

## **A PILOT PLANT STUDY OF THE RECYCLABILITY OF PRESSURE SENSITIVE ADHESIVES (PSA)**

Bruce R. Crossley  
Senior Research Engineer  
Beloit Pulping Group R&D Center  
Pittsfield, MA. 01201

David B. Grimes  
Senior Research Engineer  
Beloit Pulping Group R&D Center  
Pittsfield, MA. 01201

Said Abubakr  
Supervisory Chemical Engineer  
USDA Forest Products Lab  
Madison, WI 53705

Rajendra Kumar  
Materials Engineer  
US Postal Service  
Merrifield, VA 22082

### **ABSTRACT**

This paper discusses the operation and results obtained from a pilot plant study of the recyclability of post consumer pressure sensitive adhesive (PSA) postage stamp material. The trial work was carried out in May of 1999 at the Beloit Pulping Pilot Plant in Pittsfield MA., in cooperation with the U.S. Postal Service, and the U.S.D.A. Forest Products Lab in Madison WI. This work is a part of a much larger USPS development program currently under way with the main objective being "to develop postage stamps that do not adversely affect the environment". The goal of the project is to develop a PSA material which can be successfully recycled in the typical mixed office waste (MOW) deinking system producing a pulp for inclusion in printing and writing grades. This trial looks at a "new generation" PSA developed specifically to improve its recyclability when compared to the products in current use by the Postal Service. The adhesive supplied for these trials breaks down in the pulping process into primarily larger sized and two dimensional particles which are generally removable using very fine slotted screens. The screening system design and mass rejects rates at which the screens are run both have an impact on the removal efficiency of the adhesive used for this testing.

### **INTRODUCTION**

This study was part of the United States Postal Service's ongoing efforts to develop environmentally benign pressure sensitive adhesives for postal applications. The trials discussed here were conducted in May and September of 1999 at the Beloit Pulping Group Research and Development Center in Pittsfield, MA. The trials used primarily commercial sized equipment installed in the pilot plant recycled fiber system. The trials were conducted following a system design, and the testing protocol developed by the U.S.D.A Forest Products Laboratory in Madison, WI. The objective of the trials was to study the removal of newly developed second generation pressure sensitive adhesives (PSA's) in the various contaminant removal operations which are currently found in today's typical mixed office waste (MOW) deinking systems. This discussion focuses primarily on the screening system design used for the two trials and the results obtained from those trials.

### **EQUIPMENT & PROCEDURE**

The trial plan and procedure was designed to follow as closely as possible the testing protocol provided by the USDA Forest Products Lab. The material used for the trial was a blend of 95%, clean, 20# basis weight, envelope paper, and 5% printed standard stamp laminate adhered to a portion of the copy paper. This proportion resulted in approximately 1% by weight of adhesive in the pulp used for all of the trials. The adhesive provided as a component of the stamp laminate was a water based acrylic. This trial was intended to simulate a post consumer waste stream, and as such contained no release paper. The system design was provided as part of that protocol. and generally consisted of; high consistency pulping, coarse and fine screening (0.30 mm and 0.10 mm slots respectively), forward cleaning, through flow cleaning, flotation, washing, and dispersion as outlined in the following block diagram. The May 1999 trial was run in the continuous recycling system and the September 1999 trial was run in the batch operation mode in order to minimize the quantity of material required to conduct the trials.

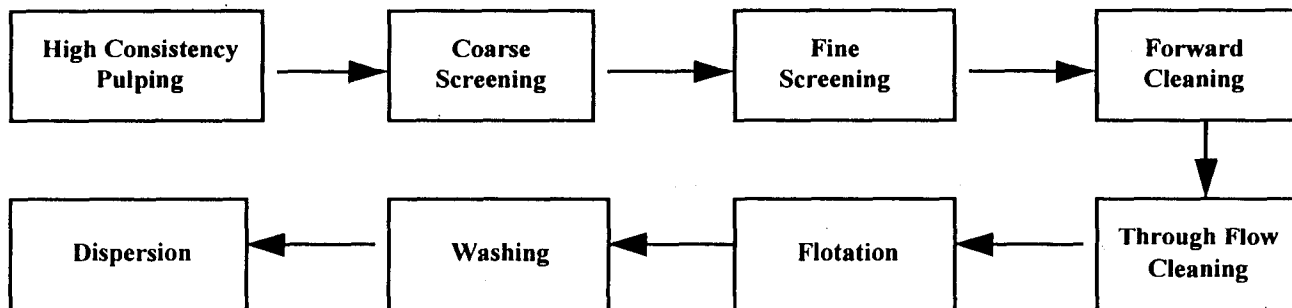


Figure 1. The system block diagram.

