Pilot plant studies: two methods for deinking sorted office paper

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ABSTRACT

Pilot tests were conducted to study deinking of sorted office paper to produce tissue, white linerboard, and other grades with less stringent optical requirements than printing and writing grades. Two types of deinking chemistry were evaluated: dispersion and agglomeration. The deinking line was configured as a satellite system. Unit operations for both processes included pulping, fine screening, throughflow cleaning, forward cleaning, and washing. The dispersion process also included a flotation stage. Target optical properties for deinked pulp were achieved using 0.25% (based on dry furnish weight) of deinking agent (dispersant or agglomerant). For both processes, washing was the unit operation that provided the greatest brightness gain. For dispersion deinking, washing and flotation removed a considerable fraction of the microscopic (<60 μm) ink particles. Flotation was the most effective operation for removal of visible (60–225 μm) ink particles, while centrifugal cleaning was the most effective unit operation for removal of "dirt" particles (>225 μm). For agglomeration deinking, fine screening was the most effective unit operation for removing large "dirt" particles.

Application:

Presents pilot results for two deinking processes. One promotes dispersion of the detached ink particles for removal by flotation; the other promotes agglomeration of particles for removal by screening.

THE CURRENT EMPHASIS IN recycling post-consumer fibers is to produce printing and writing paper using a low-cost furnish (mixed office paper) and a very extensive series of unit operations, including kneading and dispersion *(1)*. A second approach is to use a somewhat more costly furnish and a less costly process design to produce a pulp containing higher residual ink levels than acceptable for printing and writing paper but adequate for other end uses, such as white linerboard and tissue products. Mills built using the latter philosophy have a lower capital cost but produce a less valuable deinked product.

This paper presents the results of pilot plant trials conducted at the Beloit Research Center in Pittsfield, MA. The objective was to evaluate the performance of two deinking processes and proprietary deinking agents on sorted office paper.

Two types of deinking agent chemistry were chosen: dispersing and agglomerating. Whether a deinking agent is dispersing or agglomerating can be determined by image analysis of pulper pads. Dispersing surfactants form a greater number of ink particles than do toner-agglomerating agents. The dispersant SDA-47 was chosen because it is used commercially to deink a variety of furnishes, including computer printout (CPO) and books. The agglomerating agent SDA-64 was chosen because it was designed as an improved version of two deinking agents (SDA-44 and SDA-43) that performed well in earlier laboratory and pilot plant tests *(2)*. The deinking agents are commercially available (Nonatell® surfactants, Shell Chemical Co.).

EXPERIMENTAL

Furnish

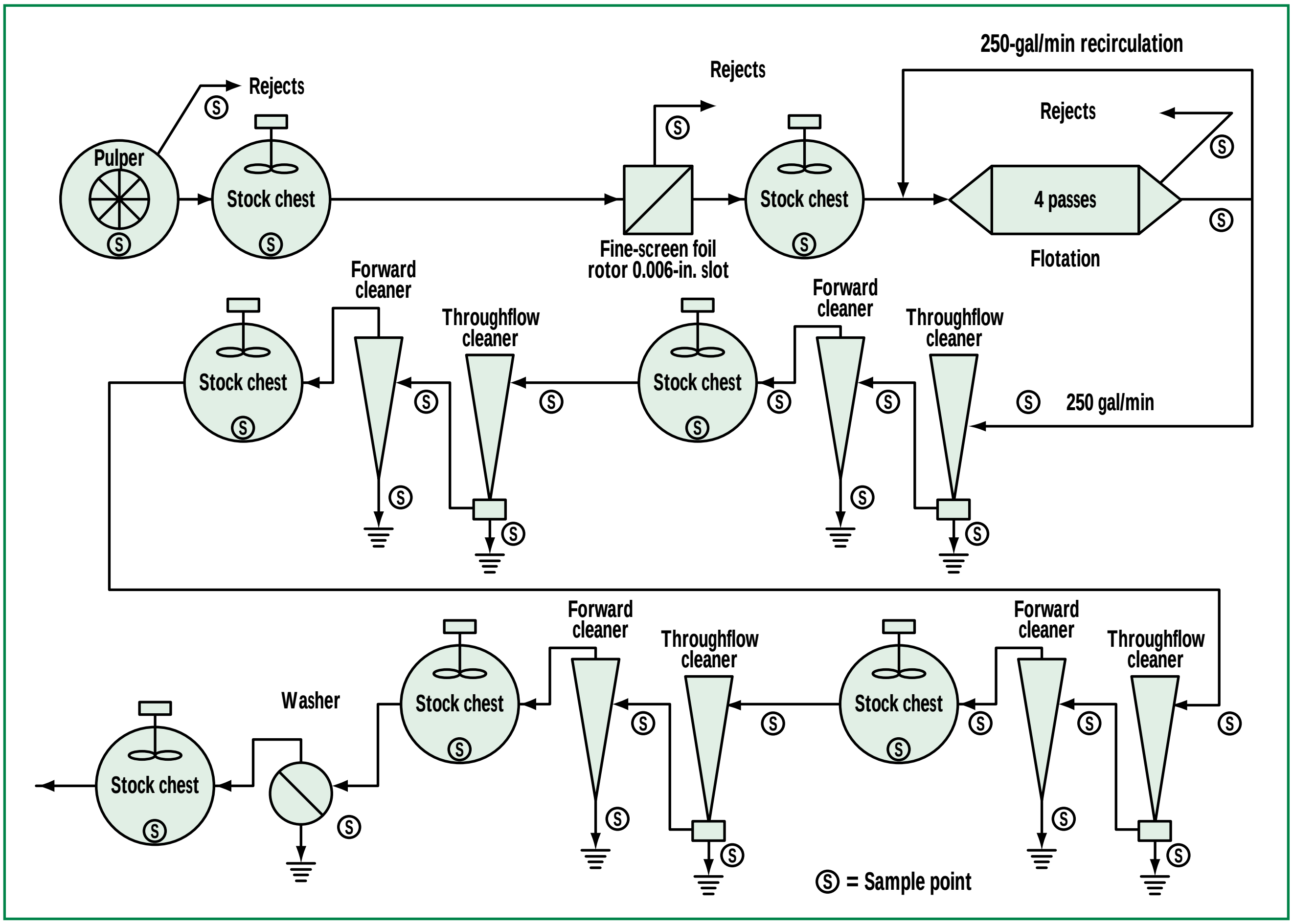
The furnish, provided by a commercial mill, was typical of the sorted office paper that it routinely processes. Inspection indicated that the bales contained a high percentage of both nonimpact-printed papers (laser-printed and photocopier paper) and computer printout (CPO), as well as small amounts of nonacceptable materials such as brown grades, file folders, and plastic wrap. These nonacceptable materials were not removed from the furnish. The material provided the usual range of contaminants for this type of post-consumer fiber. Groundwood content of the furnish was very low, well below 5%, indicating no need to add hydrogen peroxide to the pulper to prevent lignin yellowing of the pulp.

