Theoretical considerations on rejects disposal

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KEYWORDS: • Waste papers • Rejects • Recycling • Efficiency • Waste disposal

The level of contamination in secondary-fiber furnishes is constantly increasing. In today's OCC (old corrugated containers) and mixed-waste furnishes, for example, contamination rates can vary from 3% to 15%, depending upon the locality and the demand. The availability of landfill sites, on the other hand, is constantly decreasing, primarily in populated areas. Disposal of contaminants in secondary-fiber furnishes is becoming increasingly expensive, with prices as high as $30 per wet ton of rejects. These conditions provide processors of secondary fibers with a powerful incentive to minimize both the volume and the wet weight of their rejects.

Mills also have a strong economic incentive to maximize the reuse of their process waters. Raw mill effluents are no longer tolerated in our rivers, lakes, and seashores, and it is becoming increasingly expensive to have them treated by municipalities.

The solution

The first step in solving the problem of rejects disposal is effective liquid-solids separation. Various degrees of rejects thickening can be accomplished using available technology. **Table I** lists the available rejects thickeners in ascending order of outgoing consistency. These devices yield filtrates of varying clarity. Depending upon the mill's end-product tolerance or the applicable environmental restrictions, these filtrates may have to be processed by various degrees of treatment.

There are four possible ways of handling the filtrate from rejects treatment.

1. Return directly to system dilution if end-product quality can tolerate it.
2. Send to city sewer if the cost is permissible.
3. Clarify and return to system dilution.
4. Clarify and either spill or send to city sewer.

Each of these alternatives carries implications about the required decontamination efficiency of the mill's secondary-fiber treatment system.

The implications

Contaminants can be classified by their degree of differentiation from fiber. This differentiation can exist in the form of:

- Shape, size, and rigidity. Contaminants that differ in one or more of these characteristics are said to be screenable or washable.
- Surface characteristics and specific weight. Contaminants that differ in either of these characteristics are said to be cleanable and/or floatable.

Starting from the repulper and until the end of the fine-screening module, a secondary-fiber system rejects primarily screenables, although some of the screenables also happen to be cleanables. Forward and reverse fine cleaners and flotation modules (deinking) remove most of the residual nonscreenable contaminants.

When the mixed-contaminant population in the combined rejects from a system is thickened, the resultant filtrate may or may not be suitable for reutilization in the system's dilution network. This brings us to the question of compatibility between a system's degree of sophistication and its rejects-treatment effort.

Compatibility

The effect of rejects treatment on the operation of a secondary-fiber processing system can be measured by calculating the effect of reject treatment on the overall efficiency of the processing system. **Figure 1** illustrates a system where only coarse- and fine-screening modules are needed to obtain satisfactory end-product cleanliness. This system has no rejects treatment.

We begin our analysis by calculating the inefficiency of this system configuration. System inefficiency (I_{SYS}) is defined as residual contamination in the end product as a percent of feed. The overall inefficiency in this system can be calculated using Eq. 1.

$$I_{SYS} = (1 - E_{CS})(1 - E_{FS})\,100\% \qquad (1)$$

where

E_{CS} = efficiency of coarse screen

E_{FS} = efficiency of fine screen

A system with an 80% efficiency for coarse screening and 70% efficiency for fine screening would have a system inefficiency of 6%.

$$I_{SYS} = (1 - 0.8)(1 - 0.7)\,100\% = 6\%$$

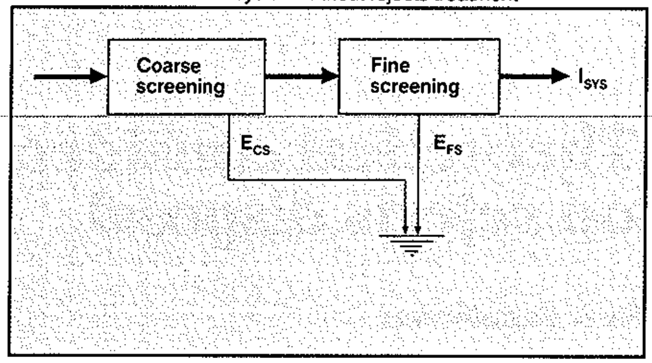
Figure 2 shows the system in Fig. 1 after the addition of an inclined screw to thicken the system's rejects. It is clear that returning the thicken-

