BEHAVIOR OF PRESSURE SENSITIVE ADHESIVE MATERIAL IN INDUSTRIAL PRESSURE SCREENS AND LABORATORY SCREENS

Bradley E. Lucas, Richard A. Venditti*, and Hasan Jameel
*Corresponding author

North Carolina State University
Department of Wood and Paper Science
Box 8005
Raleigh, NC 27695-8005
Telephone: (919) 515-6185

ABSTRACT

The objective of this research was to investigate the behavior of adhesive contaminants in industrial and laboratory screens. A single type of acrylate based pressure sensitive adhesive label was applied to copy paper and pulped. The pulp was then screened using an industrial pressure screen, a Pulmac MasterScreen, and a Valley Flat screen, all having 0.006 inch slots. A dyeing and image analysis method was utilized to detect the stickies. As expected, the laboratory screens were much more efficient than the industrial screen. The industrial screen was found to breakdown the adhesive particles, which contributed to the lower screening efficiency of the industrial screen. These results indicate that the use of laboratory screens to predict the screenability of adhesive materials is not acceptable. Currently, there is not an effective method in the laboratory to predict the screenability of adhesive materials in industrial pressure screens but one is needed.

BACKGROUND

Adhesives enter the wastepaper stream as stamps, labels, envelopes, etc. [1-4]. When wastepaper is repulped, the adhesives are broken down into smaller particles, which are commonly referred to as sticky contaminants or simply stickies [3,5-7]. Stickies deposit on the paper machine equipment, which causes problems in production [2,8-10]. Reported methods for removing stickies from recycled fiber are screening, cleaning, flotation, and washing [2,7,9,11].

One very difficult to remove class of adhesives is the pressure sensitive adhesive (PSA) [3]. Pressure sensitive adhesives are defined as "permanently tacky and will adhere to a variety of dissimilar surfaces upon contact" [6]. To be tacky, PSA materials are formulated with a glass transition temperature less than 20°C. They are deformable and elastic during recycling operations [6,10,11]. PSA materials are typically applied to paper at a thickness of about 0.001 inch. After pulping this thin film is ruptured producing either fragments of the thin film, or particles in the shape of a sphere or fiber depending on the pulping conditions [3,6,7,10-12]. It has been proposed that the size, shape and deformability of the PSA cause removal efficiencies in screening operations to be low [1,3,5,6]. Also, PSA materials often have a specific gravity near one, causing difficulty in removal using cleaners [1,3,9-11,13].

Macro and micro are the two size categories generally used to describe stickies [8,14-16]. Macro stickies are defined as the stickies that are retained on a 0.006 inch slotted laboratory screen, while micro stickies pass through the 0.006 inch slotted laboratory screen [8,14,15]. The macro stickies are collected on the screen and analyzed, while the micro stickies remain with the accepted pulp [2,14-16]. By definition, laboratory screens remove 100% of the macro stickies [14,15]. On the paper machine, micro stickies may agglomerate and deposit on the equipment [2,14].

The commonly held method to remove stickies is the pressure screen in a multistage system [18]. The pressure screen is a cylindrical vessel containing a screen basket, rotor, and multiple ports [4,18]. The screen basket has either holes or slots designed to block large contaminants but allow good fibers to pass through [17]. The size of the holes or slots is the most important screen parameter in the removal of stickies [17,18]. For the removal of small stickies particles, fine screens are used because of their narrow slot sizes ranging from 0.004 to 0.012 inches. A limit exists for the minimum opening size, which is related to the width of a papermaking fiber. Further, operating problems like plugging are more probable at the smaller opening sizes.

For fine screens, typical removal efficiencies of stickies are only 70-80% [19]. To explain this, it has been proposed that some macro stickies extrude through the openings due to the pressure difference across the screen or by shear forces [8,20]. In contrast, laboratory screens do not have appreciable pressure difference or shear forces and therefore have higher removal efficiencies. Due to this difference, the laboratory screens do not provide an adequate representation of industrial pressure screens for stickies removal. This lack of a laboratory test indicative of industrial screening of adhesives limits research by adhesive manufacturers' and the paper industry. Thus, it is important to understand on a detailed level the differences in operating principles and performance between laboratory and industrial screens.

In this study, the removal efficiencies of adhesive contaminants by industrial and laboratory screens were compared. A model system of copy paper and pressure sensitive adhesive labels was prepared in a pilot plant hydropulper and screened in a pilot plant industrial screen and two laboratory screens with the same slot sizes. One of the main findings was that breakage of adhesive particles occurred in the industrial screen and was an important phenomenon contributing to the low screening efficiencies.