Deinking processes

The deinking processes are depicted in **Figs. 1 and 2**. The sequence of unit operations for the dispersion process consisted of pulping, detrashing, fine screening, four passes of flotation, four centrifugal-cleaning passes using throughflow cleaners and forward cleaners in an alternating sequence, followed by washing (Fig. 1). The configuration for the agglomeration process consisted of pulping, detrashing, fine screening, throughflow cleaning followed by two stages of forward cleaning, a second pass through these three cleaners, and then washing (Fig. 2).

Pulping

The pulper is a 1000-lb, vertical (bottom-mounted rotor) pulper equipped with a 35-in.-diam. impeller. The impeller is driven by a 200-hp variable-frequency, variable-speed drive. The pulper is equipped with a detrashing unit that effectively removes large contaminants from the pulp stream.



1. Process flow diagram for pilot plant dispersion deinking process

Water (120°F) was added to the pulper, and the pH was adjusted to 8–9 with sodium hydroxide. Dispersing agent SDA-47 (0.25% based on dry furnish weight) was then added. The furnish (1000 lb on a dry paper basis) was added to give a consistency of 12%. Pulping time was 30 min. The pulp pH was 8.1 after all the components of the pulper slurry were added. This did not increase above 8.3 during the 30-min pulping period. The pulp temperature (122–129°F) increased slightly with time.

The completed pulper batch was diluted and dumped through the detrasher to remove large contaminants and transferred to a stock chest. There the pulp was diluted to 1.2% consistency for the fine-screening operation.

Fine screening

A horizontal-shaft screen was used. The screen rotor was driven at 600 rpm by a 75-hp variable-frequency, variable-speed drive. The fine-screening operations used a three-foil rotor and 0.006-in. slotted basket. The stock was pumped through the fine screen, and the rejects valve was cycled open and shut to simulate normal operating conditions. The purge cycle for the rejects was a 5 s purge every 25 s, which gives approximately 5% rejects by volume. The accepts were piped to a stock chest. There they were further diluted to 1.0% consistency to feed the continuous flotation and cleaning system.

