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The Recyclability of Glassine Paper

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THE RECYCLABILITY OF GLASSINE PAPER

BY

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Denis Dumont
Technical Manager
Glassine Canada, Inc.
845 Industrial Avenue
Quebec, Quebec City G1K7K7

ABSTRACT

The objectives of this thesis were (1) to prove/disprove the recyclability of glassine paper (2) to find the optimal conditions for glassine recyclability (if it indeed was recyclable) (3) to study the effects a 20% glassine furnish had on strength properties compared to a furnish with no glassine in it. The conditions varied in this experiment were temperature (127 °F to 190 °F), pH (7.5 to 10.5) and time (0 to 60 minutes). The tests performed were the image analyzer (for glassine specks), freeness, burst, tear and tensile. The last three tests were indexed.

The results from the image analyzer showed no increase in specks for all runs except 2 and 3 where increases did actually occur. Results also indicated freeness values dropped dramatically after the glassine was mixed into the original furnish. As a whole, tear, burst and tensile index values decreased after the glassine was added to the original furnish and continued to decrease with time.

Under the experimental conditions outlined in my report I was able to conclude several things. The first conclusion I made is that glassine is recyclable. Secondly, glassine fully recycles if the pH is at least 8.5 or higher. Third, strength properties were lower with 20% glassine handsheets than they were for handsheets containing no recycled glassine.

Based upon this experiment I would recommend a 20% glassine furnish be recycled with a minimal pH of 8.5 but not much higher than this so as to preserve strength properties. I would recycle the glassine with a minimal temperature of 130 °F for the same reason. At these two conditions I would recycle the glassine for at least 20 to 30 minutes to insure good glassine redispersion without using up excess time and energy.

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INTRODUCTION

The main objective of this experiment was to prove or disprove the recyclability of glassine paper with glassine ratiod into a 50/50 hardwood (HW)/softwood (SW) furnish at 20%. The conditions varied were time, temperature and pH.

By varying these conditions and analyzing the resulting pulp for freeness, and the handsheets for dirt counts (specks), burst, tear and tensile values, not only could it be found that glassine was recyclable but also the optimal conditions it recycled under could be found. This then became the second objective of this report.

Because in my experimental design glassine was added between the 0 and 10 minute samples, the resulting strength properties could be compared between handsheets with no glassine and handsheets with 20% glassine. The other samples taken were at 20, 30 and 60 minutes. Even though the original furnish (no glassine) did not have time (mechanical action) acting on it (otherwise pH and temperature remained constant throughout the trial), it is believed strength properties of the 10 - 60 minute sample could still be compared with the 0 minute sample because the mechanical action supplied throughout the trial was with a Morden Slushmaker. This piece of equipment simply supplies a stirring action and not a refining (fiber shortening) action. Therefore, the third objective of this experiment became comparing strength properties of a furnish with no glassine in it to a furnish with 20 percent glassine in it.

THEORETICAL AND BACKGROUND DISCUSSION

Literature Review

Trying to find information on the recyclability of glassine proved to be difficult. Other than finding a definition of glassine, a literature search conducted in the Paper Institute Index from 1933 to present revealed no information on the recyclability of glassine. I then resorted to contacting manufacturers of glassine papers in North America. I was able to reach John VanBiervliet, Mill Manager for James River Corporation in Millford, NJ, an ex-manufacturer of glassine papers (1). He remembered heat and caustic were used to redisperse glassine broke from the papermachines. This contact gave me my first clue as to glassine's ability to recycle.

I learned a study had been done for Nicolet Paper Company by Integrated Paper Services in April of 1990 upon contacting Roger Wolf of Nicolet Paper Company, DePere, WI (2). This study tried proving glassine was recyclable by recycling both 100% glassine stock and envelopes with a glassine window patch. This study concluded glassine was recyclable because British handsheets made from the recycled furnish had good brightness values, contained no visual specks (specks that were glassine) and that the glassine was visually repulpable in water.

This study is inadequate in proving the recyclability of glassine because none of the results were quantifiable except for brightness. Brightness is not entirely if at all a good

measure of recyclability. Prior to recycling, the glassine had also been soaked in water for a rather unrealistic (in comparison to real life conditions) 24 hour period (3).

Definition of Glassine

The Dictionary of Paper defines glassine as a:

> "smooth, dense, transparent or semitransparent paper manufactured primarily from chemical wood pulps which have been beaten to secure a high degree of hydration of the stock. This paper is greaseproof." (4, 111)

I have learned from contacting current manufacturers of glassine that all glassine in North America is manufactured from the Kraft pulping process. Historically, glassine was first manufactured as a grade in 1907, had grown slowly until WWI and then took off. Around 1950 approximately fourteen North American companies produced 100,000 TPY of glassine. Around 1975 only five companies manufactured about the same amount of glassine (5, 34). Today, only three North American companies produce about 33,000 TPY of glassine.

Glassine Manufacture

Most papers are made within a range of 200 to 500 mL CSF to preserve strength properties and opacity values. Glassine papers are refined typically to freeness values of around 50 to 100 CSF. These low freeness values help develop the papers' transparency and greaseproof properties at the expense of strength properties. Glassine is typically made from HW chips which are put through a Kraft pulping process. This pulp is then washed, bleached, and refined to the above freenesses. The paper is then formed on a Fourdrinier type machine, with slow machine speeds because of the slow

drainability of the low freeness pulp, then pressed and dried. Next, the paper is moistened with steam and passed through a supercalender under heat and pressure. This is where the process ends for manufacturing glassine.

