"A Cost Effective Deinking System For Production of Pulp Substitute For Use As Furnish in Fine Papers"

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ABSTRACT

This Paper will outline the philosophy of system designed to fit the requirements of producing a Pulp substitute to be a part of the furnish of high grade fine papers.

Deinking is essentially a separation process. Object here is to separate the ink and the other contaminants from the fiber. Over a period of two decades contaminant removal and fiber reject rate have directed the development of all new separation equipment and systems for recycling of secondary fiber.

Description of unit operations stage by stage and chemistry of each stage is discussed for a simple cost effective system

INTRODUCTION

Raw material availability at affordable cost is the prime concern and constraint for Indian Pulp & Paper Industry.

Deprived of the facility for growing captive plantations in waste lands, Indian Paper Industry has to depend heavily on agro-residues like bagasse and waste paper.

Bagasse once through of as a waste material in Sugar Mills is no more available easily for paper making-as Sugar Mills are encouraged to go in for cogeneration. In Maharastra and elsewhere a few bagasse based mills are closed or have curtailed their production for want of bagasse. Cultivating sugar cane is said to be shrinkling for various reasons.

Indian Paper Mills have been traditionally using waste paper of all grades. In addtition substantial quantities are being imported in to India from Overseas.

To meet the demand in the coming years Indian Industry will be forced to use more and more waste paper by recycling as well as by imports.

The Paper Mills which are not presently using waste paper will be forced to go in for this. Those which are using small amounts will be required to increase the use of Recycled fibers.

ADVANTAGES & CHALLENGES IN USING DEINKED FIBER

Deinked fiber can be cost-effective component

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of a paper furnish, and such fibers have been used successfully in the manufacture of several paper grades, primarily Newsprint and Tissue. Use of Deinked Pulp in furnishes will bring down the specific power consumption, capital required, and effluent treatment costs compared to a pulp mills from 100% virgin fibers.

Deinking technology in its present state of development, is well equipped to remove cost contaminants and inks. However the advent of new printing techniques and the complex ink formulations in use today have made ink removal a challenging task.

Technical challenges involved in greater and better utilisation of waste paper is improving the quality of these fibers to the same level as that of Virgin fiber that is being replaced.

The difficulties for countries like India will be that they will be forced to deal with ever decreasing quality of waste paper (both imported and indigenous) as time goes on.

IMAGE ANALYSER

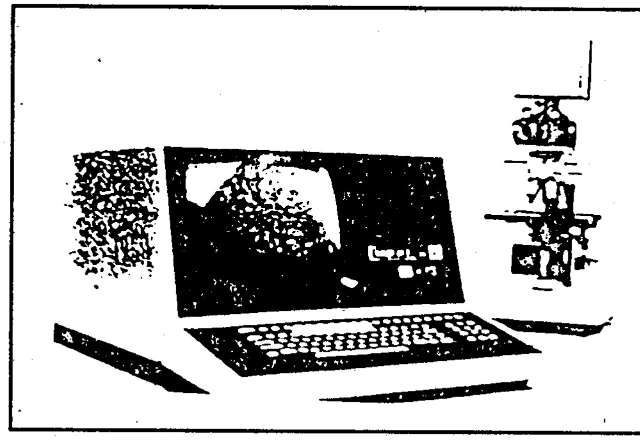
To meet this challenge deinking systems must be sophisticated. To make this philosophy viable, fundamental understanding of the mechanisms of the separation of contaminants from pulp should be developed. To obtain this understanding the following three critical stages are required.

1. Development of analytical techniques to determine the nature and concentration of the contaminants.
2. Determination of the major parameters that control the separation process for each specific operation.
3. Optimization of these controlling parameters.

This programme has contributed to the development of a new generation of highly efficient contaminant removal devices. These unit developments have in turn lead to major improvements in system design. These developments have enabled the efficiency of contaminant removal to be increased and the reject rate to be reduced for individual separation units. The amount of reject material to be treated in the secondary stage is very significantly reduced.

In the period 1978-81 an exhaustive investigation evaluating all possible methods that could be utilised to determine these contaminants, was carried out. These studies showed that the application of *"Automatic Image Analysis"* (FIG.1) techniques would enable reliable and reproducible methods to be developed.