All of the pulper batches used for both trials were approximately 400 kg in weight and were pulped in the laboratory helical pulper such that it contained the required proportions of stamp material & clean envelope paper. Sufficient water was placed in the pulper to result in a 15% pulp consistency (after pulping), pH adjusted to 10 using NaOH, and heated to 40° C with the addition of direct steam. The pulper was started and the envelope paper added to start the breakup of this material prior to adding the stamp material. This process took approximately 4 minutes with the pulper impeller running at 250 RPM. Pulping time was 20 minutes. Upon completion of the required pulping time, the pulp was diluted (in the pulper) to 6.0% consistency and pumped into the pulper dump chest for further dilution to screening consistency. Both of the dilution steps used warm dilution water so as to maintain the operating temperature at 40° C. The May (continuous) trial used clarified white water for dilution throughout the system, and the September (batch) trial used warm fresh water for all dilution operations.

The screening systems used for the two trials were different in their design: The May trial used a primary coarse screen equipped with a 0.30 mm slotted contour style basket, and a primary fine slotted screen equipped with a 0.10 mm slotted contour screen basket. Both screens were run at low consistency (approximately 1%) using foil type rotors. The rejects from both primary screens were combined, diluted to the targeted consistency, and processed in a common secondary screen equipped with a 0.10 mm slotted basket. The accepts from the secondary screen were taken to the feed of the primary coarse slotted screen in typical cascade fashion. The rejects from the secondary screen were taken to the system rejects handling system. This is illustrated in Figure 2 below.

### May 1999 Trial System

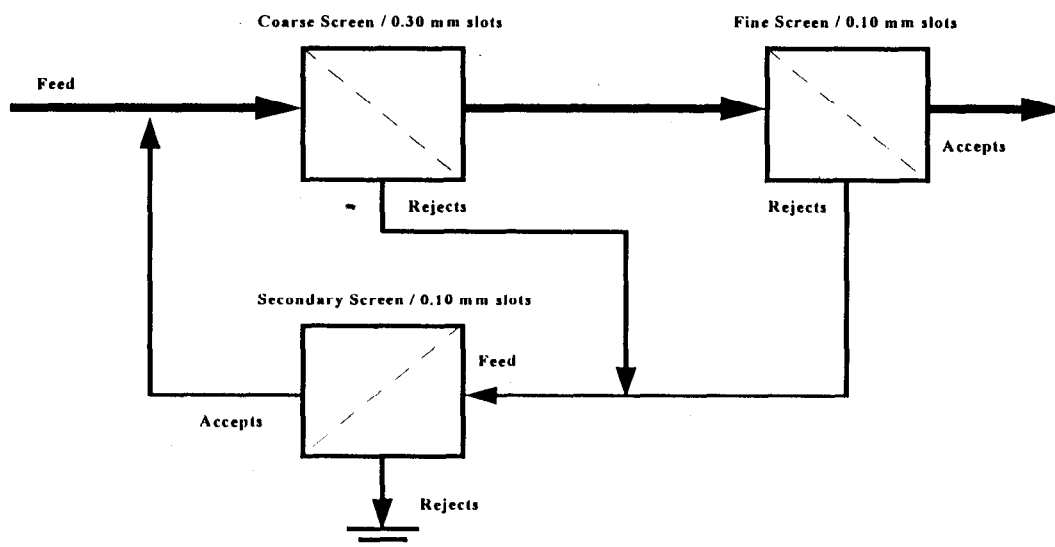
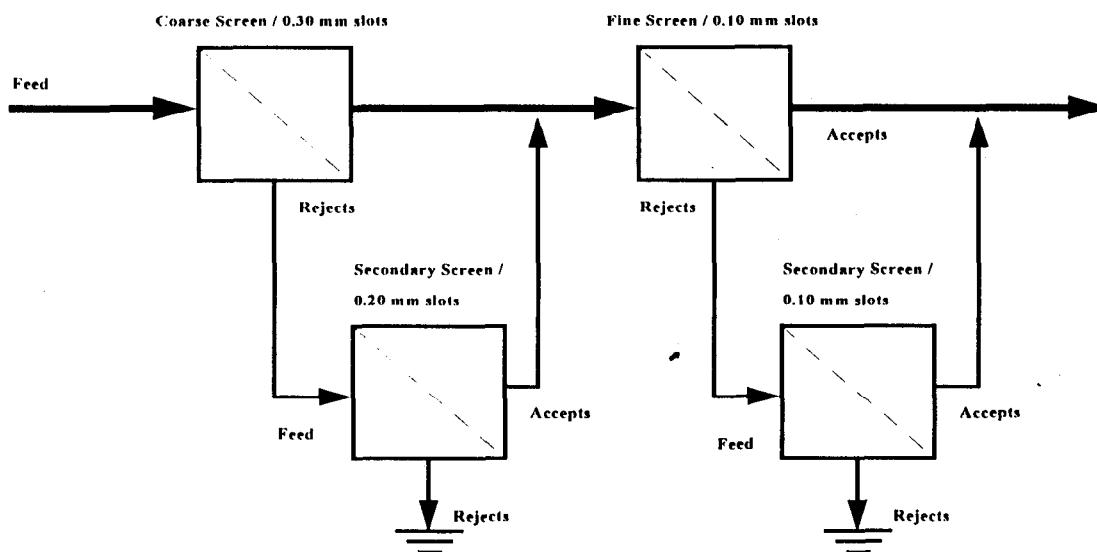