Flotation

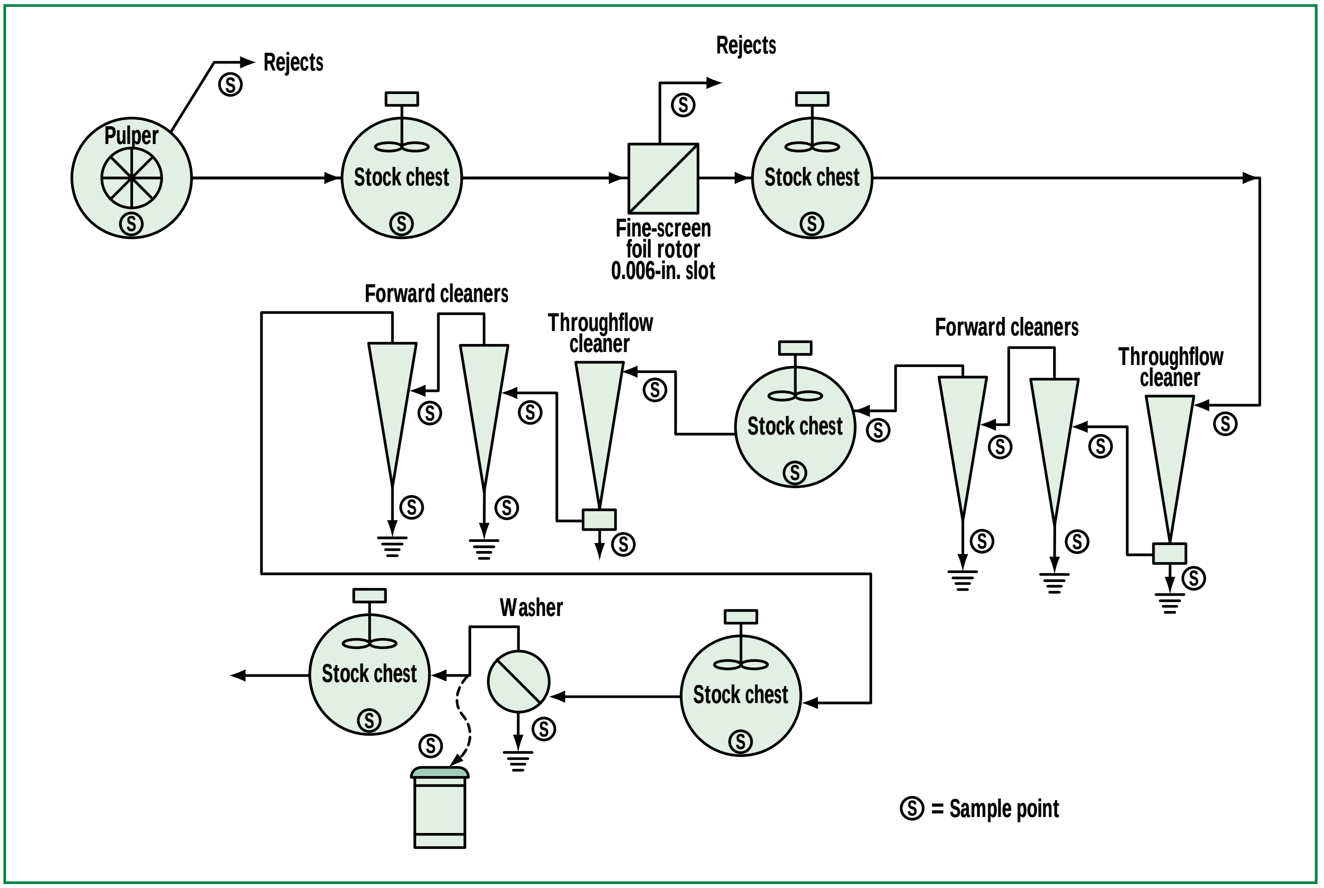
Flotation was used only in the dispersion deinking process. Pulp was fed to the pressurized flotation cells at a rate of approximately 412 U.S. gal/min, with 212 gal/min being recycled to simulate four passes of flotation through the two cells. Flotation was performed using two pressurized flotation cells *(3, 4)* connected in series and fitted with a recirculation line. Air addition to the flotation cells was maintained to give a gas/liquid ratio of between 0.4 and 0.5. The volumetric reject rate target was between 1.0% and 2.0%.

The actual number of passes for both cleaning and flotation in the final design for the system will be determined by the results of the pilot trial. It is assumed that the number of passes will be fewer than in the trial itself. The flotation accepts (approximately 200 gal/min) were discharged into the feed tank to be diluted and fed into the centrifugal cleaners.

Note that the flotation step and two of the throughflow cleaner stages were not used in the agglomeration trial.

Centrifugal cleaning

The pulp was diluted to a consistency of 0.6% for centrifugal cleaning. The cleaning system consists of a single



2. Process flow diagram for pilot plant agglomeration deinking process

primary pass of throughflow (reverse) cleaners followed by a single primary pass of forward cleaners *(5)*. Each cleaner bank is fed by its own variable-speed centrifugal pump system, which allows the direct coupling of the stages without interstage tanks. The system is piped with bypass connections, which allows the operation of any combination of the three cleaner stages.

For the dispersion deinking trials, the stock was run through this system of cleaners four times. The accepts from the forward cleaners were discharged into a stock chest. They were then transferred to a second stock chest to run a second pass through the cleaners. This step was then repeated twice more for a total of four passes through the cleaners. The accepts were discharged to the empty first stock chest to feed the washer.

In the agglomeration process, the cleaning system consisted of a single primary pass of throughflow cleaners followed by two passes through forward cleaners. This reverse-cleaner/forward-cleaner sequence was then repeated.

The forward cleaners were operated in the high "G" white-grade configuration. In this configuration, the pulp inlet velocity in the forward cleaners is maximized using feed inserts. This provides the unit with enough *g* force to separate the specks. Extended rejects tips provide the residence time and undisturbed boundary-layer flow to allow the contaminants to be rejected with a minimum mass reject rate. This cleaner configuration is recommended for deinking pulp to be used in the manufacture of white paper grades and tissue. It is also recommended for use with agglomerating agents. Besides removing high-density contaminants, the high "G" white mode also removes lower-density ink specks often found in office-paper furnishes.

Washing

The washing operation took place in a horizontal-shaft, pressurized mechanical washer consisting of an element rotating at approximately 1200 rpm inside an 18-in.-diam. cylindrical filter media with 0.006-in.-diam. holes *(6)*. The rotor is driven by a 125-hp (connected) variable-frequency, variable-speed drive.

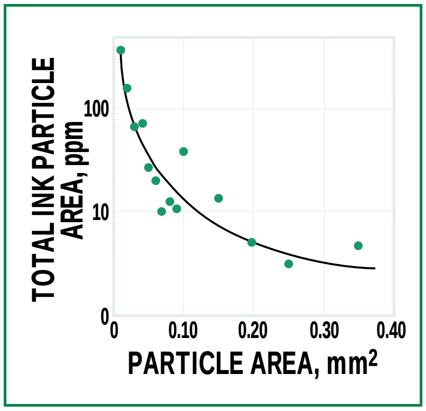
The washer was operated in such a way as to deliver the cake to the No. 2 stock chest and the effluent to sewer. Samples of the washer cake were placed in a 55-gal drum. The sample was later dewatered using a centrifuge.

