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The Separation of Low Density Polyethylene Laminates from Paper

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THE SEPARATION OF LOW DENSITY POLYETHYLENE LAMINATES FROM PAPER

by

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ABSTRACT

Low density polyethylene is a very popular plastic which is commonly found in laminations which are extruded onto paper and paperboard. It is often used on products used for food packaging because of its inert and protective properties. With the aid of a corona discharge, polyethylene becomes ink receptive and forms a strong bond with the substrate; however, this bond is not a major problem when polyethylene laminated paper is recycled. The problems with recyclingcan be contributed to the heat sensitivity of the polyethylene. At high temperatures the polymer stretches and forms tangled conglomerations which trap fibers. Therefore the key to recycling of matarial lies in finding the proper equipment to disentegrate the polyethylene laminted paper.

The scope of this thesis describes variables that affect the separation of low density polyethylene and presents an experimental procedure which can be used to obtain a successful separation using conventional screening and reverse cleaning equipment in an aqueous medium.

In general, the experimental data shows that low temperatures and long beating times are required. In a pilot plant trial the low density polyethylene was disentegrated in a Hollander Beater and screened through a Jonsson Screen, Selectifier Screen and C.E. Bauer reverse cleaner.

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INTRODUCTION

As the cost of paper products increases each year, the need for more efficient recycling processes has become one of the paper industry's top priorities. Furthermore, at least 50% by weight of municipal solid waste consists of paper and paper products. Recycling of waste paper is an important means of decreasing solid waste as well as a source of secondary fiber and raw matarials.

One of the most serious technological obstacles to more efficient recycling is the presence of plastic contaminants which are originally in the form of paper laminates and specialty coatings.

Low density polyethylene is a very popular plastic which is commonly found in laminations which are extruded onto paper and paperboard. Because of its inertness, excellent dimensional stability, transparency, toughness at low temperatures, water resistence, and good heat sealability, it is often used in food packaging materials.

The purpose of performing this study was to focus on determining a procedure that will thoroughly and economically disentegrate and separate low density polyethylene laminates from paper products using conventional screening and cleaning equipment so that both substances can be used for secondary uses.

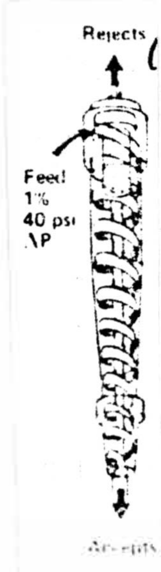
THEORETICAL DISCUSSION

The major objective of this study was to accomplish a complete separation of low density polyethylene from paper. Before undertaking any extensive laboratory work an examination of the literature was performed.

Low density polyethylene is a crystalline polymer which is derived from the basic structure of ethylene. It has a density range between 0.916-0.935 g/cm^3, which makes this substance lighter than water. [1] The basic structrue of polyethylene consists of a $-CH_2-CH_2-$ polymer chain with the low density types being highly branched. The branching takes place under high pressure.

Jerry Bliss of Black Clawson Corporation has recorded some success with an aqueous separation process using a Black Clawson single cleaner laboratory test cannister to remove lightweight contaminants, however he encountered problems with measuring the amount of polyethylene present. He recommends the use of reverse cleaner for the removal of lightweight plastics, such as low density polyethylene. The basic concept of the removal using a research cleaner is as follows:[2]

> As the stock enters the cleaner it spins along a helical path. The heavier components will accumulate at the outside wall of the cone. The lighter components are displaced toward the center of the cleaner. As the stock approaches the apex end of the cleaner, some of the flow reverses direction and follows a helical path toward the vortex end located at the base of the cleaner.



Efficiency measurements can be used to evaluate the effectiveness of a reverse cleaner. Bliss based his efficiency measurements on spot counting the contaminants present. Krueger and Bowers have recommended hot pressing of handsheets in identifying sticking particles, such as plastics, to aid in the counting. According to these researchers, these guidelines should be followed:[3]

1. At least two pressing temperatures should be used. (230 and 325 ^{o}F)
2. Pressing will detect particles as small as .25 mm^2 depending on the type of matarial.
3. Cooling under pressure provides a greater total count and more legitimate counts.

Factors that affect plastic contaminant removal efficiency include; temperature, feed consistency, pressure, particle size and shape, speed, dwell time, and type of contaminant. Bliss recommends a temperature range between 55-65 ^{o}C, pressure around 40 psi, and a feed consistency of 1.0%. In general, efficiency increases as the temperature and pressure drop increase, and efficiency decreases as the feed consistency increases.

The softening point of low density polyethylene is substantially below that of boiling water (100 ^{o}F) which is good for heat sealing.[4] Unfortunately, it is this property which is a major problem when the laminated paper is disintegrated in a heat generating process which takes place in a Jordan refiner or hydrapulper.

Chemicals and fillers are added to plastics for two main reasons; 1) To modify, improve, or add more desirable properties into the plastic, and 2) To reduce the cost of the original plastic using cheaper filling matarials.[5] The most common additives are slip agents, anti-

block agents, antistatic agents, and antioxidants. A summary of these matarials can be found in the Appendix in Table I.

Low density polyethylene contributes many properties to the final paper product. Some of the more important properties include; increased tear resistence, puncture strength, scuff resistence, barriar to liquid penetration, and provides a heat seal medium. Polyethylene is tasteless, odorless, and gives no toxic effects.