EXPERIMENTAL

Pilot Plant Screening

Avery Dennison "White Shipping Labels", product number 5164, were applied to sheets of Weyerhaueser Husky Xerocopy paper to achieve an adhesive content of 0.2% adhesive on OD paper. Through the use of infra-red spectroscopy the adhesive material was determined to be an acrylate based PSA. Three batches were prepared, each containing 50 OD lbs. of paper and 0.5 lbs. of labels. Each batch was pulped in a 200 gallon hydropulper from Black Clawson Co. The hydropulper was operated at a consistency of about 6% for 20 minutes at a rotor speed of 800 rpm. The initial temperature of each batch was between 50 and 55°C. All three batches of pulp were collected in a stock tank and diluted to a consistency of 0.80% with water heated by steam. The pulp was allowed to mix for 20 minutes.

The industrial pressure screen utilized is a cylindrical vessel with feed, accept, and reject valves for flow control. Typical operating parameters for this screen are a 100 gpm feed flow rate and a 1-3% feed consistency. A screen basket with 0.006 inch wide slots and a contoured surface was installed in the vessel. Also, a shower and rotor inside the screen basket are used to prevent the accumulation of material on the face of the basket. The rotor speed is 1800 rpm.

Figure 1 shows the pilot plant layout for the experiment. Pulp was pumped from the feed stock tank through a flow meter and the feed valve of the pilot plant screen. The accepts passed through the screen and the accept valve of the pilot plant screen to a second stock tank. During the experiment, feed samples were scooped from the top of the feed stock tank (1). Accepts samples were collected from the outlet of the pipe feeding the second stock tank (2). Rejects samples were collected from the reject valve outlet of the pilot plant screen (3).

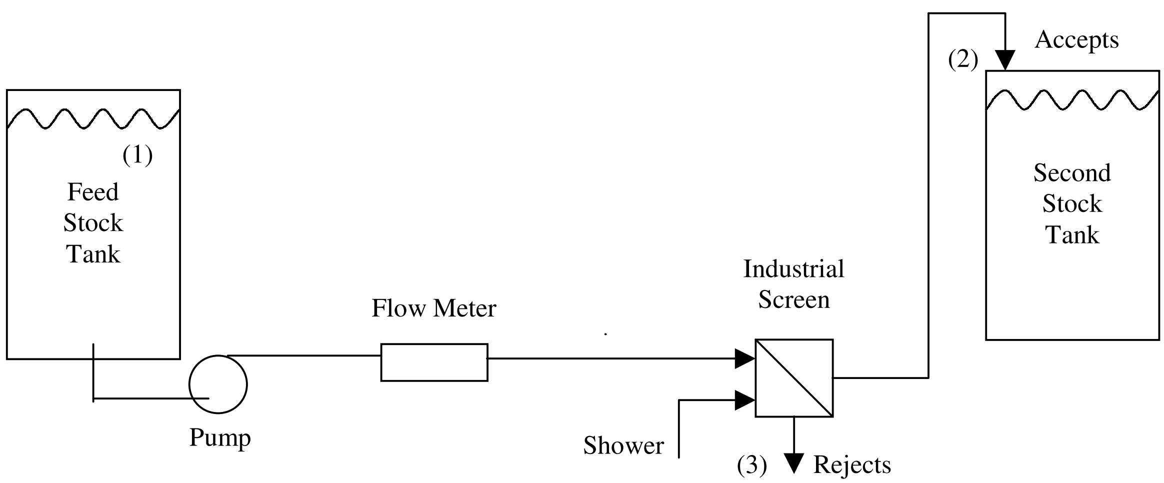

Figure 1. Flow diagram of the pilot plant screening experiment.

The pilot plant screen feed valve was adjusted until the flow rate through the flow meter was 4.4 ft/s, or about 96 gpm. The shower water for the screen was set at 5 gpm and the gauge pressures were at 2 and 5 psig for the feed and accept streams, respectively.

The reject valve was adjusted until a reject rate of 10 gpm was achieved, at which point samples of the rejects, accepts and feed were collected. The feed temperature was 50°C and the accept temperature was 51°C. Then, the reject valve was adjusted until a reject rate of 8 gpm was achieved and samples of the rejects, accepts, and feed were collected. The feed temperature was 50°C and the accept temperature was 52°C. Next, the reject rate was decreased to about 5.45 gpm and a third set of rejects, accepts, and feed samples were collected. The feed temperature was 48°C and the accept temperature was 52°C. Samples were stored in a cold room in sealed plastic buckets.