Analyses

All samples were prepared and tested by Beloit personnel in accordance with TAPPI test methods. The sole exception was image analysis (Optimax V HR image analyzer), which was carried out using procedures previously developed *(7)*. The software functioned using the older definition of

Process step	PULP PROPERTIES: Pulp consis-tency, %	Pulp free-ness, mL CSF	Ash, %	TAPPI bright-ness, %	IMAGE ANALYSIS RESULTS: Visible ink (60-225 µm) particles/m²	Visible ink (60-225 µm) ppm	TAPPI dirt (225-1000 µm), ppm	Microscopic ink (1.2-60 µm), ppm
Pulping	12.5	...	10.2	73.7	12,215	449	222	1,282
Fine-screen accepts	1.0	270	8.5	73.6	12,778	403	193	1,133
Flotation								
Feed	0.92	...	8.6	73.2	11,241	294	...	...
Cell 1 accepts	0.89	...	8.7	74.4	...	...	...	...
Cell 2 accepts	0.90	...	10.3	74.4	...	...	...	...
Centrifugal cleaners								
1st throughflow cleaner feed	0.58	...	...	...	...	...	...	...
1st throughflow cleaner accepts	0.52	...	9.5	74.9	7,263	284	156	792
1st forward cleaner accepts	0.52	275	10.3	75.6	5,104	196	107	746
2nd throughflow cleaner accepts	0.51	...	7.7	75.7	3,834	158	86	666
2nd forward cleaner accepts	0.48	...	8.8	75.0	3,520	127	64	712
3rd throughflow cleaner accepts	0.51	260	7.7	74.7	2,687	111	62	401
3rd forward cleaner accepts	0.48	...	7.1	75.8	2,863	110	61	555
4th throughflow cleaner accepts	0.48	...	7.9	75.4	2,147	80	38	485
4th forward cleaner accepts	0.45	260	8.5	75.1	2,570	100	56	427
Washer accepts	4.1	580	0.9	83.4	2,546	85	36	107

I. Pilot plant results for dispersion deinking (SDA-47 deinking surfactant)



3. Image analysis of visible ink particles after pilot plant pulping—dispersion deinking

TAPPI dirt count. (To qualify as a dirt particle, the ink particle size had to measure at least 225 µm with a surface area of 0.04 mm².)

RESULTS

Pulp ash content was 10.2% in both trials. The stickies content was quite low, about two per gram of furnish. Pulping left plastics and other soft contaminants in large pieces that remained in the detrasher after the stock was drained through it. These solids consisted of staples, paper clips, plastic strips, etc.

Dispersion deinking

Results for the dispersion deinking tests are summarized in **Table I**. A duplicate test indicated that these image-analysis results are reproducible, as seen in **Table II**.

Pulping and screening. **Figure 3** depicts the image analysis results showing the distribution of ink particle size after pulping. TAPPI dirt count was 222 ppm, and total visible ink was 449 ppm after pulping.

The trial did not include a coarse screening stage. The fine-screening operations were performed using an intermittent rejects purge. The intermittent rejects purge was used to illustrate the net result of an entire screening system with regard to accept fiber quality and total fiber losses from the system. The rejects from the fine-screening module contained staples, plastic strips, and other large debris.

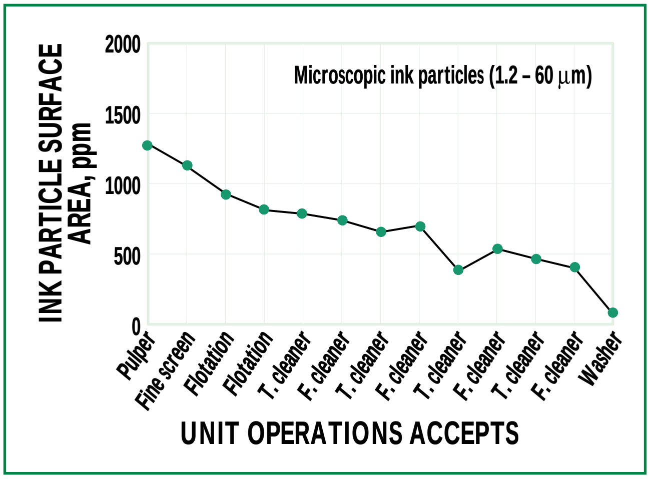
Flotation. **Figure 4** depicts the surface area of microscopic (1.2–60 µm) ink particles through the entire deinking process. Flotation reduced the surface area of microscopic ink particles from 1251 ppm to 736 ppm. **Figure 5** shows the corresponding reduction in the surface area for visible (60–225 µm) ink particles. The first flotation cell provided the greatest removal of these ink particles. **Figure 6** illustrates the reduction in dirt (225–1000 µm) particles over the course of the dispersion deinking process. Again, the first flotation cell provided the greatest removal of ink particles. The brightness gain of 1.2 points upon flotation occurred in the first flotation cell, as seen in Table I.

Centrifugal cleaning. There were four passes of the pulp through the throughflow and forward cleaners. Examination of the throughflow cleaner rejects showed that they contained very high amounts of small ink particles. The stickies content of the furnish was very low, about two per gram of total material. The majority of the stickies present tended to be removed in the screen rejects. This is because the pulper did not break the contaminants into small particles.