Bonding

Adhesion is the force which bonds polyethylene to a substrate. It can be mechanical or chemical in nature. In general, as density increases, chemical adhesion increases, as the melt index increases, mechanical adhesion increases, and as the molecular weight distributuion broadens, chemical adhesion decreases.[6]

Low density polyethylene is bonded to paper by the use of a corona discharge. The corona discharge increases the printability of the laminate as well as serving as a bonding aid. Because polyethylene is inert, traditional adhesives require modification in order to perform well. In general, corona is a high frequency, high voltage electrical discharge that is applied to the polyethylene as it is extruded onto a substrate. In the application process, carbon to carbon and carbon to hydrogen bonds on the surface of the laminate are broken, which leads to the formation of radicals. These radicals,with the help of high temperatures, react with oxygen in the air to form hydroperoxides which produce new radicals. A treatment of 39.5 dynes/cm produces an ink receptive surface.[7]

Extrusion Process

In the extrusion process a thin layer of molten polyethylene is extruded from a slit die. The film is drawn down to it final gauge in the air gap formed between the die lips and the point at which the molten film contacts a continuous sheet of paper. The bond is set as the sheet containing the layer of polyethylene is pressed and cooled between the pressure roll and a chill roll.[8] Due to a high viscosity and short contact time before the solidification occurs it can be assumed that only a limited quantity of matarial actually penetrates the sheet. Because of the high pressure applied by the chill roll nip, it is expected that the polyethylene effectively fills nearly all of the surface voids of the sheet. Therefore, the problem which arises is one of distinguishing between the amount of matarial that fills the surface voids of the sheet and the excess matarial that builds up above the surface, rather than between the surface matarial and that which penetrates the sheet.

It has been documented that when polyethylene is extruded, the amount of plastic required for a nominal 1-mil coating does not raise the caliper of the coated paper by 1-mil.[9] The difference between the expected caliper increase and the actual measured increase represents the amount of polyethylene necessary to fill the surface voids. Figure 2a. found on the next page illustrates a typical paper cross-section with expected irregularities. A nominal line can be drawn to define the surface, with many voids before the sheet is laminated, approximating its bulk density. Figure 2b. shows what can be expected at low coat weights. The surface voids are not completely filled. Figure 2c. illustrates that at high coat weights the polyethylene surface becomes smoother as the voids become completely filled.[10]

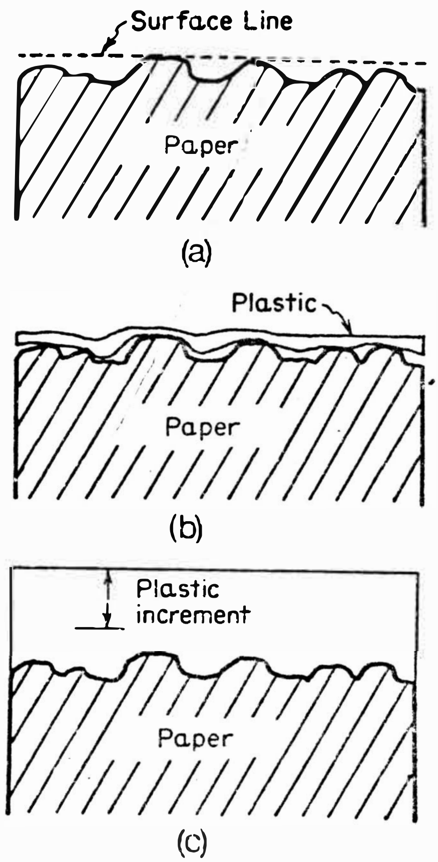


Fig. 1. Idealized cross sections of polyethylene-coated paper. (a) Uncoated, showing nominal surface voids. (b) Light coating, voids not completely filled. (c) Heavy coating. At high levels, incremental increase in polyethylene coating adds caliper expected for a smooth sheet.

Poor adhesion can be related to these major variables:

1. Resin melt temperature too low. (Should be 540-615 °F)
2. Film striking chill roll before meeting the web.
3. Incorrect chill roll temperature.
4. Incorrect sizing agents on the paper surface.
5. High moisture content in the paper.
6. Poor mixing.
7. Contaminants.

Effect of Additives

Additives commonly tend to exude to the surface if the added compound is incompatible with the polyethylene. Organic antiblock and slip agents are generally chosen with special properties to enhance their rapid migration to the surface to form solid and liquid layers. Slip agents can cause problems if the film is treated after an additive has had time to fully bloom to the surface. It is believed that the overlayer of the slip agent protects the polyethylene surface from the effects of the corona discharge.[12]

Present Recycling and Disposal Processes

Riverside Corporation in Neenah, Wisconsion developed a dry cleaning method to remove low density polyethylene and other plastic laminates from paper. It is a patented process. The Black Clawson Corporation has acquired rights from the Riverside Corporation for the use of this process which is commonly called the "Poly-solv" method.[13] This process utilizes trichloroethylene or other chlorinated hydrocarbons to dissolve the polyethylene or wax coatings from paper or paperboard. Generally, the matarial is subjected to multiple batch washings in a pressurized rotary reactor at high temperatures. Upon completion of the washing cycles and drying, the reactor is opened up and the fiber which is plastic-free can be further processed in stock preparation equipment. The contaminated solvent is distilled for purification and can be recycled in susequent batches. The plastic is discharged as a contaminant from the process in a easily handled liquid form. The amount of polyethylene present can be determined from a difference in weight from the total amount that was originally used minus the weight of the fiber.

