
Red	100	100	75	92	80	100	67	100	89	89	100	
Yellow	88	25	0	33	44	67	50	71	58	58	63	
Orange	-	-	-	-	-	-	-	-	-	-	-	
% Eff. Sm.: Blue	90	96	68	82	69	95	88	97	71	361	71	
Red	67	78	42	55	53	77	69	81	45	39	57	
Y/O	29	39	13	22	48	53	14	9	0	3	23	
Overall % Eff.	79	73	50	64	66	82	65	76	61	103	69	
		Runs 455-456: 0.63% contaminant debris			Run 458: 0.48% contaminants		Run 460: 0.64% debris		Runs 462-463: 0.47% contaminant debris			

Run #	466	467	468	469	470	471	472	473	474	475	476	477
Date	6/29/95	6/29/95	6/29/95	6/29/95	6/30/95	6/30/95	6/30/95	6/30/95	6/30/95	6/30/95	6/30/95	7/6/95
Furnish	465	465	467	465	OCC w/	OCC w/	471	OCC w/	473	OCC w/	475	Water
	Accepts	Accepts	Accepts	Accepts	Waxboard	Waxboard	Accepts	Waxboard	Accepts	Waxboard	Accepts	
Stock Temp, F	107	107	107	107	114	114	114	114	114	115	115	72
Cleaner	1.0 NACR#5	Beloit P1	Beloit P2	X-Clone P1	1.0 NACR#5	Beloit P1	Beloit P2	X-Clone P1	X-Clone P2	Hatton P1	Hatton P2	REX
	2.75" diam.	4" diam.	4" diam.	3" diam.	2.75" diam.	4" diam.	4" diam.	3" diam.	3" diam.	2.75" diam.	2.75" diam.	24" vort. find.
Ave. Fd cons.	0.934	0.934	0.912	0.934	0.982	0.982	0.831	0.877	0.895	0.846	0.796	
Cons.:Fd	0.934				0.982		0.831	0.877	0.895	0.846	0.796	
Cons.:Acc	1.12	0.912	0.917	1.060	1.325	0.989	0.913	0.957	0.997	0.887	0.827	
Cons.:Rej	0.431	1.114	0.305	0.554	0.233	0.227	0.100	0.137	0.098	0.242	0.342	
Flow: (bal. Fd)	27	42	42	55	28	45	49	49	52	34	34	
Flow: Fd	27	43	43	51	27	46	46	50	52	34	34	350
gpm Acc	19.2	40.7	40.5	45.3	19.3	43.9	43.9	44.0	46.4	32.2	32.4	340.9
Rej	7.82	2.3	2.5	5.7	7.72	2.2	2.1	6.0	5.6	1.8	1.6	9.1
Pulp Flow: Fd	1.50	2.39	2.28	3.08	1.65	2.64	2.43	2.58	2.82	1.74	1.64	0.00
t/d Acc	1.29	2.23	2.24	2.89	1.54	2.61	2.41	2.53	2.78	1.72	1.61	0.00
Rej.	0.20	0.16	0.05	0.19	0.11	0.03	0.01	0.05	0.03	0.03	0.03	0.00
Press.: Fd	60	30	30	30	60	30	30	30	30	45	45	70
Press.: Acc	0	10	10	10	0	10	10	10	10	10	10	2
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	60	20	20	20	60	20	20	20	20	35	35	68
%Hyd.R.R.	29.0	5.4	5.7	11.1	28.6	4.7	4.5	12.0	10.8	5.4	4.7	2.6
% R.R. B.O.P.	13.4	6.5	1.9	6.6	6.8	1.1	0.5	1.9	1.2	1.5	2.0	
Thick. Factor	1.20	0.98	1.01	1.13	1.35	1.01	1.10	1.09	1.11	1.05	1.04	
% Eff. Lg.: Blue												
Red												
Yellow												
Orange	Efficiencies not calculated for OCC.				Efficiencies not calculated for OCC.							
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												

Run #	478	479	480	481	482	483	484	485	486	487	488	489
Date	7/6/95	7/6/95	7/6/95	7/6/95	7/6/95	7/6/95	7/6/95	7/6/95	7/10/96	7/10/96	7/10/96	7/11/96
Furnish	Water	Water	Water	Water	Water	Water	Water	Water	Bl. virgin	Bl. virgin	487	Bl. virgin
									w/ hot melt	w/ hot melt	Accepts	w/ hot melt
Stock Temp, F	72	72	72	72	72	72	72	72	120	120	120	119
Cleaner	REX	REX	REX	REX	REX	REX	REX	REX	1.0 NACR#5	Beloit P1	Beloit P2	1.0 NACR#15
	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	2.75" diam.	4" diam.	4" diam.	2.75" diam.
Ave. Fd cons.	-	-	-	-	-	-	-	-	1.063	1.063		0.847
Cons.:Fd									1.063			0.847
Cons.:Acc									1.572	1.104		1.380
Cons.:Rej									0.083	0.093		0.074
Flow: (bal. Fd)									32	48		29
Flow: Fd	350	350	350	350	350	350	350	350	30	48		29
gpm Acc	317.0	311.1	301.3	292.7	282.0	272.4	266.5	257.0	21.4	46.0		17.0
Rej	33	38.9	48.7	57.3	68.0	77.6	83.5	93.0	8.6	2.0		12.0
Pulp Flow: Fd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.07	3.07		1.46
t/d Acc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02	3.06		1.41
Rej.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01		0.05
Press.: Fd	70	70	70	70	70	70	70	70	60	30		60
Press.: Acc	2	3	4	5	6	7	8	9	0	10		0
Press.: Rej	0	0	0	0	0	0	0	0	0	0		0
Pressure drop	68	67	66	65	64	63	62	61	60	20		60
%Hyd.R.R.	9.4	11.1	13.9	16.4	19.4	22.2	23.9	26.6	28.7	4.2		41.4
% R.R. B.O.P.									2.2	0.4		3.6
Thick. Factor									1.48	1.04		1.63
% Eff. Lg.: Blue												100
Red												100
Yellow												86
Orange	Water hydraulics runs - no efficiencies.											-
% Eff. Sm.: Blue												93
Red												85
Y/O												43
Overall % Eff.												85

Black Clawson Company - Shartle Division - Technology Center

Run #	490	491	492	493	494	495	496	497	498	499	500a	500
Date	7/11/96	7/11/96	7/14/95	7/14/95	7/14/95	7/19/95	7/19/95	7/19/95	7/21/95	7/21/95	7/21/95	7/11/95
Furnish	Bl. virgin	490	OCC w/	OCC w/	493	OCC w/	OCC w/	496	OCC w/ 15% waxboard		499	Bl. Virgin
	w/ hot melt	Accepts	waxboard	waxboard	Acc	waxboard	waxboard	Acc	& Inland Cont. Sludge		Acc	w/ hot melt
Stock Temp, F	119	118	118	118	119	120	120	120	120	120	120	105
Cleaner	Beloit P1	Beloit P2	1.0 NACR#15	Beloit P1	Beloit P2	1.0 NACR#15	Beloit P1	Beloit P2	1.0 NACR#15	Beloit P1	Beloit P2	REX
	4" diam.	4" diam.	2.75" diam.	4" diam.	4" diam.	2.75" diam.	4" diam.	4" diam.	2.75" diam.	4" diam.	4" diam.	24" vort. find.
Ave. Fd cons.	0.847	0.780	0.861	0.861	0.913	0.88	0.88	0.78	0.99	0.99	0.77	2.260
Cons.:Fd		0.780	0.861			0.88		0.78	0.99		0.77	2.260
Cons.:Acc	0.890	0.840	1.290	0.913	0.943	1.4	0.95	0.81	1.45	0.99	0.86	2.410
Cons.:Rej	0.068	0.068	0.213	0.169	0.120	0.25	0.46	0.22	0.31	0.7	0.25	1.240
Flow: (bal. Fd)	47	49	27	47	46	30	51	47	29	46	52	347
Flow: Fd	47	47	28	46	46	29	48	47	29	47	48	345
gpm Acc	45.0	45.0	16.1	44.2	44.2	17.0	46.0	45.0	17.2	45.1	45.9	304.3
Rej	2.0	2.0	11.9	1.9	1.8	12.0	2.0	2.0	11.8	1.9	2.1	40.7
Pulp Flow: Fd	2.42	2.28	1.40	2.44	2.52	1.61	2.68	2.22	1.72	2.77	2.41	47.16
t/d Acc	2.41	2.27	1.25	2.43	2.51	1.43	2.63	2.19	1.50	2.69	2.38	44.13
Rej.	0.01	0.01	0.15	0.02	0.01	0.18	0.06	0.03	0.22	0.08	0.03	3.04
Press.: Fd	30	30	60	30	30	60	30	30	60	30	30	69
Press.: Acc	10	10	0	10	10	0	10	10	0	10	10	3
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	20	20	60	20	20	60	20	20	60	20	20	66
%Hyd.R.R.	4.3	4.3	42.5	4.0	4.0	41.4	4.2	4.3	40.7	4.0	4.4	11.8
% R.R. B.O.P.	0.3	0.4	10.5	0.8	0.5	11.8	2.2	1.2	12.7	2.9	1.4	6.5
Thick. Factor	1.05	1.08	1.50	1.06	1.03	1.59	1.08	1.04	1.46	1.00	1.12	1.07
% Eff. Lg.: Blue	73	64										
Red	7	100										
Yellow	0	29										
Orange	-	-										
% Eff. Sm.: Blue	37	30										
Red	58	65										
Y/O	20	6										
Overall % Eff.	33	49										
	Rums 489-490: 0.49% debris											0.50% debris

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Run #	501	502	503	504	505	506	507	508	509	510	511	512
Date	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95	7/11/95
Furnish	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin	Bl. Virgin
	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt	w/ hot melt
Stock Temp, F	105	105	105	108	108	108	103	103	103	102	102	102
Cleaner	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX
	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.
Ave. Fd cons.	2.260	2.260	2.260	1.610	1.610	1.610	1.100	1.100	1.100	0.790	0.790	0.790
Cons.:Fd				1.610			1.100			0.790		
Cons.:Acc	2.560	2.400	2.300	1.830	1.980	2.040	1.140	1.130	1.240	0.810	0.810	0.860
Cons.:Rej	1.300	1.390	1.520	0.800	0.860	0.930	0.560	0.560	0.520	0.520	0.550	0.520
Flow: (bal. Fd)	354	335	349	371	385	392	339	329	348	340	337	349
Flow: Fd	345	345	345	345	345	345	345	345	345	345	345	345
gpm Acc	278.7	275.0	340.2	312.4	288.4	279.7	309.8	296.0	282.3	308.7	295.6	283.9
Rej	66.3	70.0	4.8	32.6	56.6	65.3	35.2	49.0	62.7	36.3	49.4	61.1
Pulp Flow: Fd	48.11	45.57	47.52	35.97	37.29	37.99	22.44	21.78	23.02	16.18	16.04	16.60
t/d Acc	42.93	39.71	47.08	34.40	34.36	34.33	21.25	20.13	21.06	15.04	14.41	14.69
Rej.	5.19	5.85	0.44	1.57	2.93	3.65	1.19	1.65	1.96	1.14	1.63	1.91
Press.: Fd	69	69	69	69	69	69	69	69	69	69	69	69
Press.: Acc	5	7	1.75	3	5	7	3	5	7	3	5	7
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	64	62	67.25	66	64	62	66	64	62	66	64	62
%Hyd.R.R.	19.2	20.3	1.4	9.4	16.4	18.9	10.2	14.2	18.2	10.5	14.3	17.7
% R.R. B.O.P.	11.1	12.5	0.9	4.7	8.8	10.9	5.2	7.2	8.6	6.9	10.0	11.7
Thick. Factor	1.13	1.06	1.02	1.14	1.23	1.27	1.04	1.03	1.13	1.03	1.03	1.09
% Eff. Lg.: Blue												
Red												
Yellow												
Orange												
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												
	Runs 500-512: 0.50% contaminant debris											

Black Clawson Company - Shartle Division - Technology Center

Run #	513	514	515	516	517	518	519	520	521	522	523	524
Date	7/17/95	7/17/95	7/17/95	7/17/95	7/17/95	7/17/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95
Furnish	OCC w/	OCC w/	OCC w/	OCC w/	OCC w/	OCC w/	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	waxboard	waxboard	waxboard	waxboard	waxboard	waxboard	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	125	125	125	125	125	125	120	120	120	120	120	120
Cleaner	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX
	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	24" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.
Ave. Fd cons.	0.72	0.72	0.72	0.72	0.72	0.72	1.94	1.94	1.94	1.61	1.61	1.61
Cons.:Fd	0.72						1.94			1.61		
Cons.:Acc	0.72	0.737	0.743	0.771	0.757	0.781	2.28	2.38	2.4	1.62	1.73	1.82
Cons.:Rej	0.605	0.549	0.524	0.53	0.563	0.564	1.39	1.29	1.34	0.89	1.23	0.87
Flow: (bal. Fd)	344	344	342	353	347	356	369	349	343	327	328	320
Flow: Fd	345	345	345	345	345	345	330	325	325	340	330	335
gpm Acc	336.5	310.1	300.4	295.0	287.6	283.1	290.0	237.0	216.0	306.0	243.0	236.0
Rej	8.5	35.0	44.6	50.0	57.5	61.9	40.0	88.0	109.0	34.0	87.0	99.0
Pulp Flow: Fd	14.89	14.90	14.84	15.28	15.04	15.40	43.13	40.77	39.98	31.65	31.73	31.03
t/d Acc	14.58	13.75	13.43	13.69	13.10	13.30	39.78	33.94	31.19	29.83	25.29	25.84
Rej.	0.31	1.15	1.40	1.59	1.95	2.10	3.35	6.83	8.79	1.82	6.44	5.18
Press.: Fd	69	69	69	69	69	69	69	69	69	69	69	69
Press.: Acc	2.5	3	4	5	6	7	3	5	7	3	5	7
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	66.5	66	65	64	63	62	66	64	62	66	64	62
%Hyd.R.R.	2.5	10.1	12.9	14.5	16.7	17.9	12.1	27.1	33.5	10.0	26.4	29.6
% R.R. B.O.P.	2.1	7.7	9.4	10.7	13.0	14.1	8.7	18.0	23.2	5.5	20.1	16.0
Thick. Factor	1.00	1.02	1.03	1.07	1.05	1.08	1.18	1.23	1.24	1.01	1.07	1.13
% Eff. Lg.: Blue												
Red												
Yellow												
Orange												
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												
	Runs 513-518: approximately 10% waxboard by weight in OCC						Runs 513-518: 0.24% hot melt contaminant - 0.95 specific gravity > 14 mesh					

Black Clawson Company - Shartle Division - Technology Center

Run #	525	526	527	528	529	530	531	532	533	534	535	536
Date	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/3/95	8/22/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	120	120	120	120	120	120	120	120	120	120	120	120
Cleaner	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX
	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	23" vort. find.	36" vort. find.
Ave. Fd cons.	1.02	1.02	1.02	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.80
Cons.:Fd	1.02			0.75								1.80
Cons.:Acc	1.15	1.11	1.15	0.78	0.85	0.84	0.76	0.83	0.84			1.86
Cons.:Rej	0.67	0.58	0.62	0.56	0.51	0.52	0.47	0.47	0.48			0.269
Flow: (bal. Fd)	379	338	335	365	367	342	281	293	287			335
Flow: Fd	351	345	338	361	353	340	300	300	300	270	270	340
gpm Acc	315.0	273.0	249.0	325.0	280.0	250.0	240.0	218.0	197.0	174.0	208.0	322.0
Rej	36.0	72	89	36	73	90	60	82	103	96	62	18
Pulp Flow: Fd	23.25	20.75	20.55	16.47	16.56	15.45	12.67	13.21	12.93			36.33
t/d Acc	21.80	18.23	17.23	15.25	14.32	12.64	10.97	10.89	9.96			36.04
Rej.	1.45	2.51	3.32	1.21	2.24	2.82	1.70	2.32	2.97			0.29
Press.: Fd	69	69	69	69	69	69	50	50	50	45	45	68
Press.: Acc	3	5	7	3	5	7	3	5	7	3	5	3
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	66	64	62	66	64	62	47	45	43	42	40	65
%Hyd.R.R.	10.3	20.9	26.3	10.0	20.7	26.5	20.0	27.3	34.3	35.6	23.0	5.3
% R.R. B.O.P.	6.7	11.9	16.0	7.4	14.1	18.4	12.5	17.1	22.0			0.8
Thick. Factor	1.13	1.09	1.13	1.04	1.13	1.12	1.01	1.11	1.12			1.03
% Eff. Lg.: Blue												
Red												
Yellow												
Orange												
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												
	Runs 519-535: 0.24% hot melt contaminant - 0.95 specific gravity larger than 14 mesh											0.5% debris

Black Clawson Company - Shartle Division - Technology Center

Run #	537	538	539	540	541	542	543	544	545	546	547	548
Date	8/22/95	8/22/95	8/22/95	8/22/95	8/23/95	8/23/95	8/23/95	8/23/95	8/23/95	8/23/95	8/23/95	8/23/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	120	120	120	120	120	120	120	120	120	120	120	120
Cleaner	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX	REX
	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.	36" vort. find.
Ave. Fd cons.	1.80	1.80	1.45	1.45	1.45	1.45	1.02	1.02	1.02	1.02	0.80	0.80
Cons.:Fd			1.45				1.02				0.80	
Cons.:Acc	2.05	2.11	1.48	1.59	1.65	1.60	1.08	1.14	1.18	1.14	0.82	0.86
Cons.:Rej	0.43	0.65	0.18	0.20	0.33	0.40	0.32	0.14	0.18	0.28	0.25	0.14
Flow: (bal. Fd)	341	309	331	334	323	298	356	343	331	306	340	328
Flow: Fd	335	330	340	338	335	332	345	340	335	330	345	345
gpm Acc	290	234	322	300	271	249	333	302	277	256	326	297
Rej	45	96	18	38	64	83	12	38	58	74	19	48
Pulp Flow: Fd	36.92	33.47	28.87	29.16	28.18	25.97	21.87	21.03	20.29	18.81	16.37	15.78
t/d Acc	35.77	29.71	28.67	28.70	26.90	23.97	21.64	20.71	19.67	17.56	16.08	15.37
Rej.	1.15	3.76	0.19	0.46	1.27	2.00	0.23	0.32	0.63	1.25	0.29	0.41
Press.: Fd	68	68	68	68	68	68	68	68	68	68	68	68
Press.: Acc	5	7	3	4	5	6	3	4	5	6	3	4
Press.: Rej	0	0	0	0	0	0	0	0	0	0	0	0
Pressure drop	63	61	65	64	63	62	65	64	63	62	65	64
%Hyd.R.R.	13.4	29.1	5.3	11.2	19.1	25.0	3.5	11.2	17.3	22.4	5.5	13.9
% R.R. B.O.P.	3.2	10.5	0.7	1.6	4.3	6.9	1.1	1.5	3.1	6.2	1.7	2.5
Thick. Factor	1.14	1.17	1.02	1.10	1.14	1.10	1.06	1.12	1.16	1.12	1.03	1.08
% Eff. Lg.: Blue												
Red												
Yellow												
Orange												
% Eff. Sm.: Blue												
Red												
Y/O												
Overall % Eff.												