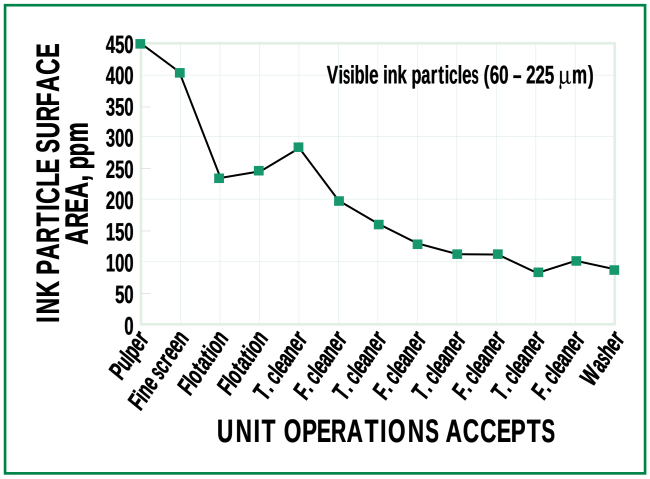
The surface area of both visible particles (60–225 µm) and large dirt particles (225–1000 µm) increased in the first throughflow cleaner accepts, as seen in Figs. 5 and 6, respectively. The reason for this is not understood. There was a brightness gain of 0.5 points across the throughflow clean-

Process step	VISIBLE INK (60-225 µm) particles/m² Test 1	Test 2	VISIBLE INK (60-225 µm) ppm Test 1	Test 2	TAPPI DIRT (225-1000 µm), ppm Test 1	Test 2	MICROSCOPIC INK (1.2-60-µm), ppm Test 1	Test 2
Pulping	12,215	...	449	...	222	...	1,282	...
Fine-screen accepts	12,778	9,798	403	385	...	198	1,133	1,208
Flotation								
Feed	11,241	8,201	294	294	...	141	...	1,251
Cell 1 accepts	...	...	...	234	...	121	...	936
Cell 2 accepts	...	6,172	...	244	...	134	...	811
Centrifugal cleaners								
1st throughflow cleaner feed	...	4,928	...	178	...	85	...	736
1st throughflow cleaner accepts	7,263	...	284	215	156	112	792	686
1st forward cleaner accepts	5,104	5,069	196	188	107	99	746	658
2nd throughflow cleaner accepts	3,834	...	158	...	86	...	666	...
2nd forward cleaner accepts	3,520	4,776	127	173	64	85	712	700
3rd throughflow cleaner accepts	2,687	...	111	...	62	...	401	...
3rd forward cleaner accepts	2,863	...	110	...	61	...	555	...
4th throughflow cleaner accepts	2,147	...	80	...	38	...	485	...
4th forward cleaner accepts	2,570	...	100	...	56	...	427	...
Washer accepts	2,546	...	85	...	36	...	107	...

II. Image analysis results for Tests 1 and 2 – dispersion deinking



4. Surface area of microscopic ink particles (1.2–60 µm) after each unit operation in the dispersion deinking process (T.Cleaner = throughflow cleaner; F.Cleaner = forward cleaner). Flotation data from Test 2 (Table II).

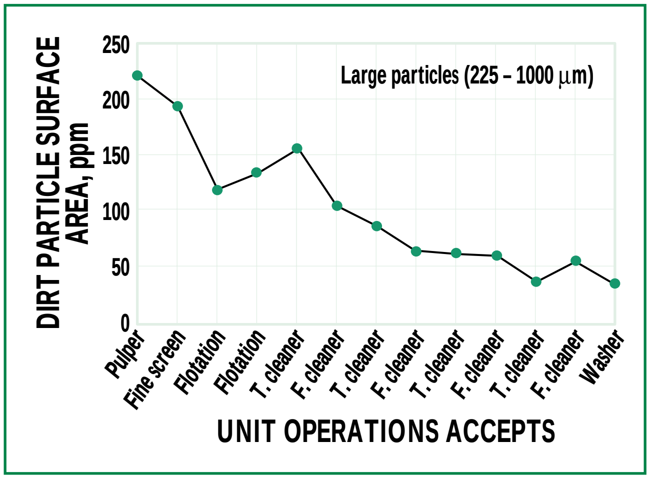


5. Surface area of visible ink particles (60–225 µm) after each unit operation in the dispersion deinking process (T.Cleaner = throughflow cleaner; F.Cleaner = forward cleaner). Flotation data from Test 2 (Table II).

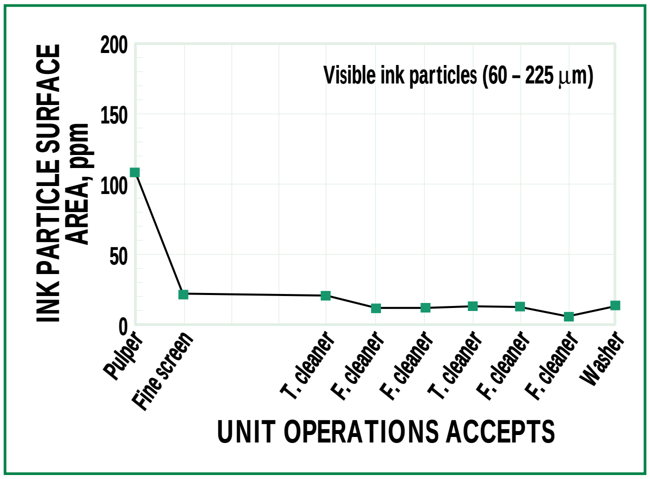
ers, which is typical of gains in other deinking processes. The throughflow cleaners rejected an average 9.5% by volume and 1.5% by mass.