James River Corporation in Kalamazoo, Michigan is presently burying the trim scraps from the polyethylene extruders which are usually in operation seven days a week. The trim scraps are bailed and disposed of in sanitary landfills.

Conclusions based on Literature Search

There are three ways to resolve this type of separation problem. First, waste paper can be presorted, removing all matarial that has some form of lamination on it. Secondly, changes in the formulations and manufacturing processes can be done to produce water soluable substances. Lastly, an improvement of contaminant cleaning and removal methods in recycled fiber processing can be worked on. Thirty-eight companies sponsored an IPC/API research program and endorsed the third method as the best approach to overcome this recycling problem.[14]

Recycled polyethylene can be used in such products as trash bags, and non-food related products. The present market price for recycled low density polyethylene is between 12-14¢/lb. The fiber that is recovered can be used for recycled "filler ply" matarial for paperboard because it will not be exposed to a printing surface.

Bonding is an important factor in such a study, however the physical properties of polyethylene must be considered also. The low softening temperature is indeed a major stumbling block in recycling of low density polyethylene laminates to obtain a recovery of both the polyethylene and fiber fractions.

EXPERIMENTAL DESIGN

The purpose of an experimental design is to obtain useful information in a limited period of time with the equipment available. This is usually accomplished by careful planning.

The experimental design for this thesis consists of two parts. The first part involves performing laboratory work which is required in order to define important variables needed to run a successful pilot plant trial. The second part involves the actual performance of a pilot plant trial, using the facilities in the Paper Science and Engineering Department at Western Michigan University.

Sample Collection

The samples used in the experimental work consisted of trim scraps of lightweight food wrapping paper which has a bleached Kraft base and a low density polyethylene laminate on one side. These samples were obtained from James River Corporation with the permission of Mr. Bob Nitz, Technical Director.

Selection of Variables

The most important variables that influence the separation of low density polyethylene from paper include; temperature, amount of TSPP, dwell time during disintegration, consistency, and particle size and shape. The corona discharge treatment which is applied to the polyethylene surface during extrusion to increase printability was not found to cause a major problem.

Method of Evaluation

Determining the actual removal efficiencies of each piece of equipment was difficult. An overall matarial and water balance could not be done because the flow patterns could not be recorded during the pilot plant trial. Therefore, the method of evaluation is based on "spot counting" the amount of polyethylene found on handsheets made on a British Barrel handsheet former.

EXPERIMENTAL PROCEDURE

Part I: Laboratory Work

Equipment

Laboratory Apparatus with single impellar attached to the base of a large Waring Blender.

1 metal beaker

1 powerstat

Regular Waring Blender

Morden Slushmaker with variable speed and temperature control

Laboratory Flat Screen with 1/8" holes

Laboratory Valley Beater with 5.5 kg weights

British Barrel Handsheet Former

Matarials and Chemicals

Tetra Sodium Polyphosphate (TSPP)

"Calocid Blue-Black Extra Concentrated" dye by Cyanimide

Perchloroethylene

Triton X-100

Procedure

The first piece of equipment which was used consisted of an apparatus with a single impellar with 5" blades that was attached to the base of a large Waring Blender mounted on a four-legged stand. The impellar speed was regulated by a powerstat. A metal beaker served as the holding device for the pulp slurry. A total weight of 78.7 grams of sample was placed in the metal beaker. Two liters of water was added and .10 ml of Triton X-100 was added as an aid in the separation. This mixture was pulped at 25 rpm for about 10 minutes. The pulping action was very poor because the trim

wrapped around the impellar blades, forming a tangled clump. The separation was unmeasurable. This procedure was repeated again, this time the samples were manually cut into small segments with a pair of scissors. The separation was still poor.

Next, a regular Waring Blender was used. This apparatus has shorter blades and a variety of speeds and cutting actions are obtainable. This time 13.8 grams of sample were mixed with 700 ml of water to obtain a 2.0% consistency. Five percent (based on dry weight of sample) TSPP was added to the mixture to aid in the separation. The mixture was pulped on the "grind" setting for approximately three minutes. Consequently, the same problem with wrapping and clumping of the samples occurred. This procedure was repeated again, this time the polyethylene trim scraps were precut. The blending improved and disintegration of the samples could be visually observed. The polyethylene-pulp mixture was screened on a laboratory flat screen with 1/8" holes and the separation was very good. The polyethylene was collected on the flat screen in strips that were approximately 5-8 cm in length. The accepted pulp was save for handsheets.

The Morden Slushmaker was used next because of its larger capacity and rotor which resembles that found in a mill hydrapulper. (The use of a hydrapulper was was proposed in the original experimental procedure for this thesis.) By this time low consistencies were being used because they seemed to give the best results. In the first attempt, 400 grams of sample were added to twenty liters of water (68^{o}F) to obtain a 2.0 % consistency. Again 5% TSPP was added to aid in the separation. The slushmaker was run at medium speed for 20 minutes. This mixture was allowed to sit for 10 minutes in the slushmaker, then it was repulped again for fifteen minutes. After pulping the mixture was drained into a bucket and stored overnight. Finally,

the mixture was screened through the laboratory flat screen. The separation was fair, with bundles of tangled polyethylene strips and fiber settling on top of the screen. This procedure was repeated again, this time the consistency was lowered to 1.0%. The final results were relatively the same; the separation was fair. The fibers appeared to be trapped inside the tangled cluster of polyethylene strips. The screening time was shorter, however. The accepted fiber was collected and save for handsheets.