A second pilot plant experiment was used to evaluate the effect of the pilot plant pumps on the adhesive and also to evaluate a different reject rate for the pilot plant screen. **Figure 2** shows the pilot plant layout for the pumping experiment. Pulp containing 0.2% adhesive on OD paper was prepared in the hydropulper in a similar manner to the first pilot plant experiment. During the experiment, pulp samples were collected from the top of the pulp in the dilution tank (4), the outlet of the pipe feeding the feed stock tank (5), the top of the pulp in the feed stock tank (6), and the outlet of the pipe back to the feed stock tank (7). Pulp was pumped from the dilution tank to the feed stock tank and then from the feed stock tank through a flow meter and back to the feed stock tank. A valve in the recirculation line was used to set the flow during the recirculation at 96 gpm. With the tank liquid volume of approximately 500 gallons, a quantity of about half of the tank contents was recirculated in this experiment.

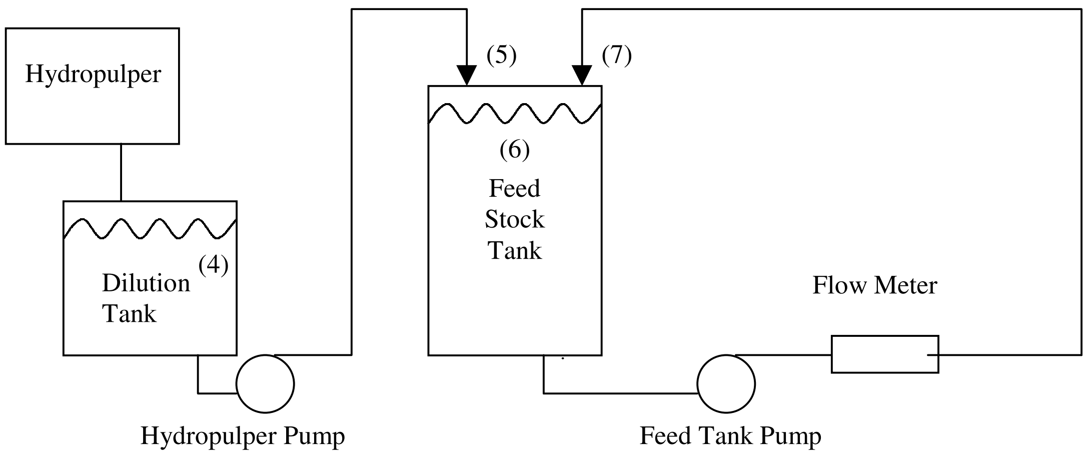

Figure 2. Flow diagram of the pilot plant pump experiment.

After stopping the recirculation flow, pulp from the feed stock tank was directed toward the screen as in Figure 1. The pilot plant screen feed valve was adjusted until the flow rate through the flow meter was 4.4 ft/s, or about 96 gpm as before. The shower water for the screen was set at 5 gpm and the gauge pressures were 2 and 5 psig for the feed and accept streams, respectively, also as before. The reject valve was adjusted until a reject rate of 15 gpm was achieved, at which point samples of the rejects, accepts and feed were collected. The feed temperature was 53°C and the accept temperature was 54°C.

Laboratory Screening: Pulmac MasterScreen

The Pulmac MasterScreen consists of a feed tank, a screening chamber, and a collection tube. The screening chamber has a screen plate with 0.006 inch slots and a spinning rotor (500 rpm), which agitates the stock and prevents blinding of the screen plate. The collection tube collects the rejects from the screening chamber on coarse filter paper.

Pulp of a known consistency in the plastic sample bucket was stirred to obtain a uniform distribution of contaminants. A pulp sample containing 25 OD g of pulp was taken. The Pulmac MasterScreen was turned on and subjected to two wash cycles. The mesh and screen plates were removed and washed with deionized water and replaced in the screen. A Fischerbrand Filter Paper P8 of measured OD weight was placed in the rejects tube and the Pulmac screening cycle was initiated. The temperatures of the pulp and water were determined to be approximately 25°C for each experiment. The accepts were collected from the accept stream in a 150 mesh basket and the rejects were collected on the filter paper on the mesh plate. The accepts were removed from the basket and placed in a plastic bag for cold storage. The filter paper containing the rejects was placed in a 105°C oven to dry overnight.

Laboratory Screening: Valley Flat Screen

The Valley Flat screen is a rectangular vessel with a rectangular horizontal screening plate containing 0.006 inch slots. A vibrating diaphragm on the accept side of the plate is used to back flush the screen openings on a cyclic basis. A water shower is used to keep the pulp stock diluted throughout a normal screening experiment.