The TAPPI dirt count in the process remained approximately constant until the first pass of the pulp through the forward cleaners, after which it declined from 156 ppm to 56 ppm, as seen in Table I. Observation of the rejects showed that the majority of specks were removed in the first cleaner pass. The rejects in the second pass showed fewer specks. Regardless of the experimental uncertainty, the dirt-removal efficiency was quite good, particularly considering the low reject rates. Again, small reject rates and multiple stages for cleaning and flotation were used to determine the minimum number of cleaners needed to achieve the desired optical properties.

The percentage of microscopic ink particles smaller than 44 µm increased somewhat during centrifugal cleaning, indicating the preferential removal of larger ink particles. However, there was some removal of microscopic (1.2–60 µm) ink particles during centrifugal cleaning, as indicated by the results in Table I and Fig. 4.



6. TAPPI dirt count (ink particles measuring 225–1000 µm) after each unit operation in the dispersion deinking process (T.Cleaner = throughflow cleaner; F.Cleaner = forward cleaner). Flotation data from Test 2 (Table II).



7. Surface area of visible ink particles (60–225 µm) after each unit operation in the agglomeration deinking process (T.Cleaner = throughflow cleaner; F.Cleaner = forward cleaner)

Process step	TAPPI brightness, %	Ash content, %	Pulp freeness, mL CSF
Pulping	73.3	10.5	...
Fine-screen accepts	73.1	9.8	231
1st forward cleaner accepts	72.4	10.4	229
2nd forward cleaner accepts	72.6	10.9	...
3rd forward cleaner accepts	72.5	11.1	208
4th forward cleaner accepts	71.7	10.9	216
Washer accepts	82.1	1.6	545

III. Pilot plant results for agglomeration deinking (SDA-64 deinking surfactant)

The brightness gain occurred entirely on the first pass through the cleaners, as seen in Table I. This is most likely due to the residual air bubbles from flotation adhering to some ink particles. These bubbles cause some of the smaller ink particles to behave like lightweight contaminants in the centrifugal flow field of the throughflow cleaners, allowing them to be separated from the pulp.

Washing. There was an 8.3-point gain in TAPPI brightness upon washing, as seen in Table I. The greater brightness gain in the washing step compared with flotation (1.2 points) clearly indicates the greater effectiveness of washing in removing very small ink particles. Washing reduced the microscopic (1.2–60 µm) ink particles from 427 ppm to 107 ppm, for a removal efficiency of 75%. The washing step clearly plays a critical role in achieving the target brightness and reducing bleaching requirements, as seen in Table I.

Ash removal. Washing removed 90% of the ash present in the final forward cleaner accepts. The results in Table I indicate that little ash removal occurred in the other processing steps. The ash content in the flotation accepts suggested that the low reject rate of the flotation step, while concentrating the ash in the rejects, could remove only a limited amount of ash from the pulp slurry.

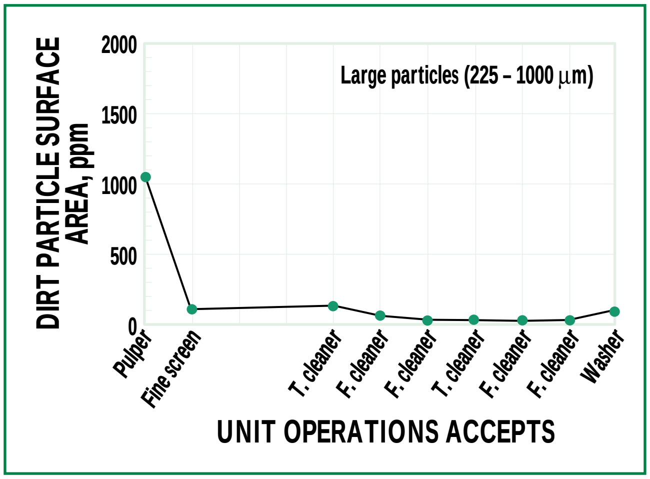
The presence of ash reduces pulp freeness, and the freeness results in Table I are consistent with the ash analyses. There was no decrease in pulp freeness until the washing step. The washing step provided both a large increase in freeness and a substantial reduction in pulp ash content.

Agglomeration deinking

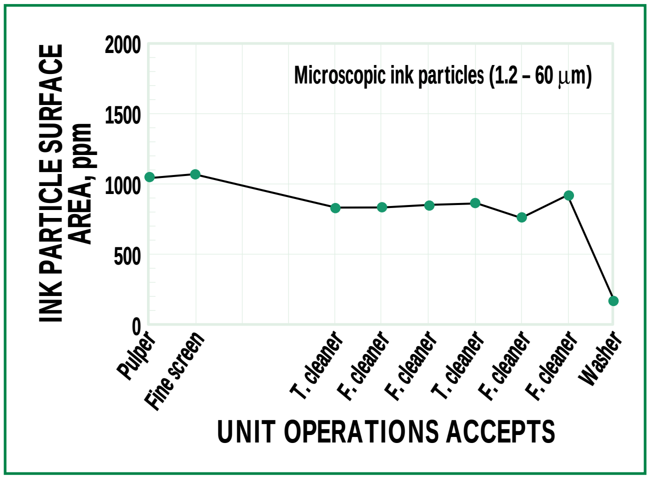
Results for the agglomeration deinking tests are summarized in **Table III**.

Pulping. The pulping temperature (122–129°F) was substantially less than the glass-transition temperature of commonly used toner resins (150–160°F). Thus any softening and agglomeration of toner particles was due to the deinking agent. Image analysis indicated that the average ink particle size after pulping was 338 µm. The average size of the microscopic ink particles was 9.2 µm, indicating that a sufficient number of <5-µm ink particles were present to substantially reduce pulp brightness *(8)*.