The final piece of equipment which was used turned out to be successful. This piece of equipment was the Laboratory Valley Beater. First, 150 grams of sample was mixed with 20 liters of cold water in the Morden Slushmaker. Again, 5% TSPP was used. This mixture which had a .67% consistency was prefibrillated in the slushmaker for about two minutes. Next, the mixture was poured into the Valley Beater which had previously been cleaned with cold water. The reason for using the cold water was to keep the polyethylene as cold as possible so that it would not reach its softening temperature. he polyethylene-pulp mixture was circulated around the beater for five minutes without using weights, then 5.5 kg weights were used for 10 minutes. The separation turned out to be excellent, with the polyethylene completely disintegrated to a size of approximately 1-4 cm in length. After screening through the laboratory flat screen, there was a definite separation. A total yield was not made, however samples were collected for handsheets.

The coat weight of the polyethylene laminate was determined by using the "POLY-SOLV" method which was outlined in the literature search. This was accomplished using perchloroethylene which was heated in a hood. A preweighed sample was placed in the hot solution and the polyethylene was dissolved. The final weight of the paper sample minus the total weight of the original laminated sample determined the coat weight which was found to be 37%.

The accepted pulp samples which were collected from the pulping equipment were made into handsheets using the British Barrel Handsheet Former because the smaller area of the sheet was convenient to work with. Also, the polyethylene left in the accepted pulp was drawn to the surface of the sheet which was helpful in performing an accurate spot count.

Some of the accepted pulp was dyed with "Calocid Blue-Black Dye" by Cyanimid in an attempt to produce a dark background which would enable the low density polyethylene to stand out. This method proved to be very successful. The dye, which was originally in a powder form, was dissolved in a 3% Alum solution. This solution was heated over a flame until it boiled. This hot solution was poured over the pulp. This mixture was stirred for approximately five minutes until a noticeable color change was observed.

Part II: Pilot Plant Trial

A detailed flow diagram of the actual pilot plant equipment which was used can be found on page in the Appendix. The trial was performed on two separate days.

On the first day, 150 dry pounds of polyethylene trim scraps which arrived in bale form,were loaded into the Hollander Beater. The beater was filled with cold water and 5% TSPP (based on dry weight of sample) was added. The overall consistency was approximately 3%. Pulp samples were collected at 5, 10, 20, 30, 45, 60, 75, 90, 105, and 120 minute intervals. The total beating time was two hours, which was longer than expected. After beating was completed the pulp was pumped to Chest #1.

The pulp was sent through the cleaning equipment on the second day. First the pulp in Chest #1 was diluted to 1.61 % consistency. After dilution

the stock was sent through the Jonsson Screen with 1/8" holes. The rejected stock was sent back to Chest #1 so that it could be passed through the screen again for improved efficiency. The accepted stock was sent to Chest #5. The accepted fiber which passed through the Jonnson Screen after the second pass was sent to the sewer. The rejected plastic, which was very clean, was collected in a large rubber bucket.

The stock from Chest #5 had a consistency of 1.39%. This pulp was sent through the Selectifier Screen which had a .013" cut plate. The accepted stock was sent to Chest # 4, and had a consistency of 1.1%. The rejected matarial was sent to Chest # 2, and had a consistency of .78%.

The pulp from Chest #4 was sent to C.E. Bauer Reverse Cleaners. The accepted stock had a consistency of 1.0%, while the rejects had a consistency of .49%. The accepts were collected in Chest #6.

Flow information could not be obtained because there was a breakdown in the control devices, therefore an overall mass balance could not be calculated.

A second trial was originally scheduled which would have involved the use of a Jordan refiner located in the pilot plant, but this was eliminated because of the limitations of the pumps. A long beating time would have been needed again to disintegrate the samples to a size which could be safely pumped.

Samples of the accepts and rejects from each stage were collected and saved. These samples were used to make consistency measurements and handsheets.

PRESENTATION OF RESULTS

Detailed data tables are available for examination in the appendix. The data presented in this section is a summary of these tables. Included in the appendix are samples of the polyethylene which was separated from the pulp samples in the Laboratory Valley Beater and Jonsson Screen.