I. Rejects thickeners

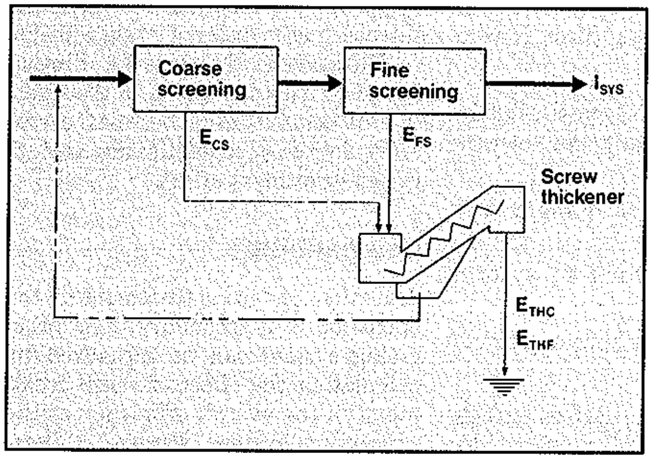
Rejects thickeners	Consistency, % In	Consistency, % Out	Condition of filtrate
Clarifiers	WW*	3-4	Clear
Side-hills	WW*-1	3-5	Rich
Screw thickeners	2-5	8-15	Rich
Screw presses	3-6	15-30	Rich
Belt presses	2-4	20-50	Lean

*WW = white water

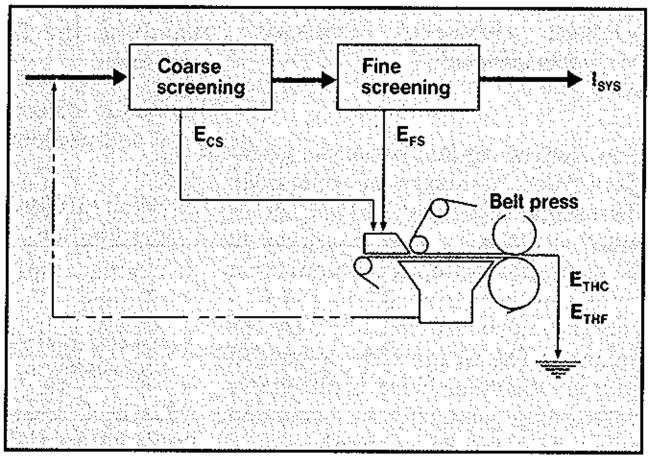
1. Contaminant-removal system without rejects treatment



2. Contaminant-removal system with inclined-screw rejects thickener



3. Contaminant-removal system with belt-press rejects thickener



er's filtrate to the system will increase the system's inefficiency. The degree of increase depends on the type of thickener.

Let us assume that the inclined-screw rejects thickener in Fig. 2 has 0.079-in. holes. This thickener is compatible with the coarse-screening module and will probably thicken and reject about 95% of all the rejects from this module. However, a thickener with 0.079-in. holes is incompatible with the fine-screening module, and its efficiency in removing the finer contaminants would be about 20%.

The efficiency of this system configuration can be calculated using Eq. 2.

$$I_{SYS} = \left[\frac{1 - E_{CS}}{1 - [(E_{CS})(1 - E_{THC})]}\right] \left[\frac{1 - E_{FS}}{1 - [(E_{FS})(1 - E_{THF})]}\right] 100\% \quad (2)$$

where

E_{THC} = efficiency of inclined-screw thickener on coarse rejects

E_{THF} = efficiency of inclined-screw thickener on fine rejects

A system with an 80% efficiency for coarse screening, 70% efficiency for fine screening, 95% efficiency for the inclined-screw thickener on coarse rejects, and 20% efficiency for the inclined-screw thickener on fine rejects would have a system inefficiency of 14.2%.

$$I_{SYS} = \left[\frac{1 - 0.8}{1 - [(0.8)(1 - 0.95)]}\right] \left[\frac{1 - 0.7}{1 - [(0.7)(1 - 0.2)]}\right] 100\%$$

$$= 14.2\%$$

In this case, the introduction of a rejects thickener that is incompatible with the fine-screening module's contaminant-retention efficiency results in a residual contamination of the end product that is higher by a factor of 2.37 (14.2%/6%). To correct the situation, it is necessary to select a compatible thickener.

Figure 3 shows the system in Fig. 1 after the addition of a belt press to thicken system rejects. The belt press will retain about 98% of all the coarse screening rejects and about 90% of all fine-screening rejects. By applying Eq. 2, we can calculate that the inefficiency of this system would be 6.56%.