Removal of visible ink particles. Visible ink content of the pulp at each stage of the deinking process is given in **Table IV** and **Fig. 7**. Fine screening reduced the dirt count by 83%, as seen in **Fig. 8**. Throughflow cleaning did not decrease the dirt count. (This was not surprising, as the throughflow cleaners are designed to remove dispersed adhesive particles and other lightweight contaminants.) The first two passes of forward cleaning reduced the dirt count by 71%. The reduction after the third and fourth passes through the forward cleaners was 75%. Washing did not reduce the visible ink content of the pulp. The dirt count after the final pass through



8. TAPPI dirt count (ink particles measuring 225–1000 µm) after each unit operation in the agglomeration deinking process (T.Cleaner = throughflow cleaner; F.Cleaner = forward cleaner)



9. Surface area of microscopic ink particles (1.2–60 µm) after each unit operation in the agglomeration deinking process (T.Cleaner = throughflow cleaner; F.Cleaner = forward cleaner)

the forward cleaners was 7 ppm. After washing, the dirt count was 20 ppm, and the total dirt occupied 81 ppm of the sheet surface area.

Brightness. There was little change in pulp brightness until the washing step (Table III). This is consistent with what is known about the efficiency of fine screens and centrifugal cleaners in removing microscopic ink particles. However, washing produced a large brightness increase (10.4 points), indicating the presence of many subvisible ink particles in the pulp. This is consistent with analysis of the subvisible ink content (1.2–60-µm particles) in the pulp, illustrated in **Fig. 9**, which shows a steep decline after washing.

Ash content and removal. The ash content of 10.5% after pulping (Table III) is typical for this type of furnish and almost identical to that observed after pulping the furnish used in the dispersion deinking process, 10.2% (Table I). There was little selective loss of ash prior to the washing step. The ash content—constant at 9.8–11.1% by weight of the solids through the agglomeration deinking process—decreased to 1.6% after washing. This drop in ash content was accompanied by a large increase in the freeness from 208–231 mL CSF to 545 mL CSF. (Freeness is an indicator of how fast water will drain from the pulp on the paper machine. Higher freeness values indicate the paper machine can be run at higher production rates, thus improving mill economics.)

Process step	VISIBLE INK PARTICLE COUNT (60-225 µm), particles/m² — Dispersion (Agent SDA-47)	VISIBLE INK PARTICLE COUNT (60-225 µm), particles/m² — Agglomeration (Agent SDA-64)
Pulper	12,215	12,338
Fine-screen accepts	12,778	1,478
Centrifugal cleaners		
1st throughflow cleaner accepts	7,263	1,643
1st forward cleaner accepts	5,104	833
2nd forward cleaner accepts	...	739
2nd throughflow cleaner accepts	3,834	681
2nd forward cleaner accepts	3,520	...
3rd forward cleaner accepts	2,863	692
4th forward cleaner accepts	2,570	317
Washer accepts	2,546	645

*The deinking processes are illustrated in Figs. 1 and 2.

*IV. Removal of visible ink particles–dispersion and agglomeration deinking**

DISCUSSION

Pulping

The brightness obtained after pulping in the presence of the dispersion and agglomeration deinking agents differed by less than 0.5 TAPPI units (Tables I and III, respectively). The surface area for microscopic ink particles was also comparable: 1282 ppm for the dispersant (SDA-47) and 1043 ppm (SDA-64) for the agglomerant (SDA-64). Table I shows that the 12,215 total visible ink particles produced a visible ink surface area of 449 ppm after pulping in the presence of the dispersant (SDA-47). The number of visible ink particles formed in the presence of the agglomerant (SDA-64), was similar, 12,338, as seen in Table IV.

The TAPPI dirt count after pulping in the presence of the agglomerating agent (SDA-64) was 1047 ppm (Fig. 8), substantially greater than the dirt count of 222 ppm (Table I and Fig. 6) for the dispersing agent (SDA-47). This result would be expected if agglomeration were indeed occurring in the pulper in the presence of SDA-64.

Process step	IMAGE ANALYSIS PARTICLE COUNT, particles/m² 1.2–60 µm	1.2–3.0 µm	PARTICLES MEASURING 1.2–3.0 µm,* %
Pulper	618	116	18.8
Fine-screen			
Feed	523	70	13.4
Accepts	519	56	10.8
Centrifugal cleaners			
1st throughflow cleaner accepts	444	59	13.3
1st forward cleaner accepts	515	67	13.0
2nd throughflow cleaner accepts	355	54	15.2
2nd forward cleaner accepts	410	51	12.4
3rd throughflow cleaner accepts	344	80	23.3
3rd forward cleaner accepts	377	72	19.1
4th throughflow cleaner accepts	355	60	16.9
4th forward cleaner accepts	412	85	20.6
Washer accepts	117	40	34.2

*Percent of particles <60 µm

V. Analyses for smallest (<3.0 µm) ink particles–dispersion deinking

Removal of visible ink particles

Screening did not decrease the number of visible ink particles that were formed when pulping in the presence of the dispersing agent (SDA-47). This is in sharp contrast to the 88% decrease in visible ink particles observed when the pulp containing the agglomerating agent (SDA-64) was screened in the same manner (Table IV). The decrease in ink particle surface area using SDA-64 was 92%, as seen in Fig. 8.