Runs 538-549: 0.5% contaminant 0.95 & 0.97 sp. grav. (-8,+14) and (-14,+80)

Run #	549	550	551	552	553	554	555	556	557	558	559	560
Date	8/23/95	7/31/95	7/31/95	7/31/95	7/31/95	7/31/95	7/31/95	7/31/95	7/31/95	7/31/95	7/31/95	7/31/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	120	120	120	120	120	120	120	120	120	120	120	120
Cleaner	REX	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1
	36" vort. find.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.
Ave. Fd cons.	0.80	0.904	0.904	0.904	0.904				0.904	0.904	0.904	0.904
Cons.:Fd		0.853								0.955		
Cons.:Acc	0.91	1.33	1.171	1.121	1.123				1.4	1.531	1.576	1.602
Cons.:Rej	0.20	0.073	0.084	0.081	0.086				0.066	0.116	0.098	0.101
Flow: (bal. Fd)	338	26	28	29	29				29	35	34	35
Flow: Fd	345	30	31	32	32	32	33	32	32	33	33	34
gpm Acc	284.0	16.8	20.6	22.6	22.4	22.7	22.2	20.7	18.0	19.4	18.8	18.7
Rej	61	13.16	10.43	9.38	9.65	9.35	10.8	11.32	14.04	13.59	14.23	15.29
Pulp Flow: Fd	16.28	1.41	1.50	1.57	1.56				1.57	1.88	1.86	1.90
t/d Acc	15.55	1.35	1.45	1.53	1.51				1.51	1.79	1.78	1.80
Rej.	0.73	0.06	0.05	0.05	0.05				0.06	0.09	0.08	0.09
Press.: Fd	68	60	65	70	67	74	70	70	70	65	65	74
Press.: Acc	5	0	5	10	7	15	6	8	9	5	6	15
Press.: Rej	0	0	5	10	7	15	6	6	5	2	2	10
Pressure drop	63	60	60	60	60	59	64	62	61	60	59	59
%Hyd.R.R.	17.7	43.9	33.6	29.3	30.2	29.2	32.7	35.4	43.9	41.2	43.1	45.0
% R.R. B.O.P.	4.4	3.5	3.1	2.6	2.9				3.2	5.3	4.7	5.0
Thick. Factor	1.14	1.47	1.30	1.24	1.24				1.55	1.69	1.74	1.77
% Eff. Lg.: Blue		100	100	79	3				100	100	100	100
Red		100	100	37	100				100	100	100	100
Yellow		-	-	-	-	no sheets made			-	-	-	-
Orange		good	good	bad	good				good	good	good	good
% Eff. Sm.: Blue		100	100	100	100				100	100	100	100
Red		100	100	0	100				100	100	100	100
Y/O		-	-	-	-				-	-	-	-
Overall % Eff.		100	100	54	76				100	100	100	100
	0.5% hot melt	Runs 550-560: 0.5% contaminant of size -14, +20 hot melt of 0.95 and 0.97										

Black Clawson Company - Shartle Division - Technology Center

Run #	561	562	563	564	565	566	567	568	569	570	571	572
Date	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95	8/10/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	120	120	120	120	120	120	120	120	120	120	120	120
Cleaner	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2	1.0 NACR#2
	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.
Ave. Fd cons.	0.925	0.925	0.925	0.925	0.925	0.925	0.954	0.954	0.954	0.954	0.954	0.954
Cons.:Fd	0.925						0.954					
Cons.:Acc	1.697	1.838	1.773	1.928	1.864	2.001	1.819	1.905	1.453	1.422	1.437	1.464
Cons.:Rej	0.076	0.094	0.107	0.128	0.135	0.159	0.112	0.144	0.076	0.084	0.079	0.076
Flow: (bal. Fd)	34	30	28	31	31	30	31	30	35	31	31	32
Flow: Fd	32	32	33	33	33.5	34	32	34	34	32	32	32
gpm Acc	17.7	14.3	13.2	13.7	14.2	12.3	15.1	13.5	22.4	20.1	19.8	20.0
Rej	14.3	17.68	19.8	19.29	19.29	21.7	16.9	20.55	11.61	11.93	12.22	11.96
Pulp Flow: Fd	1.87	1.68	1.54	1.74	1.75	1.69	1.77	1.72	2.01	1.78	1.77	1.82
t/d Acc	1.80	1.58	1.41	1.59	1.59	1.48	1.65	1.54	1.96	1.72	1.71	1.77
Rej.	0.07	0.10	0.13	0.15	0.16	0.21	0.11	0.18	0.05	0.06	0.06	0.05
Press.: Fd	60	66	67	68	69	70	65	70	70	68	67	66
Press.: Acc	0	6	6	8	9	10	5	10	6	4	3	2
Press.: Rej	0	5	5	5	5	5	5	6	10	8	7	6
Pressure drop	60	60	61	60	60	60	60	60	64	64	64	64
%Hyd.R.R.	44.8	55.3	60.0	58.5	57.6	63.8	52.8	60.4	34.1	37.3	38.2	37.4
% R.R. B.O.P.	3.7	5.6	6.9	8.1	8.4	11.0	6.2	9.1	2.7	3.3	3.2	3.0
Thick. Factor	1.83	1.99	1.92	2.08	2.02	2.16	1.91	2.00	1.52	1.49	1.51	1.53
% Eff. Lg.: Blue	93	100	100	100	100	100	100	100	100	93	100	100
Red	25	100	75	100	100	100	75	100	100	100	100	100
Yellow	25	0	75	0	0	25	0	50	0	75	0	25
Orange	-	-	-	-	-	-	-	-	-	-	-	-
% Eff. Sm.: Blue	100	96	98	98	94	96	96	96	100	100	94	98
Red	87	85	76	74	77	76	77	81	83	89	68	77
Y/O	11	8	18	8	13	0	11	0	1	21	18	24
Overall % Eff.	57	65	74	63	64	66	60	71	64	80	63	71
	Runs 550-560: 0.5% contaminant of size -14, +20 hot melt of 0.95 and 0.97											

Run #	573	574	575	576	577	578	579	580	581	582	583	584
Date	8/10/95	8/11/95	8/11/95	8/11/95	8/11/95	8/11/95	8/11/95	8/11/95	8/23/95	8/23/95	8/23/95	8/23/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	120	120	120	120	120	120	120	120	120	120	120	120
Cleaner	1.0 NACR#2	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#1	1.0 NACR#9	1.0 NACR#15	1.0 NACR#9	1.0 NACR#15
	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	2.75" diam.	flush cap	reg. cap	flush cap	reg. cap
Ave. Fd cons.	0.954	1.059	1.059	1.059	1.059	1.059	1.059	1.059	1.01	1.01	1.01	1.01
Cons.:Fd		1.059							1.01			
Cons.:Acc	1.756	1.747	1.51	1.418	1.501	1.474	1.605	1.419	1.55	1.65	1.59	1.63
Cons.:Rej	0.078	0.084	0.072	0.081	0.085	0.081	0.076	0.069	0.059	0.125	0.074	0.152
Flow: (bal. Fd)	33	27	31	27	27	26	28	28	30	30	28	30
Flow: Fd	32	30	32	31	31	32	32	31	30	31	30	31
gpm Acc	17.1	15.7	20.9	19.2	18.2	18.1	17.5	20.2	19.0	17.5	17.5	17.4
Rej	14.9	14.29	11.13	11.81	12.77	13.87	14.49	10.83	11.0	13.5	12.5	13.6
Pulp Flow: Fd	1.87	1.72	1.94	1.69	1.71	1.68	1.76	1.77	1.81	1.84	1.73	1.83
t/d Acc	1.80	1.65	1.90	1.64	1.65	1.61	1.69	1.72	1.77	1.74	1.67	1.71
Rej.	0.07	0.07	0.05	0.06	0.07	0.07	0.07	0.04	0.04	0.10	0.06	0.12
Press.: Fd	60	60	66	67	68	69	70	65	60	60	60	60
Press.: Acc	0	0	6	7	8	9	10	5	0	0	0	0
Press.: Rej	0	0	5	5	5	5	5	5	0	0	0	0
Pressure drop	60	60	60	60	60	60	60	60	60	60	60	60
%Hyd.R.R.	46.7	47.6	34.8	38.1	41.2	43.3	45.3	34.9	36.7	43.5	41.7	43.9
% R.R. B.O.P.	3.8	3.8	2.4	2.9	3.3	3.3	3.2	2.3	2.1	5.4	3.1	6.6
Thick. Factor	1.84	1.65	1.43	1.34	1.42	1.39	1.52	1.34	1.53	1.63	1.57	1.61
% Eff. Lg.: Blue	100	96	100	100	100	100	100	100	100	100	100	100
Red	100	100	100	100	100	100	100	100	100	100	100	100
Yellow	50	71	77	65	71	88	88	77	0	25	100	75
Orange	-	-	-	-	-	-	-	-	-	-	-	-
% Eff. Sm.: Blue	94	96	94	100	90	98	100	100	84	88	80	76
Red	76	82	78	65	78	85	84	84	90	60	60	50
Y/O	18	9	12	0	0	2	0	0	10	24	23	10
Overall % Eff.	73	76	77	72	73	79	79	77	64	66	77	68
	Runs 561-573: 0.5% hot melt size -14, +100 of 0.95, 0.97 & 0.995 sp.grav. At 574 20 g (1/3 each color) added to maintain debris level.								rightside up	upside down	rightside up	upside down

Run #	585	586	587	588	589	590	591	592	593	594	595	596
Date	8/29/95	8/29/95	8/29/95	8/29/95	8/29/95	8/29/95	8/29/95	8/29/95	8/29/95	8/29/95	9/8/95	9/8/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	120	120	120	120	120	120	120	120	120	120	103	103
Cleaner	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9	1.0 NACR#9
	reg. cap	reg. cap	reg. cap	reg. cap	reg. cap	reg. cap	flush cap	flush cap	flush cap	flush cap	regular cap	regular cap
Ave. Fd cons.	1.071	1.071	1.071	1.071	1.071	1.071	1.063	1.063	1.063	1.063	0.920	0.920
Cons.:Fd	1.071						1.063				0.920	
Cons.:Acc	1.715	1.628	1.602	1.391	1.221	1.760	1.735	1.714	1.846	1.573	1.430	1.540
Cons.:Rej	0.071	0.070	0.066	0.063	0.061	0.066	0.053	0.061	0.069	0.063	0.297	0.108
Flow: (bal. Fd)	27	28	27	25	20	25	28	26	28	29	27	30
Flow: Fd	29	30	30	31	29	27	29	27	29	31	27	30
gpm Acc	16.6	17.9	17.7	18.4	17.3	14.7	16.7	15.6	15.9	19.1	14.6	17.2
Rej	12.4	12.2	12.3	12.6	11.7	12.3	12.3	11.4	13.1	11.9	12.4	12.8
Pulp Flow: Fd	1.77	1.80	1.75	1.59	1.31	1.61	1.78	1.65	1.82	1.85	1.48	1.68
t/d Acc	1.71	1.75	1.71	1.54	1.27	1.56	1.74	1.61	1.77	1.81	1.26	1.59
Rej.	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.05	0.22	0.08
Press.: Fd	60	65	70	70	72	50	60	50	65	70	50	60
Press.: Acc	0	12.5	17	10	22	0	0	0	13	10	0	0
Press.: Rej	0	5	10	3	15	0	0	0	5	3	0	0
Pressure drop	60	52.5	53	60	50	50	60	50	52	60	50	60
%Hyd.R.R.	42.8	40.5	41.0	40.6	40.3	45.6	42.4	42.2	45.2	38.4	45.9	42.7
% R.R. B.O.P.	2.8	2.6	2.5	2.4	2.3	2.8	2.1	2.4	2.9	2.3	14.8	5.0
Thick. Factor	1.6	1.5	1.5	1.3	1.1	1.6	1.6	1.6	1.7	1.5	1.6	1.7
% Eff. Lg.: Blue	100	100	100	100	100	100	100	-	-	-	100	100
Red	100	100	100	100	100	100	100	-	-	-	100	100
Yellow	0	100	100	33	100	100	33	-	-	-	75	100
Orange	-	-	-	-	-	-	-	-	-	-	-	-
% Eff. Sm.: Blue	91	100	100	100	100	100	100	-	-	-	97	93
Red	100	100	100	100	100	100	100	-	-	-	69	79
Y/O	0	100	100	100	0	0	0	-	-	-	53	47
Overall % Eff.	65	100	100	89	83	83	72	-	-	-	82	87
	Runs 585-594: 0.25% hot melt size (-8,+14) of 0.95, 0.97 & 0.995 sp.grav.; (35 g. in 400 gal at 1% cons.) -- cleaner right-side up										Runs 595 - 599: 0.5% debris	

Run #	597	598	599	600	601	602	603	604	605	606	607	608
Date	9/8/95	9/8/95	9/8/95	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	103	103	103	120	120	120	120	120	120	120	120	120
Cleaner	1.0 NACR #9	1.0 NACR #9	1.0 NACR #9	REX	REX	REX	REX	REX	REX	REX	REX	REX
	regular cap	regular cap	regular cap	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.
Ave. Fd cons.	0.92	0.92	0.92	2.07	2.07	2.07	2.07	1.53	1.53	1.53	1.53	0.98
Cons.:Fd				2.07				1.53				0.98
Cons.:Acc	1.48	1.66	1.40	2.29	2.34	2.40	2.44	1.58	1.74	1.77	1.82	0.98
Cons.:Rej	0.10	0.10	0.12	0.61	0.78	0.95	0.29	0.28	0.34	0.43	0.56	0.25
Flow: (bal. Fd)	27	33	25	356	343	339	295	349	347	341	334	346
Flow: Fd	30	31	29	350	345	340	335	350	345	340	335	350
gpm Acc	16.0	17.2	15.3	311.0	283.0	261.0	239.0	335.0	295.0	280.0	257.0	344.0
Rej	14.0	13.8	13.7	39	62	79	96	15	50	60	78	6
Pulp Flow: Fd	1.51	1.80	1.39	44.28	42.74	42.20	36.76	32.10	31.90	31.37	30.79	20.37
t/d Acc	1.42	1.72	1.29	42.85	39.84	37.69	35.09	31.85	30.88	29.82	28.14	20.28
Rej.	0.09	0.09	0.10	1.43	2.89	4.51	1.68	0.26	1.02	1.55	2.64	0.09
Press.: Fd	65	70	72	69	69	69	69	69	69	69	69	70
Press.: Acc	12	10	22	3	4	5	6	3	4	5	6	3
Press.: Rej	5	3	15	0	0	0	0	0	0	0	0	0
Pressure drop	53	60	50	66	65	64	63	66	65	64	63	67
%Hyd.R.R.	46.7	44.5	47.2	11.1	18.0	23.2	28.7	4.3	14.5	17.6	23.3	1.7
% R.R. B.O.P.	5.1	5.0	6.1	3.3	6.7	10.7	4.0	0.8	3.2	4.9	8.6	0.4
Thick. Factor	1.6	1.8	1.5	1.1	1.1	1.2	1.2	1.0	1.1	1.2	1.2	1.0
% Eff. Lg.: Blue	100	100	100									
Red	100	100	100									
Yellow	100	100	75									
Orange	-	-	-									
% Eff. Sm.: Blue	91	90	93									
Red	96	90	88									
Y/O	47	50	63									
Overall % Eff.	89	88	87									
	Runs 595 - 599: 0.5% debris: lg. & sm. 0.95, 0.97, 0.995			Runs 600 - 615: 0.5% lg. (-8,+14) hot melt 0.95, 0.97 spec. grav. & 0.3% sm. (-14,+100)								

Run #	609	610	611	612	613	614	615	616	617	618	619	620
Date	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95	8/30/95	9/8/95	9/8/95	9/8/95	9/8/95	9/8/95
Furnish	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market	Bl. Market
	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt	+ hot melt
Stock Temp, F	120	120	120	120	120	120	120	102	102	102	102	102
Cleaner	REX	REX	REX	REX	REX	REX	REX	1.0 NACR #9	1.0 NACR #9	1.0 NACR #9	1.0 NACR #9	1.0 NACR #9
	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	30" vort. find.	flush cap	flush cap	flush cap	flush cap	flush cap
Ave. Fd cons.	0.98	0.98	0.98	0.69	0.69	0.69	0.69	0.90	0.90	0.90	0.90	0.90
Cons.:Fd				0.69				0.90				
Cons.:Acc	1.03	1.09	1.02	0.71	0.76	0.80	0.76	1.48	1.63	1.56	1.53	1.30
Cons.:Rej	0.22	0.29	0.34	0.27	0.23	0.25	0.26	0.14	0.11	0.13	0.10	0.13
Flow: (bal. Fd)	331	331	303	351	345	350	322	26	27	29	33	24
Flow: Fd	345	340	335	350	345	340	335	27	29	29	31	29
gpm Acc	307.0	282.0	269.0	335.0	300.0	285.0	270.0	14.5	14.0	15.9	18.3	15.5
Rej	38	58	66	15	45	55	65	12.5	15	13.1	12.7	13.5
Pulp Flow: Fd	19.52	19.50	17.86	14.56	14.34	14.54	13.38	1.39	1.47	1.59	1.76	1.31
t/d Acc	19.03	18.49	16.51	14.31	13.72	13.72	12.35	1.29	1.37	1.49	1.68	1.21
Rej.	0.49	1.00	1.35	0.25	0.62	0.82	1.03	0.10	0.10	0.10	0.08	0.10
Press.: Fd	70	70	70	70	70	70	70	50	60	65	70	72
Press.: Acc	4	5	6	3	4	5	6	0	0	12	10	22
Press.: Rej	0	0	0	0	0	0	0	0	0	5	3	15
Pressure drop	66	65	64	67	66	65	64	50	60	53	60	50
%Hyd.R.R.	11.0	17.1	19.7	4.3	13.0	16.2	19.4	46.3	51.7	45.2	41.0	46.6
% R.R. B.O.P.	2.4	5.0	6.9	1.7	4.3	5.8	7.4	6.9	6.1	6.5	4.6	6.5
Thick. Factor	1.1	1.1	1.0	1.0	1.1	1.2	1.1	1.6	1.8	1.7	1.7	1.4
% Eff. Lg.: Blue								100	100	100	100	100
Red								100	100	100	100	100
Yellow								75	63	88	88	88
Orange								-	-	-	-	-
% Eff. Sm.: Blue								86	96	90	96	96
Red								78	75	81	75	86
Y/O								47	50	73	60	30
Overall % Eff.								81	81	89	87	83
	Runs 600 - 615: 0.5% lg. (-8,+14) hot melt 0.95, 0.97 spec. grav. & 0.3% sm. (-14,+100)							Runs 616 - 620: 0.5% debris: 1/8 each: 0.95, 0.97, 0.995 sp. gr.; lg. (-8,+14) & sm. (-14,+100)				

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APPENDIX VIII

New Cleaner Development for Lightweight Contaminant Removal

Elizabeth L. Maze

ABSTRACT

The paper industry's need to remove lightweight contaminant particles more efficiently prompted the conception, development and production of a new, highly efficient lightweight cleaner system. This paper reviews the research and development process that began with an evaluation of existing literature on hydrocyclone design theory. Prototype development was based upon interpretation and application of various basic design principles. Comparative testing of prototype and conventional cyclone designs was accomplished by choosing a standard furnish and generating standard contaminants. The final prototype design, now in production, is able to achieve over 95% efficiency in lightweight contaminant removal compared to 63% for conventional through-flow units under the same conditions.