Figure 2. The screening system configuration used in the May 1999 trials.

The screening system used for the September trials was changed to separate the coarse and fine slotted screening operations completely. The primary coarse screen used a foil type rotor and the same 0.30 mm slotted basket as the previous trial, but the rejects from that screen were taken to a dedicated secondary screen for that module. The secondary coarse screen was equipped with a 0.20 mm slotted basket. The accepts from the secondary coarse screen were fed forward to combine with the accepts from the primary screen. The rejects from the secondary screen were samples and removed from the system. The fine slotted screening system also consisted of primary and secondary screens arranged in the same way as the coarse screening system (secondary feed forward). In this case both stages of screening were equipped with 0.10 mm slotted baskets. The operating consistencies for this trial were similar to those used in the earlier trials, approximately 1%.

### September 1999 Trial System



**Figure 3. The screening system configuration used in the September 1999 trials.**

The remainder of the operations were essentially the same for both trials. Forward (heavies) cleaning was the next operation to take place, and that used the 3" heavyweight cleaner. This cleaner operates with a 4.4 kPa pressure drop and atmospheric rejects discharge. Two series primary passes of forward cleaning were used with the rejects from each pass combined and processed for fiber recovery in a single pass of secondary cleaners. The accepts from the secondary cleaner was directed to the feed of the first pass primary cleaner, and the rejects from the secondary cleaner was removed from the system. Feed, accepts and rejects samples were collected for analysis during the cleaner operation. The "heavies" cleaning operation was followed by two passes of through flow cleaning for removal of the lightweight contaminants. The through flow cleaners operate with a very low mass rejects rate so no secondary fiber recovery stage was used for this operation.

Flotation, using a pressurized deinking cell, followed the cleaning operations in the trial plan. This is a pressurized flotation cell which utilizes dispersed and dissolved air in the pulp to float the targeted contaminants to the surface of the pulp, and separate them from the cleaned pulp. The cell consists of an inlet zone where compressed air is added to the pulp stream, followed by a static mixing zone where the contaminant particles are made to contact the air bubbles. The pulp discharges from the mixing zone into the flotation chamber where the air bubbles are allowed to carry the contaminant particles to the surface of the pulp. The rejects pass over a weir, and are conveyed under pressure to a liquid/gas cyclone which breaks the foam and extracts the air. This allows the contaminant laden rejects stream to be pumped to the system rejects handling system. The cleaned pulp passes under the weir, and is

conveyed under pressure to the next unit operation in the system. The stock was prepared for flotation by adjusting pH to an acceptable level and followed by the addition of the flotation chemistry at a 0.1% addition rate by mass.