Glassine Paper Properties

Glassine is a paper with some interesting properties. Because the fibers have been refined so short they take on a gelatinous semi-transparent form when formed into a sheet and then supercalendered. The extremely short fibers bond together to create a very hydrated paper with high density, especially when further densified by supercalendering processes. This hydration within the sheet allows the paper to give good grease resistance. If glassine is rewetted, these hydrogen bonds start to break readily and thus give glassine poor wet strength properties (4, 111).

Glassine Uses

Glassine has lost much of its business to the plastic/polyethylene industry over the years. The obvious reasons were that products made from plastics offered better barrier and strength properties and would help to preserve the food contents of packages longer. Today, glassine is not used as much as it used to be for cereal packages and candy bar wrappers, but M & M candies still come in glassine wrappers. Nowadays glassine is likely to be used as backings for fast food wrappers and pressure sensitive labels. Usually the glassine will have a special coating applied to it to enhance its barrier properties. The literature search

revealed the Japanese are heavily involved with special coatings for glassine. To a limited extent glassine has found its way into the envelope market where it has replaced the plastic windows for glassine window patches. Sprint Long Distance phone bills use glassine window patches on their envelopes. Most of the mills that can produce glassine have converted their manufacturing operations over to the manufacture of other specialty grades of paper.

STATEMENT OF PROBLEM

Polyethylenes and plastics may have some great advantages over glassine, but their major downfall is that they can not be recycled. They will end up in a landfill taking up volume and not completely degrade for a long time. Plastics are also a major contaminant in the recycle stream in the paper industry. The industry has made large capital expenditures on cleaning equipment to remove plastics and other lightweight contaminants.

At a certain point I started to think that if glassine is made from paper it can certainly be recycled like paper. When I researched this area a little more I found two sides to the issue. Although I have already discussed my literature search, the real lack of literature on the recyclability of glassine seemed to indicate I was crazy for even thinking it was recyclable. On the practical side, however, I had to imagine mills manufacturing glassine had to have broke systems. This is when I was able to contact the manufacturers of glassine who then were able to give me ideas

for an experimental plan.

EXPERIMENTAL

Design:

Appendices 1 and 2 show the complete design of my experiment in flowchart form. I obtained approximately 50 pounds of raw glassine paper and ratiod this into a furnish at 80%. This furnish was 50/50 HW and SW pulp refined to a freeness of about 300 CSF and then thickened to try to bring it up to a higher consistency. I chose to use a 20% glassine furnish because this percentage is a worse case condition not likely to be exceeded in real life. Appendix 3 shows only about 11% of the total area on an average sized envelope is due to the window patch. In real life, bales of 100% envelopes are not likely to be fed to the hydrapulper so the percentage portion of glassine in that furnish is even lower.

The next part of the thesis I had to design was the number of trials I was going to run and at what conditions I could run them under in order to achieve glassine recyclability. John VanBiervliet (1) had mentioned glassine broke redispersed with a temperature of around 150 °F with caustic added. Other industrial contacts confirmed the temperature but not the pH range. Based upon this knowledge, I decided trials should definitely be carried out at 150 °F with a range of + or - 20 °F. I then decided two sets of trials at a pH of 7 and 10 should be run to look at the effects pH had on glassine recyclability. I wanted to

look at the effect time had on recycling of glassine, so I sampled the furnish at 0, 10, 20, 30 and 60 minutes. Because I wanted to look at the effect a 20% glassine furnish had on strength properties as compared to a furnish with no glassine, the 0 minute sample was without glassine. Glassine was then added after the 0 minute sample and samples withdrawn after 10, 20, 30 and 60 minutes.

After the trials were designed, I needed to find out what tests had to be run in order to prove my objectives. Freeness and the image analyzer 3600 tests were going to be run on the pulp and British handsheets respectively. Glassine recyclability could then be determined by perhaps a dramatic decrease in freeness from the original furnish and the image analyzer could pick up the glassine specks in the handsheets. By making British handsheets and testing for strength properties on all of the trials at all of the sampling times the optimal conditions of glassine recyclability could be isolated. The latter, if done on the 0 and 10 minute runs, was also going to allow me to compare the effects of strength properties between a 20% glassine furnish and a furnish with no glassine in it. Strength properties tested were tear, tensile and burst, and all values were to be indexed to account for sheet weight fluctuations.

Materials:

The raw materials needed for my experiment were raw glassine and HW and SW pulps. In order to refine the 50/50 HW/SW furnish to a freeness of around 300 CSF, I needed

access to Valley Beaters.

Running the trials involved varying three parameters: time, temperature and pH. The device used in order to study the effect of time was a Morden Slushmaker. Temperature was varied by adding steam from a steam line that was attached to the Morden Slushmaker. pH was controlled by adding sodium hydroxide (caustic).

Running tests on the pulp required a lab with a freeness tester in it. Making handsheets required a proportionater and British handsheet maker. Running the strength properties required a lab standardized at TAPPI conditions equipped with tear, burst and tensile testing equipment. Running speck counts required the use of a Image Analyzer 3600.