KEYWORDS

Adhesives, Efficiency, Hot melts, Hydrocyclones, Product development, Reclaimed fibers, Specific gravity, Stock preparation.

INTRODUCTION

In the last decade, the paper industry has been increasing the use of recycled fiber, bringing a larger quantity and greater variety of adhesives, waxes, hot melts, and other contaminants into the recovered paper stream. These contaminants must be appropriately handled by the stock preparation system. Generally, contaminants are categorized as either being light (specific gravity less than that of water) or heavy (specific gravity greater than water). The industry has expressed the need to remove lightweight contaminants more effectively, particularly the waxes and hot melts, in order to produce a better sheet on the paper machine, reduce picking in dryer felts, and minimize other undesirable side effects such as wax buildup.

Hydrocyclone Theory

A literature search was conducted for articles describing the influences and variables associated with the separation of solid particles from a fluid medium.

Hydrocyclones were first introduced to the paper industry early in the century when MacNaughton obtained a patent in 1906 for a centrifugal cleaning apparatus to remove heavy contaminants from paper stock (1). A wealth of information now exists regarding the design and operation of hydrocyclones. Bliss (2,3) discussed aspects of conventional reverse and through-flow cleaning. He explained the importance of parameters such as temperature, pressure drop, hydraulic reject rate, feed consistency, and contaminant properties– factors which significantly affect removal efficiency. Svarovsky (4), Tarr (5), Fern (6), Lister (7) and Hofmann (8) discuss in detail, the theoretical design parameters that affect cyclone efficiency. These parameters include cyclone diameter, inlet diameter, accept diameter, reject diameter, internal surface characteristics, vortex finder length, body length, and cone angle, just to list a few. For example, cyclone diameter has a significant effect on the size of contaminant separated. Generally, the larger the diameter of the cyclone, the coarser the separation, meaning that only the larger particles are separated with good efficiency. Conversely, the

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smaller the diameter of cyclone the finer the separation and the higher the efficiency on a given size and specific gravity particle.

Development Program: Application of Theory

The examination of existing hydrocyclone literature enabled two terms to be defined for our development project. The first term, *Necessary Average Radial Velocity (NARV)*, is the ratio of the cleaner radius at the inlet to the retention time in the cleaner. This term quantifies the velocity that a given particle must have in the radial direction to reach the axial core. *NARV* takes into account the fact that the likelihood of particle removal in a designated stream depends on the particle's tendency to migrate radially to a point where the designated stream can remove it.

Necessary Average Radial Velocity = the average velocity a particle must travel to reach the air core of the centrifugal cleaner.

$$NARV \text{ (m/s or ft/s)} = \frac{\text{radial distance at inlet}}{\text{retention time in cleaner}}$$

The second term defined for the use of the development project, *Cleaning Value Factor (CVF)*, considers the effect of the tangential velocity, or more specifically, the centrifugal force on the particle. It is the ratio of the centripetal acceleration at the inlet to the *NARV*. It is known that increasing the rotational speed of the fluid in a hydrocyclone will increase the force moving particles radially, as long as velocity does not create excessive turbulence or mixing.

Cleaning Value Factor = a measurement of the centripetal acceleration on the particle vs. the average velocity necessary to reach the air core.

$$CVF \text{ (1/sec)} = \frac{(\text{tangential velocity})^2}{\text{radius} \times NARV}$$

Although neither CVF nor NARV specifically considers factors such as reject rate, surface friction, solids characteristics, and others, these terms served as design tools allowing cleaner designs to be evaluated based upon physical parameters, and were used to predict the general impact on efficiency when changing a particular parameter.

The terms NARV and CVF define the point to which a lightweight particle must travel to be included in the reject stream. The path that a particle takes may vary, but it must move a certain radial distance during the time it is in the cleaner to be removed by the reject stream. Our cleaner design modifications increased the lightweight particle concentration (in the reject flow) by decreasing the distance a particle must travel radially and providing more time to accomplish this movement (residence time). The purpose of a hydrocyclone in removing specific contaminants is to concentrate solid particles in a desired stream; these two design factors, NARV and CVF, address this importance.

Simply increasing a volumetric reject rate changes the volumetric ratio of accept and reject streams but does not necessarily increase the concentration of contaminant particles in the reject stream. Since the purpose of these cyclones is concentration of solid particles in a desired stream, a change in reject rate is not a critical design factor. Granted, the hydraulic split between the accept and reject streams will affect the distance a particle must move. However, by increasing the reject rate, a larger portion of the boundary layer around the air core is pulled toward the reject port, at the same time pulling in more of what would be accepts, i.e. fiber, thereby reducing reject contaminant concentration.

Hydrocyclone theory supports the assumption that the efficiency of a cleaner not only depends upon physical design and flow conditions, but also on the difference in specific gravity between the contaminant and fluid medium. The relative difference in inertial mass of the particle versus the fluid medium will determine the radial direction and velocity of the particle movement at given conditions. In addition, the resistance to particle movement increases or decreases due to temperature effects, consistency, particle shape, particle size, drag force, and other factors.

Relating the general concepts and empirical observations conveyed by Kelsall (9, 10), Svarovsky (11), Bouchillon (12) and Franko (13) in the area of hydrocyclones, and using the aforementioned theoretical design parameters, as many as 26 cleaner prototypes were developed. The first prototypes were constructed from pieces of production cleaner units in such a way that they could be tested for one or two variables to verify a concept, then taken apart to be modified to test another concept. As the development continued, more sophisticated models were made. Both reverse and through-flow cleaner designs were investigated while applying the theoretical and empirical data. All designs were tested using a specified consistency, temperature, and range of inlet pressure and pressure differentials,

while using standard furnish and contaminants. The prototypes testing setup is shown in Fig. 1.

Figures 2–4, described in the results section, illustrate how the theoretical terms NARV and CVF assisted in prototype selection.

Development Program: Standard Furnish and Contaminants

Very early in the development program it was determined that in order to adequately compare efficiencies for each style or variation, a standard furnish and standard contaminants were needed. Key characteristics were envisioned before the choices were made.

Previous trial work and information gathered by Arnold and Wise (14, 15) indicates that conventional lightweight cleaners are generally efficient in removing particles with specific gravities less than 0.98, but beyond this level approaching the specific gravity of water, 1.00, the current technology does not provide adequate contaminant removal. To effectively evaluate cleaner designs, contaminants in this narrow band of specific gravities were desired. It was necessary that the standard contaminant be a readily available, commercially used adhesive, provided by an established adhesive manufacturer, and be available in at least three specific gravities in the "difficult" range as previously tested, from 0.94 to 1.0.

Petroleum based ethylene vinyl acetate hot melts were supplied by H.B. Fuller Company. Three specific gravities were used in our initial testwork as standards: 0.95, 0.97, and 0.995. The standard hot melt adhesives were color coded and processed according to Procedure 1: Color and Size Separate Hot Melt (see Appendix).

Please note that only reference specific gravity values are reported. We realize that specific gravity of water and of hot melts changes as temperature changes. However, in comparing the performance of different cleaners, the absolute values of specific gravities are not necessary.

Two contaminant size ranges were chosen as standards for the cleaner development program. The larger particles, 1.40 to 2.36 mm (0.055 to 0.093 in) in one dimension, would typically be found in the coarse screening loop, depending on screen hole size. The smaller particles, 0.15 to 1.40 mm (0.006 to 0.055 in), would pass through typical coarse screen holes, but (depending on slot size and particle shape) may or may not be removed by the fine screens. Research was conducted (16) for which particle size was believed to be a major factor in hot melt removal efficiency by centrifugal cleaners, using particles from 0.25 to 1.4 mm in size (0.010 to 0.055 in). Typically, the larger the particle, the more easily it may be removed by stock preparation equipment. For this reason, it was necessary that both larger and smaller particles be used for coarse and fine tuning of cleaner prototype designs.

The furnish chosen was bleached softwood, due to the following characteristics: relatively free of foreign debris, consistent quality, long fiber length, ease of pulping, lack of need to pre-screen or preclean, and bright white color. The high brightness and lack of foreign debris made quantifying the standard contaminants, when colored, a much easier task.

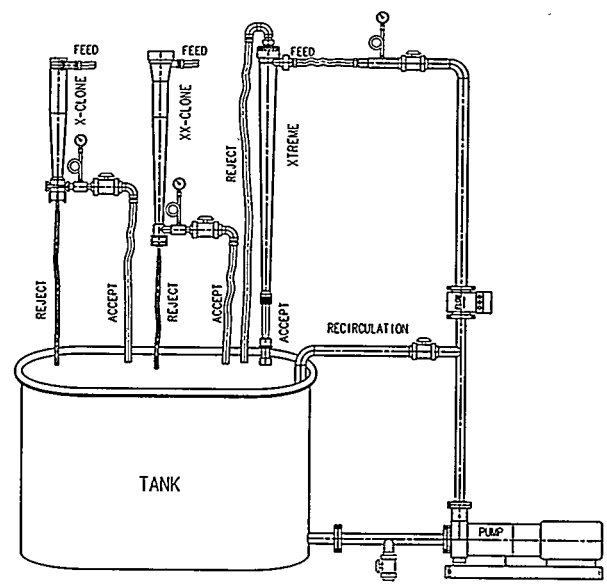

Figure 1: **Cleaner testing setup.**

EXPERIMENTAL

The bleached softwood was first slushed in the pulper, then transferred to the cleaner test tank, Fig. 1, to be adjusted for consistency and temperature. Trials were conducted at two temperatures, 32° C (90° F) and 49° C (120° F), and most runs were performed at 1% consistency. The hot melt contaminants were added at the same level for each batch tested: 0.5% contaminant debris level based on OD basis weight of pulp. An equal weighed quantity of the six vials of adhesive (small and large particles of each of the three specific gravity prepared) were added to produce the total 0.5% contaminant

debris level. Following the preparation to ensure proper tank conditions, the weighed hot melt was added to the test tank. The tank contents were then re-circulated using the pump to attain complete dispersal before testing and sampling began. Complete operational data and details of each test condition for each cleaner type were compiled over the course of the project.

Analytical Techniques

Contaminant particles were manually counted with the aid of a magnifying lens in handsheets placed upon a lighted table. Size determination was done using a TAPPI Dirt Estimation Chart (TAPPI Test Method T437 om-96) to categorize the standard colored hot melt contaminants in both feed and accept sheets. Contaminant removal efficiencies were calculated as follows:

Contaminant removal efficiency, h

$$h = \frac{(Sf - Sa)}{Sf} \times 100\%$$

Sf = number of contaminants in Feed sheets
Sa = number of contaminants in Accept sheets

It was determined that visual examination of contaminants, when compared to image analysis and scanning techniques, was more reliable and repeatable for three main reasons:

1. The sensor settings of the image analyzer are sensitive to the smoothness and brightness of the sheet. Slightly different threshold settings altered the repeatability of the equipment.
2. The image analyzer and scanner devices did not have the capability of differentiating colored contaminants.
3. The amount of time to manually count was actually shorter than the amount of time to have an operator scan or image analyze the sheets.

RESULTS

Two cleaner designs were developed through this test program: a new reverse cleaner, which will be marketed as XTREME™, and a new through-flow cleaner, named XX-CLONE™. The XTREME cleaner differs from conventional reverse cleaners in that it optimizes the various critical hydrocyclone design parameters that influence efficiency. This reverse cleaner provides a longer dwell time by manipulating cleaner length, diameter, cone angle, etc.

The XX-CLONE is a modification of conventional flow-through units, as special attention was given to stabilizing the air core. The XX-CLONE through-flow unit will be utilized to tail the primary rejects from the XTREME cleaner. In this capacity, the unit serves to reduce the hydraulic loading of system rejects by further concentrating debris in the system reject stream. This can be accomplished without compromising the high efficiency of the primary stage. Specific design details on these two cleaners cannot be divulged since proprietary patent issues are involved.

The data points for Figs. 2–4 are from runs at 1% consistency, 49° C (120° F), and 1.0 atmosphere (15 psi) differential pressure for the through-flow units and 4.1 atm. (60 psi) for the reverse cleaner units. Figure 2 relates cleaner inlet velocity to contaminant removal efficiency. As inlet velocity increases, the efficiency of the cleaner unit increases, provided that separation is stable.

Figure 3 illustrates the use of the NARV term as a design tool by showing that as NARV is minimized, the contaminant removal efficiency is maximized for both through-flow and reverse cleaner designs.

Figure 4 shows the relationship between CVF and efficiency. Contaminant removal efficiency increases as the CVF increases, provided that the rotation within the unit is stable and turbulent mixing does not occur.

Performance of the new reverse cleaner is compared to a conventional through-flow cleaner in Fig. 5. Operating conditions for the new reverse cleaner were 4.1 atm. (60 psi) pressure differential, 114 l/m (30 gpm) feed flow rate, and 40% volumetric reject rate. The conventional through-flow cleaner operated at

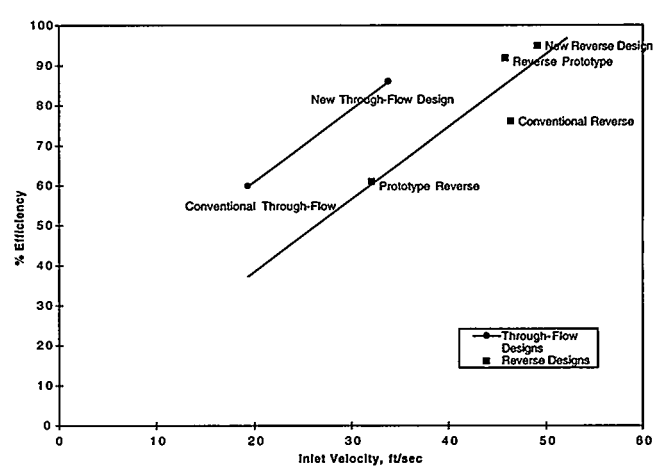

Figure 2: **Efficiency vs. inlet velocity.**

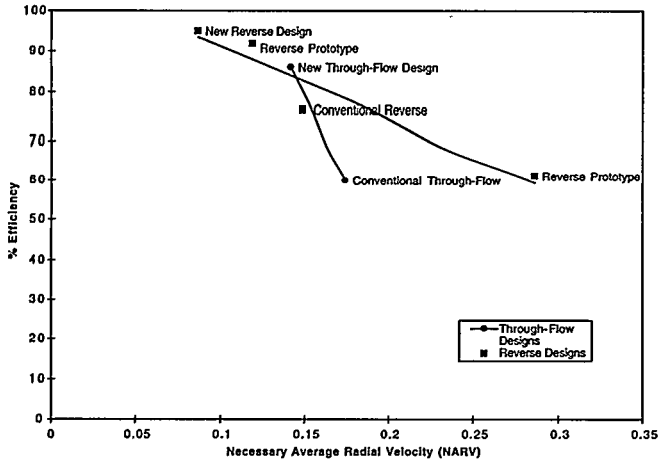

Figure 3: **% Efficiency vs. necessary average radial velocity (NARC).**

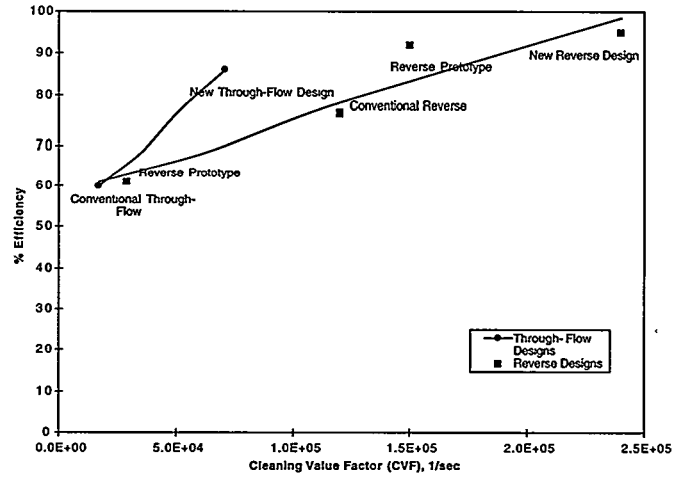

Figure 4: **% Efficiency vs. cleaning value factor.**

1.4 atm. (20 psi) pressure differential, 170 l/min (45 gpm) feed flow rate, 10% volumetric reject rate.

The data in Fig. 5 supports the supposition that the larger the particle, the more easily it is removed with the centrifugal cleaner. This verifies previously referenced work. The data contained in Fig. 5 also supports the presumption that the relative difference in specific gravity between the particle and the surrounding medium plays a role in contaminant removal efficiency; the greater the difference the more easily the particle is removed from the fluid medium. It is understood that specific gravity is affected by changes in temperature. It is assumed, however, that the change in temperature could affect both the contaminant and the fluid, thus a differential will still affect its separation.