Efficiency

A summary of the efficiencies which were determined from the spot counting of handsheets made from the accepted and rejected pulp from each cleaning stage are as follows:

Equipment	% Fiber	% Polyethylene
Jonsson Screen		
feed:	63	37
accepts:	85	15
rejects:		100
Selectifier Screen		
accepts:	99.28	0.72
rejects:	24	76
Reverse Cleaners		
accepts:	99.71	0.29
rejects:	98.30	1.70

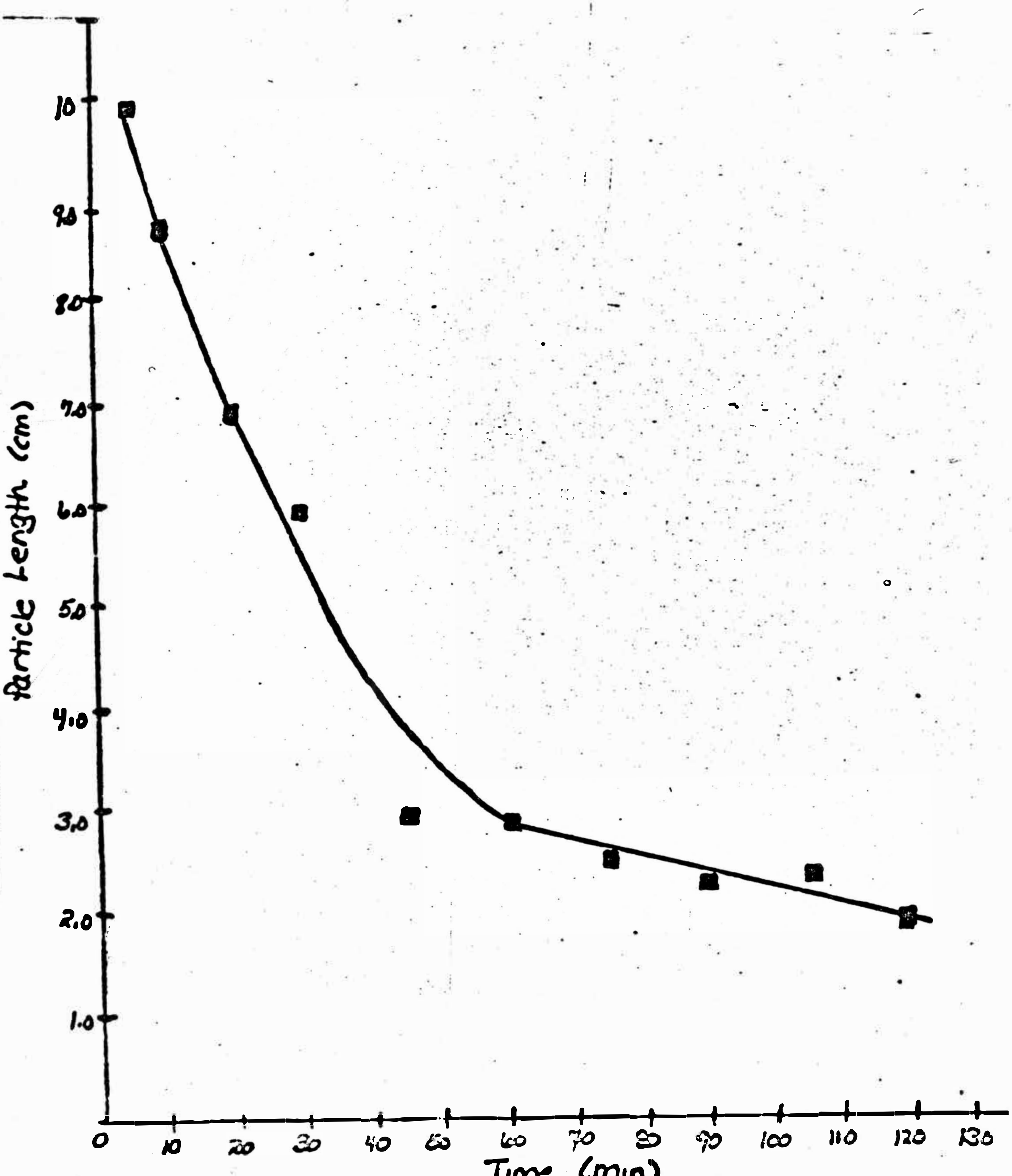
Particle Length vs. Beating Time

A graph of the particle length of the polyethylene which was disintegrated in the Hollander Beater vs. Beating Time in minutes was obtained after measuring the length of the polyethylene samples with a meter stick. This graph is found on the following page.

GRAPH OF PARTICLE LENGTH OF POLYETHYLENE

VS.

BEATING TIME



DISCUSSION OF RESULTS

The heat sensitivity of low density polyethylene is a major factor when an aquous beating and cleaning system is used to separate polyethylene from paper.

The particle size of the polyethylene which was obtained after disintegration in the Laboratory Valley Beater had a shorter average length than the size of the polyethylene which was collected from the reject portion of the Jonsson Screen. This difference in size could be contributed to the amount of heat which was generated in the Hollander Beater in comparison to the much smaller quantity of heat generated in the Valley Beater. Obviously, a colder temperature can be more easily maintained in a smaller apparatus than in a large Hollander Beater or Jordan refiner in a mill situation. Graph #1 shows the effect that heat may have on the particle size (length) of the samples. The points on the graph show that during the first hour of beating time the particle size continued to decrease, however; after the one hour period the particle length reaches a constant size and does not appear to be reduced in size significantly. This may be contributed to an increase of temperature close to the softening point of the polyethylene so that the matarial may undergo stretching as it changes from a solid brittle matarial to a soft, pliable plastic.

The Jonsson Screen was very effective in removing a large amount of the polyethylene which was originally in the pulp slurry. The average size of the polyethylene which was removed in this stage was approximately 2.0 cm. The Selectifier Screen had an excellent efficiency also. The particles collected on this screen seemed to be long and thin in nature, rather than short and thick, as was the case with the particles removed

in the Jonnson Screen. The reverse cleaners were able to remove a fair amount of the polyethylene fragments that were left in the pulp, however not all of the polyethylene was removed.