FIG. 1



Since 1981 image analysis have been used on a daily basis to determine contaminant removal efficiencies of screening, cleaning and deinking systems and units. In development of new units in this field :Automatic Image Analysis" has played an important fundamental role.

DEINKING SYSTEM

The washing and flotation operation require chemicals to help them perform efficiently. Strategies for efficient deinking must therefore include an evaluation of both the chemical and equipment involved.

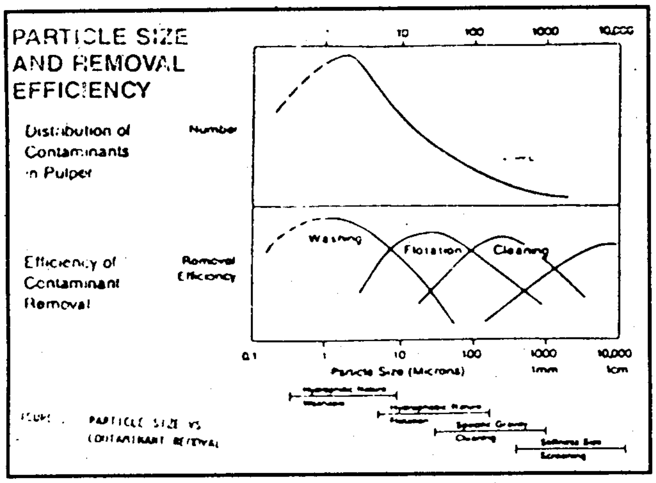
PARTICLE SIZE AND PROCESSES TO REMOVE INK PARTICLES

The philosophy of the system design arises from over ten years of careful study of the deinking processes. Once removed from the fibre the ink exists in the pulp slurry in a wide selection of particle sizes (FIG. 2).

Washing is most effective on the smaller particles below about 10 microns.

Flotation Between 10 and 100 microns (1.0 mm).

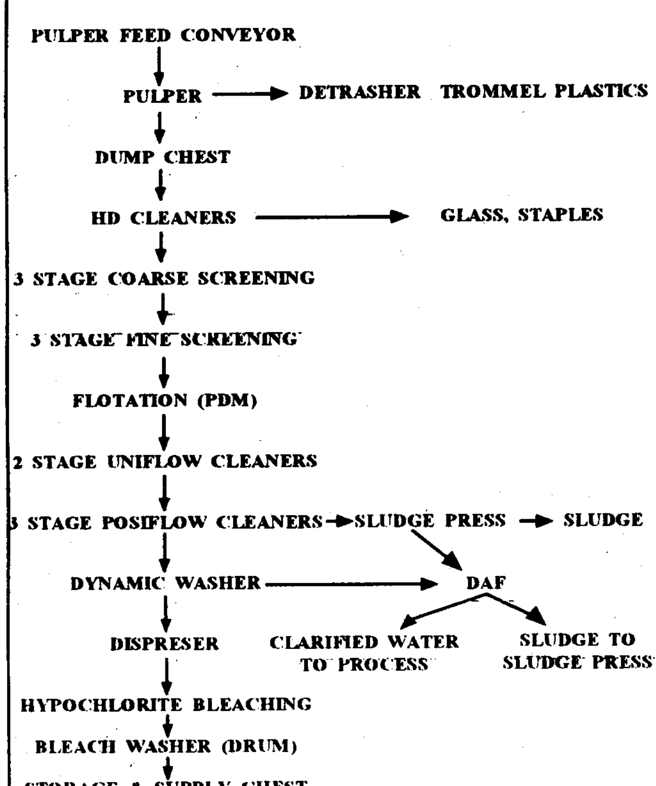
FIG. 2



Cleaning operation is effective for separation of particles, over 100 microns and conducive to gravity separation.

A modern deinking plant will probably contain most of those separation techniques for the removal of ink and other contaminants.

FIG.17



COST EFFECTIVE DEINKING SYSTEM (FIG. 17)

The deinking system suggested for production of pulp substitute for furnish in fine papers is shown in the above figure. The only change made here is that a side hill screen is proposed as an alternate equipment to the dynamic washer.

UNIT OPERATIONS & CHEMISTRY

Pulper and Belpurge Unit

Pulping in batch pulpers gives the best control of chemical addition and defibering. The consistency best suited for office paper containing xerox and laser type inks is between 14% and 18%. This is achieved in a Helidyne pulper fixed with a helical rotor. Fiber-fiber rubbing action is the key principle involved for dispersing new impact inks. Temperature should be held below about 40°C so that plastics hot melts and stickies do not soften, which makes them more difficult to remove. Soft materials can be forced through screens whereas harder, unflexible materials are more easily rejected.