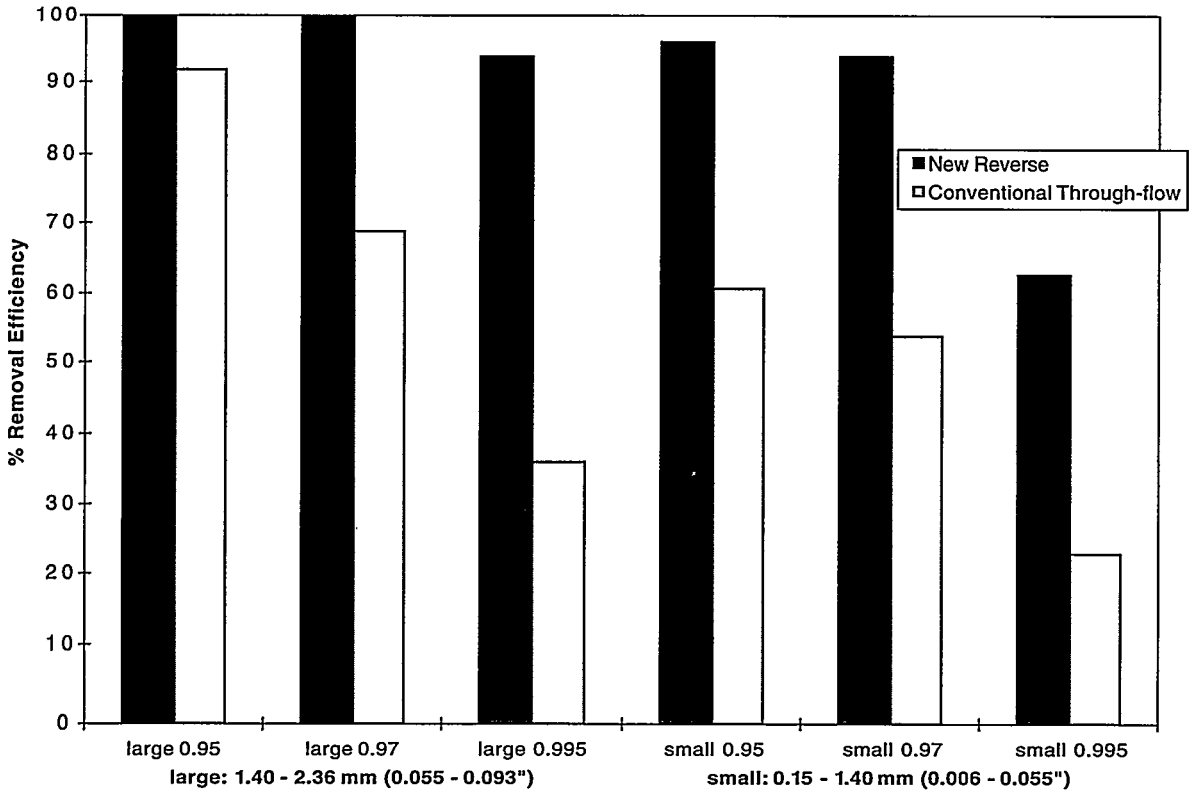

Figure 5: **New reverse cleaner vs. conventional through-flow cleaner (0.5% debris based on pulp; 0.9% cons. bleached softwood; 50° C).**

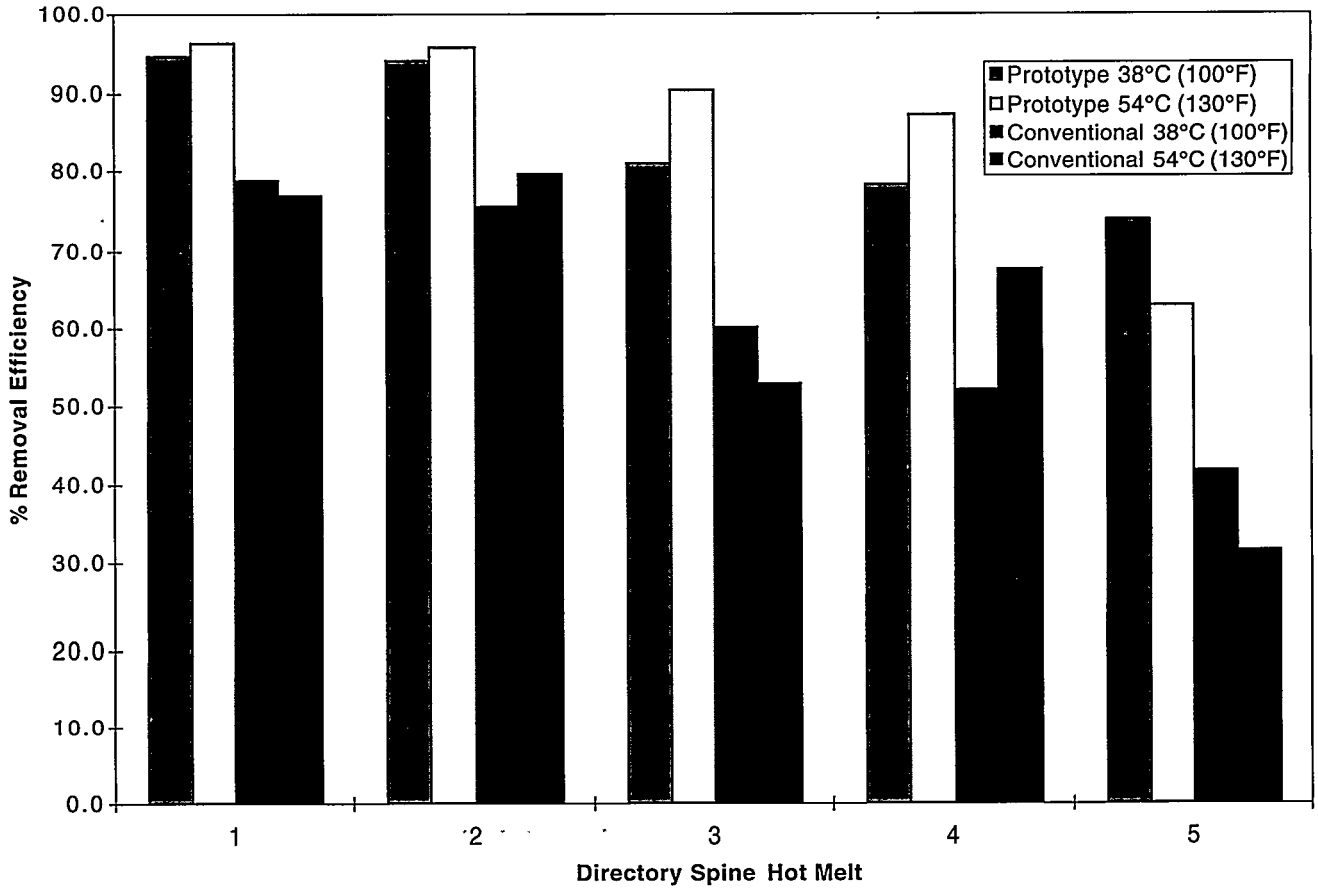

Figure 6: **Prototype reverse cleaner vs. conventional through-flow cleaner (efficiency based upon mm² area).**

Additional Test Work

An opportunity arose during the comparison and evaluation process that allowed for the testing of several different types of adhesives as contaminants. The contaminants were generated by repulping phone directory spines. The directory spines were made using five different hot melts of specific gravities varying from 0.93 to 0.98. The hot melts were polyethylene–based and ethylene vinyl acetate–based. In the pulper, the spines tended to break into long, thin fragments rather than small spherical or cubical pieces. The presence of directory ink coating the fragments was also observed. As expected, the shape of the contaminant, as well as the material make-up, affected the separation.

Separation of contaminants was examined at two temperatures: 38° C (100° F) and 54° C (130° F). The advanced prototype reverse cleaner operated at a 4.1 atm. (60 psi) pressure differential, feed flow rate of 110 l/min (29 gpm), and 44% volumetric reject rate. The conventional through-flow unit operated at 1 atm. (15 psi) pressure differential, feed flow rate of 170 l/min (45 gpm), and at 13% volumetric reject rate. Test results are shown in Fig. 6.

This work provided a more complete picture of the current status of the experimental design development and what modifications were required to optimize performance. Figure 6 illustrates the level of efficiency with an advanced prototype compared to a conventional through-flow unit. In reviewing the data, the reverse cleaner prototype outperformed the conventional through-flow for each contaminant. The removal efficiency was generally better at the higher temperature, with the exception of the last hot melt type.

CONCLUSIONS

The removal efficiency of adhesives of varying specific gravities by through-flow cleaners has been reported (17) to be 63% at 0.95 specific gravity and dropping steadily to 47% at 0.97. Similar results were attained for the conventional through-flow units in development testing (Fig. 5). The new reverse cleaner can achieve 95%, or higher, removal efficiency at these specific gravity levels.

The ability to attain improved product quality, or to enable the use of lower quality incoming furnish

has obvious economic advantages. Conventional cleaners are unable to efficiently remove contaminants that have specific gravities approaching 1.0. The new reverse cleaner significantly outperforms these conventional units.

FUTURE WORK

Research will continue in the application of this new technology on a broad range of contaminants, and will strive to identify new parameters that affect performance. Operating data will be gathered from numerous field unit installations of the XTREME cleaning system to document the effects at various mill conditions.

APPENDIX

Procedure 1: Color and Size Separate Hot Melt

1. Obtain 1.5 kg hot melt and weigh pigment. The amount and color of pigment to add is as follows:

   * 4.5 grams Sunfast Blue (248-3745) Sun-Chemical for 0.95 specific gravity - 0.30% dry ratio.
   * 4.5 grams Sunbrite Red (215-0013) Sun-Chemical for 0.97 specific gravity - 0.30% dry ratio.
   * 4.5 grams Sunbrite Orange (276-2384) or Yellow (275-0023) for 0.995 spec. grav. - 0.30% dry ratio.
   * 4.5 grams Sunfast Green (264-8142) Sun-Chemical for 1.04 specific gravity - 0.30% dry ratio.

[Hot melt manufactured by H.B. Fuller Co., under identification codes: 0.95 sp. gr. = HM-4646; 0.97 sp. gr.= HM-2055; 0.995 sp. gr. = HL-7248; 1.04 sp. gr.= HM-1690.]

a. Use a disposable pan such as a large metal coffee can to heat hot melt to liquid phase on a hot plate.
b. Stir in pigment with a disposable stirrer until well mixed. A wooden paint stirrer works well.

2. Pour colored hot melt into disposable aluminum cooking trays.
   a. Allow hot melt to solidify at room temperature. Place pans in a refrigerated cooler or freezer.

3. Remove colored hot melt slabs from aluminum pans.

4. Fracture slabs into 2.5 x 2.5 x 1.2 cm (1 x 1 x 0.5 in.) pieces using a chisel.

5. Pulverize hot melt chunks in a high-speed, 3.78 l (1 gal) (Waring) blender using cold water and half-full batches. (Replace water often so that the hot melt will not be warmed to melting.)
   a. Blend times may vary with material. Check particle size between 30 sec blend cycles.

6. Use mesh screens to classify by size.

a. Place mesh screens atop one another as illustrated in Fig. 7, in a sink.
b. Place disintegrated hot melt fragments in the top mesh screen and rinse for several min until separation is complete. Repeat as needed for each subsequent screen.

7. Pour hot melt fragments onto blotter paper. Allow hot melt to air-dry overnight.

Alternative Steps:

6. Pour hot melt fragments onto blotter paper. Allow hot melt to air-dry overnight.

7. Use mesh screens to separate by size.

a. Place mesh screens atop one another as illustrated in Fig. 7.

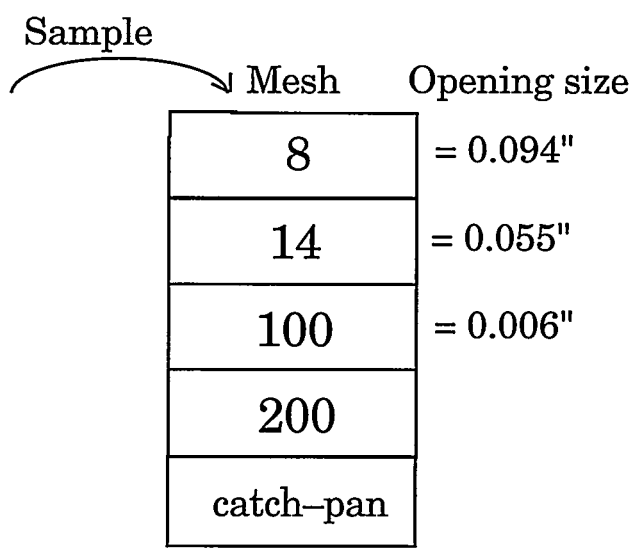

Figure 7: **Apparatus used to classify hot melt particles by size.**

b. Place air-dried hot melt fragments in the top mesh screen and shake the column for several minutes until separation is complete.

ACKNOWLEDGMENT

This research was partly funded by a grant from the United States Department of Energy. The author would like to gratefully thank H.B. Fuller Company (Shelley Kueppers and Jeff Swoboda) for the hot melt contribution. Gratitude is also expressed to those members at Black Clawson whose contributions made this project a success, giving special recognition to Christopher E. McCarthy, Senior Research Engineer, Steven E. Slattery, Design Engineer, and David P. Churchill, Product Manager of Cleaners

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Issue **FOCUS:**
RECYCLING

At Green Bay Packaging's Green Bay, Wis., mill, a new cleaning system enhances a rebuild to produce 100% recycled linerboard

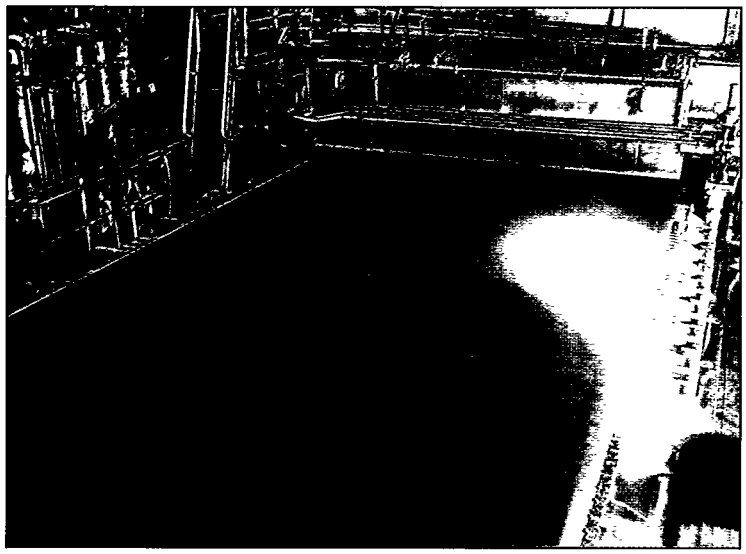
BY MONICA SHAW, *Associate Editor*

Cleaning Upgrade Improves Sheet Quality at Green Bay Packaging

ONE OF THE FIRST TOTALLY EFFLUENT-FREE paper mills in the world, Green Bay Packaging's Green Bay, Wis., mill has a history of implementing advanced technologies to achieve its business and papermaking goals. In the late 1940s, the Green Bay mill was the first to use neutral sulfite semichemical pulping in its production of corrugating medium.

Over time, the mill continued its migration toward more environmentally sensitive papermaking, recycling old corrugated containers (OCC) in the late 1950s and achieving 100% mill closure in 1974 while producing 50% recycled corrugating medium. Since 1991, however, Green Bay has focused on the challenging production of 100% recycled linerboard at its totally effluent-free mill. And a series of recent modernization projects, with a concentration on the recycled fiberline, has focused on improving the mill's furnish quality.

In the late 1980s, Green Bay noted the growing demand for recycled corrugated packaging and decided that technology had evolved enough to produce a high-quality, 100% recycled linerboard grade for the corporation's northern box plants. Insistent that this new grade be of comparable quality to its virgin kraft counterpart, Green Bay committed to a $40 million capital expenditure program in 1988 to rebuild the mill and completely close the water system. By 1991, the mill had successfully produced the industry's first high-performance linerboard made from recycled furnish. In 1992, Green Bay became the world's first totally effluent-free mill.



Green Bay Packaging's 1991 rebuild included a new primary headbox and a modified fourdrinier table.

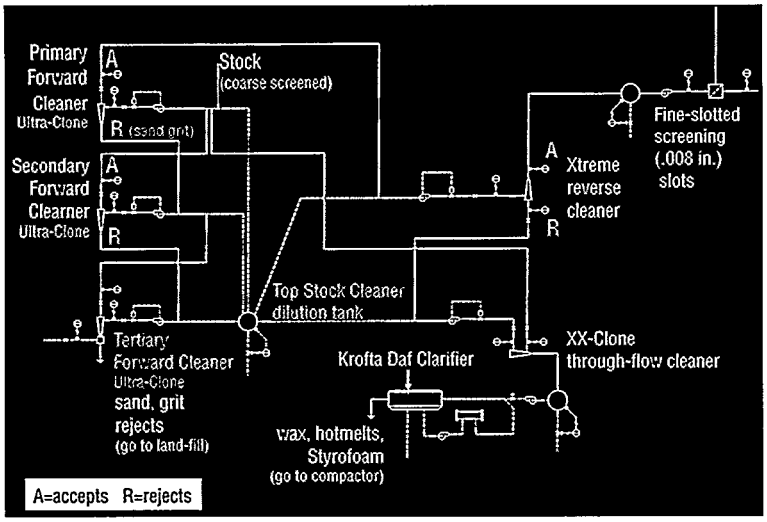
As customer requirements for improved linerboard quality increase at the same time as raw materials quality decreases, Green Bay continues to implement new technologies. Most recently, Green Bay has focused on improving its linerboard quality by becoming the first mill in the world to incorporate modified reverse cleaning technology. In March of this year, the new cleaning technology was completely integrated at the mill with immediate positive results.

Customers, including Green Bay's internal box customers as well as external ones, have been impressed with the appearance improvements in the product. In addition, process improvements, such as the elimination of plugging in the new cleaners and an improved coefficient of friction (COF) that requires less anti-skid coating, have also been noted.

REBUILDING THE MILL. In 1988, the decision was made to rebuild the Green Bay mill and convert it from a producer of 50% recycled corrugating medium to 100% recycled linerboard. According to Jeff Walch, vice president and general manager of Green Bay Packaging's mill division, the decision was based on business, as well as technological, considerations.

"The rebuild project was somewhat driven by the fact that we are still a privately owned, integrated producer of linerboard and corrugated containers," explains Walch. "Our owners have always had a vision of making linerboard in the north for our box plants. If you go back to the 1980s, the only linerboard made

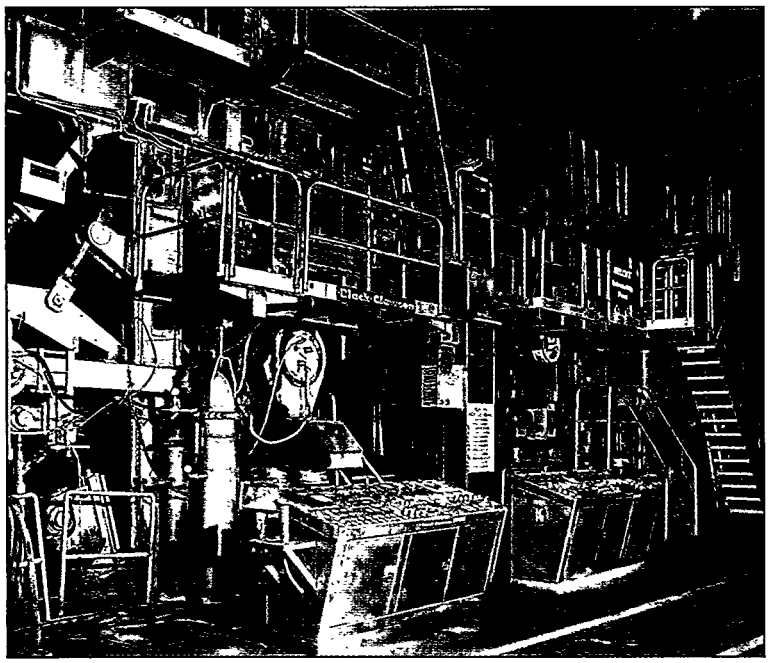
FIGURE 1: *A flow diagram shows Green Bay Packaging's newly designed cleaning system.*



in the north was a recycled grade that was inferior to virgin kraft. In the late 1980s, Green Bay Packaging decided that the technology had come far enough to make a grade of recycled linerboard that would compete head-to-head with virgin kraft."