The next unit operation to take place was pulp washing using the Beloit DW-18, Dynamic Washer. This is a pressurized mechanical washer utilizing a drum type rotor rotating inside a cylindrical filter media having 0.008” diameter drilled holes. The feed stock is conveyed under pressure into the annular area between the rotor and filter media. Water and small contaminants are allowed to pass through the filter media, while the fiber is retained on the surface of the media and through the device to the stock discharge port. The rotor is rotated at such a speed so as to keep the pulp fluidized and not form a fiber mat on the surface of the filter media. The thickening ratio (water extraction) and production rate are controlled by means of flow control valves on both the effluent and fiber discharge streams. The flotation cell accepts was discharged directly into the washer feed chest, and again no further dilution took place prior to this operation. The washer cake discharged from the washer at 3.4% consistency and was thickened to approximately 30% consistency using a horizontal screw press.

All sample collection and testing, except stickies analysis, was carried out by Beloit Technical Personnel according to Tappi Standard Procedures. Stickies analysis was performed using the Optomax Speck Check, 600 DPI scanner based system following a procedure developed and provided by the USDA Forest Products Lab in Madison, WI.

## DISCUSSION

The stamp stock was affixed to a portion of the copy paper prior to being introduced into the pulping operation, and as such simulates a post consumer waste stream (no release paper). The 5% addition rate of the stamp laminate is clearly higher than that which would be normally found in the typical MOW paper used as a raw material in the production of copy paper. This addition rate does provide a high enough population of adhesive, 1%, to allow a reasonable measurement of contaminant reduction as the pulp is processed through the trial system. The pulping process in both trials resulted in complete defibering of the furnish at the end of the specified 20 minute pulping time, with what appeared to be complete release of the adhesive from the fiber.

The focus of the adhesive development program has been to develop products which would break up in pulping into primarily larger sized particles which are then easily removed using tine slotted screening. The adhesive provided for September ‘99 trials did break up into predominately larger particle sizes (greater than 0.1 sq. mm) than the May ‘99 as can be seen in the following figure:

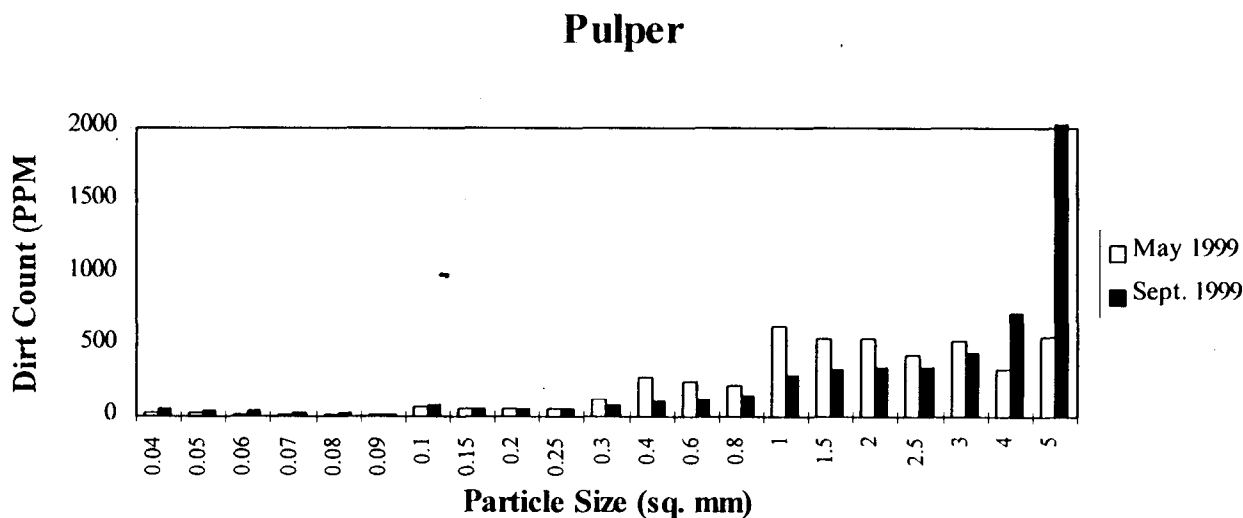


Figure 4. Pulper particle size distribution.