DETRASHING UNIT

The pulper is equipped with a detrashing unit. The defibered pulp at the end of pulping cycle is diluted to 4-5% consistency and taken out through the detrasher. The detrasher goes through several wash cycles in which clarified water is used to wash the plastics. The heavy weight materials are dumped through a double valve dump arrangement through which the light weight materials are purged to a trommel unit for the separation of plastics and fibers.

PULPER CHEMISTRY

Deinking chemicals are added to each batch in the pulper to modify the environment in such a way to optimise ink removal.

The principal chemicals involved in the pulper are: Sodium hydroxide, Sodium silicate, Chelating agents, Hydrogen peroxide, Surfactants (FIG. 3).

SODIUM HYDROXIDE (NaOH)

Sodium hydroxide is used not only to adjust the pH to the alkaline region, but to saponify and/or hydrolyze the ink resins. The alkaline environment is often reported to "swell" the fibers. This term is more descriptive than reality. At the pH conventionally

FIG. 3

Pulper Chemistry

Typical Formulation

. Caustic Soda (NaOH)
. Sodium Silicate (Na_2SiO_3)
. Hydrogen Peroxide
. Chelant
. Surfactant

FIG. 4

Caustic Soda

NaOH

. Raises pH
  . Aids in Ink Release
  . Activates Hydrogen Peroxide
  . Modifies Additives & Contaminants
Causes Yellowing in Mech. Fiber
  . Lignin release
  . Peroxide prevents yellowing
. Alternatives
  . Soda Ash
  . Sodium Silicate
  . Ammonia

used for pulping, 9.5-11.0, the fibers would take up some water and become more flexible, rather than puff up lime cellulose ballons (FIG.4)

The addition of caustic soda to wood-containing furnishes will cause the pulp to yellow and darken. This is a phenomena that is often referred to as "alkali darkening."

The problem with alkali darkening is only of concern with wood containing furnishes Higher pH is (11.0) can be used with wood free furnishes with no alkali darkening.

HYDROGEN PEROXIDE

Hydrogen peroxide is usually added to prevent yellowness to strip the colour and to increase the brightness.

The decomposition of peroxide can be reduced by the addition of "stabilizing" agents such as chelants and sodium silicate.

FIG. 5

Hydrogen Peroxide

H_2O_2

. Prevents Mech. Fiber Yellowing at high pH
. Bleaching at med-high cons.
. Alternatives (Reductive)
  . Sodium Hydrosulfite
  . Formamidine Sulfinic Acid (FAS)

Hydrogen peroxide is also used as post bleaching agent. The balance between how much peroxide should be added in the pulper versus how much in the bleaching stage must be optimized for each furnish. It should be remembered that the peroxide is added to the pulper simply to offset the formation of chromophores created by the alkaline pH (FIG.5).

CHELATING AGENTS

DTPA (diethylene triamine penta acetic) is the most commonly used chelant but EDTA (ethylene diamine tetra acetic acid) is also used. The role of the chelant is to form soluble complexes with heavy metal ions. The complexates prevent these ions from decomposing the hydrogen peroxide (FIG.6).

SODIUM SILICATE (Na_2SiO_3)

The Sodium silicate most commonly used in deinking mills is at 41.6^0 Baume solution of sodium metasilicate which contains roughly equal amounts of SiO_2 and Na_2O (FIG.7)

FIG. 6

Chelants

I. Functions

Metal Ion Chelation
Peroxide Stabilization
Assist in Preventing
Brightness reversion

Silicate aids in deinking through an ink dispersant action or by preventing the ink from redepositing on the fibre surface. The anti-redeposition effect is what made silicate popular in laundry soaps. The dirt or soil was emulsified and prevented from sticking back on the clean wash.