The $40 million rebuild took place in three phases between 1989 and 1991 that corresponded with three mill shutdowns. The first two phases involved the replacement of old equipment as well as the addition of new equipment required for 100% recycled linerboard production; the third phase involved closing the NSSC pulp mill.

Phase One. The longest and most complicated phase of the mill rebuild took place in 1989 during a 34-day shutdown. As part of this phase, Green Bay installed several pieces of equipment, including a new primary headbox and Extended Nip Press (ENP) from Beloit. The fourdrinier table was also modified by AES. In addition, the mill reconfigured the first press section—a Black Clawson model—from a bi-nip press into a straight-through press.



The 1991 rebuild at Green Bay Packaging included the change from a bi-nip press to a straight-through press in the first press section and the addition of a new Beloit Extended Nip Press.

Phase One also involved the rebuild of the paper machine dryer section using equipment from such companies as Valmet, Beloit, Sandy Hill, and Black Clawson. An entirely new ABS machine drive system was installed, as well as a new reel and rewinder from Beloit and a new Bailey distributed control system (DCS). The project marked the first use of AC variable felt roll driven dryers in the paper industry. In addition, the project included the first ever use of an AC variable winder drive that had an AC backstand on it.

As part of Phase One, Green Bay made several upgrades to its wastepaper cleaning system in preparation for the mixture of post-consumer OCC and double-lined kraft (DLK) clippings from its box plants. The upgrades included installation of Black Clawson X-Clone and reconfiguration of existing Contra-Clone cleaners.

Phase Two. In 1991, the Green Bay mill completely changed over to 100% recycled linerboard production. In the fiberline, dispersers were installed for cleaning the linerboard's top stock. On the paper machine, this changeover required a new secondary headbox from Beloit to take advantage of two-ply sheet forming technology. In addition, a Beloit BelBond top wire unit was installed to improve dewatering. By the time the machine rebuild was completed, the original 162-in.-reel trim Beloit machine was the operational equal of a new paper machine.

"This machine would compete very, very effectively with the newest machines in the marketplace right now," explains Walch. "It's not quite the show piece, because we don't have the brand new building, but I think we have made the conversion quite effectively."

The first linerboard was produced in February 1991 and was introduced to the market in March of that year. The mill began producing 550 tpd of the 100% recycled linerboard—a production rate that was maintained until cleaning system improvements allowed an increase. From the start, Green Bay was pleased with the linerboard's quality.

"The results we saw right from the beginning were exceptional, with strength numbers better than we expected," states Walch. "We have run continual comparisons between recycled linerboards, recycled corrugating mediums, and recycled corrugated shipping containers. Test results indicate excellent performance, particularly when using edge crush tests (ECT)."

Green Bay Packaging's box plants that use the Green Bay mill's linerboard are located throughout the North and Midwest, including Green Bay, De Pere, and Wausau, Wis.; Minneapolis/St. Paul, Minn.; Kalamazoo, Mich.; Fremont and Cincinnati, Ohio; and Tulsa, Okla. Through these box plants, Green Bay Packaging's 100% recycled linerboard is used by such external customers as Procter & Gamble, Fort James, Kimberly-Clark, and Whirlpool.

RECLOSURE OF THE WATER SYSTEM. The Green Bay mill operates with a completely closed water system. No process water is discharged from the mill, there is no connection to a municipal treatment plant, and there is no onsite treatment facility. This technology was first developed by Green Bay Packaging in the early 1970s while manufacturing 50% recycled corrugating medium. When the decision was made to rebuild the mill to manufacture 100% recycled linerboard, maintaining this technology was one of the primary design criteria. Reclosure of the process water system was accomplished in September 1992.

The original closure. In 1966, Green Bay started up a fluidized bed reactor to burn spent pulping liquor. With this step alone, the mill's biological oxygen demand (BOD) loading to discharge was reduced by 60%. However, closure took another eight years of work.

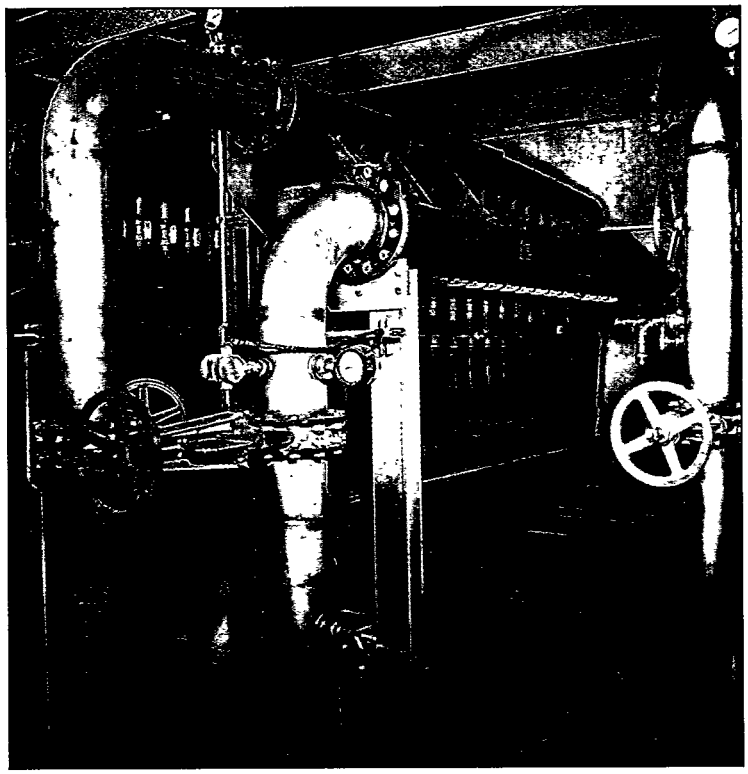
To close the mill, Green Bay had to determine exactly where every water source originated and where it discharged. To accomplish this, Green Bay measured the flow of its discharge as well as its city water usage. Next, the mill divided the process into subsections to determine the contribution of each area. Fortunately, the paper mill, pulp mill, wood room, secondary fiber plant, boiler room, chemical makeup building, and the new recovery plant all discharged into a common discharge line. However, tracing their individual points of entry to this common line provided yet another challenge.

Using dye tracers, Styrofoam beads, and visual observation downstream, Green Bay traced all discharge piping, much of which did not appear on its latest engineering drawings. The next step involved a rather unique application of an atomic absorption spectrophotometer purchased for byproduct analysis. All newly mapped discharge streams were injected with a tracer element. Sampling was done downstream, and, by determining the difference in concentration—knowing the original concentration, tracer flow, and the background level—flow was accurately determined.

The next step involved eliminating all river water from contact with the process water system. The machine basement trench was divided, and the vacuum pump cooling water (river water) was discharged separately. River water fire hoses were converted to city water, as were all river water flushing lines, and river water hoses for washup were abandoned. Next, all freshwater inputs to the process had to be discovered, documented, and measured.

Although closing the mill was difficult, the theory behind closure was simple. In Walch's words, "Water in had to equal water out." The sum of all the freshwater sources had to be equal or less than the evaporation in the dryer section. Even the smallest leak of high solids process water would seriously raise the BOD load. In 1982, much of the mill had to be converted to stainless steel construction to prevent corrosion.

With the further addition of vacuum separators, the mill had a recovery rate of 98% to 99.5% of all pollutants by 1979. The process water system leveled out with soluble solids between 6% and 8%, the temperature at about 165°F, and suspended solids between 18 and 25 lb/1,000 gal. The sheet ash—the only outlet for system solids—leveled out at about 12.5%.



The new cleaning system uses Thermo Black Clawson Ultra-Clone cleaners in the primary, secondary, and tertiary positions.

Reclosing after the rebuild. The process water system remained closed until February 1991, when process changes resulting from Green Bay's conversion to 100% recycled linerboard totally disrupted the balance between freshwater input and evaporation. In anticipation of these early problems, the mill negotiated a short-term solution with the Green Bay, Wis., municipal treatment plant. When the mill's inventory of water was too high, it could call the city and request permission to discharge.

From the beginning, chemical suppliers did not believe that Green Bay could make 100% recycled linerboard without freshwater. It was a recognized fact that starch required at least 49 lb of water for every 1 lb of starch, and that water had to be fresh to ensure that the cationic charge was not stripped. This equated to a requirement of 60 gpm of freshwater to make 500 tpd of linerboard. Retention aids—also cationic—required additional freshwater dilution of up to 10 gpm. Once again, Green Bay surveyed the mill to further restrict freshwater input.

However, Green Bay managed to find solutions to these challenges. Chemical suppliers brought in retention aids that either used no freshwater make down or could use process water. A process water seal system was installed, additional showers were eliminated in the press section, and all large freshwater wash-up hoses were converted to process water.

Since September 1992, Green Bay's process

system has been totally closed. According to Walch, the mill personnel are responsible for this accomplishment.

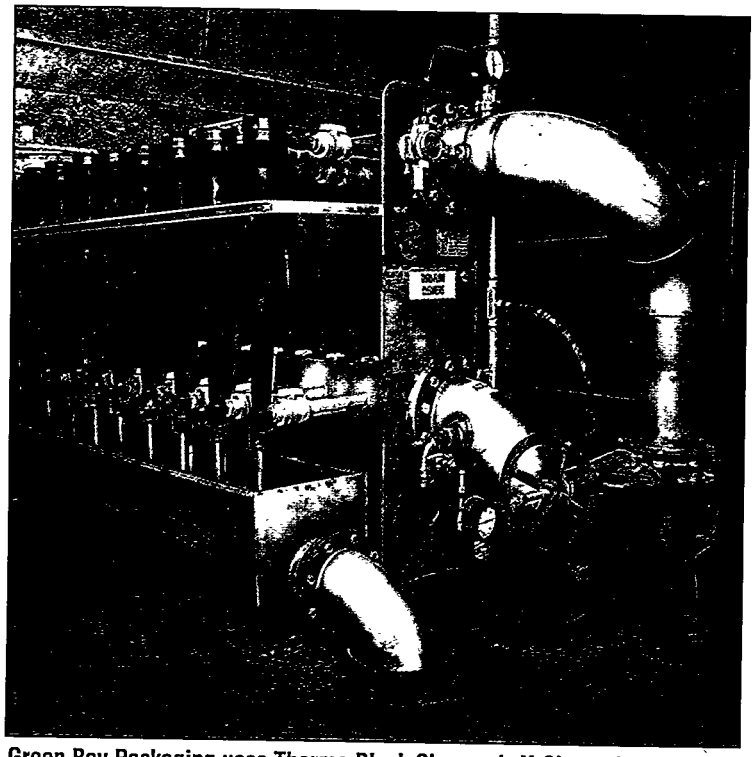
"The people out in the mill are acutely aware of what it takes to remain closed," explains Walch. "They are the ones willing to put up with the challenges associated with this system, and they are the ones who understand why all freshwater is discretionary."

A NEW CLEANING SYSTEM. Despite the success of the mill rebuild and reclosure projects, Green Bay did not become complacent about its linerboard accomplishments. Instead, the mill continued to closely monitor the quality of its linerboard for appearance, strength, and other characteristics.

In 1994, when it felt that its linerboard had fallen behind the industry's appearance standards, Green Bay began examining how a new cleaning system might improve the appearance of its top stock. For Green Bay, however, the constant improvements required to stay competitive are a positive force.

"Everybody is working to make performance grades and the standard is being raised," states Walch, "People used to look at performance board as being board that had a cross-direction ring crush value of 2.0 times basis weight. Now, those numbers keep going up from 2.0 to 2.1 to 2.2. Overall, I think these higher standards are healthy for the industry in that it makes us better at competing with alternative packaging sources. So, a new cleaning system was just one segment of trying to make the highest-quality packaging materials that we can."

To reach its appearance goals, Green Bay began examining the latest cleaning equipment and techniques available in 1994. After conducting detailed trials, the mill chose to install a modified reverse cleaner, becoming the first mill to do so—and with excellent results.



Green Bay Packaging uses Thermo Black Clawson's X-Clone cleaners as its through-flow cleaners.

Furnish. Green Bay's current raw material mix is 80% to 85% post-consumer OCC, with the balance in DLK, primarily from its own container plants. Since the installation of the cleaning system, the mill is phasing out its use of DLK, though whether it completely phases it out has not been decided. This is mainly because three of Green Bay Packaging's box plants are located near the mill. Depending upon supply and demand of each grade and the pricing involved, it may or may not be cost-effective to eliminate all of the DLK, according to Walch.

In 1994, Green Bay established its own brokerage division. Known as Bay Fibers, this division has been working to change the mill's raw material supply mix, selling off some of the material that it no longer requires.

"We are basically procuring post-consumer OCC," explains Walch. "We are not running any mixed waste at this point, but I think realistically the time may come that all mills utilizing wastepaper may find it necessary to use some percentage of a lower-quality grade than OCC, which would probably be a mixed waste grade."

The flexibility to handle variations in fiber supply was yet another concern for Green Bay as it sought a new cleaning system.

Selecting the new system. According to Doug Vandenberg, assistant production coordinator at the Green Bay mill, selection of the new cleaning system centered around two goals as the mill began examining systems in 1994.

"We were pulping DLK clippings for our top stock. First, we wanted to improve our sheet's appearance. Secondly, we wanted to realize some cost benefits by reducing raw material costs. Anything else that we improved—whether smoothness, strength, or coefficient of friction—would just be a bonus," Vandenberg says.

With appearance and cost savings as the two major goals, Green Bay identified four cleaning technologies for examination. The first was a cleaner based on the centrifuge principle—the Gyroclean by Fiberprep. The mill also wanted to take a closer look at dispersion cleaning, since the mill was successfully doing a small amount after the coarse screening and fine screening of the DLK. The third technology for consideration was fine slotted screening, while the fourth was other cleaning alternatives.

For throughput and mechanical reasons, Green Bay eliminated the centrifugal cleaner early on. Dispersion was also eliminated early in the selection process.

"Because we have a closed water system, we were very concerned about technology that might not totally remove contaminants from the stock, causing us to have to deal with them when we reuse process water for repulping the OCC," explains Vandenberg. "Dispersion breaks down contaminants and hides them, but runs the risk of leaving those contaminants in the system. Dispersion is also a high-cost technology."

At that point, Green Bay was basically left with a choice between fine screening and cleaning equipment. The mill tested one vendor's screening baskets with 0.004-in. slots. Though they performed well, Green Bay decided, after three months of trials, that the equipment did not fully meet its requirements.

"We were very pleased with the handsheets from the fine screens," says Vandenberg. "But, some hot melts and waxes are going to pass through 0.004-in. slots. We already had a coarse and a fine screening system, so it was going to be hard to justify going to finer slots while still not totally taking care of the problem. This made us somewhat cautious about going to corporate and saying we needed more fine screens."

Green Bay was then left to examine other alternative cleaning equipment to reach its goals. Ironically, the mill had shut down its Thermo Black Clawson XX-Clone through-flow cleaners and Contra-Clone reverse cleaners in 1992 due to throughput and stringing and plugging problems. However, upon reexamination, factors other than equipment issues became apparent.

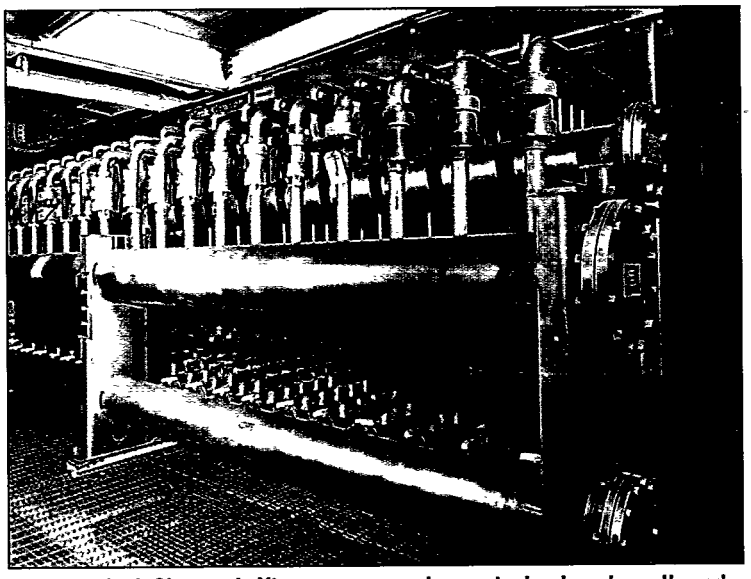
"In retrospect, it probably wasn't an equipment problem," says Walch. "It was probably an application problem having to do with where they were installed in our process and how the process was configured. However, some skepticism existed among our operators concerning this equipment."

Despite past problems, the mill embarked upon a series of detailed cleaner trials. The study involved getting various cleaner models from different manufacturers and running them on Green Bay's process for 24 hours a day to evaluate cleaning efficiency as well as plugging susceptibility. Above all, Green Bay wanted to validate manufacturer's claims on its own turf.

"We tested one of the XX-Clones we had previously used, we tested the Uniflow cleaners from Beloit, and we also tested forward cleaners for the removal of the fine sand and grit that we could see in our sheet," describes Vandenberg.

With the help of three co-op students, Vandenberg compiled handsheet after handsheet indicating linerboard appearance. During a period of five months, six different cleaners were tested. The cleaning systems, at best, proved to be only 90% to 94% effective. However, during this period, Thermo Black Clawson indicated that they would soon have a new cleaning system that might help the mill achieve its goals. In the summer of 1995, Thermo Black Clawson proposed that Green Bay test the yet unnamed Xtreme reverse cleaner followed by the newly designed XX-Clone through-flow cleaner.

Developed by Black Clawson with joint funding from a U.S. Dept. of Energy grant, the Xtreme cleaner was designed to remove lightweight contaminants. When used with the XX-Clone cleaner in the tailing position, only two stages are required to minimize fiber loss and maximize removal of small contaminants such as wax, lightweight hot melt adhesives, and stickies. With a 60 psi pressure drop, the Xtreme cleaner uses long residence times in a small diameter cleaner to extract very small contaminants that approach the specific gravity of fiber itself, while the XX-Clone, with its 30 psi pressure drop, is operated as a secondary cleaner to collect any residual debris left over from the Xtreme cleaning process.



Thermo Black Clawson's Xtreme reverse cleaner technology has allowed Green Bay to improve its linerboard sheet appearance.