The polyethylene which was collected from the Jonnson Screen is pure and relatively fiber-free. There is a good possiblity that it could be reused again. The fiber fraction obtained from the reverse cleaners is 99+% free of polyethylene and could be used in filler plies in the production of paperboard however no literature information could be found to determine the concentration of plastic which is acceptable. Generally, any pulp which has a plastic contaminant in it will be rejected.

CONCLUSIONS

The goals that were established in the early stages of this thesis project have been accomplished. A relatively good separation of low density polyethylene laminates from paper was accomplished using pulping and screening equipment in an aqueous medium.

The major problem in performing a separation was not due to bonding, as once was thought. Instead, the problem is related to the low softening temperature of the polyethylene which makes disintegration of polyethylene laminates difficult, especially at high temperatures which are observed during pulping.

If a system could be developed to control the high temperatures which are evolved during pulping the system that was outlined in the pilot plant trial could be used without the problems that were encountered in this thesis study. Perhaps a final stage of this procedure could involve some form of flotation to remove the last traces of polyethylene which were not separated in the other types of cleaning equipment.

The final products are both lightweight in nature which makes handling a minor consideration. Presently, the cost of such a system is expensive and uses large amounts of energy, which may discourage its use on a large scale at this time. At least it has been demonstrated that such a separation is possible, and could be used in a paper mill.

RECOMMENDATIONS

There were a few general areas that could have been examined in greater detail if more time had been available.

A second pilot plant trial could be performed indentically to the one outlined in this thesis; however, this time three pases could be made through the Jonsson Screen, and the reverse cleaning stage could be followed by a flotation method to remove the last traces of polyethylene.

A comparison of the "POLY-SOLV" method and the method described in the experimental procedure of this thesis would be useful if a study was made on the actual separation efficiencies, time involved, and strength of the fiber after the separation.

Sincere thanks are due to my advisor, Lyman Aldrich, of Western Michigan University, Bob Nitz of James River Corporation in Kalamazoo, and my parents, Mr. and Mrs. Andrew Selchan, for their generous help and support of this thesis experiment.

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16. Personal conversation with Mr. Bob Kinsey