Procedure:

I began my experiment by obtaining a 50 pound roll of glassine which provided me with more than enough glassine for my experiment. I calculated the amount of materials needed for each trial based upon the conditions needed to run the Morden Slushmaker. The Morden Slushmaker manual called for a 6% consistency slurry weighing a total of 30,235 grams. 30,235 grams of pulp at 6% consistency multiplied together yields 1814 grams of actual fiber. 20% of this yielded 362.8 grams of glassine to be needed for each trial. This left 1451.5 grams of 50/50 HW/SW furnish needed. Since the 50/50 furnish was going to be refined in the Valley Beater, this worked out nicely to be four beater loads of 363 grams. The Valley Beater normally calls for run conditions of 360 grams

of pulp at 1.57% consistency, so this called for 181.5 grams of oven dried HW and SW together for each beater run. The HW used was Burgess. The SW used was Drydens DCX. After accounting for a 5.5% atmospheric moisture content in the paper, the 50/50 furnish was made up to 17 liters in a slushmaker and slushed for two minutes, then placed in the Valley Beater and made up to 20 liters (6). I then refined each beater load for about 25 minutes to yield a freeness of about 300 CSF. I did this four times to provide enough 50/50 furnish for each of the six trials, a total of 24 beater runs. Because the volume of the pulp was so great at 1.57% consistency, I used a mesh casing to dewater the furnish until all of the four beater runs could fit together in a five gallon bucket. This mesh had small enough holes to not allow fines to pass through it.

The glassine, in preparation to be added to the 50/50 furnish, was weighed out to 384 grams to account for a 5.5% moisture content as well. It was then cut into pieces of paper 2" by 5" to represent window patch sizes on envelopes as closely as possible.

The 50/50 furnish was then placed in the Morden Slushmaker and water was added up to the volumetric level it was designed to hold. The slushmaker was then turned on for a brief 5 to 10 minute mixing period to insure a uniform trial temperature and pH. Caustic was added for the runs that needed to be run at a pH of 10. This was done by adding 300 mL of a 40 g NaOH/1000 mL water solution during the

mixing period. Temperature was adjusted by hand utilizing a steam line located at the bottom of the slushmaker. With all the conditions set right for running a particular trial, a 0 minute sample was taken and then the glassine was ratiod in at 20%. At intervals 10, 20, 30 and 60 minutes later, approximately one liter samples were taken from the slushmaker at each of the sampling times. For exact run conditions see Appendix 1 "Experimental Design."

The worse case conditions in my experiment were repulping at a pH of 10 at a temperature of 170 °F. I ran this trial first to see if the glassine did or did not disperse to see if I was going to have to make adjustments in my experimental plan. Fortunately, the glassine did disperse and I kept the rest of my experimental design the same.

With the one liter samples of pulp I used part to test for pH and freeness and the rest for British handsheet making. Freeness was run according to TAPPI Standards (7). Because 2.5 gram handsheets took too long to drain because of the resulting low freenesses, 1.5 gram handsheets were made instead to speed up the draining and sheet forming processes. The sheets were then pressed and dried. Approximately six handsheets were made at each time interval for each trial. The handsheets were then analyzed for dirt counts/glassine specks under the Image Analyzer 3600. Two sampling locations were viewed at different locations under the image analyzer for a total of twelve samples at each time interval. Results were tabulated in area and then converted over to ppm using

TAPPI T 437 method (8).

After the speck analyses were completed, three out of the six handsheets that had the best formation and closest sheet weight ranges were selected to perform the strength tests on. These sheets were all conditioned for at least 24 hours prior to testing according to TAPPI conditions (75 °F, 50% relative humidity). Then tear, burst and tensile tests were all performed and the values indexed according to TAPPI Standards (9) (10) (11). Six burst tests were taken, two to six tear tests at six plies and three to six tensile tests were taken and the values averaged. The number of tests varied due to running out of sample because of paper cutting errors, etc. See Appendix 4 for sample calculations of these tests.

All test values were then graphed and results analyzed. Finally conclusions were made from the results and presented to the reader in this report.

RESULTS

Glassine Recyclability:

From Figures 1 and 2 the effects of increased recycling of glassine can be seen according to run number and conditions. Figure 1 shows between 0 and 10 minute runs freeness values dropped by approximately a factor of 2.6. Between the 10 and 60 minute runs freeness continued to drop but only by a factor of 120%.

In trying to prove the recyclability of glassine, Figure 2 shows high glassine speck counts for runs 2 and 3. Run 2

had approximately a tenfold increase between the 0 and 10 minute runs, then gradually continued to decrease until finally at the 60 minute sample an increase by a factor of two could be noted. Run 3 had increasing glassine specks in it up to 30 minutes, then decreased. The rest of the runs showed little change between the 0 min sample and the 10, 20, 30, and 60 minute samples.

Optimal Recycling Conditions:

Figures 2 - 5 show the data necessary to determine the optimum conditions for glassine recyclability. In this way Figure 2 shows runs 2 and 3 had the highest glassine speck counts, while the others were dramatically lower, with run one having the lowest glassine speck count. Figure 3 shows run 1 having the highest, most consistent tear properties. Figures 4 and 5 show run 1 having the 2nd to 3rd highest burst and tensile values as compared to the other values, respectively. Looking back at Figure 1, it is seen that the original 0 minute furnish was initially not advantaged with a high freeness for run 1 either.