The most likely explanation for the substantially greater efficiency of the screens in removing >225-µm particles in the agglomeration process is a change in ink particle geometry promoted by SDA-64. Toner particles usually exist as flat flakes after detachment from fibers. Such flat ink particles are formed in the presence of dispersion deinking agents similar to SDA-47 *(2)*. The gap size of the 0.006-in. screen is only about 150 µm. Consequently, in some orientations, the flat ink particles can pass through the 0.006-in. slots, even though the other two ink particle dimensions are substantially greater than 150 µm. Confocal laser scanning microscopy has shown that deinking agents of the SDA-64 type increase the three-dimensional character of toner particles *(2)*, making them thicker and less able to pass through 0.006-in. slots. It is this increase in ink particle thickness that is the most probable cause of the increased screening efficiency in the agglomeration deinking test.

This interpretation is consistent with conclusions drawn from mill experience with a different agglomeration agent. Rhodes *(9)* noted that "the size of the particles was not as big a factor as originally thought. As long as the agglomerates were round, there was a high probability of removal."

The objectives of this trial were (a) to evaluate the performance of a specific deinking process using both a dispersing deinking agent (SDA-47) and an agglomerating deinking agent (SDA-64) on a sorted office-paper furnish and (b) to recommend a satellite deinking system for a customer. The washing and flotation unit processes were of special interest, since the efficiency of these operations is most influenced by the deinking surfactant. Figures 5 and 6 indicate that the flotation stages in the dispersion process were the most effective unit operations in removing visible ink particles and "dirt" particles larger than 225 µm.

Overall, the dispersion process produced deinked pulp having the lowest residual visual ink count. However, this may have been due to variations in the furnish used in the two types of deinking tests. The dispersion process removed 84% of the ink particles in the TAPPI dirt count size range (>225 µm). The agglomeration process removed 94% of the ink particles in this size range. The primary reason for the greater efficiency of the agglomeration process was the greater ink-removal efficiency of the fine-screening step. Using a 0.006-in. fine screen removed 88% of the >225-µm ink particles (and 82% of all visible ink particles) in the agglomeration process. In the dispersion process, fine screening removed 13.1% of the >225-µm particles (and 10.2% of all visible ink particles).

Removal of subvisible ink particles

The dispersion process was more effective than the agglomeration process in removing subvisible ink particles. Removal of 1.2–60-µm ink particles was 92% in the dispersion process compared with 82% in the agglomeration process. This was consistent with the greater brightness gain in the dispersion process (10 points) than in the agglomeration process (9 points). In both deinking processes, the washing step produced the largest brightness gain, indicating that washing is the most efficient unit operation in removing microscopic ink particles. Again, image analysis results were consistent with this interpretation (Table I).

KEYWORDS

Additives, agglomeration, box boards, combination boards, container boards, cylinder boards, deinking, dispersing, fibers, flotation, ink, lined boards, liner boards, mixing, packaging materials, packaging papers, paper board grades, reclaimed fibers, sorted waste papers, surfactants, toners, vat lined boards, waste papers, white paper boards.

The ratio of the number of microscopic (1.2–60 μm) particles to the visible (0.02–5 mm^2) particles was 2.86 after pulping in the presence of SDA-47. This ratio was 4.27 in the accepts from the fourth stage of centrifugal cleaning, indicating the expected preferential removal of larger particles in fine screening, flotation, and centrifugal cleaning. This ratio decreased to 1.26 in the washer accepts, indicating the expected preferential removal of smaller ink particles in this unit operation.

Detailed study of the particle size distribution of the subvisible ink particles suggests the greater tendency of the smallest ink particles to redeposit on the fibers. In Test 1, the 1.2–3-μm particles constituted 19% of the <60-μm particles immediately after pulping, as seen in **Table V**. Washing reduced the <60-μm particles by 72%, while the 1.2–3-μm particles were reduced less, by only 53%. As a result, the 1.2–3-μm particles constituted 34% of the particles <60 μm in size. A duplicate test (Test 2) indicated that these results were reproducible.

If the increase in the relative amount of the smallest ink particles was due to redeposition of ink particles smaller that about 3 μm, the addition of an antiredeposition agent such as carboxymethyl cellulose or sodium poly(acrylate) may significantly improve pulp brightness. The beneficial effect of antiredeposition agents on the brightness of deinked flexographic newsprint has been reported *(10)*. Flexographic newsprint produces large numbers of very small microscopic ink particles on pulping.

CONCLUSIONS

Pilot-plant trials showed that a sorted office-paper furnish can be deinked to produce 100% recycled tissue products or white linerboard. Two commercially available deinking surfactants—one a dispersing agent and the other an agglomerating agent—were tested in two different plant configurations.

The dispersion deinking process can produce deinked pulp that meets the quality specifications of 83 TAPPI brightness and a TAPPI dirt count of 36 ppm. The agglomeration deinking process also produced a pulp meeting the mill's specifications. In both processes, inclusion of a washing step was vital in meeting the brightness specification. Deinked pulp from both processes was suitable for use in production of 100% recycled tissue or white linerboard.

In the dispersion process, the four passes through the forward cleaners were the most efficient operations in reducing the number of large visible ink particles. In the agglomeration process, fine screening was the most efficient unit operation in reducing the dirt count. The greater effectiveness of fine screening in the agglomeration process was probably due to a change in ink-particle geometry to thicker particles promoted by the agglomerating surfactant.

For both the dispersion and the agglomeration processes, the number of centrifugal cleaning stages could be reduced to two. In the dispersion process, the number of flotation stages could be reduced to two.

The washing step provided the greatest reduction in ash content and increase in pulp freeness in both the dispersion and agglomeration processes. **TJ**

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