This results in an adhesive population which should be primarily removable through slotted screening, although not necessarily at high efficiency in the 0.30 mm coarse slotted screen. The following table compares the pulper and coarse screen Tappi dirt counts for the two trials:

Primary Coarse Screening Results				
Trial	Dirt Count (PPM Tappi Dirt)			
	Pulper	Coarse Screen Inlet	Coarse Screen Act.	% Reduction
May	4253	4734	3356	29.1%
September	2874	3437	2054	40.2%

It must be recognized that this is not an equal comparison since the feed to the coarse screen in the May trial contains accepts from the common secondary screen (0.10 mm slot) used in the system, compared to the feed of the coarse screen in the September trial which does not contain accepts from a secondary screen at all (that system used a feed forward secondary screen). This then explains to some extent the difference in the removal efficiency and particle size differences for the coarse screening systems. The resulting particle size distributions are compared to each other.

### Coarse Slotted Screen Accepts

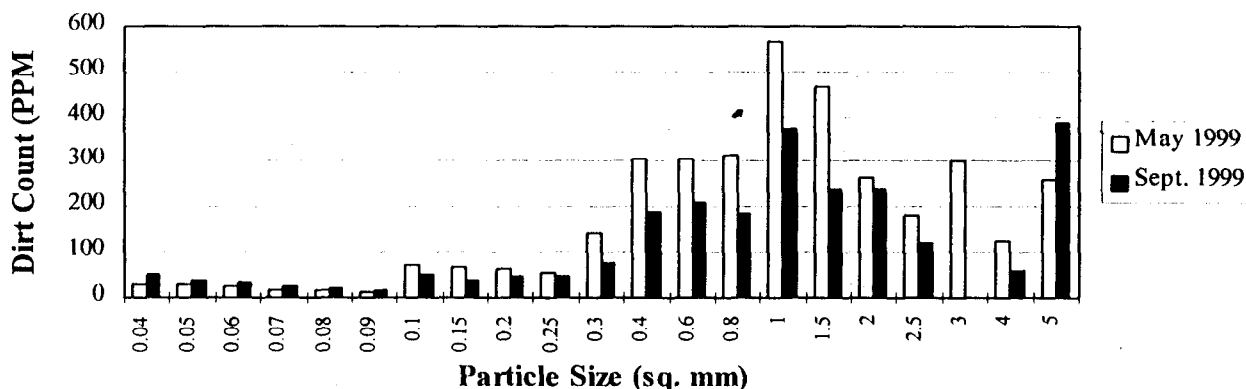


Figure 5. Coarse slotted screen accepts sample particle size distributions.

A comparison of the coarse screen inlet and accepts samples for the two trials (Figures 4 & 5) shows that the higher removal efficiency for the September trial was primarily due to the higher population of large particle sizes in that pulp (4 sq. mm & above) which was removed in the coarse screens.

In order to maintain maximum over-all system removal efficiency, the contaminant material found in the primary coarse screen rejects must be removed from the system. This is often accomplished with the use of smaller sized slots in the secondary (and tertiary) screens than those installed in the primary stage. In the case of the September trials a 0.20 mm slotted basket was installed in the secondary coarse screen tailing the rejects from the 0.30 mm primary screen. The effectiveness of the 0.20 mm slotted basket used in the secondary coarse screen can be seen in Figure 6 where its accepts particle size distribution is compared to that of the primary coarse slotted screen accepts. The measured dirt count for the 0.20 mm slotted secondary screen was 403 PPM (Tappi dirt) compared to 2054 PPM for the primary coarse slotted screen with the 0.30 mm slot size. This clearly shows how much more effective the smaller slot size is and how the use of that 0.20 mm slot easily allows the accepts from the secondary screen to be fed forward without any detrimental effect on the over-all system efficiency or contaminant removal, thus eliminating an additional opportunity for soft contaminants to be broken down in size as they are passed again through the primary screen in a cascade system.