Pulp of a known consistency in the plastic sample bucket was stirred to obtain a uniform distribution of contaminants. A pulp sample containing 25 OD g of pulp was measured. The Valley Flat screen was rinsed out and refilled to above the water shower with deionized water. The water shower supply valve was opened all the way and the motor for the diaphragm was started. The outlet valve was adjusted until the water level was constant. The temperatures of the pulp and water were measured. The water temperature was approximately 25°C for each experiment. The pulp sample was poured onto the screen and the temperature of the diluted pulp was measured. After 5 minutes, the water supply valve was closed. The motor was stopped when the water level was about 1 inch above the screen plate. The remaining water was allowed to drain. The accepts were collected in a 150 mesh basket and then placed in a plastic bag for storage. The rejects remaining on the screen were transferred to Whatman Filter Paper #541 and placed in a 105°C oven to dry overnight.

Another procedure for the Valley Flat screen involved the use of hot water instead of room temperature tap water from the water shower. Five 4 L beakers were filled with deionized water and were heated in a microwave to about 48°C. Instead of opening the water supply valve on the shower, one beaker of hot water was poured onto the screen before the pulp was added. Each beaker of heated deionized water was poured onto the screen when the water level dropped to 1 inch above the screen plate. The temperature of the pulp stock during screening was 40-45°C. The screen motor was turned off after the last beaker was added and the water level was about 1 inch above the screen plate.

Dyeing and Rinsing of Handsheets

The dyeing and rinsing method was critical for the image analysis of the handsheets. Undyed white adhesive particles are indistinguishable from the fiber by image analysis. An increased contrast between stickies and the handsheets is thus required to detect the stickies properly. Two dye solutions and several dyeing methods were tested in previous work [21]. The two dye solutions were Drew's Blue Stickies Dye-Ethanol and Morplas Blue-Heptane. For Drew's Blue Stickies Dye-Ethanol, rinsing with water and Ethanol were evaluated. For Morplas Blue-Heptane, the number of rinses in Heptane were compared, the dyeing and rinsing times were varied, and different methods of drying rinsed handsheets were considered. The best method was found to be with Morplas Blue-Heptane involving dyeing and rinsing each handsheet for ten seconds and removing rinsed handsheets as soon as they were dry. This method was used in this research and is described in this report.

Handsheets containing 1.2 OD g of pulp were prepared in sets of twelve using the TAPPI standard method. After the handsheets had dried overnight, ten handsheets were selected out of each set of twelve for dyeing.

Morplas Blue-Heptane dyeing solution was prepared in a vacuum hood. A mass of 0.670 g of Morplas Blue was weighed out in a metal pan using an analytical balance and poured into a 1000 ml volumetric flask. The flask was filled to the mark with 95% Heptane from Sigma-Aldrich. A magnetic stirrer was placed in the flask and a stopper was placed in the top. The flask was set on a stirring plate to stir overnight.

The Morplas Blue-Heptane dyeing solution was filtered using Whatman Filter Paper #1 in a Buchner funnel. The filtered solution was collected in a 1000 ml Erlenmeyer flask. 250 ml of the filtered dye solution was measured out in a 500 ml graduated cylinder and poured into a crystallizing dish. One handsheet was submerged in the dye solution and swirled for ten seconds. The handsheet was removed with forceps and hung from a string with a binder clip. These steps were repeated for the other nine handsheets to be dyed. The handsheets were allowed to dry overnight.

The next day, the handsheets were removed from the string. 500 ml of 95% Heptane was measured out in a 500 ml graduated cylinder and poured into a crystallizing dish. One handsheet was submerged in the Heptane solution and swirled for ten seconds. The handsheet was removed with forceps and hung from a string with a binder clip. These steps were repeated for the other nine handsheets to be rinsed. Each handsheet was removed as soon as it was dry.

Image Analysis

The SpecScan 2000 program by Apogee Systems Inc. was used to scan each set of ten handsheets, before and after dyeing, to determine the stickies content of the samples. The scanner was a Hewlett Packard Scanjet 4c with a 600 dpi resolution. A standard sample was scanned sixteen times in order to warm up the scanner bulb before image analysis was performed on real samples. The detection threshold was set to 80% of the average grayscale value. Both the felt and wire sides of each of the handsheets in a set were scanned. The parts per million of stickies (PPM) and the average particle size for particles greater than or equal to 0.040 mm^2 for each set of handsheets were determined for each side. Also, a histogram of particle sizes in terms of area and count was recorded. The values for the felt and wire side for each set of handsheets were averaged to obtain values for the total area of the set.