FIG. 7

Na_2SiO_3

- Buffers pH
- Stabilizes Hydrogen Peroxide
  - Complexes with Metals
- Aids in Ink Dispersion
- Alternatives
  - Phosphates
  - Chelants

FIG. 8

I Definitions

- "Surfactant" = Surface Active Agent
- "Hydrophilic" = Water - loving
- "Hydrophobic" = Water - fearing

FIG. 9

Surfactants

III Functions

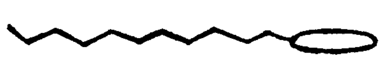
- Detergency
- Dispersion & Emulsification
- Collection
- Frothing (Foam Stabilization)

FIG. 10

Surfactants

II Structure

Hydrophobic "Tail"



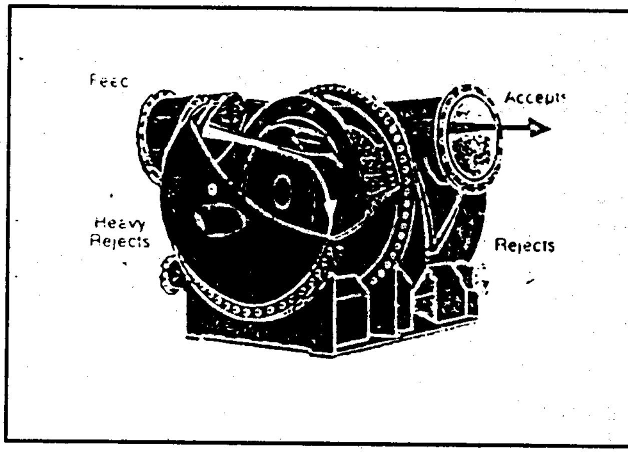
Hydrophilic "Head"

The fact that silicate is a source of alkalinity and will affect the pH must be kept in mind when adjusting the pulper chemistry. Increasing the silicate will increase the pH and this may call for a reduction in the sodium hydroxide addition rate.

AGGLOMERATING CHEMICALS

These products are relatively new on the market and are used for deinking fused toner papers such as laser and xerox print which are found in office waste.

FIG. 11



Typical Recycling Plant Screen (Beloit Corp.)

SURFACTANTS (FIG.8)

The term surfactant is derived from their functioning as *surface active agents*. "Surfactant" is a catch all term that covers uses like dispersants, collectors, wetting agents, displectors, anti-redeposition aids and the like (FIG.9)

Surfactants that are used for deinking will have two principal components - a hydrophilic and a hydrophobic component (FIG.10). During flotation, the hydrophobic end will associate with the ink oil and dirt while the hydrophilic end will remain in the water.

Some of the most common surfactants used in deinking are the Eo/Po copolymers (ethylene oxide/ propylene oxide). The hydrophilic (water liking) is the ethylene oxide and the hydrophobic (water hating) end is the propylene oxide end.

DISPERSANTS

Dispersants are products whose function is take the ink and dirt particles that have been freed during the pulping operation and keep them in suspension, such that they can be removed during a washing or thickening stage. The name of these products well defines their action. Dispersants are primarily found in wash deinking mills and for the newer "short sequence" deinking processes.

H.C. CLEANERS

The high consistency cleaning and coarse screening loop is fed from the pulper dump chest and usually operates at 3 to 5% consistency.

H.C. Cleaner is designed to protect the screen from large heavy contaminants such as glass, stones, nuts and bolts. These contaminants collect in rejects sump which is periodically flushed and dumped.

COARSE AND FINE SCREENING (FIG.11)

The H.C. cleaner accepts go direct to the primary coarse screen which has 1.4 mm diameter holes, though other sizes may be chosen to suit a specific application.

Accepts of the screen are directed to the Coarse Screen Accepts Weir Box, and the rejects are discharged to an agitated Secondary Coarse Screen Feed Tank. Rejects are diluted and pumped to Secondary Coarse Screen, equipped with a 0.047" (1.2 mm) holes perforated basket. The accepts from the secondary coarse screen join the Primary Coarse Screen Accepts at the coarse screen accepts Weir Box. The secondary coarse screen rejects are discharged directly to the special weir box which directly feeds the tertiary screen.

The tertiary screen is a Separplast screen. The separplast Screen is designed to separate coarse contaminants such as plastic polystyrene foam and hot melt from usable fiber. The rejected material is concentrated and rejected at atmospheric conditions and forwarded to the rejects handling system. Accepted material is fed to the secondary coarse screen feed tank.