Through its tests of the new system, Green Bay found that there was a visible difference in handsheet blemishes—even with the fluctuating quality of its incoming recovered fiber. The mill also found that the system had little effect on overall fiber balance, and that it apparently maintained the whitewater quality in its closed water system. Because of these findings, Green Bay committed to a $4 million purchase of the new cleaning equipment.

System design and startup. In January 1997, Green Bay began the installation of its new cleaning system. The new Thermo Black Clawson equipment included a Liqui-Filter reverse screen designed to thicken pulp in-line, three stages of Ultra-Clone forward cleaners, Xtreme reverse cleaners, XX-Clone through-flow cleaners, and fine slotted Ultra-V pressure screens.

As Figure 1 shows, three stages of Thermo Black Clawson Ultra-Clone forward cleaners are installed for the removal of small, heavyweight debris. Rejects from this cleaning sequence are sent to the landfill, while the primary forward cleaner accepts are diluted and sent to the Xtreme reverse cleaners for removal of lightweight debris. Accepts from the reverse cleaners are sent through Ultra-V 0.008-in. fine slotted pressure screens and on to the stock preparation area, while rejects continue through to the XX-Clone secondary cleaners. Accepts from the XX-Clone cleaner are diluted and sent back through the primary Ultra-Clone cleaner, while rejects, consisting of stickies, adhesives, and wax, are processed by a Krofta dissolved air flotation clarifier and then sent to a compactor.

Green Bay's top stock cleaning system started up in March of this year. In July, the full cleaning system became operational, when the mill "closed the loop" on reject filtrate by bringing the water from

thickened and compact rejects back to the Krofta clarifier.

According to Walch, "There was a learning curve in March, and it has only been since July 24th that the whole rejects tailing loop has been closed and the whole cleaning system has been balanced out the way we want it to be. Since then, we have seen some very dramatic changes in what is going on within our system and within our product, such as appearance improvements and a 10% reduction in the use of DLK clippings."

Results. From a product performance standpoint, Green Bay's linerboard quality has seen dramatic improvements in appearance. No problems with stringing and plugging have been noted since the system began operating. Other operation improvements include additional reject thickening, a new compactor, and seal water screening. Yet another improvement has stemmed from the linerboard's improved coefficient of friction, since less wax now enters the final sheet.

"At the end of our paper machine, we spray on a non-skid product with a shower boom across the sheet," explains Walch. "Because of the linerboard's improved coefficient of friction, we have seen a reduction in the amount we have had to use to maintain our degree of slide angle quality specs. And, our box plant in town has been able to reduce the amount of non-stick agent they apply as well."

From an investment perspective, the new cleaning system required about $4 million in capital. Walch describes its results as integral to Green Bay's future direction.

"It was a very small part of a very big project—and a part of it that was totally quality driven. It's just part of our philosophy that you have to produce the best sheet—that you just can't afford not to. By the time we finish the cleaning system improvements and complete a good quantitative study evaluating it, we'll probably need to start looking for that next step," states Walch.

"For right now, we have done as much as possible. But I think we realize that, from an operational, technical, and research perspective, we need to keep monitoring our system not only in terms of quantitative analysis of all the reject streams and the efficiency of all the equipment, but also watching all the new developments. The day will come—whether that is next year or the year after or 5 years from now—where we and everybody else will be taking that next step."

Vandenberg also maintains this "raising the bar" perspective, and specifically mentions further cleaning of the base stock as a potential requirement in the future. "Right now, our top stock cleaning system cleans about 33% of our stock," explains Vandenberg. "Because we have seen such dramatic improvements from cleaning this stock with the new system, we have to consider the impact of additional cleaning for the other two-thirds in the future." ■

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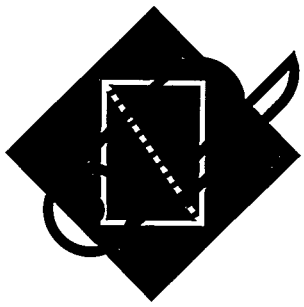
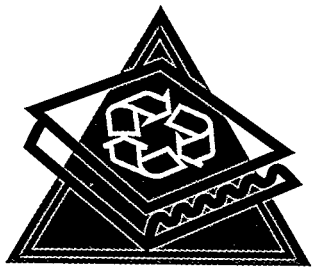
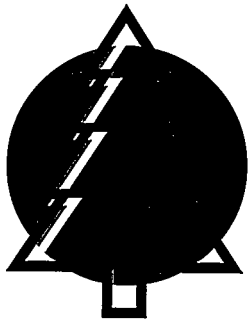


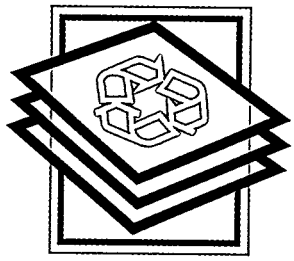
Approach Flow



Brown Fiber Recycling



Chemical Pulping



White Fiber Recycling

THERMO BLACK CLAWSON INC.
A Thermo Fibertek company

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THERMO BLACK CLAWSON INC.

A Thermo Fibertek company

Technology Center - Middletown, Ohio

January 16, 1998

Report Number: 38,005

Dry Pulper Development Report

For:

Thermo Black Clawson, Inc
Research and Technology Center
Middletown, Ohio

By:

Don Scott

Thermo Black Clawson Distribution

W. J. Fondow/ P. Seifert / R&D Files
A. F. Kelly/ D. E Chupka/ R&D Files
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N. E. Lacey (2)
M. A. Sieron/ R&D Files
W. South/ M. Gilkey/ C. Vitori

Customer Distribution

THERMO BLACK CLAWSON INC.

A Thermo Fibertek company

Report Number: 38,005 Date: **January 17, 1998**

Dry Pulper Development Report

Summary

A pulper has been developed which disintegrates paper in a virtually dry state, solids content ranging from 30% to 70%. Simultaneously, the pulper disperses friable contaminants such as non-impact printing inks found in wastepaper grades such as PS-40, white ledger, and PS-38, office waste. It imparts a significant dispersion effect to reduce the pepper-like contaminants which are visible after conventional pulping.

Other contaminants are also made smaller, for example, stickies. Some evidence has shown that the contaminants are left in a large enough size to be removed by fine screening, but the efficiency is somewhat reduced. That is why the first field applications for the machine should be with grades like white ledger, where the stickies problem is minimal.

Because the unit combines pulping and dispersion into one step, the thickening and dispersion steps can be eliminated from deinking systems. There is also the possibility that the entire 'second loop' can be removed.

THERMO BLACK CLAWSON INC.

A Thermo Fibertek company

Report Number: 38,005

Date: **January 17, 1998**

Dry Pulper Development Report

The development of this pulper was partially sponsered by the U.S. Department of Energy under a cooperative agreement which has since ended. Thermo Black Clawson, Inc. owns all patent rights, but has certain obligations regarding the manufacturing of the machines.

History / Background

The Dry Pulper Project has, to date, spanned a period of nearly four years, beginning in January 1994 during the investigation period of the New Disperser Project. At that time, Dave Chupka of the Research and Development department was exploring patents and existing machinery in an effort to help in the development of a new kneading type dispersion unit.

Prototype Design

We believed that the Komar design was not fully suitable for our application for several reasons. Among those are:

- Large 'dead' zones, with opportunity for collecting undefibered papers
- We needed a more uniform clearance between the auger flights and the tub walls
- Their cantilevered design was too expensive and not necessary for our process
- Opening of the entire tub bottom was also believed to be unnecessary
- For a given tub volume to process paper, a much lighter duty unit was needed

In light of these reasons, we set out to design and build our own unit for R&D use.

The design phase of the prototype machine was started in August of 1994. During this phase, a number of different designs were proposed. Ultimately the final and current design was decided upon and Dave Chupka submitted final drawings on October 28, 1994. These drawings are shown as Figure 3. The prototype unit was placed on order with Brown-Singer Company on October 6, 1995.

Test Program

Installation

While the Dry Pulper was being built, discussions were initiated with several area hydraulic drive vendors, and Scott Industrial, Inc. was chosen to supply the drive system. The complete hydraulic system was ordered from Scott Industrial on October 16, 1995 and was delivered on December 1, 1995. The Dry Pulper prototype itself arrived at the Technology Center on December 8, 1995.

The prototype was moved to the R&D area of the Technology Center and installation began. The Technology Center mechanics fabricated a base from steel I-beams and installed the unit on it for support. The hydraulic system was then installed, and the drive system tested. Various drive and gearbox guards were fabricated and put in place, and after mechanical checkout the machine was ready for testing. The installation was essentially completed in late February of 1996.

Early Runs

After installation, a few runs were made to further mechanically check out the prototype. These runs were made at slow speeds, typically 30 revolutions per minute (rpm), and for short periods. During these runs the machine often jammed quite hard, and was reversed manually via the hydraulic drive pump. A coupling bolt broke in one of these initial test runs and severely scored one of the shaft ends. On considering the cause of the break, the blame was placed on the tendency for paper to compress and jam hard between the auger ends and the walls of the machine. This happened most severely on the 'left' shaft side. (The designation 'Left Shaft' will always refer to the shaft that is joined in the center at the cone bases.) To correct the problem, sections of the auger flights nearest the wall were cut away in an effort to remove the ability of the auger to pack against the wall. Additionally, sweeper bars were placed on the wall of the left side of the machine, and a sweeper disc was placed on each wall of the right side of the machine. This turned out to be a rather lengthy repair. The unit was reassembled by mid-March of 1996.

THERMO BLACK CLAWSON INC.

A Thermo Fibertek company

Report Number: 38,005 Date: **January 17, 1998**

Dry Pulper Development Report

Run Chart – Design Phase and Controls Check-out

The table that follows indicates the test runs that were made during the design evolution period of the Dry Pulper prototype. Early in this period, the key considerations for success of a given modification were, overall power consumption, and defibering rate. Chiefly, we looked at defibering rate, but were aware that power was needed to both defiber and disperse ink simultaneously. In the early stages, efforts were made to increase power consumption. This usually led to commensurate increases in defibering rate. Defibering rate was determined by measuring the percentage of the furnish that would pass through a ¼" square screen opening. The test data sheets in the Appendix show these defibering rates for most of the runs listed below.

THERMO BLACK CLAWSON INC.

A Thermo Fibertek company

Report Number: 38,005 Date: January 17, 1998

Dry Pulper Development Report

Run Chart

Run #	Date	Batch Size, lbs	Cons., %	Shaft Speed, rpm	Duration, min	Mechanical Change	Comments
1	3/29/96	250	50	30	120	None	First 'real' test run
2	4/2/96	250	50	30	120	None	
3	4/11/96	250	35	30	120	None	Consistency change.
4	6/3/96	250	55.07	30	90	Stator Ribs	
5	6/4/96	250	52.43	83	90	None	Speed change.
6	6/6/96	500	50	83	90	Knives (Teeth)	Larger batch size.
7	6/7/96	500	70	83	90	None	Higher consistency.
8	6/13/96	750	50	83	110	None	750# batch size.
9	7/2/96	500	50	47/83*	60	Axial bars	L shaft excessive amps
10	7/12/96	500	47.6	73/83	60	Mod. Axial bars	L better, still high
11	7/25/96	500	45.0	104/144	60	New 23:1 gear	Ran higher than FLA
12	8/16/96	500	52.3	76/131	60	None	Moderated motor load
13	8/28/96	500	51.75	74/128	60	None	Contaminant testing
14	1/21/97	~100	~50-70	Slow	<3	New controls	1st control check-out needs more calibration
15	1/24/97	<100	90	Slow	<3	None	R screw jams in reverse, reversing too much
16	2/10/97	<100	90	Slow	15	None	Control better, R screw still locks-up in reverse
17	2/18/97	<100	50	Slow	45	R Shaft add 'paddles'	R screw runs better but still jams
18	3/4/97	500	50	75/80	60	41:1 gearbox on R shaft	R shaft runs much better, but slower
19	3/14/97	500	50	80	60	None	Test full load at once; worked OK, but bridged a lot, time to actually start
20	4/16/97	500	50	80	60	None	ONP testing
21	5/6/97	500	50	80	60	None	OCC Testing

* Two speeds indicate Left and Right shaft speeds were different. (L/R)

APPENDIX XII

The Black Clawson Company
Shartle Division - Technology Center
Middletown, Ohio

September 13, 1996

Report Number: 37,006

High Air Rate Addition Tower (HARA-T) Flotation Cell

By:

C. McCarthy
J. Buchheit

Black Clawson Distribution

A. F. Kelly/ D. E. Chupka/ R&D Files
W. J. Fondow/ P. Seifert/ R&D Files
M. W. Gilkey/ W. South/ R&D Files
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R. MacIntosh/L. Bonday
C. McCarthy/J. Buchheit

Customer Distribution

OBJECTIVE

Develop a flotation cell for the removal of ink and stickies from deinking grade furnishes. Target efficiency for visible particle removal is 95%, both for sub-TAPPI and for TAPPI size groups. Target efficiency for removal of stickies is typically 90%.

INTRODUCTION

The HARA-T cell derives its name from High Air Rate Addition, in a Tower flotation cell. The concept was originally proposed by Messrs. Chris Vitori and Dave Suica and adopted in the 1995 Deinking Summit. It features the following main components:

- Mixer, with two rotors, in the feed line (Figure 1)
- Upflow/downflow separation tower (Figure 2A and 2B)
- Reintroduction and aeration of a part of the accepts flow, to introduce more air, in a gentle fashion (John Pimley suggestion). Air injectors shown in Figure 3, supplied by BCL
- Deinking was envisioned to require three or four stages.

The overall test loop is shown in Figure 2A and 2B.

The cell was originally conceived for an inlet flow of 1200 GPM, plus a nominal recirculation. Air addition was planned at 600%, distributed over four stages. During the test work, it was found that flow rate and air proportion had to be drastically reduced to obtain good efficiencies.

The flow through the HARA-T tower was continuous, but the accepts portion was simply recirculated back to the feed port. Thereby, multiple stages would be simulated in a single cell loop.

The furnish that we focused on was a 50/50 mixture of Mixed Office Waste and PS-40. This make-up provided us with a furnish that had enough ink and stickies plus enough contrast to evaluate the removal efficiency of ink and sticky particles in the various size ranges by scanning on the Hewlett Packard Scanjet 3c unit. For evaluation, five 8" by 8" square handsheets were made for the inlet, first pass, second pass, third pass, and fourth pass through the unit and evaluated on the Scanjet. The results are discussed later in this report.

Minor modifications were made on the unit to optimize operation. Most modifications were performed to allow greater proportions of air to be input without destroying the foam froth.

Written by: Chris McCarthy, Senior Research Engineer

Jamie Buchheit, Research Engineer

Approved by: Al Kelly, Director of New Product Development

BACKGROUND

Much of this work was assisted by the United States Department of Energy for the removal of "sticky" particles. "Stickies" are tacky, amorphous materials that attach to the equipment and paper causing blemishes and breaks on the paper and detrimental build-ups on the equipment. "Stickies" have various chemical and physical characteristics which account for the difficulty in their removal. Also, because of their nature and the attachment process in flotation, some of these materials will float very well while others may not attach as readily or under the conditions.

In certain markets, we are not licensed to sell the IIM Flotator and need a flotation cell to supply in our Deinking systems. This unit was originally designed to employ the concept of using a mechanical rotor to input air into the unit. The spargers were added due to their reported effectiveness in competitive cells in removing large ink particles, in the 250 micron in diameter range to 500 microns diameter. An objective efficiency that was designated by R &D was to remove ink particles at an efficiency of 95% in the 50 to 275 micron range and 275 to 500 micron range. Necessary stickies removal efficiency was designated as 90% in the 50 to 275 micron diameter size range.

RESULTS AND DISCUSSION

TEST LOOP

The Hara-T Flotation cell was originally designed as is shown in Figure 4 with a mixer box, a recirculating sparger system with 4 spargers available. The rejects were taken as an overflow into a 10" diameter pipe. The accepts were recirculated around in piping back into the mixer box and re-introduction into the cell. The tank itself was to be operated at full height, (10 feet high), and had an overflow weir in the center of the 4 foot tank that extended from the bottom of the tank to just below the bottom of the 10" diameter pipe. The piping decreased to 6" in diameter and increased to 12" in diameter at varying points. The AN-1 pump was used as the accepts/feed pipe and was operated on a variable speed drive. A HMS pump was used for the recirculating pump. The test loop of the laboratory installation is shown in Photos 5 and 6.

CENTER PIPE

After the initial installation was operated with Xavier Marquat present from BCE, the overflow weir was replaced with a pipe that came in the side of the tank and rose up at the axial center of the 4' diameter tank. The pipe increased diameter from 12" at its entrance to 24" at its release point. This pipe was manufactured to extend to just below the 10" reject overflow pipe. It was also designed to be removable at the reducer. Runs performed with full internal pipe height were HT20 - HT30 in Table 7. This internal pipe was removed at the reducer in subsequent runs (runs HT31 - HT42 in Table 5) and performed better, probably due to the fact that it disrupted the surface less as is shown in Figure 8 versus Figure 9. The laboratory installation with its internal pipe is shown in Figure 2A and 2B. Table 7 shows

the various test runs, by number, including the various mechanical configurations tested. A total number of 42 runs are listed.

FLOW RATE

The single greatest variable found during testing was the flow rate through the unit. At the designed flow rate of 1200 GPM (runs HT1 - HT7 on Table 5), the unit was unable to perform efficiently on any particle size. The highest efficiency at a flow rate of 1000 GPM or greater was 83% for small particles (>50 micron and <230 micron),and 58% on large particles (>230 micron). The flow rate was then decreased to 600GPM (runs HT8, HT11, HT16 and HT17 on Table 5) and the efficiency did not improve (82% on small particles and 55% on larger particles). It was found that operating at 300 GPM or less was necessary to achieve the 95% efficiency on the smaller range of particles. This was accomplished at this flow rate under all conditions and shown in Figure 10. Decreasing the flow rate to 200 GPM did not significantly improve removal efficiency of large or small ink particles. The large particles were still not being removed at a 95% efficiency. For sticky particles, efficiency was continually improved until inlet flow was reduced to 135 GPM

CHEMISTRY/pH VALUE

In order to obtain the required efficiency of 95% on large particles, it was established that a pH change was necessary. Also, a chemistry change was necessary. Serfax chemistry, which is a fatty acid soap, was used in the neutral conditions.. This resulted in large spec efficiency that reached 95%. This was demonstrated in runs HT29 - HT33 and HT37 - HT39 in Table 7 and shown in Figure 11 versus Figure 12. It was interesting to note that run #9 was performed supposedly under alkaline conditions, but was actually at a pH of 7.3. This run also accomplished the efficiency desired.

FLUID LEVEL

Another variable tested for actual installation practicality is the fluid height of the cell. This also determines whether it was retention time which is the important factor in efficiency or whether it is rise velocity. In actuality, as was shown in runs HT13 - HT17 and HT33 - HT37 on Table 7, the height made an insignificant difference in efficiency and rise velocity was the important variable. This is excellent information in the fact that it allows the manufacture and sale of a smaller unit in terms of height.