RESULTS AND DISCUSSION

The stickies parts per million results (PPM) from the pilot plant screening experiments are shown in **Table 1**. The screen was operated at several different reject flow rates. This resulted in different values of the mass reject ratio, R_w:

$$R_W = V_R C_R / V_F C_F$$

where V is the volumetric flow rate and C is the solids consistency and R and F indicate the rejects and feed, respectively. The values of R_w increased with increasing reject flowrate as expected, Table 1. Samples from the pilot plant feed, accepts, and rejects were screened with the Pulmac and Valley screens. The PPM of the accepts for the Pulmac, Valley 25^{o}C, and Valley 45^{o}C are also shown in Table 1. Notice that the PPM values for the pilot plant screen feed, accepts, and rejects are much greater than those for the accepts from all of the laboratory screens.

This confirms that the lab screens are significantly more effective in removing stickies from pulp.

		Parts Per Million, PPM			
Feed Flow Rate, gpm		96 gpm	96 gpm	96 gpm	96 gpm
Reject Flow Rate, gpm		5.45 gpm	8 gpm	10 gpm	15 gpm
Mass Reject Ratio, %		4.5 %	12 %	15 %	25 %
Pilot Plant Feed (1)		1600	1840	2260	2940
Pilot Plant Accepts (2)		980	840	1120	830
Pilot Plant Rejects (3)		11300	7770	9620	4080
Pilot Plant Feed (1)	Pulmac	-	14	12	-
	Valley, 25°C	-	22	52	-
	Valley, 45°C	-	2	35	-
Pilot Plant Accepts (2)	Pulmac	40	78	52	-
	Valley, 25°C	67	177	71	-
	Valley, 45°C	228	247	201	-
Pilot Plant Rejects (3)	Pulmac	73	168	42	-
	Valley, 25°C	112	457	88	-
	Valley, 45°C	353	306	432	-

Table 1. Parts per million values of screening experiments.

The cleanliness efficiency, E_C, was determined by the following equation [22]:

$$E_C = 1.0 - (S_A / S_F)$$

where S_A and S_F are the PPM of stickies in the accept and feed streams, respectively. (The subscript A indicates accepts.) The cleanliness efficiency indicates how clean the accept stream is relative to the feed stream. The reject efficiency, E_R, can be calculated as either:

$$E_R = (V_R C_R S_R) / (V_F C_F S_F)$$

or equivalently:

$$E_R = 1.0 - (V_A C_A S_A) / (V_F C_F S_F)$$

The reject efficiency measures the fraction of incoming contaminant that is separated into the reject stream. E_R is a better descriptor than E_C of an operation to remove a contaminant because it is based on the material balance of the contaminant, not just the concentrations in the feed and accepts. E_c may be artificially high and misleading in cases where the amount of total reject material is large compared to the accept stream.

The efficiencies described above were calculated from the data in Table 1 and are shown in **Table 2**. For the lab screening experiments, it was found that the OD mass of the feed ($V_F C_F$) essentially equaled the OD mass of the accepts ($V_A C_A$). This was due to the facts that (a) essentially no fiber was found in the rejects and (b) the mass of the adhesive in the experiment was comparatively small relative to the fiber. If this equality is true, then the reject efficiency and the cleanliness efficiency are equal. Thus, the result from the equation for E_C is shown in Table 2, but is also equal to E_R.

		Screening Efficiency, %			
Reject Flow Rate, gpm		5.45 gpm	8 gpm	10 gpm	15 gpm
Mass Reject Ratio, %		4.5 %	12 %	15 %	25 %
Pilot Plant Cleanliness Eff.		38.8	54.5	50.5	71.7
Pilot Plant Reject Eff.		58.8	58.7	55.1	77.4
Pilot Plant Feed (1)	Pulmac	-	99.2	99.5	-
	Valley, 25°C	-	98.8	97.7	-
	Valley, 45°C	-	99.9	98.4	-
Pilot Plant Accepts (2)	Pulmac	95.9	90.6	95.4	-
	Valley, 25°C	93.1	78.8	93.6	-
	Valley, 45°C	76.7	70.4	82.1	-
Pilot Plant Rejects (3)	Pulmac	99.4	97.8	99.6	-
	Valley, 25°C	99.0	94.1	99.1	-
	Valley, 45°C	96.9	96.1	95.5	-

Table 2. Efficiencies of screening experiments.

The pilot plant screen provided cleanliness efficiencies between 38.8 and 71.7% and reject efficiencies between 55.1 and 77.4%. This result is similar to a previous investigation in which a 0.012 inch slotted screen was used to remove stickies [19]. In that report, for R_W = 15% the removal efficiency was reported to be about 50%. The stickies removal efficiency of the work herein for the pressure screen experiment is similar, despite the considerable difference in slot sizes. However, the parameters of that study, such as the temperature, consistency, flow rates, and stickies content, were not reported, so an exact comparison is not possible.