FIG. 12

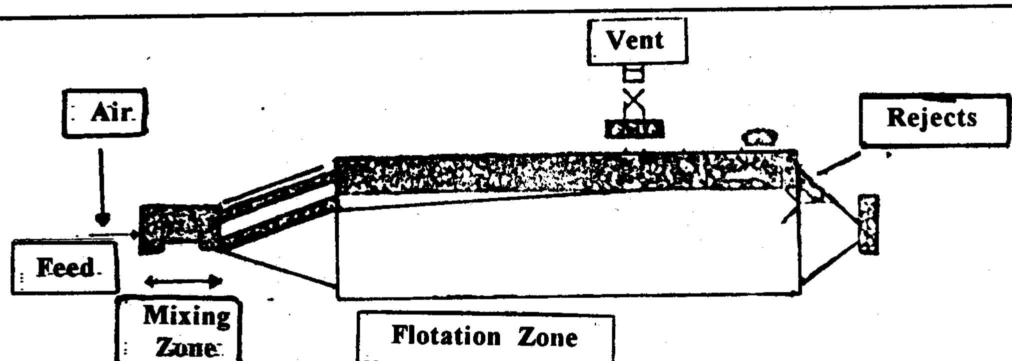


Figure-12 PRESSURISED DEINKING MODULE PDM-1

FIG. 13

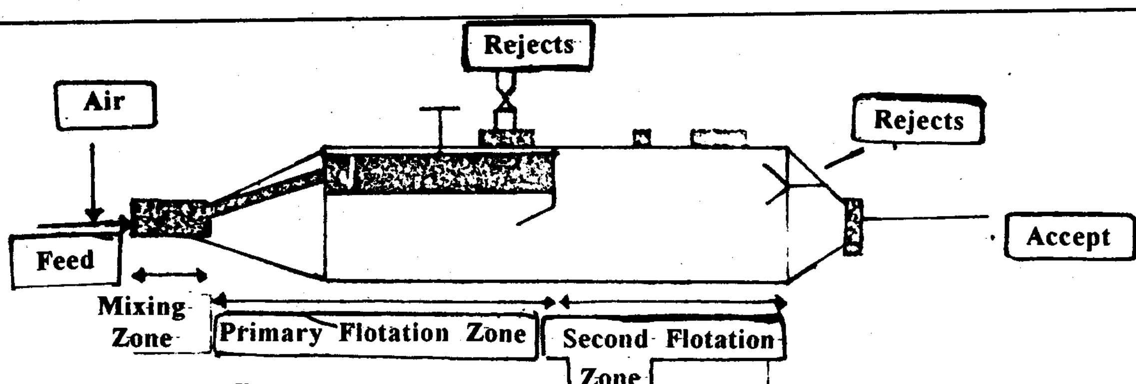


Figure-13 PRESSURISED DEINKING MODULE PDM-1I

FINE SCREENING

Accepts from the coarse screen Accepts Weir Box flow to the Fine Screen Feed Tank; Consistency will be adjusted and pumped to the Primary Fine screen. This unit is a MR 48 screen, equipped with a 0.004" (0.1 mm) slots. Accepts from the Primary Fine Screen will flow to the Fine Screen Accepts Weir Box. Rejects will flow to the Primary Fine Screen Rejects Tank.

The contents of the Primary Fine Screen Rejects Tank will have the consistency adjusted and pumped to the Secondary Fine Screen. The screen will be equipped with a 0.004" (0.1 mm) slotted basket. Accepts will be returned to the Primary Fine Screen Rejects Tank and the rejects will be discharged to the rejects handling system.

DEINKING MODULE-PDM

PDM-FLOTATION

Flotation is a three stage process-collision, attachment, and separation. Ink particles and air bubbles collide in the first stage. In the second stage the ink particles and air bubles become attached. The air bubbles and ink are separated from the pulp.

PDM is one of the most innovative developments in deinking technology in the last ten years.

1. Deinking efficiency is improved by using a pressure to maximize the ink particles and air bubbles become attached. The air bubbles and ink are separated from the pulp.

2. Runnability is improved by using pressurized level control strategy as well as pressurized rejects removal system.

3. Maintenance is minimized because the air in take system does not require the use of ventury devices which are prone to plugging.

4. The sealed design of any potential air pollution problems.

WORKING OF PDM 1 (FIG.12)

Air is added to feed pulp just prior to a *mixing zone* where high turbulence serves to form the froth. It is primarily here that the work of forming bubbles and creating bubbles to particle, *collision, occurs.* This is where the hydrodynamic conditions promote bubble formation and *attachment* of ink particles to bubbles. Of course, surface chemistry must be right for this process to be efficient and for the stability of the ink bubble attachments.