## Coarse Screen Accepts September 1999

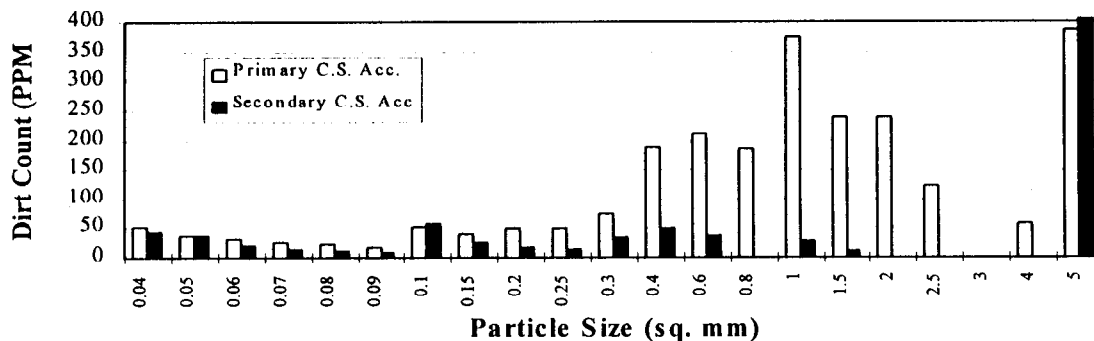


Figure 6. Coarse screen accepts particle size distributions for the September 1999 trials.

The fine slotted screening systems used for the two trials differ in the direction in which the secondary screen accepts were taken, and the make-up of the feed to the secondary screen. In both trials the primary screens were equipped with 0.10 mm slotted baskets and foil rotors. In the May trials, the rejects from the coarse and fine screens were combined and taken to the secondary fine slotted screen, with the accepts from that secondary screen being taken back, cascade fashion to the feed of the primary coarse screen. The system used for the September trial consisted of a secondary screen with a similar hardware configuration but the accepts were taken forward to combine with the accepts of the primary fine screen to feed the forward cleaning system. The Tappi dirt count in the fine screen accepts from the May trial was 1007 PPM compared to 215 for the September trial. This represents reductions of 78.7% for the May 1999 trial compared to 93.7% for the September trial. This is summarized in the following table:

Primary Fine Screening Results			
Trial	Dirt Count (PPM)		% Reduction
	Fine Screen Inlet	Fine Screen Accepts	
May	3356	1007	70.0%
September	2054	215	89.5%

The particle size distributions for the two screening system accepts samples are compared in Figure 7 below.

## Primary Fine Slotted Screen Accepts

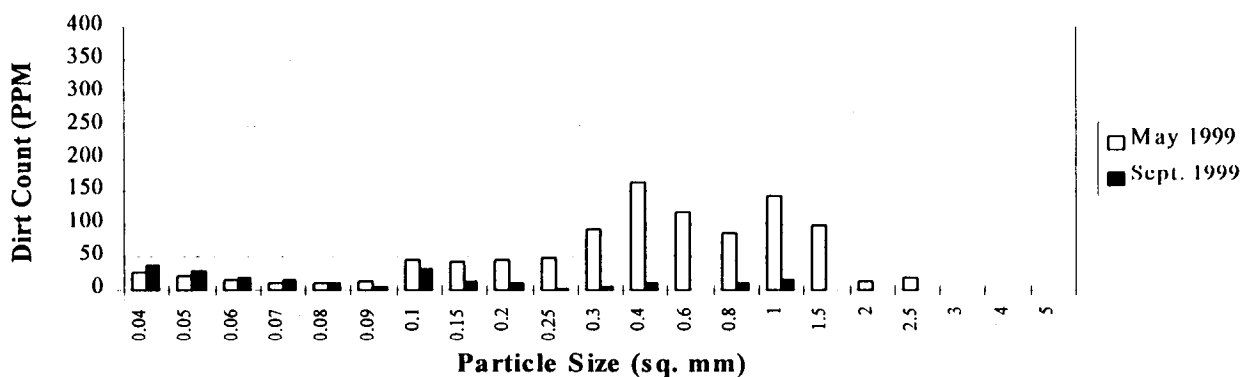
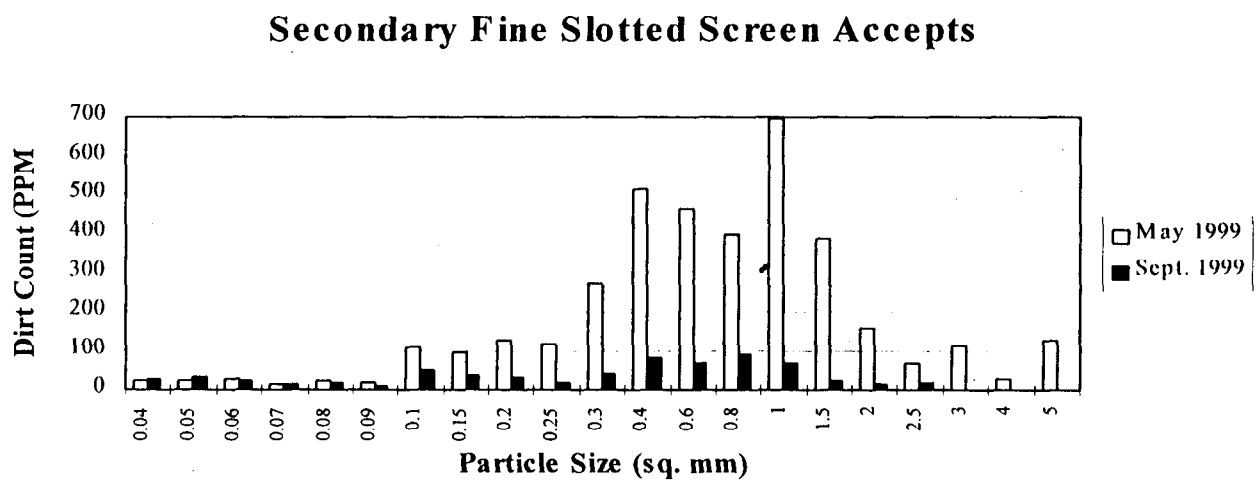