In mill data reported by Union Camp for an acrylate PSA, the primary screens provided removal efficiencies of about 74% and the secondary screens provided removal efficiencies of about 59% [1]. In pilot plant experiments by the USDA Forest Service, 0.006 inch slotted pressure screens provided efficiencies of pressure sensitive adhesives between –14.0% and 68.4% [23]. In the data for the upgrade of the Haindl Paper Schongau mill, a fine screen with 0.20 mm wide slots was reported to have a removal efficiency of about 60% [24]. While replacing one of the fine screens at Bowater Pulp and Paper Canada's Gatineau mill, the removal efficiency was reported to increase from 33.7% in the old screen to 62.6-83.4% in the new screen [25]. In experiments conducted on a small commercial unit from Black Clawson Co., negative removal efficiency was reported for small model adhesive particles at 1% consistency [26].

In comparison to the efficiencies of the above industrial screens, all three laboratory screening experiments performed in this report had a E_c of greater than 97% for the pilot plant feed pulp sample (1). These results confirm that both of the laboratory screens are significantly more efficient than the industrial screen in removing adhesive, as expected.

Table 2 also shows that the cleanliness efficiency of stickies in the laboratory screens is lower for the pilot plant accepts sample (2) than for the pilot plant feed sample (1) or rejects sample (3). This was expected because the pilot plant accepts contained stickies that already had passed through the 0.006 inch slotted screen basket in the pilot plant screen. Also, the pilot plant accepts average particle size was significantly smaller than the feed; see **Table 3**.

		Average Particle Size, mm^2			
Reject Flow Rate, gpm		5.45 gpm	8 gpm	10 gpm	15 gpm
Reject Mass Ratio, %		4.5 %	12 %	15 %	25 %
Pilot Plant Feed (1)		2.61	1.97	2.02	1.88
Pilot Plant Accepts (2)		0.38	0.34	0.35	0.31
Pilot Plant Rejects (3)		0.86	0.90	0.90	0.65
Pilot Plant Feed (1)	Pulmac	-	0.08	0.09	-
	Valley, 25°C	-	0.11	0.10	-
	Valley, 45°C	-	0.04	0.09	-
Pilot Plant Accepts (2)	Pulmac	0.12	0.12	0.09	-
	Valley, 25°C	0.12	0.16	0.10	-
	Valley, 45°C	0.18	0.17	0.15	-
Pilot Plant Rejects (3)	Pulmac	0.13	0.12	0.14	-
	Valley, 25°C	0.14	0.17	0.15	-
	Valley, 45°C	0.18	0.18	0.17	-

Table 3. Average particle sizes of screening experiments.

Temperature appears to be an important parameter in the laboratory screening of stickies. At room temperature, i.e., 25°C, the Pulmac and Valley screens provided similar cleanliness efficiencies for the feed and rejects, Table 2. However, in general, at higher temperature, 45°C, the cleanliness efficiency of the Valley Flat screen decreased for the pilot plant accepts and rejects relative to screening at 25°C. This decreased efficiency at 45°C was not observed for the pilot plant feed sample. This may be due to the pilot plant feed pulp having a much larger average particle size (about 2 mm^2) than that of the accepts (about 0.3 mm^2) and rejects (about 0.8 mm^2); see Table 3. The very large particles in the pilot plant feed sample may have prevented the higher temperature from having an effect on the cleanliness efficiency of the Valley Flat screen. It is hypothesized that the higher temperature softens the adhesive, causing adhesive particles that are *just slightly* too large to pass through the slots at 25°C to be able to pass through at 45°C. The screen may still block significantly larger particles at 45°C despite the softening.

Table 3 shows the average particle size of the stickies from the pilot plant and laboratory screening experiments. Notice that the average particle size in the accepts from the laboratory screens is smaller than that in the accepts from the pilot plant screen. The average particle size of the pilot plant accepts ranges from 0.31 to 0.38 mm^2, whereas the laboratory screen accepts range from 0.04 to 0.18 mm^2. This is despite the fact that all of the screens have a slot width of 0.006 inches. It is widely thought that the passage of relatively large adhesive particles through the industrial pressure screen is due to the pressure difference extruding the elastic, deformable adhesives through the screen [1,3,5,6].