After the mixing zone bubbles rise in a less turbulent flotation zone to form surface froth which is *separated* at the reject weir and removed through the reject valve.

The process operates under positive typically 1-2 bar with higher pressures for those situations where there is a second series PDM cell without an inter stage booster pump.

Rejects froth is expelled through the reject valve and passed through a separator cyclone to separate excess air from the collapsed foam. Rejects are then transferred to a sludge collection chest for further processing and disposal.

Level control is accomplished by means of an automatic control valve at the vent position which responds to a differential pressure level sensor system. The vent control valve opens incrementally in response to sensing a level below the set point or closes incrementally in response to sensing a level above the set point.

NEXT GENERATION PDM II- DESIGN MODIFICATIONS (FIG.13)

Four specific design changes comprise the PDM II CONFIGURATION

1. Flow baffles, 2) New Reject Weir, 3) Small recirculation stream, 4) New type & position of level sensor.

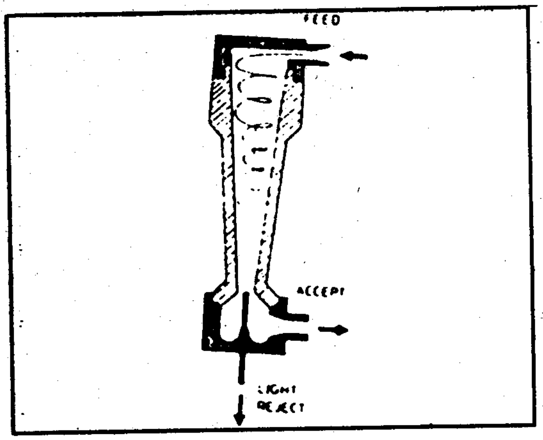
The benefits from PDM II improvements include-

Increase in brightness gain, Increase in ink speck removal, Decrease in rejects or yield increase. Improvement in automatic level control & Significant production capacity increase.

UNIFLOW CLEANERS (FIG.14)

Accepts from the PDM's will flow to the cleaner stock tower. The Accepts are reduced in consistency to approximately 0.8% and fed to the Primary Uniflow Cleaner. The Uniflow Cleaner is designed to remove lightweight contaminants in the pulp slurry. Accepts from the Primary Uniflow Cleaners flow to the suction standpipe feeding the Posiflow Cleaners.

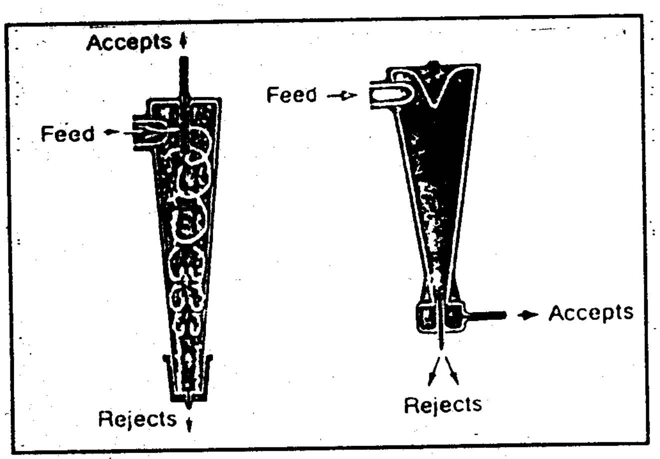
FIG. 14



Rejects of the Primary Uniflow Cleaners are discharged to the secondary Uniflow Cleaner feed pump suction. The stock is then pumped to the Secondary Stage Uniflow Cleaners. Accepts of the Secondary Uniflow Cleaners are returned to the PDM Feed Standpipe Rejects of the Secondary Uniflow cleaners are fed to the clarifier feed chest.

A *reverse cleaner* normally separates the feed stock into two fractions an accept and a light reject. The Stock fed tangentially, the accept fraction is taken from the bottom and the light reject is taken from the top of the cleaner but in the uniflow cleaners. Both the accepts and reject fractions are taken from the bottom (FIG.15).

FIG. 15



Centrifugal Cleaners for Contaminants with sg >1 (Left) and sg <1 (right) (Beloit Corp.)