17. Personal conversation with Mr. Bob Nitz, James River Corporation

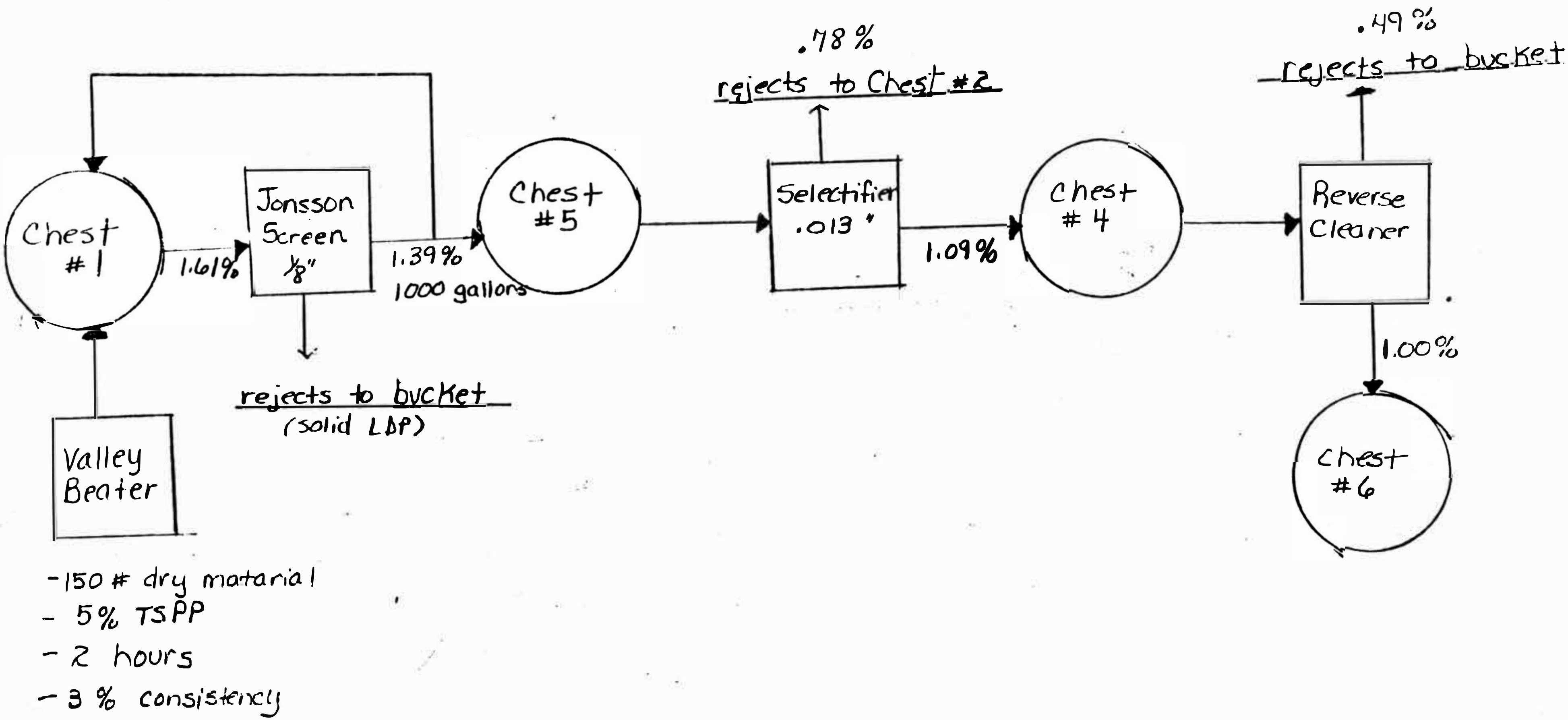
APPENDIX

TABLE I

Matarial	Chemical Composition	Use
Slip Agents	Fatty Acid Amides	Allows film to move smoothly over flat surfaces.
Antiblock Agents	Very fine powders (silica)	Discourage layers from sticking together.
Antistatic Agents	Quaternary Ammonium salts, Glycerol additives	Eliminate Static Electricity.
Antioxidants	Aromatic Amines, Substituted phenols, 2% Carbon Black	Prevent oxidation, especially under U.V. light.
Dyes and Inks	Basic, Oil Soluable	Printing & Coloring.

1

PILOT PLANT TRIAL



A. Determination of Coat Weight

Weight of original sample with laminate :	.1757 g
Weight of sample after treatment with perchloroethylene	.0468 g
	.1289 g

Therefore ratio = $\frac{.1289}{.0468} = \frac{2.75}{1}$ = 36%

B. Consistencies

1. Jonsson Screen : Feed

Amount of pulp used: 300 ml
Weight of filter paper: 1.30 g
Dry weight: 6.12 g

% consistency = 1.67

Jonsson Screen: Accepts

Amount of pulp used: 300 ml
Weight of filter paper: 1.25 g
Dry Weight : 5.41 g

% consistency= 1.39

Jonsson Screen: Rejects - no consistency measured (solid plastic)

2. Selectifier Screen : Accepts

Amount of pulp used: 300 ml
Weight of filter paper: 1.20 g
Dry weight: 4.475

% consistency = 1.09

Selectifier Screen: Rejects

Amount of pulp used: 300 ml
Weight of filter paper: 1.20 g
Dry Weight: 3.55 g

% consistency = .785%

3. Reverse Cleaners: Accepts

Amount of pulp used: 500 ml
Weight of filter paper: 1.20 g
Dry Weight: 3.67 g

% consistency = .494%

Reverse Cleaners: Rejects

Amount of pulp used: 500 ml
Weight of filter paper: 1.30 g
Dry Weight of paper: 6.73 g

% consistency = 1.09%

C. Evaluation of Handsheets – spot counting summary *

Feed to Johnson Screen			Jonnson Screen Accepts			Selectifier Accepts
20	25	60	1	10	3	.05
5	50	70	1	20	3	.09
50	50	25	5	15	5	.005
40	5	60	5	5	1	.001
15	10	10	25	10	1	.005
25	50	60	15	1	1	.002
10	90	5	3	10	5	.002
20	80	40	5	5	10	.001
40	70	5	20	5	10	.01
20	20	25	1	5	5	.001
80	2	25	30	30	5	.001
30	60	30	30	1		.01
10	60	45	60	1		.001
5	50	25	60	5		.001
10	70	25	30	15		25
80	10	60	90	1		2
50	20	70	1	3		.01
40	20	90	1	3		.02
10	30	10	5	3		.02
50	90	10	10	60		.01
25	40	10	1	10		.002
15	80	20	5	20		.01
15	70	70	10	10		1
20	40	90	30	15		.01
20	10	40	30	25		.01
5	20	95	30	10		.03
15	2	70	40	10		.03
5	70	30	1	10		.02
2	40	2	50	5		.001
2	30	5	40	1		.02
5	50	20	25	10		1
25	10	90	10	1		.002
5	45	100	25	5		.001
25	70	20	15	5		.002
60	70	30	25	5		.001
25	50	10	10	25		.001
25	40	15	5	25		.001
5	50	15	15	1		.001
25	20	80	5	1		.001
40	15	70	25	1		.001
2	60	20	30	20		.001
15	40	15	50	25		.01
25	30	45	25	24		.01
40	50	60	40	20		.002
15	15	20	20	5		1
30	5	10	30	1		
25	10	30	25	1		
20	100	20	25	25		
25	100	100	25	25		
		20	10			
37		Avg; 37		Avg. 15		Avg. 0.72

Selectifier Rejects

60	60	70
50	95	95
95	75	95
95	80	100
90	80	60
90	80	15
50	70	90
80	80	90
80	30	99
100	95	99
100	95	30
90	40	90
98	50	70
85	30	95
100	40	80
100	40	80
100	85	50
95	50	95
50	80	80
50	95	95
90	98	30
75	95	30
75	90	50
50	95	70
60	70	60
80	70	100
80	70	100
90	70	50
90	90	100
90	30	70
100	80	100
95	70	95
90	50	95
85	75	90
80	70	80
80	50	
80	80	
95	70	
75	70	
30	50	
70	60	
60	80	
25	100	
50	90	
70	25	
80	50	
80	99	
30	99	
40	90	
40	80	
100	80	
90	95	
40	80	
70	90	
70	90	
50	80	
85	95	
	75	