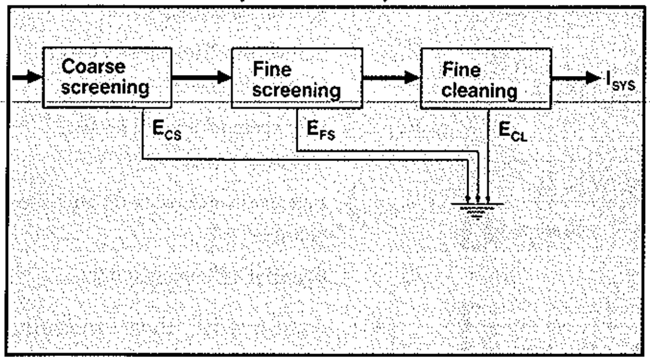
$$I_{SYS} = \left[\frac{1 - 0.8}{1 - [(0.8)(1 - 0.98)]}\right] \left[\frac{1 - 0.7}{1 - [(0.7)(1 - 0.9)]}\right] 100\%$$

$$= 6.56\%$$

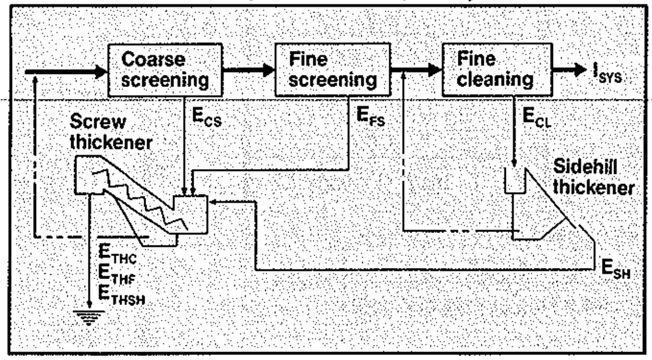
In this case, the addition of rejects thickening results in a residual contamination of the end product that is higher by a factor of 1.09 (6.56%/6%). The end product would be 9.3% dirtier, which is a small price to pay for easy rejects disposal.

In evaluating the adequacy of different combinations of equipment, it is useful to consider the concept of

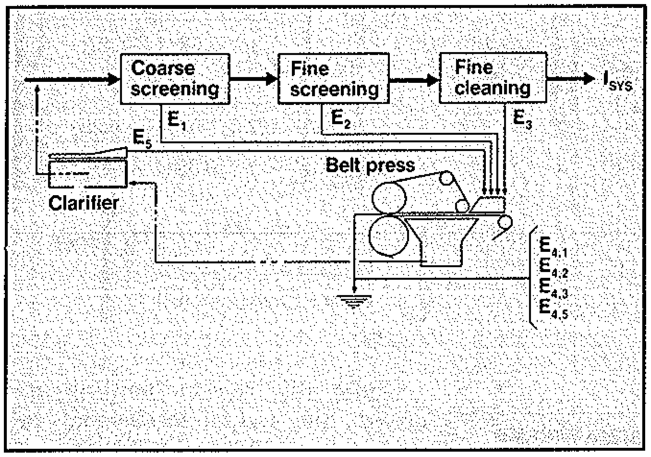
4. Contaminant-removal system without rejects treatment



5. Contaminant-removal system with inadequate rejects treatment



6. Contaminant-removal system with proper rejects treatment



II. Compatibility of three rejects-treatment units with various system modules that generate rejects

Rejects treatment unit	*Origin of rejects:* *Coarse screen*	*Fine screen*	*Reverse cleaner*	*Forward cleaner*	*Flotation cell*	*Washer filtrate*
Screw thickener*	Yes	Not adequate	No synergism	No synergism	No synergism	Not applicable
Belt press	Yes	Yes	No synergism	No synergism	No synergism	Not applicable
Clarifier	Not required	Not required	Yes	Yes	Yes	Yes

*Holes range from 0.062 in. to 0.094 in.

synergism. A synergetic equipment configuration consists of mutually cooperative equipment utilizing the same principle of contaminant removal. In this case, screening is the principle of contaminant removal, and in one instance we experienced inadequacy because of a different order of efficiency magnitude. For example, both 0.010-in. slotted screens and 0.062-in. thickener perforations are similar in nature (synergetic), and both remove contaminant through mechanical separation. However, they do not operate within the same contaminant size spectrum and, therefore, are incompatible in efficiency.

Synergism

All screens and/or mechanical separators are synergetic, regardless of incompatibilities resulting from differences in the degree of magnitude in size separation. Asynergism occurs when we expect screenables to be rejected by cleaners and vice-versa.

Consider a system utilizing coarse and fine screens as well as fine cleaners to remove contaminants. This system is illustrated in **Fig. 4.** The use of an inclined screw to thicken the rejects and then returning the thickener filtrate to the system would be asking for trouble.