MIXER OPERATION

Tests were performed with the top rotor operating alone, the bottom rotor operating alone, both rotors operating, air turned off at the bottom, air turned off at the top inlet, and with the rotors rotating in opposite directions and at various speeds to determine the characteristics that would permit the greatest air introduction with the least disruption of the surface. The final design has only the bottom air inlet open with the bottom rotor operating at full speed in the counter-clockwise direction when faced from the motor and the top rotor rotating at full speed in the clockwise direction when facing from the motor.

A modification was made to the original mixer box design also. The half-moon baffles were removed due to the suspicion that a large air bubble was accumulating on the flotation cell side of the top baffle. A foil-shaped baffle was placed in the unit to see if a little back pressure and velocity in the accused area would decrease the chance of the large bubble forming. This modification, as shown in

Figure 13, 14, and 15, did improve the operation, but only slightly. A nipple connection was welded onto the transition piece at its highest point and a hose was connected with the flow running through a sparger and into the cell. This allowed the large accumulated air bubble to be discharged prior to its accumulation and release into the cell. This final modification resulted in preventing the large bubble to accumulate and allowed an increase of 33% air into the cell on hydraulic runs in comparison to runs without this modification. It is believed that the sloping of the pipe would provide the same result with the present baffle design in a production unit. An actual comparative run with this modification has not been performed at the time of the report. For the commercial design, we recommend an upward sloping feed pipe to prevent the accumulation of air into a large air bubble which disrupts the stability of the surface froth.

EFFICIENCY OF INK REMOVAL

The included tables describe in detail the actual effects of the changes in operation and the modifications made to the cell. Figure 16 shows the competitive runs made versus the IIM Flotator and how the efficiency is equal to this unit. Run HT39 on Table 7 versus Run HT37 and HT38 shows the effect of flotation cell sequence on efficiency and the reason that the final sequence design of a three-stage system with a mixer on the first stage and spargers on the next two stages results in the high efficiency on the M.O.W. furnish. Figure 17 shows the effect of neutral chemistry on the efficiency of the I.I.M. Flotator when using an M.O.W. furnish. Runs HT40, HT41, and HT42 show the effect on brightness on a newsprint/magazine furnish. From Table 18, it is seen that a fourth stage may be valuable on this furnish to maximize brightness increase. It was interesting to note, though, that neutral chemistry did not result in a substantial brightness increase on a news/magazine furnish.

STICKY REMOVAL EFFICIENCY

In the application of stickies removal, chemical and pH changes have shown themselves to be necessary. For the ethylene vinyl acetate that was used during the runs as a sticky contaminant, the flotation cell needed to operate at a pH slightly less than neutral, between 6.2 to 7.0. This attachment was visually determined due to some work performed by Randy McIntosh using the small bubble creation apparatus. The attachment of bubbles to stickies was videotaped and optimized in this apparatus. Consequent runs on the Hara-T proved that this chemistry did perform exceptionally well on removal of these contaminants, obtaining an efficiency of 96.5% removal on this type of hot melt. Runs HT34, HT35 and HT36 show that a lower flow rate (135 GPM) and only two stages are necessary for high removal efficiency (96%) on these hot melts. These visual dirt counts are shown on Tables 19, 20 and 21. Scanning and Image Analysis were unable in this instance to give valuable results due to the inability to distinguish hot melts from background dirt and, especially, brown fiber in the handsheets.

FINAL OPTIMIZED PARAMETERS

The final design parameters for the laboratory unit are as follows:

- Tank Diameter : 4 ft
- Center Pipe Diameter at Entrance : 12 inches
- Center Pipe Diameter at Fluid Release : 24 inches
- Fluid Level Height from Base : 6.25 ft
- Height of Internal Pipe at Release from Base : 4.75 ft
- Accept Port Diameter : 12 inches

- Reject Port Diameter : 12 inches
- Flow Rate : 300 GPM
- Sparger Recirculation Flow Rate : 150 GPM Mixer 2 rotors

The final operating parameters to obtain the necessary efficiency and minimize cost and power consumption include:

- Three stage operation
- First stage with only mixer
- Second and third stage with sparger only
- Total retention time of 12 minutes

In this form, no intermediate pumps are required, as shown in Figures 22, 23, and 24.

The results that were created in the flotation cell system final form are shown in runs numbers HT37- HT42. The only difference between these runs and production design form will be the upward slanting feed piping and transition at the mixer box on the inlet to the first cell. This results in greater air addition and reject foam froth stability. A comparison of system power, hardware and space requirements between the final HARA-T Flotation system, the initial four-stage HARA-T Flotation system, and the I.I.M. Flotator is included on Figures 25, 26, 27, and 28. respectively.

COMPETITIVE DISCUSSION

In Deinking systems, Flotation cells can be the primary ink removal device. In this capacity, its performance is critical to the system efficiency, especially in M.O.W. to Fine Paper. The Hara-T needed to obtain a 95%/95% efficiency on ink particles and 90% on stickies particles to be saleable in the market. These requirements were issued as the goal of the program and it is a competitive value which permits Black Clawson to make good, credible proposals.

In the United States, the Voith Elliptical Flotation Cell, the Fiberprep Verti-Cell, the Beloit PDM and the IIM Black Clawson Flotator are the major players in the market. The Voith cell is probably the most popular cell, but it employs a pump between each step in the series consuming increased power in relation to other cells. The Verti-Cell is probably the cheapest unit on the market, but its efficiency is probably not in the same range as the other units or the Hara-T. The Beloit PDM was popular for a short period of time, but various operational factors hurt its operation, (mainly level control), resulting in poor efficiency. The Flotator is becoming more popular, but is an expensive unit, although the efficiency is excellent. Comparative runs of the Hara-T placed its efficiency approximately equal to the Flotator, and it is projected to be less expensive when manufactured.

Internationally, reports show that many of the same players are involved, but a few other competitors are making strides. The most interest seems to be in the Comer Flotation unit. This unit claims relatively high efficiency on large ink particles, improving the visual properties (by spec removal) in the finished pulp. In tests performed in the Black Clawson Laboratory, and discussed in other sections, this is probably a result of the neutral chemistry that the unit employs. The unit itself employs multiple spargers and a mechanical foam removal device. It is similar in design to the final two stages of the Hara-T.

The Hara-T has shown itself to be as efficient as the competition at a very marketable cost. The design, incorporating a mixer in the first step followed by two steps employing sparged air, results in a system where intermediate pumps are not necessary and a large volume of air can be brought in, (up to 275% on a three stage system and 365% on a four stage system). The analysis of hardware, space and power show that the final HARA-T Flotation system has marked advantages. Its flexibility also allows easy variations for optimizing news/magazine-to-news systems and sticky removal applications. In summary, the low cost combined with efficiency goals that are approximately equal to the highest efficiency unit in the market make this cell ready for market.

PROCEDURE FOR TESTING

The Hara-T Flotation cell was operated with various modifications and under various operating conditions to obtain the efficiency of 95% on small and large particles. The evaluation procedures that were used were very simple. First, the Hewlett Packard Scan-Jet 3c scanner was chosen because it not only could give repetitive results, but also allowed us to evaluate our results on a particles size basis automatically. The furnish of 50% M.O.W./50% PS-40 was chosen because it was an actual furnish mix that would be used and it had enough ink to make the results in all size ranges significant. Also, the contrast of the black ink to the primarily white furnish allowed the scanner to operate very effectively.

The furnish was never dispersed, which would have improved flotation cell efficiency, but would have prevented a significant number of ink particles in the large size ranges from being obtained. The furnish was pulped at approximately 15% consistency in the Lab Hi-Con pulper for each run. All chemicals were added at the pulper and pH was also adjusted here. The furnish was then screened by 0.006" or 0.008" PSP or PSL slots to remove the particles that were not necessarily ink. In some cases, the material was cleaned in forward and reverse cleaners, but this did not increase or decrease efficiency in the flotation cell. Materials were removed in the cleaners, but they needed to be operated at consistencies above normal so that an inlet consistency of 1.1% could be fed to the flotation cell. The Hara-T was then filled to the proper level and operated at the proper flow rate. Samples were taken at designated times corresponding to the retention time of the loop, (i.e. 4 minutes at a 300 GPM flow rate). Each time interval corresponded to one stage of operation in a commercial system. This procedure permitted the tests to show the effects of each stage on flotation efficiency. A reject sample was taken and reject flow rate was measured on the third step of flotation. Reject flow rate did vary depending on manual froth removal enthusiasm and water addition rate which controlled the fluid level of the cell. Trials were made as comparable as possible with one variable being changed at a time, as reflected in Table 7.

On the runs that were performed to remove stickies from the furnish (runs HT34 - HT36 on Table 7), a Softwood Bleached Kraft pulp was used with ethylene vinyl acetate hot melts being seeded into the furnish. The efficiency of their removal was determined by a count, due to the fact that the scanner was unable to distinguish between the background dirt and brown fiber and the stickies that were in the furnish. Tables 19,20 and 21 show the speck counts done for runs HT34 - HT36. The efficiencies of the counts showed that stickies can be removed at the required efficiencies in two stages if the flow is reduced to 135 GPM from 300 GPM. The efficiency of removal was 96% after two stages when the flow was

decreased. This shows great promise. The question which remains is whether the large volumetric reject rate improved efficiency on the removal of this contaminant. These hot melts had a specific gravity of 1.04 which should result in their sinking in the solution, but since hot melts can act differently than ink, this should be investigated further. Also, the type of hot melt, especially its wettability, will determine the effectiveness of its removal and under what conditions it can be removed best. The conditions for attachment and the pH may vary based on the type of sticky encountered.

The evaluation on ink particles was performed by making 8" by 8" square handsheets on the Williams handsheet mold. These handsheets were approximately 2 grams each in weight. Five handsheets were manufactured for each step in the flotation sequence and on the feed sample. These handsheets were then scanned and percent removal efficiency was determined by the average number of ink particles (in the size range) in the five feed handsheets minus the average number of ink particles (in the size range) in the five accept sheets divided by the average number of ink particles (in the size range) in the feed handsheets multiplied by 100. These results are shown in Table 7. Sticky removal efficiency procedure was described in the preceeding paragraph. These numbers showed that the project goal was met.

CONCLUSIONS

Due to the competition in the Deinking market and our selling restrictions due to licensing on Flotators in certain applications, the Hara-T Flotation cell was developed at a Deinking Summit held at Shartle Division. The result of the Deinking Summit was the design of the Hara-T Flotation cell.

The Hara-T was able to meet the requirements of the "95/95 Rule". The efficency of 95% on small particles was obtained when flowrate was reduced to 300 GPM or below. The height of the unit can be reduced as long as rise velocity is maintained during scale-up. The 95% removal of large particles was only accomplished with a change in system pH and chemistry. The unit had to be operated under neutral conditions for large particle separation. This was found also to be true of the comparative runs on the Flotator. The Hara-T obtained equal efficiency to the Flotator in competitive runs on the same furnish batch, but will gain its advantage on cost and sizing flexibility. The unit has not been priced at the time of this report, but has been estimated to be considerably less.

For the removal of stickies, the Hara-T shows excellent potential. The efficiency of removal in two stages is 96% on a run with seeded ethylene vinyl acetate hot melt. Further testing can provide more answers on the ability of this flotation cell to be used under the proper conditions to relieve the problem of small sticky removal.

Table 7: Data T. or All Test Runs

HARA-T Summary

Run #	Furnish	Chemicals	pH	Feed Flow gpm	Recirc Flow gpm	Cons. %	Mixer Air SCFM	Sparger Air SCFM	Total Air %	Level Feet	Hydraulic Rel Rate % FF	Pulp Rel Rate % FF	Mixer	Stages	Equipment M (Mixer)/S (Sparger)/# 1	2	3	4	Retention Time min.	Final Eff. (count) sub-TAPPI	Final Eff. (count) TAPPI	Comments
1	A	I	Alk	1400		1				10			Old	23	M	M	M	M	20	N/A	N/A	Questionable feed sample
2	A	I	Alk	1400		0.88				10	9.27%	8.06%	Old	7	M	M	M	M	8	N/A	N/A	Rotors not running
3	A	I	Alk	1400		1.01				10	7.10%	5.45%	Old	7	M	M	M	M	6	N/A	N/A	
4	A	I	Alk	1200	50	0.89		7		10			Old	4	M/S/1	M/S/1	M/S/1	M/S/1	4	53	29	
5	A	I	Alk	800	50	0.99		7		10			Old	4.5	M	M	M	M	7	82	58	
6	A	I	Alk	1000	40	1.15		11		10	42.00%	30.30%	Old	6	M/S/2	M/S/2	M/S/2	M/S/2	7	79	56	Injector A & B used
7	A	I	Alk	1300	90	1.16		13		10	21.10%	5.25%	Old	7.5	M/S/2	M/S/2	M/S/2	M/S/2	7	83	46	Calm on top
8	A	I	Alk	600		0.93				10	40.35%	17.40%	Old	3	M	M	M		6	N/A	N/A	
9	A	I	Alk	300		0.83	13.5		34	10	6.80%	13.60%	Old	6	M/S/2	M/S/2	M/S/2	M/S/2	24	96	94	Air coming in only to bottom of mixer box (for the rest of the runs)
10	A	II	Alk	300		1.1	10		25	10	19.17%	28.00%	Old	6	M	M	M	M	24	95	80	Top rotor not running, small amount of violence on surface
11	A	II	Alk	600		1.11	9		11	10	7.07%	5.80%	Old	4	M	M	M	M	8	82	55	Top rotor not running. Furnish was 3 days old
12	A	II	Alk	200		1.11	7.5		28	10	15.65%	23.80%	Old	3	M	M	M		18	91	67	Calm surface. Top rotor not running. Furnish 3 days old
13	A	II	Alk	300		1.27	6.5		16	7	47.50%	44.20%	Old	4.5	M	M	M	M	9	93	80	Top rotor not running
14	A	II	Alk	200		1.28	5		19	7	27.45%	50.00%	Old	3	M	M	M		9	93	76	Top rotor not running
15	A	II	Alk	300		1.2	19		37	7	17.87%	7.90%	Old	6	M	M	M	M	12	94	73	Violent Run. Top rotor not running
16	A	II	Alk	600		1.38	5		0	7	12.47%	19.90%	Old	4	M	M	M	M	4	72	48	Top rotor not running
17	A	II	Alk	600			0		0	7			Old	4								Top rotor not running
20*	A	II	Alk	300	104	1.29	15	18	217	10	11.39%	5.40%	Old	4	M/S/2	M/S/2	M/S/2	M/S/2	16	95	87	Inner pipe used for first time. Top rotor not running
21	A	II	Alk	400	105	1.2	15	17	155	10	3.70%	2.80%	Old	4	M/S/2	M/S/2	M/S/2	M/S/2	12	95	80	Top rotor not running
22	A	II	Alk	200	106	1.31	15	18	375	10	2.00%	3.88%	Old	4	M/S/2	M/S/2	M/S/2	M/S/2	24	96	86	Top rotor not running
23	A	II	Alk	300		1.15	11		77	10	31.73%	19.80%	Old	4	M	M	M	M	10	93	82	Both rotors running
24	A	II	Alk	300	104	1.15	0	20	109	10	12.55%	5.47%	Old	4	S/2	S/2	S/2	S/2	16	95	86	Rotors and air were off, just Spargers were used
25	A	II	Alk	300	170	1.12	15	19	227	10	4.13%	3.96%	Old	5	M/S/3	M/S/3	M/S/3	M/S/3	20	93	79	Air was turned down in Acc 5
26	B	II	Alk	300	235	1.15	15	18.5	222	10	11.19%	4.40%	Old	4	M/S/2	M/S/2	M/S/2	M/S/2	16	94	76	Clean furnish run
27	C	II	Alk	300	207	1.11	15	19	227	10	8.57%	3.23%	Old	4	M/S/2	M/S/2	M/S/2	M/S/2	16	N/A	N/A	Hot Melts (results were not good)
28	C	II	Alk	175	120	1.09	15	18.5	380	10	8.69%	4.43%	Old	3	M/S/2	M/S/2	M/S/2	M/S/2	18	N/A	N/A	Hot Melts (results were not good)
29	A	III	Neu	300	231	0.95	15	20	237	10	25.41%	13.41%	Old	4	M/S/4	M/S/4	M/S/4	M/S/4	16	96	92	Neutral Deinking. Good results!
30	A	III	Neu	300	120	0.95	15	19.5	232	10	34.36%	20.70%	Old	4	M/S/4	M/S/4	M/S/4	M/S/4	16	97	94	Neutral Deinking. Good results!
31**	A	III	Neu	300	120	0.95	15	18	217	10	30.24%	18.20%	Old	4	M/S/3	M/S/3	M/S/3	M/S/3	16	96	93	Neutral Deinking. Good results! Top part of center pipe taken out
32	D	IV	Neu	300		0.94				10	21.90%	8.60%	New	4	M/S/4	M/S/4	M/S/4	M/S/4	16	98	94	Direct comparison to IIM
33**	D	IV	Neu	300		0.97				7	59.29%	18.90%	New	4	M/S/2	M/S/2	M/S/2	M/S/2	8	97	89	
34**	C	V	Acid	300		1.13				7	19.51%	14.20%	New	4	M/S/3	M/S/3	M/S/3	M/S/3	8	Visible Count 72		Hot melts
35**	C	V	Acid	300		0.72				7	23.91%	41.70%	New	4	M/S/3	M/S/3	M/S/3	M/S/3	8	Visible Count 90		Hot melts
36**	C	V	Acid	135		0.68				7	45.84%	18.20%	New	4	M/S/3	M/S/3	M/S/3	M/S/3	16	Visible Count 99		Hot melts
37**	A	IV	Neu	200	270	1.12	15	38.5	632	7	1.20%	4.20%	New	4	M/S/3	M/S/3	M/S/3	M/S/3	12	97	95	Four stage, mixers and spargers in every stage
38**	A	IV	Neu	200	277	1.14	15	39	639	10	4.60%	8.90%	New	4	M/S/3	M/S/3	M/S/3	M/S/3	24	98	98	Four stage, mixers and spargers in every stage
39**	A	IV	Neu	200	280	1.15	30	37.5	533	10	9.20%	8.30%	New	3	M	S/3	S/3	S/3	18	97	94	Three stage system, 1 mixer & 2 spargers
40**	E	VI	Alk	200	245	1.13	52.4	40.5	802	10	1.00%	1.96%	New	4	M/S/3	M/S/3	M/S/3	M/S/3	24	Brightness Gain +8.2		Four stage, mixers and spargers in every stage
41**	E	VI	Alk	200	245	1.12	44.9	42	639	10	1.60%	3.22%	New	3	M	S/3	S/3	S/3	18	Brightness Gain +5.5		Three stage system, 1 mixer & 2 spargers
42**	E	VII	Neu	200	244	1.07	37.4	41	600	10	3.50%	4.92%	New	3	M	S/3	S/3	S/3	18	Brightness Gain +6.2		Neutralized, Three stage system, 1 mixer & 2 spargers

Furnish

- A — 50% MOW/ 50% White Ledger
- B — 50% Nu-Con Pulp/ 50% Bleached Softwood Kraft
- C — Bleached Softwood Kraft
- D — Mixed Office Waste
- E — 70% News/ 30% Magazine

Chemicals

- I — 0.2% L-727 0.6% NaOH, 0.1% DTPA, 0.3% H_2O_2, 1.0% Na_2SiO_3
- II — 0.2% L-727 1.0% NaOH
- III — 0.6% Serfax 0.035% $CaCl_2$
- IV — 0.6% Serfax
- V — 0.2% L-727 & H_2SO_4
- VI — 0.2% L-727 0.5% NaOH, 0.1% DTPA, 0.3% H_2O_2, 1.0% Na_2SiO_3
- VII — Same as VI with addition of H_2SO_4 to Neutralize

* All runs after HT20 were done with the center pipe inserted
** Denotes shorter center pipe

APPENDIX XIV

The Black Clawson Company
Shartle Division - Technology Center
Middletown, Ohio

September 15, 1995

Report Number: 36,023

Wax Removal Studies

For:

Thermo Black Clawson, Inc.
Middletown, Ohio

By:

Don Scott

Thermo Black Clawson Distribution

W. J. Fondow/ P. Seifert / R&D Files
A. F. Kelly/ D. E Chupka/ R&D Files
J. C. Kerr/ Business Development Mgrs./
Applications Engineers/ R&D Files
N. E. Lacey (2)
J. Canon/ K. Kobelt
M. A. Sieron/ R&D Files

Customer Distribution

Wax Removal - General

Objective

Evaluate removal of wax contamination using various methods both with and without a prior dispersion step.