Figure 3 and **Figure 4** are plots of screening efficiency versus particle size for the pilot plant and laboratory screens, respectively. A comparison of these two plots reveals that the removal efficiencies of small particles, those less than 1.00 mm^2, are very different for the pilot plant and the laboratory screens. Unexpectedly, the reject efficiencies of the pilot plant screen are negative for particles < 1.00 mm^2 (Figure 3). This suggests that small particles are generated in the pilot plant system. This finding suggests another contributing factor that causes the screening reject efficiency of adhesives to be low, i.e., the screen breaks the adhesive particles into sizes that pass through the screen. In contrast to the pilot plant screen, the cleanliness efficiencies of the laboratory screens for small particles is low, but always positive (Figure 4). As there is no appreciable pressure difference in the lab screens and the shear is much less than the pilot plant screen, it is expected that less breakage would occur.

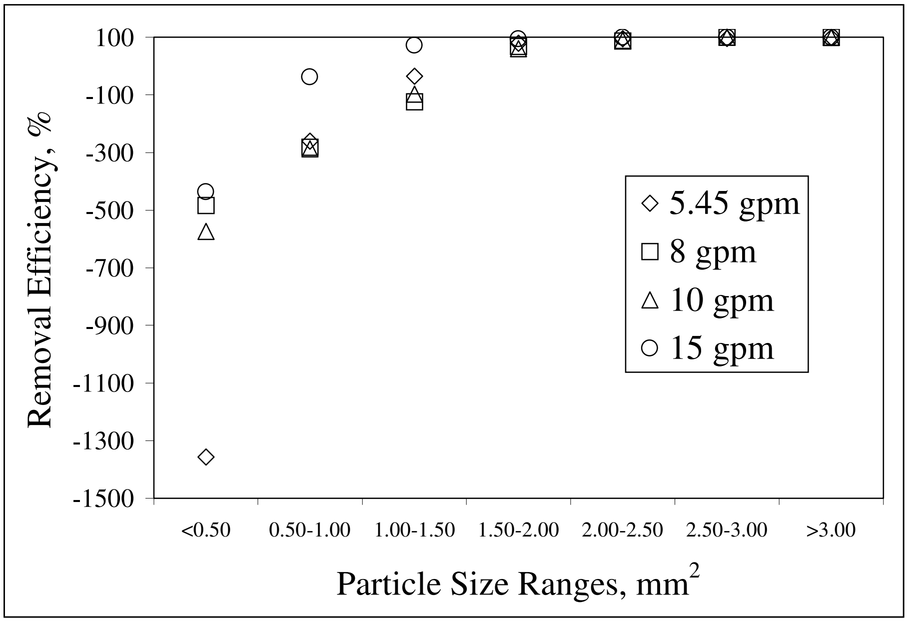

Figure 3. Removal efficiency versus particle size for the pilot plant pressure screen.

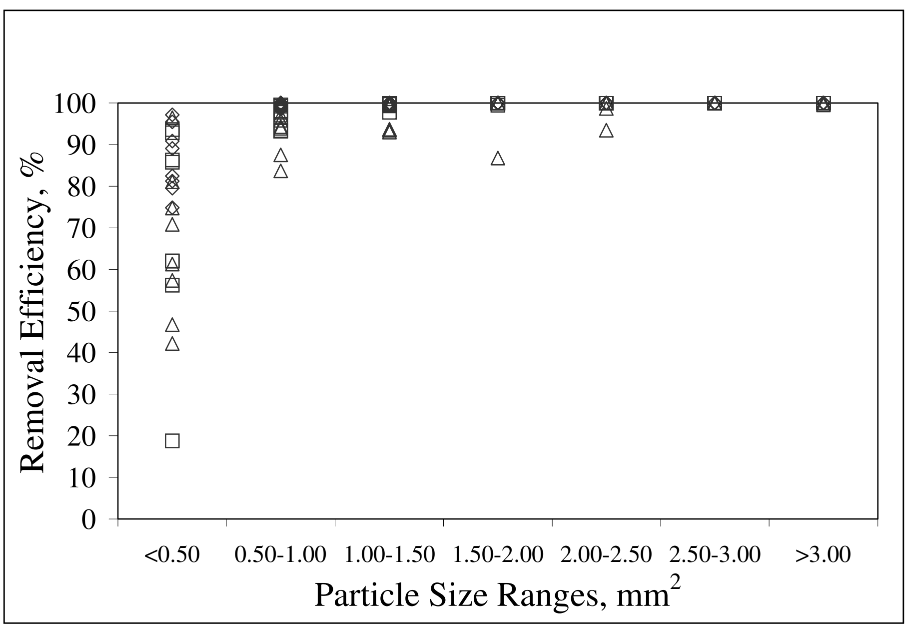

Figure 4. Cleanliness Efficiency Versus Particle Size for the Laboratory Screens Symbols indicate: ◊ Pulmac, □Valley at 25^{o}C, and Δ Valley at 45^{o}C.