The uniflow has a mass reject fraction of 2% whereas conventional reverse cleaners can reject up to 40% by mass. Consequently, these rejects have to be treated to save the usable fibre and complicated counter current cascade systems are usually employed. In actual practice, this means that there is a compromise. The cleanning efficiency of the cleaner system is considerably reduced compared to the single cleaner unit in an attempt to increase the yield. Thus, a reverse cleaner installation can be up to 3 times larger than a Uniflow installation which requires a very limited reject treatment.

POSIFLOW CLEANERS

Accepts from the Uniflow cleaners flow to the cleaner stock tower. The Accepts are reduced in consistency to approximately, 0.72%, and fed to the Primary Posiflow Cleaner. The Posiflow Cleaner is designed to remove small heavy weight contaminants in the pulp slurry. Accepts from the Primary Posiflow Cleaners flow to the suction of a booster pump feeding the dynamic washers.

Rejects of the Primary Posiflow Cleaners are discharged to the secondary Posiflow Cleaner feed pump suction. The stock is then pumped to the Secondary Stage Posiflow Cleaners. Accepts of the Secondary Posiflow Cleaners are returned to the Primary Posiflow Feed Standpipe.

Rejects of the Secondary Posiflow Cleaners are discharged to the Teritary Posiflow Cleaner feed pump suction. The stock is then pumped to the Tertiary Stage Posiflow Cleaners. Accepts of the Tertiary Posiflow Cleaners are returned to the Secondary Posiflow Feed pump suction. Tertiary Posiflow rejects flow to the rejects collection tank.

DYNAMIC WASHER

Accepted stock from the Primary Cleaners is fed to the Dynamic washer. In the Beloit Dynamic Washer stock is washed between a rotor and a finely perforated filter.

The shear gradient between the rotor and the filter media keeps the stock under continuous agitation, preventing a fiber mat from forming. The wash water (filtrate) passes through the filter while the thickened stock (washed stock) passes to the discharge located at the back of the unit. No external dilution or showers are required.

The stainless steel filter media has perforations of 0.20 mm diameter. The rotor is a Bump rotor of a special design.

Washed stock from the Dynamic Washer will flow to a constant level head box feeding the inclined screw press at approximately 3-3.5% consistency. The filtrate will have the capability to the sent either to clarification or be recycled as dilution water. This is to enable control of the over all ash removal and system yield. However the clarifiers have been sized for 100% clarification of the filtrate.

This revolutionary little machine removes up to 95% of contaminants with just one washing stage compared to about 70% with typical drum or nip-type washers.

This compact dynamic washer is the ideal system for today's deinking plants.

One key to this efficient design is our unique perforated filter which removes a wide variety of inks, filters and other fine debris up to 50 microns in size.

THICKENING AND KNEADER DISPERSION

The inclined Screw thickeners will increase the consistency from 3-4% to approximately 10-12%. From the thickening device, the pulp is fed to a Screw Press. Consistency will be increased to approximately 25-30%.

The thickened stock will then be processed with a Kneader disperser. Stock will be discharged from the dispersion unit to an Medium Consistency Standpipe where dilution water will be added reducing the pulp from 30% to 10-12% consistency. The stock will then be pumped to a high density storage.

When a given area of a white sheet of paper contain 10 specs each, 200 micron in diameter, although it may be unacceptable in quality, it maintains its high brightness. If we take these ten 200 micron specs and break them down to 25,000, 4 micron size particles (occupying the same area) although each particles will be invisible to the eye, the overall reflectance of the sheet (or its brightness) will be lower.

When using dispersion for aesthetic reasons one must be careful not to use it as a substitute for ink removal. In many instances it becomes important to first remove the maximum possible amount of ink, use dispresion on the remaining larger particle, sizes, and reapply removal on the dispersed stock with particles readjusted in size to a removal efficiency range.

If dispersion is applied prior to any ink removal, some of the easily dispersible inks can over disperse, thus creating removal problems later on. Therefore, as a general rule, the bulk of the ink removal should always take place before dispersion.

Dispersion has been used successfully on inks that are difficult to remove, such as ultraviolet inks, xerographic inks, and jet-print inks. This dispersion has been achieved at both medium consistencies (10-14%) and high consistencies (25-35%). Temperate for ink dispersion range from 120° F to 190° F. Good results have been obtained at 120° F, but there is some indication that higher temperatures (170-190° F) improve the dispersion of stickies and hot melts.