Status

Testing complete.
Report in progress.

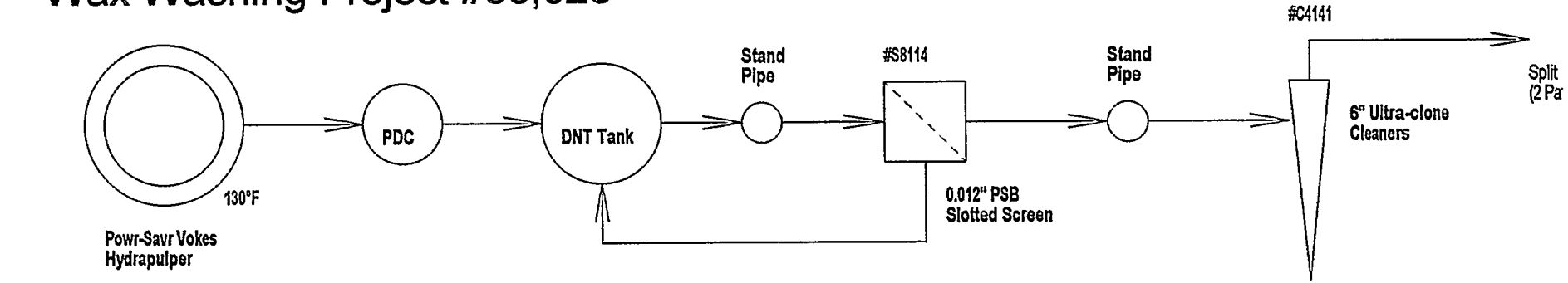
Results

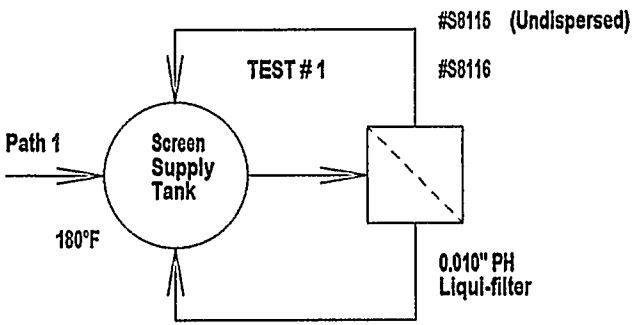
A moderate degree of wax removal is possible using the methods tested.
Inclusion of a dispersion step showed slight improvement in removal efficiency.
Although wax levels were still somewhat high in the final pulp, this may be acceptable in certain situations.
Water handling will be an issue, although this was not explored in the pilot plant tests.

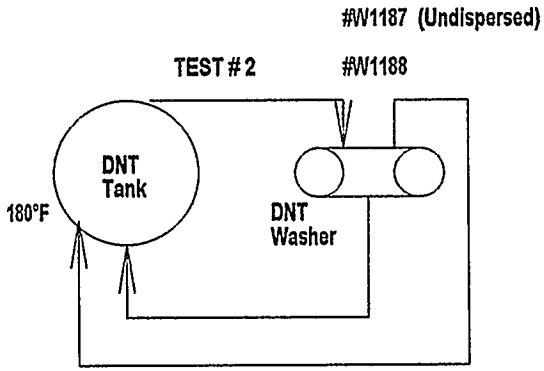
Advantages

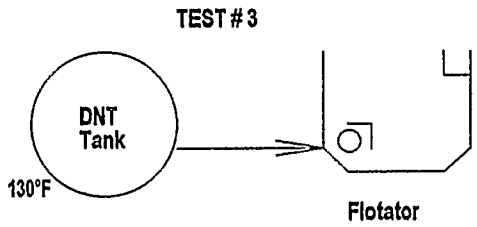
Wax levels can be reduced using currently available equipment.
Use of the Ultra Twin-Flyte kneader can improve the effectiveness.
Due to rising furnish costs, some mills are exploring the possibility of a 'satellite' system to process wax coated and other difficult or low-grade furnishes.

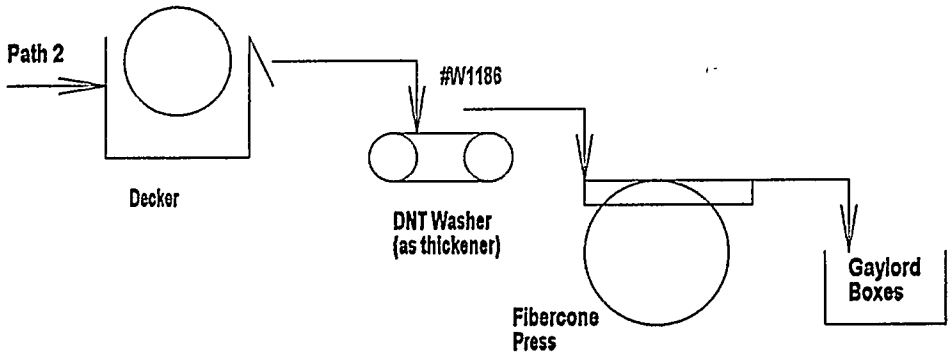
FLOW DIAGRAM -
Wax Washing Project #36,023

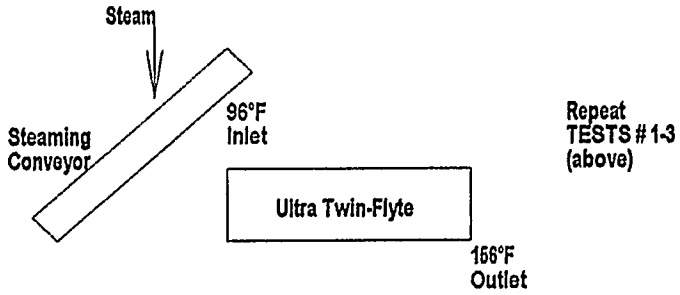




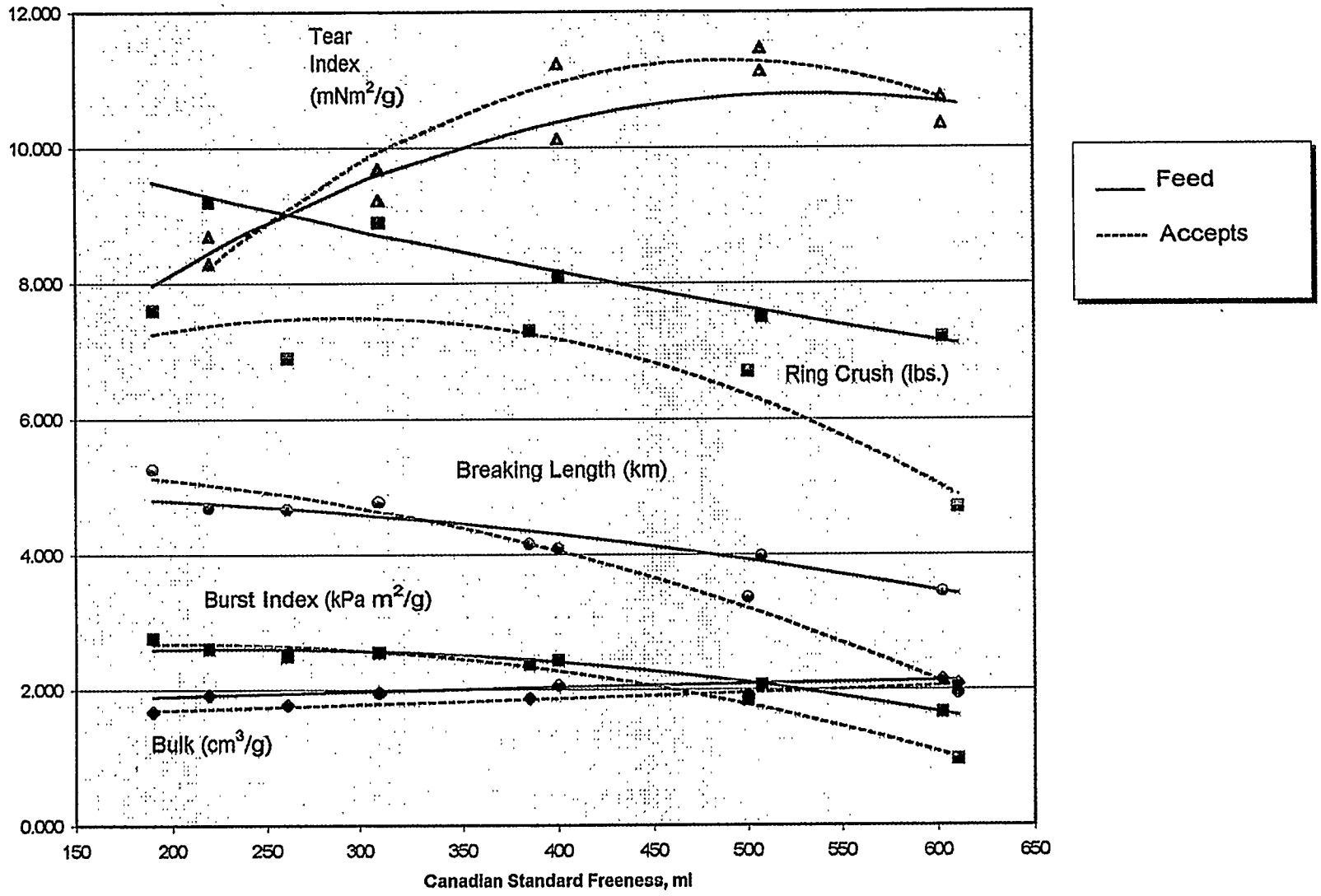








Strength Properties Comparison
Kneader Feed and Accepts

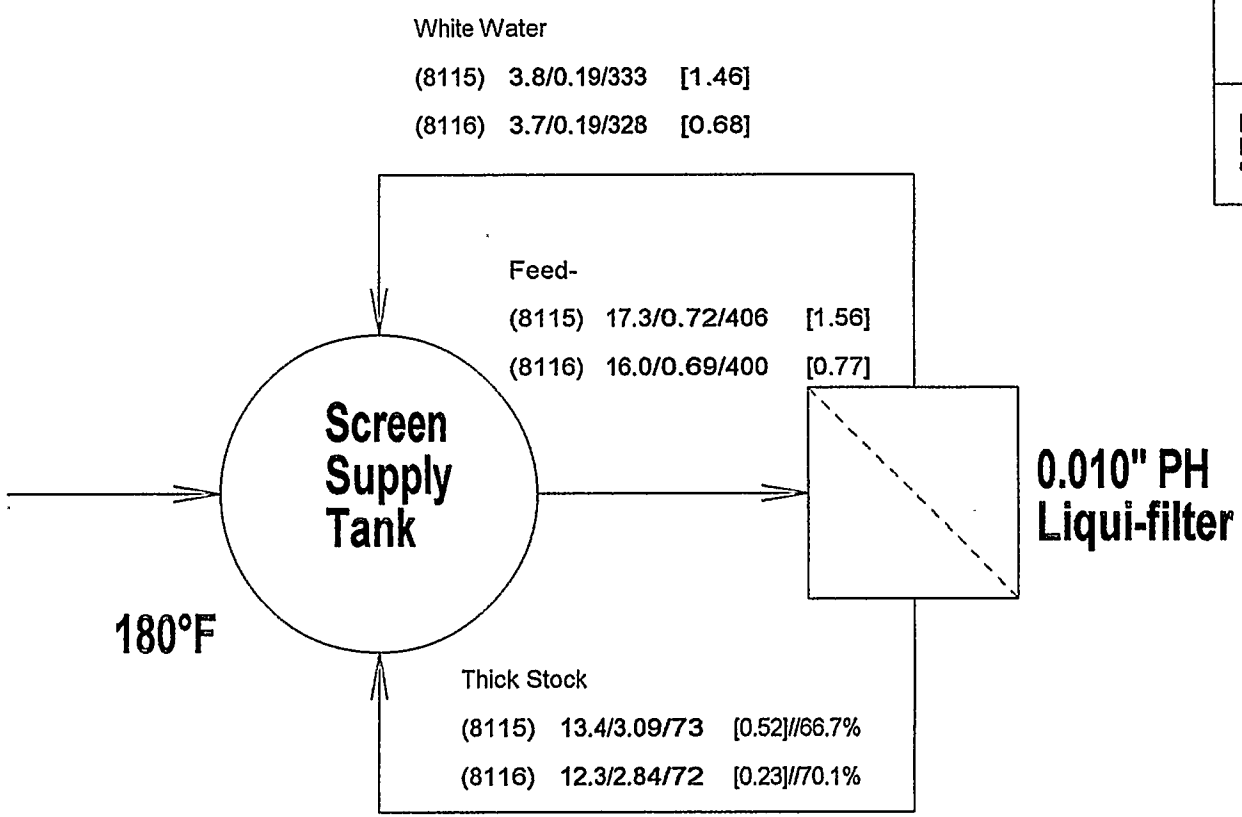


Wax Washing Trial
Project Number 36,023

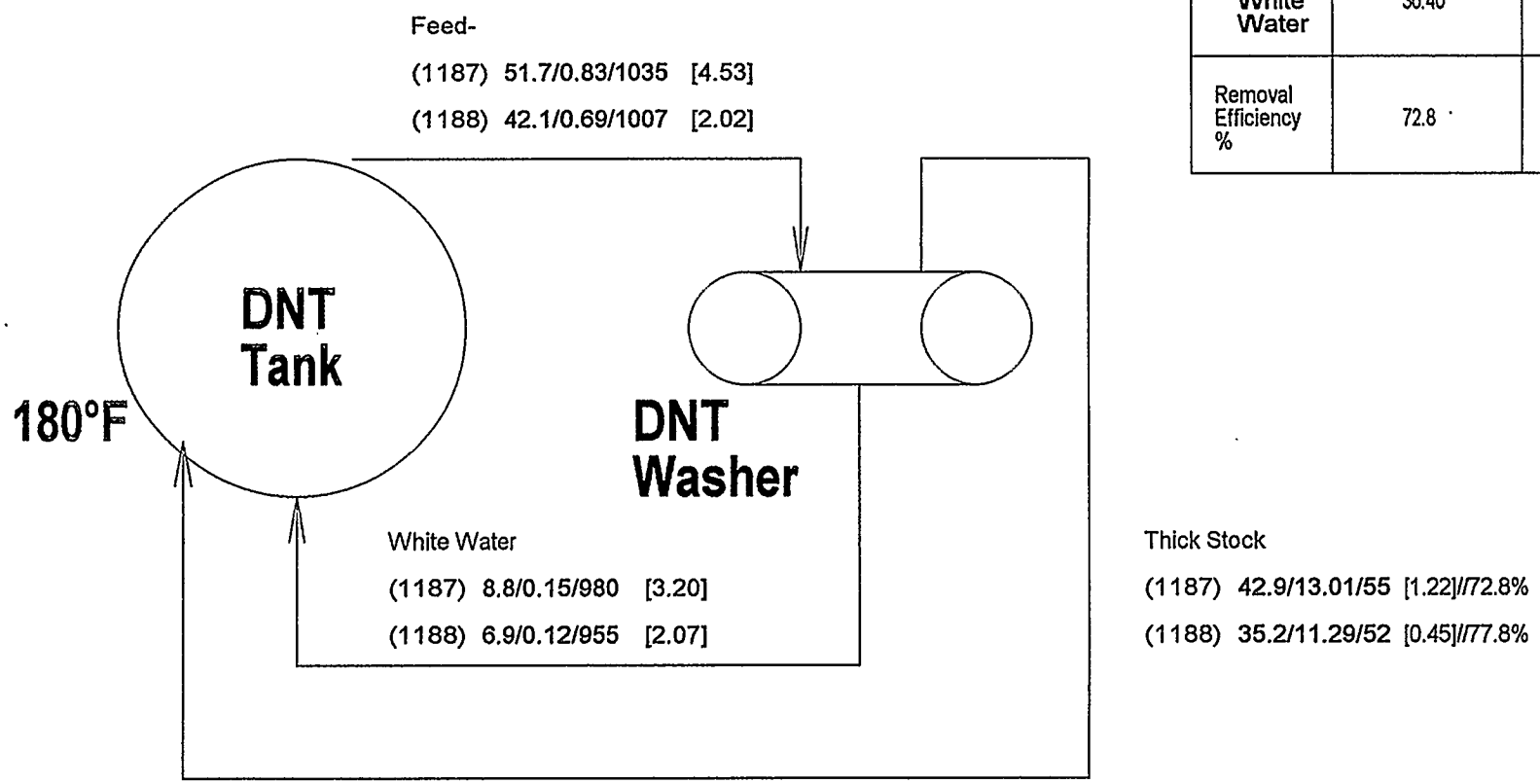
TEST #1
Liqui-filter

8115 - Undispersed
8116 - Dispersed

	Wax Content, %	
	8115	8116
Feed Stock	9.01	4.79
Thick Stock	3.88	1.86
White Water	38.61	18.36
Removal Efficiency %	66.7	70.1



TEST #2
DNT Washer

1187 - Undispersed
1188 - Dispersed

	Wax Content, %	
	1187	1188
Feed Stock	8.77	4.79
Thick Stock	2.84	1.28
White Water	36.40	29.93
Removal Efficiency %	72.8	77.8