Avg. 76

Reverse Cleaner Accepts

.01
.02
.001
.001
.02
.003
.001
.002
.001
.001
.001
.0
.01
.01
.001
.002
.01
.05
.001
.001
.001
.003
.05
.02
.001
.002
.003
.001
.002
.002
.05
2
1
.001
.002
.01
.001
.02
5
.002
.002
.002
.05
5
.001
.01

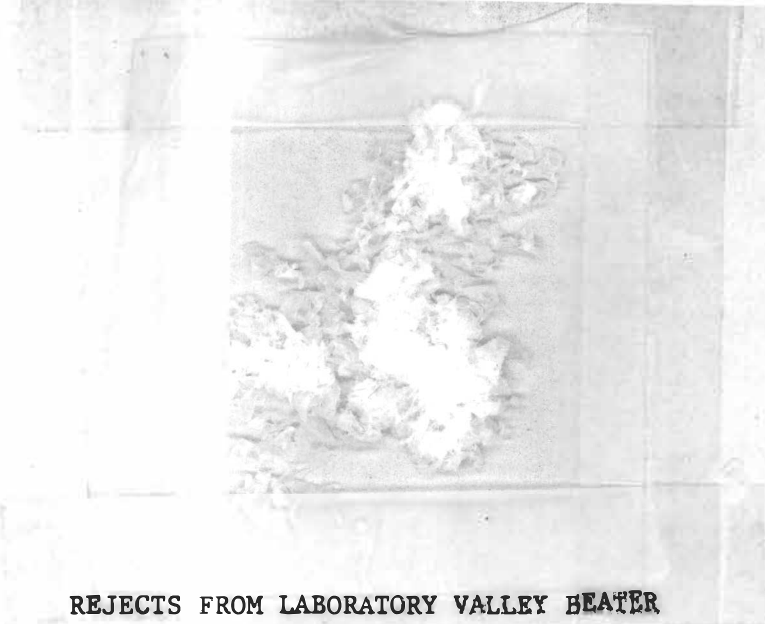
Avg. 0.29

Reverse Cleaner Rejects

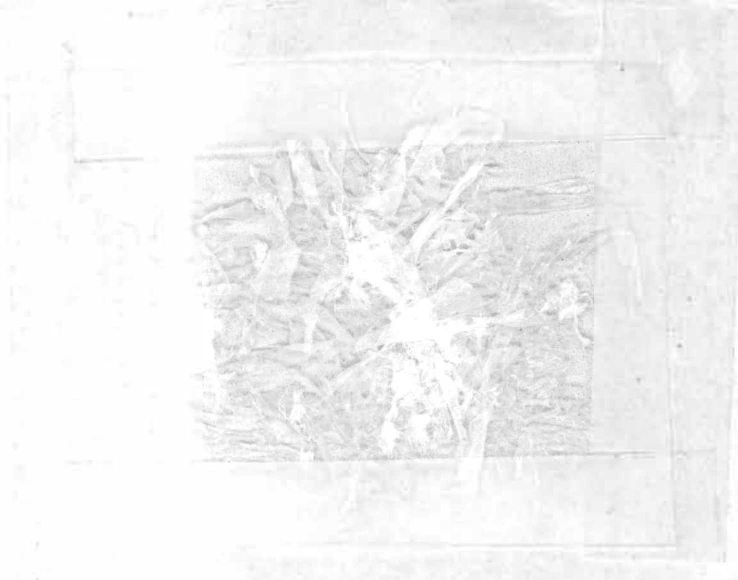
2
2
15
10
.002
.001
15
.01
.01
.001
.001
.05
.002
.002
.004
.05
.001
.003
.05
.05
.001
.001
.001
.002
.002
.05

Avg. 1.70

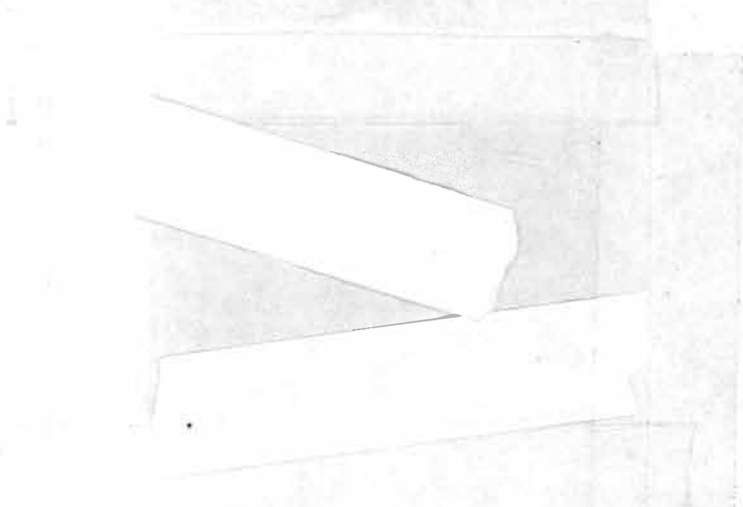
* Spot counting was performed using a grid which covered a total area of 23.5 cm^2. The individual numbers represent a percentage of area which contained polyethylene in a given square of the grid.



REJECTS FROM LABORATORY VALLEY BEATER



REJECTS FROM JONSSON SCREEN WITH 1/8" HOLES



ORIGINAL TRIM SCRAPS
(James River Corporation)