Due to the choice of sampling points illustrated in Figure 1 it was not possible to determine whether the pumps or the pressure screen were actually breaking the adhesive particles. To investigate, another pilot plant experiment was performed as shown in Figure 2 prior to a standard screening experiment. **Table 4** shows the average particle size, parts per million, and number of particles at different sampling points according to the experiment illustrated in Figure 2.

Sample	Average Particle Size, mm^2	Parts Per Million, ppm	Number of Particles in 1 m^2
Hydropulper (4)	1.28	2320	1810
Hydropulper Pump (5)	1.73	2430	1410
Feed Tank (6)	1.67	2770	1660
Feed Tank Pump (7)	1.54	2980	1940
Pilot Plant Screen Feed (1)	1.88	2940	1570
Pilot Plant Screen Accepts (2)	0.31	830	2680
Pilot Plant Screen Rejects (3)	0.65	4080	6300
Pilot Accepts + Rejects (2) + (3)	0.46	1640	3590

Table 4. Pump/Screen Experiment for Reject Rate of 15 gpm.

The results show that for the five samples taken prior to the pilot plant screen there was no significant difference in the measured average particle size, parts per million, or number of particles in 1 m^2. Thus, it was concluded that the generation of small particles was not due to the pumps. However, for samples during later screening, the values for the pilot plant accepts and rejects are significantly different than those for the pilot plant feed, both having a significantly lower average particle size and higher number of particles in 1 m^2. Accordingly, when the products of the pilot plant accepts and rejects were combined mathematically (2)+(3), i.e., a weighted average with respect to the OD mass flow rate of each stream, it was revealed that the number of particles about doubled and the average particle size decreased significantly relative to the pilot plant feed (1). The result confirms that the screen generated new, smaller adhesive particles.

Figure 5 is a plot of the number of particles in 1m^2 versus particle size for the samples from the pump and screening experiment. This plot shows that the mathematically combined pilot plant accepts and rejects contain significantly more small particles than the feed tank, feed tank pump, and pilot plant feed samples. Also, there is not a significant difference between the feed tank, the feed tank pump, and the pilot plant feed. Therefore, small particles are not generated in the pump, but in the pilot plant screen.

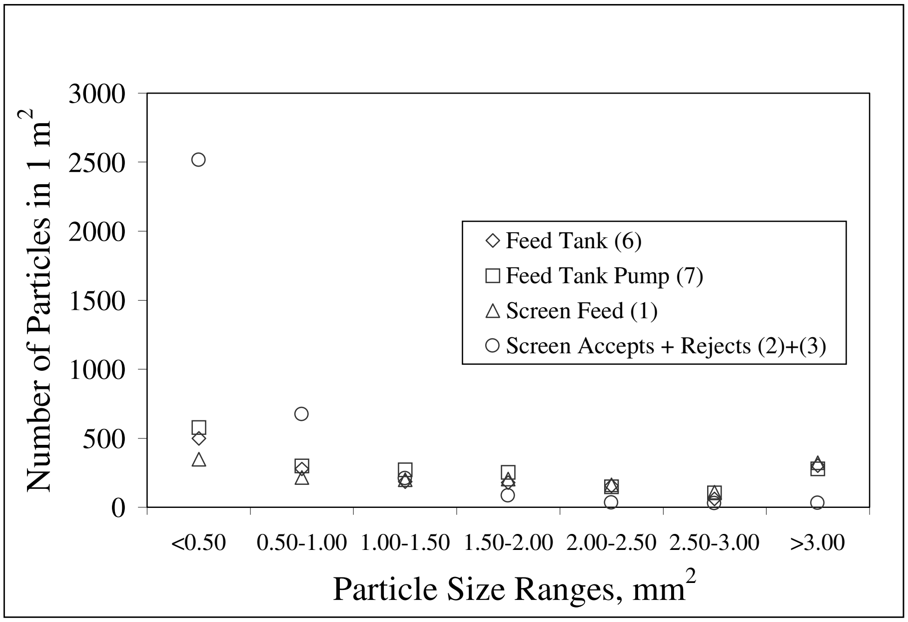

Figure 5. Particle size distribution before and after the pilot plant pump and screen.

CONCLUSIONS

Industrial pressure screens can break pressure sensitive adhesive particles, generating significant amounts of small adhesive particles and lowering the removal efficiency. Laboratory screens do not break the adhesive particles and are not good indicators of the screenability of pressure sensitive adhesives. Laboratory screens have a much higher screening efficiency than industrial pressure screens. A new laboratory test method is needed to predict the industrial screenability of pressure sensitive adhesives.

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