Strength Properties:

All 0 minute samples in Figures 3 - 5 show strength properties of the 50/50 HW/SW handsheets with no glassine added. The 10 - 60 minute samples show strength properties droppe an average of about 5 to 10% for a 20% glassine furnish ratiod into a 50/50 HW/SW furnish as compared to the 0 minute values.

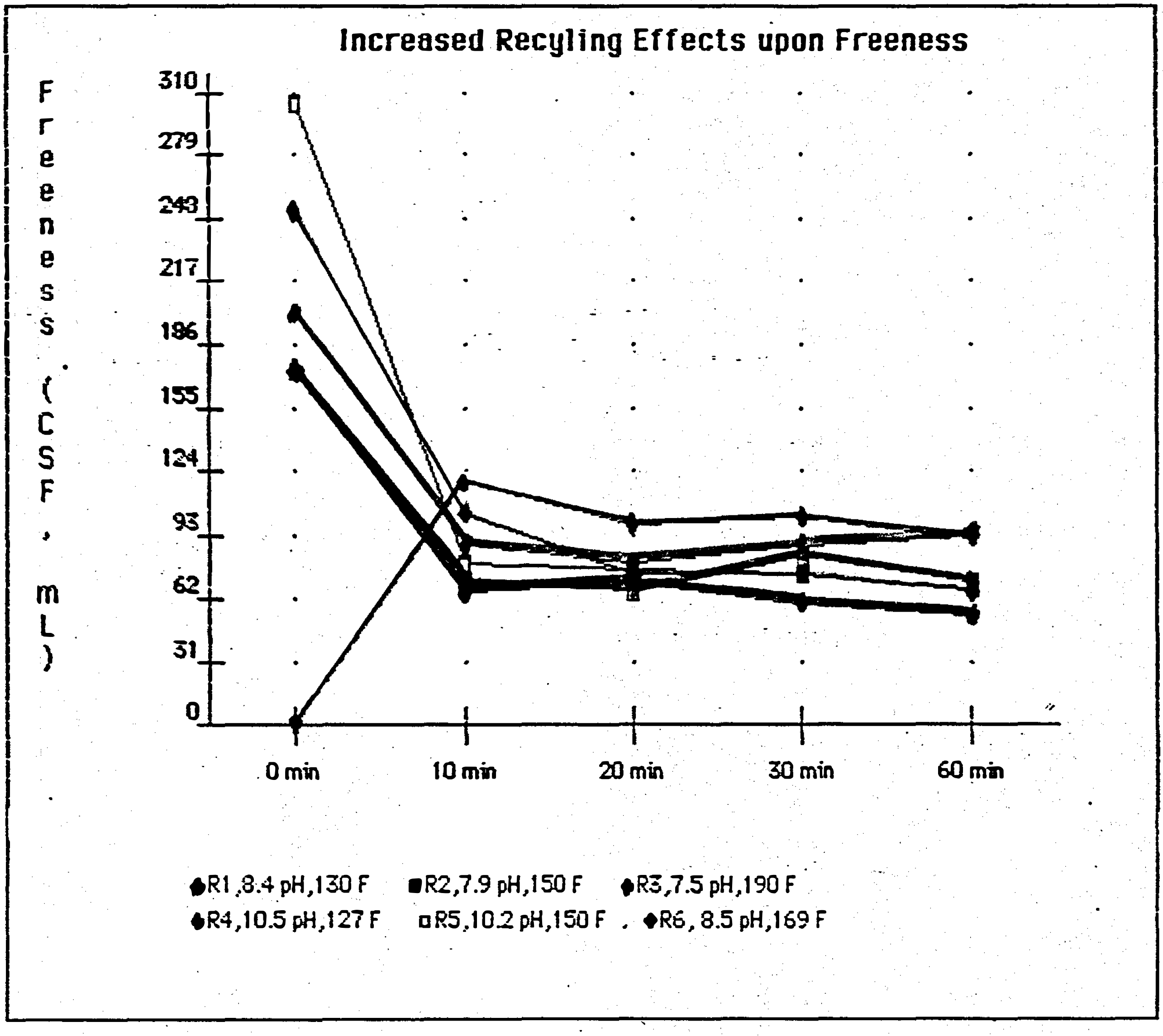
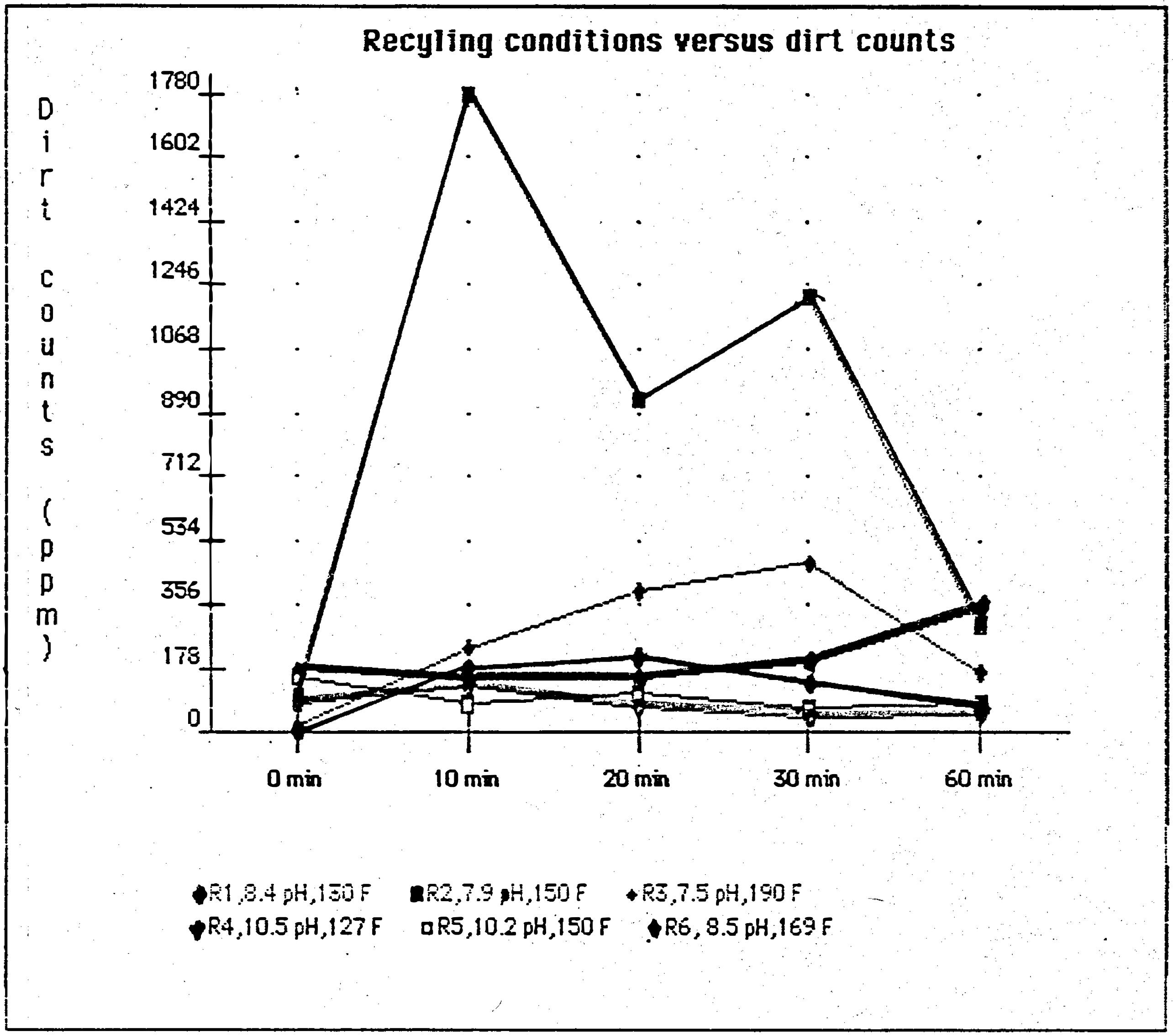
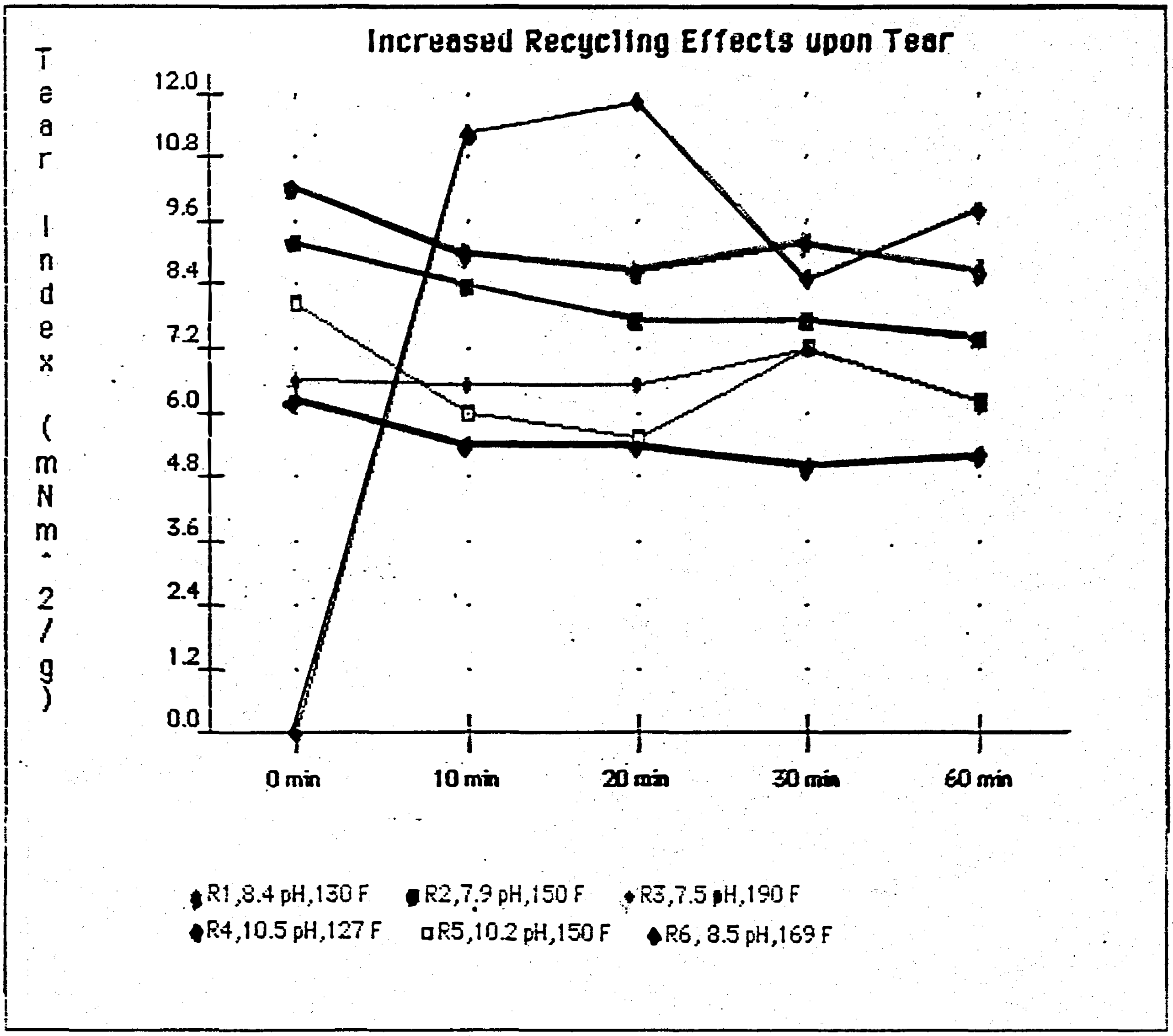
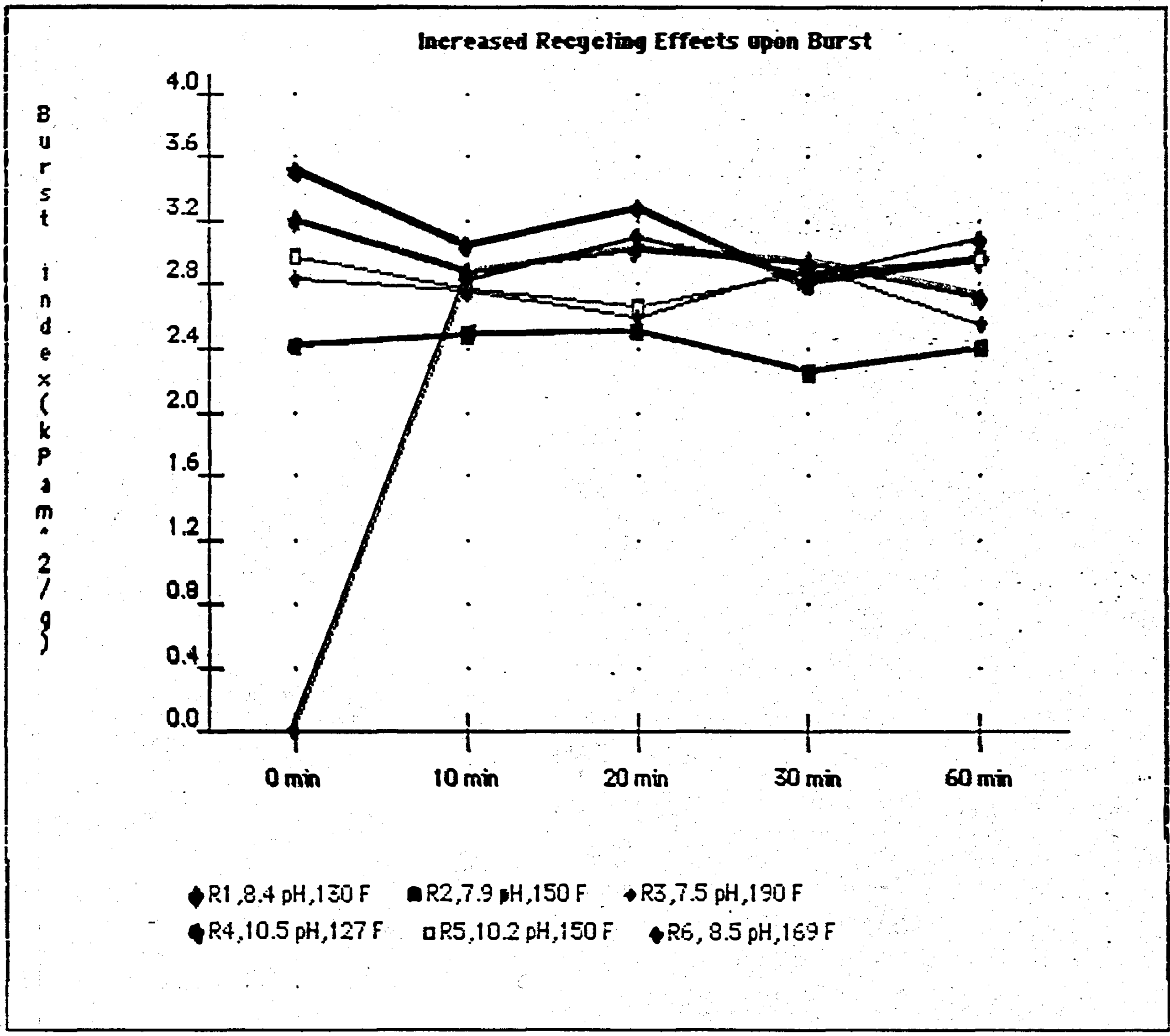