Figure 7. Primary fine slotted screen accepts contaminant particle size distributions.

These results suggest that since both of the primary screening operations used the same screen, screen basket, and were operated at similar production and rejects rates, the difference in removal efficiencies were due at least in part to the difference between the rejects system configurations, the resulting concentration of contaminant particles, and their run-around in the screening system used for the May trials. The fine screen feed dirt count was 3356 PPM for the May trials compared to 2054 PPM for the September trial.

A comparison of the accepts from the secondary fine screen from the May trials and the secondary fine screen from the September trials shows a significant difference between the quality of those different pulp streams; 3672 PPM Tappi dirt for the May trial compared to 662 PPM for the secondary fine screen from the September trial. The secondary screen accepts from the May trial was taken back into the feed to the primary coarse screen for additional processing compared to the accepts from the secondary fine screen from the September trial which was fed forward. This system difference results in a significant quantity of contaminant being reintroduced into the primary screen feed during the May trial, boosting the contaminant loading of that system. The difference in particle size distributions between the secondary fine screen accepts samples for the two trials is illustrated in Figure 8 below:



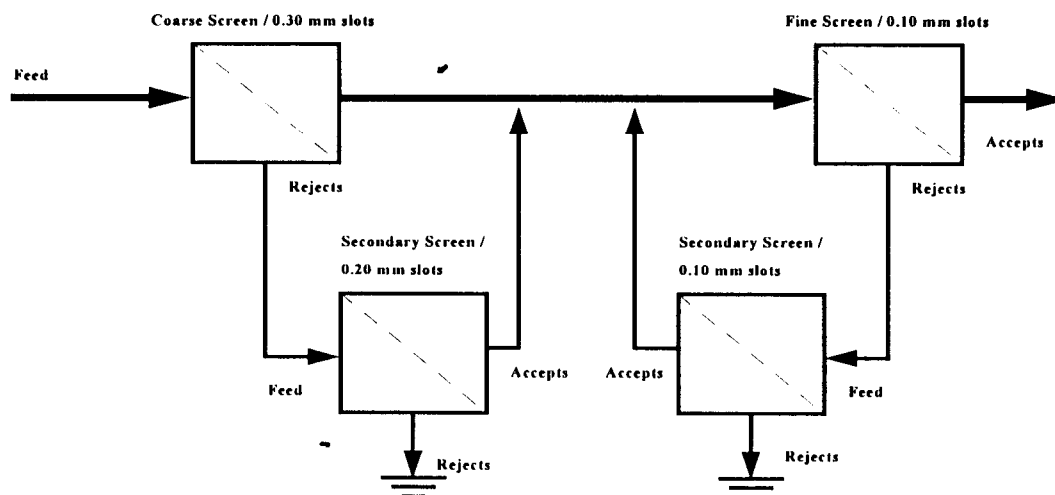
**Figure 8. Secondary fine slotted screen accepts particle size distribution.**