KNEADER Dispersion process will not decrease the freeness. The bulk and porosity of the paper increases due to curl. This is an ideal machine for tissue making.

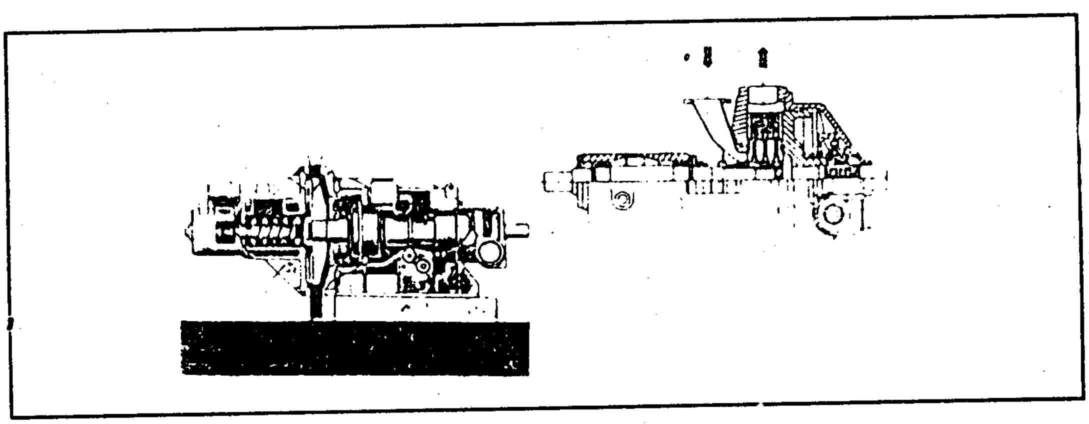


FIG. 16 Dispersel/Retainer: High Consistency Unit (left) and low consistency multidisk (right).

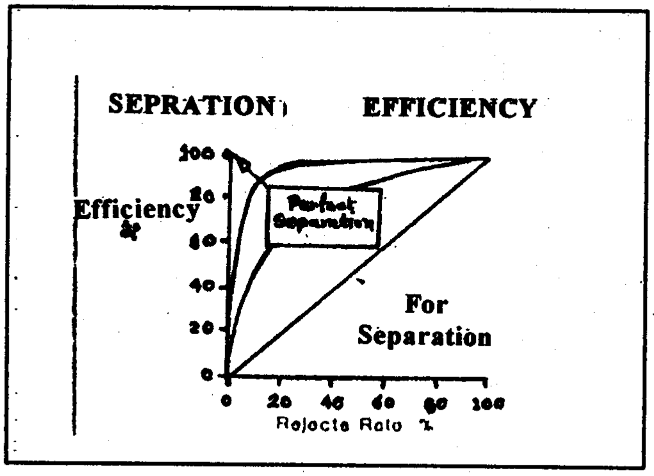


FIG. 18. Efficiency Curve for Contaminant Removal.

REFINER DISPERSION OR DISKPERSION (FIG.16)

Diskpersion at high medium consistency is used primarily to break down contaminant particles. A relatively high shear field is created between stationary and rotating elements. As an example, in the case of high consistency refiner, one plate rotates and the other is stationary. The resultant shear is transmitted through the stock and results in particles breakdown as well as refining of the fiber. Modern system designs follow this diskpersion with further flotation to remove the dispersed ink.

Since the pulp is refined at high consistency in the course of this operation, there will be increase in burst and tensile depending on the specific energy input. Tear will not drop and may even increase as is typical of high consistency refining. The freeness will drop but this is due to fiber fibrillation and not fines generation.

BLEACHING

It is not uncommon to use Calcium Hypochlorite for bleaching the deinked pulp after dispersion. Colour stripping is better with Ca-Hypochlorite as a bleaching chemical.

CONCLUSION

The R&D work done over a period of two decades has resulted in development of a perfect Deinking System which can make a better quality Deinking Pulp at higher yield by incorporating these new developments. There will be less ink and contaminants in the final deinked pulp.

In future it is the objective of Beloit's research program to produce even more efficient contaminant removal units and hence to move even closer to the point of perfect separation" (FIG.18).

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