Increased Recyling Effects upon Freeness
Freeness (CSF, mL)
310
279
243
217
186
155
124
93
62
31
0
0 min
10 min
20 min
30 min
60 min
R1,8.4 pH,130 F
R2,7.9 pH,150 F
R3,7.5 pH,190 F
R4,10.5 pH,127 F
R5,10.2 pH,150 F
R6, 8.5 pH,169 F

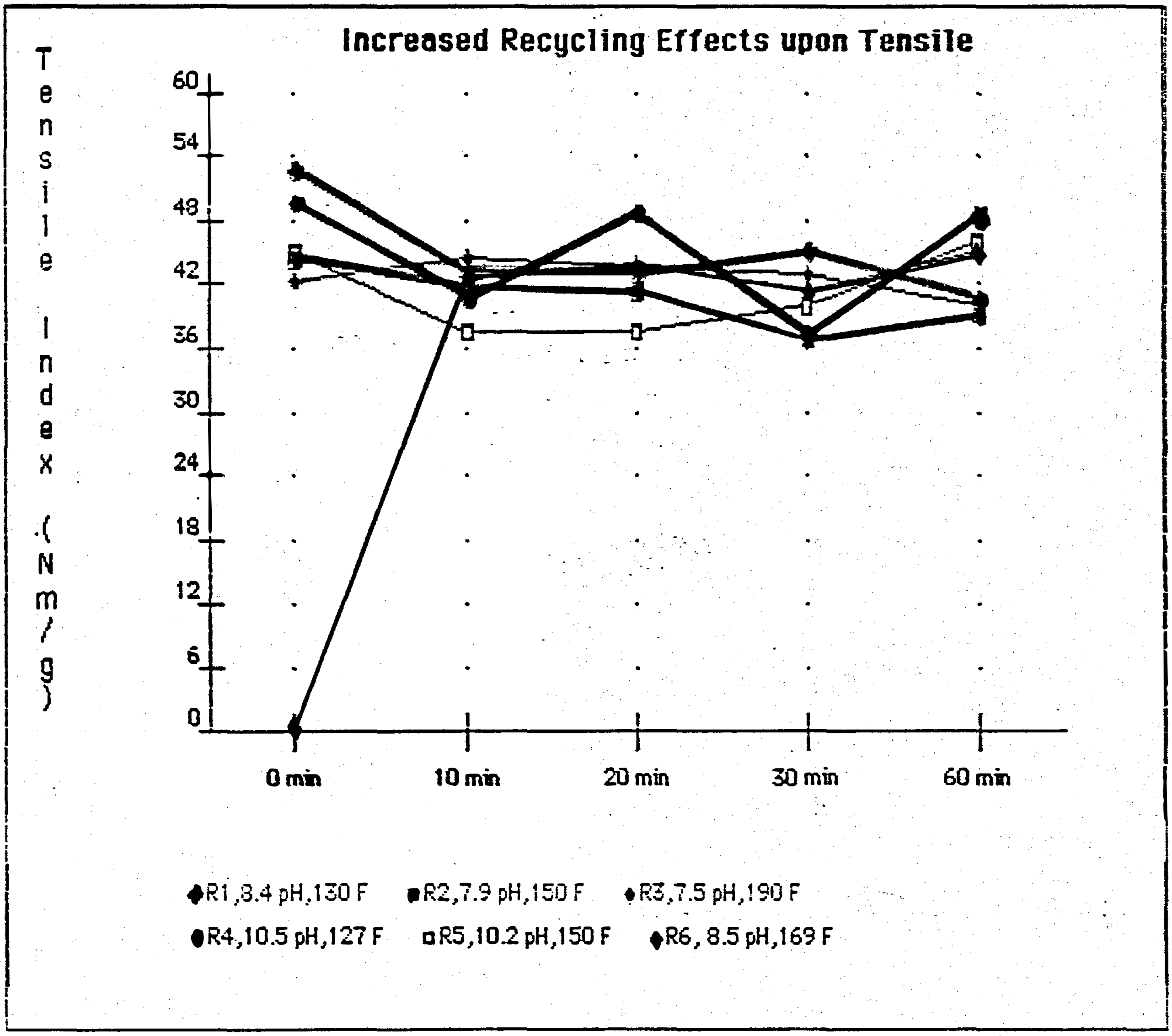
Figure 2



Recyling conditions versus dirt counts
Dirt counts (ppm)
1780
1602
1424
1246
1068
890
712
534
356
178
0
0 min
10 min
20 min
30 min
60 min
R1,8.4 pH,150 F
R2,7.9 pH,150 F
R3,7.5 pH,190 F
R4,10.5 pH,127 F
R5,10.2 pH,150 F
R6, 8.5 pH,169 F


Increased Recycling Effects upon Tear
Tear Index (mNm^2/g)
12.0
10.8
9.6
8.4
7.2
6.0
4.8
3.6
2.4
1.2
0.0
0 min
10 min
20 min
30 min
60 min
R1,8.4 pH,130 F
R2,7.9 pH,150 F
R3,7.5 pH,190 F
R4,10.5 pH,127 F
R5,10.2 pH,150 F
R6, 8.5 pH,169 F


Increased Recycling Effects upon Burst
Burst index(kPa m^2/g)
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0 min
10 min
20 min
30 min
60 min
R1,8.4 pH,130 F
R2,7.9 pH,150 F
R3,7.5 pH,190 F
R4,10.5 pH,127 F
R5,10.2 pH,150 F
R6, 8.5 pH,169 F