There was a shift in focus on the design and operation between the trials run in May and those run in September. That shift was directed at making the operation of the entire screening system more efficient at removal of pressure sensitive adhesives. This was accomplished not only by adding the dedicated secondary coarse screen, but also by increasing the mass rejects rates at which the screens were operated. This adhesive initially breaks down in the pulping process into what are primarily two dimensional particles and they appear to remain in that form at least through some of the unit initial processes through which they pass early in the system. Platelet like, two dimensional particles have the general tendency to align themselves with their thin dimension the direction of flow which presents their thickness to the slot of a screen basket. This increases their probability of passage through a slotted basket (assuming that their thickness is less than the slot width) over that which would occur if the particles were randomly oriented in the pulp slurry. This then explains the relative inefficiency of the 0.30 mm slotted basket at removing particles which are measured using image analysis as being much larger than the slot width. Image analysis does not measure the thickness of the particles in the handsheet, only the two dimensional surface area. Only the finest of slotted screen baskets have slot widths small enough to effectively separate the relatively thin adhesive particles from the fibers themselves. Additionally these fine slotted baskets also present slightly more resistance to deformation of the pliable adhesives and passage through the slots with the accepted fiber. Both of these characteristics can be enhanced by increasing the mass rejects rates at which a given screen is operated, effectively decreasing the opportunity for the contaminants to be accepted.

The mass rejects rate of the primary coarse screens were not significantly changed between the two trials;  $R_w = 11.7\%$  for the May trial versus  $R_w = 14.8\%$  for the September trial. It is unlikely that the 3% difference between the two trials could make a significant difference in the results and the data shows that it did not. The difference between the primary fine screening systems rejects rates was significant;  $13.7\%$  for the May trial versus  $25.3\%$  for the September trial. This is a great enough difference that it could have contributed to the increase in removal efficiency seen in the fine screen for the September trial. Additionally an even more significant contribution was likely made by the separation of the secondary screening function for the coarse and fine screens. This resulted in better removal from the system of the contaminants which were rejected by both of the primary screens. The secondary coarse screen was operated at a  $R_w$  of  $29.5\%$  which results in a  $R_w$  for the coarse screening system of  $3.7\%$  of the feed to the screening system. This compares to the May trial rejects rate of  $3.6\%$  for the entire screening system (both coarse and fine). The fine screening system used for the September trials also included its own secondary screen which was run at a mass rejects rate of  $29.1\%$  which results in a mass rejects from the fine screens of  $7.3\%$  resulting in a total mass rejects of nearly  $11\%$ . This is nearly 3 times that of the rejects rate run during the May trials.

The impact of reintroducing the secondary screen accepts from the May trials back into the screening system is clearly significant compared to that which the secondary fine screen accepts from the September trial had when taken forward in the system or would have had if they had been cascaded back to the feed of the primary fine screen. The testing results from the September trial indicates that the over-all adhesive removal efficiency would have been improved if the secondary fine screen accepts were cascaded back to the feed of the primary fine screen. This is based on the measured dirt count of the secondary fine screen being  $662$  PPM compared to that of the combined primary and secondary screen accepts being  $215$  PPM. This then tells us that the accepts from the secondary fine screen increased the dirt count of the pulp out of the screening system. The preferred fine screening system using  $0.10$  mm slotted baskets in both primary and secondary screens would then be a conventional cascade type system.

### Preferred Screening System



The over-all screening system yield for the September trial was lower than that of the May trial which as previously discussed contributed to the higher removal efficiency achieved during the September trial. In suggesting that the fine screening system be altered to become a cascade type system versus the feed forward system used for the September trial, it is recognized that the actual flow through the primary screen will need to be increased to maintain the desired system capacity. This will also result in an increase in the rejects flow from the primary screen to maintain the same rejects rate. This is necessary to maintain the efficiency of that operation. This then results in an increase in flow, and tonnage, to the secondary fine screen, which in turn can result in an increased yield loss for the cascade type system if the rejects rate of the secondary screen is maintained the same as for the feed forward



2000 PROCEEDINGS

# 2000 TAPPI Recycling Symposium

## Volume Two



March 5-8, 2000  
Hyatt Crystal City  
Washington, D.C.



AF&PA