The inefficiency of the system depicted in Fig. 4 can be calculated using Eq. 3.

$$I_{SYS} = (1 - E_{CS})(1 - E_{FS})(1 - E_{CL})\ 100\% \quad (3)$$

where

E_{CL} = efficiency of fine cleaning

With module efficiency values of $E_{CS} = 0.8$, $E_{FS} = 0.7$, and $E_{CL} = 0.7$, the system inefficiency will be 1.8%.

$$I_{SYS} = (1 - 0.8)(1 - 0.7)(1 - 0.7)\ 100\% = 1.8\%$$

Figure 5 illustrates the system in Fig. 4 after adding inadequate rejects treatment. The efficiency of such a system, calculated using Eq. 4, would deteriorate dramatically.

$$I_{SYS} = \left[\frac{1 - E_{CS}}{1 - [(E_{CS})(1 - E_{THC})]}\right] \left[\frac{1 - E_{FS}}{1 - [(E_{FS})(1 - E_{THF})]}\right] \left[\frac{1 - E_{CL}}{1 - E_{CL}[(1 - E_{SH}) + E_{SH}(1 - E_{THSH})]}\right] 100\% \quad (4)$$

where

E_{SH} = efficiency of side-hill thickener on fine-cleaner rejects

E_{THSH} = efficiency of the inclined-screw on side-hill (fine cleaner) rejects

In a system with the following modular efficiencies—$E_{CS} = 0.8$, $E_{FS} = 0.7$, $E_{CL} = 0.7$, $E_{THC} = 0.95$, $E_{THF} = 0.2$, $E_{SH} = 0.4$, and $E_{THSH} = 0.3$—the inefficiency of the entire system would be 11.1%.

$$I_{SYS} = \left[\frac{1-0.8}{1-[(0.8)(1-0.95)]}\right]\left[\frac{1-0.7}{1-[(0.7)(1-0.2)]}\right]\left[\frac{1-0.7}{1-0.7[(1-0.4)+0.4(1-0.3)]}\right]100\%$$

$$= 11.1\%$$

In this case, the inadequate approach to rejects treatment, as well as the asynergism between the unit operations of the cleaning/screening systems and the rejects-handling system, increases residual contamination in the end product by a factor of 6.16 (11.1%/1.8%). To correct the situation, the inclined-screw thickener must be replaced with a belt press, and a clarifier must be installed to remove all solids, including cleanables, from its filtrate. This system is illustrated in **Fig. 6**. The efficiency of such a clarifier is around 98%, and the clear water can be returned safely to the system.

The efficiency of the system in Fig. 6 can be calculated using Eq. 5.

$$I_{SYS} = \left[\frac{1-E_1}{1-\left[\frac{E_1(1-E_{4,1})(1-E_5)}{1-[E_5(1-E_{4,5})]}\right]}\right]\left[\frac{1-E_2}{1-\left[\frac{E_2(1-E_{4,2})(1-E_5)}{1-[E_5(1-E_{4,5})]}\right]}\right]\left[\frac{1-E_3}{1-\left[\frac{E_3(1-E_{4,3})(1-E_5)}{1-[E_5(1-E_{4,5})]}\right]}\right]100\% \quad (5)$$

where

E_1 = E_{CS} = 0.8

E_2 = E_{FS} = 0.7

E_3 = E_{CL} = 0.7

$E_{4,1}$ = belt press efficiency on coarse screening rejects = 0.98

$E_{4,2}$ = belt press efficiency on fine screening rejects = 0.9

$E_{4,3}$ = belt press efficiency on fine cleaning rejects = 0.4

$E_{4,5}$ = belt press efficiency on clarifier sludge = 0.4

E_5 = clarifier efficiency = 0.98

In a system with these modular efficiencies, the inefficiency of the entire system would be 1.85%.

$$I_{SYS} = \left[\frac{1-0.8}{1-\left[\frac{0.8(1-0.98)(1-0.98)}{1-[0.98(1-0.4)]}\right]}\right]\left[\frac{1-0.7}{1-\left[\frac{0.7(1-0.9)(1-0.98)}{1-[0.98(1-0.4)]}\right]}\right]\left[\frac{1-0.7}{1-\left[\frac{0.7(1-0.4)(1-0.98)}{1-[0.98(1-0.4)]}\right]}\right]100\%$$

$$= 1.85\%$$

Under this rejects-handling approach, the system inefficiency increases from 1.8% to 1.85%, which is less than a 3% change over the system without rejects handling (Fig. 4).

Table II shows the compatibility of three rejects-treatment units with various system modules that generate rejects.

Conclusion

With increased contamination of secondary-fiber furnishes and tighter environmental restrictions, the design of the rejects-handling system is as important as the design of the main fiber-processing system. Given these trends, mills with inadequate rejects-treatment systems cannot expect to achieve long-term economic survival.

The analytical view presented here is an attempt to establish some of the main parameters in the area of secondary-fiber processing. However, we must all generate more field data if our industry is to successfully quantify its efforts in the battle of the garbage.

Received for review July 6, 1988.

Accepted August 9, 1988.

Presented at the 1988 Pulping Conference.