Increased Recycling Effects upon Tensile
Tensile Index (Nm/g)
60
54
48
42
36
30
24
18
12
6
0
0 min
10 min
20 min
30 min
60 min
R1,3.4 pH,130 F
R2,7.9 pH,150 F
R3,7.5 pH,190 F
R4,10.5 pH,127 F
R5,10.2 pH,150 F
R6, 8.5 pH,169 F

Glassine Recyclability:

Figure 1 offers the strongest evidence glassine dispersed back into its low freeness fibers. The 0 minute sample represents the original freeness of the fibers before the glassine was added. The 10 - 60 minute samples represent the samples with 20% glassine in the furnish. The results indicated freeness values dropped by an average factor of 2.6 between the 0 and 10 minute samples alone.

There are two reasons these freeness values could have dropped so low. The refining of fibers lowers freeness values using mechanical action to physically cut the fibers and shorten them. This type of action is not likely to be present with a Morden Slushmaker as this device has no means of cutting fibers bur rather a stirring type action that helps to separate fibers from one another. This isn't to say that the Morden Slushmaker couldn't lower freeness values. I'm sure it does to a limited extent due to some inadvertent cutting and shortening of fibers as they are pulled apart from one another. The second and most likely reason why freeness values dropped is probably due to the fact the glassine redispersed into its original low freeness fibers. As mentioned earlier, glassine papers are typically made from 50 - 100 CSF pulps. I believe these short fibers broke apart from the glassine paper as it recycled and went back into solution and mixed with the rest of the furnish, thereby dramatically lowering the freeness values and appearing only

when freeness tests were performed on the pulps.

Figure 2 shows the image analysis picked up glassine specks for runs 2 and 3. I would like to add runs 2 and 3 had glassine specks that could be plainly seen, but the image analysis machine was used to simply quantify the amount of specks in the furnish. Figure 2 shows also the machine (the naked eye also) could detect no glassine specks for the other four runs (except for a minimal count of actual dirt, rust, etc.). This proves that at least four runs in my experiment totally recycled glassine. Thus glassine is recyclable.

<u>Optimal Recycling Conditions:</u>

Figure 2 shows clearly runs 2 and 3 do not exhibit conditions as favorable to the recycling of glassine. It is interesting to note the one major factor that distinguished these two runs from the others was the fact they had the two lowest pH values in the whole experiment (7.9 and 7.5 respectively). Apparently a minimal amount of caustic needed to be present to break apart the fibers in the glassine sheet. The next lowest pH value was from run 1 with a pH of 8.4, and according to Figure 2 had one of the lowest speck counts. At this point, I am able to conclude the results in my experiment indicate a minimal pH of about 8.5 is needed to recycle glassine. Increasing the pH continued to keep the specks of glassine to a minimal as well (Figure 2).

The effect temperature had on the pulps was more subtle. Because the run conditions varied so much in this experiment, it was hard to find a set of trials where the pH remained

constant and just the temperature was varied. In the few instances where these conditions were met, the freeness values from Figure 1 varied enough to not be able to correlate the effects the changes of temperature had upon the strength properties of pulp. I believe runs 2 and 3 show the best example of how increasing temperature affected the recyclability of glassine paper. From Figure 2 it is seen that even though run 2 had a higher pH than run 3, the specks of glassine were actually significantly lower for run 3. The only condition that could explain this is that run 3 had a very high temperature that was able to recycle more glassine to more than make up for an actual decrease in pH between itself and run 2. Although I have no way of quantifying this additional observation of mine, I would like to add that the trials operating at higher temperatures seemed to more readily disperse the glassine upon its addition to the slushmaker.

From Figure 2 it can be seen adequate removal of glassine specks occurred between the 20 to 30 minute time frames. Although additional drops in specks occurred at 60 minutes, this small gain would probably not be worth the amount of energy requirements put into it to achieve those small gains. The 20 to 30 minute time range in Figures 3 to 5 indicate as well that strength properties would be compromised to a certain extent if recycling much beyond the 20 to 30 minute time interval. Time seemed to generally decrease strength properties as more glassine recycled which

in turn further lowered freeness values as a whole (See Figure 1).

I have to pick run 1 as having the conditions that optimized glassine breakdown and strength properties. Run 1 had a pH just high enough to adequately defiber the stock, yet was run at a pH and temperature low enough so as to present the least amount of attack and harm against the individual fibers. The increased temperature and pH may have eroded strength properties by removing walls of the fibers, thereby causing them to be weaker. Figures 3 - 5 show run 1 as having the highest tear values (eliminating run 6 because of its variability) and the second to third highest burst and tensile properties. These values can't be explained away due to run 1 having higher freenesses because in Figure 1 run 1 had about an average starting freeness as compared to the other pulps.

Therefore, in my experiment the optimal conditions for glassine breakdown to occur while still being able to preserve strength properties were:

-recycling close to a pH of 8.5

-recycling for a length of 20 to 30 minutes

-recycling at low temperatures of around 130^{o}F

Strength Properties:

From Figures 3 - 5, strength properties dropped about 5 to 10% for the 10 to 60 minute samples with 20% glassine as compared to the 0 minute samples with no glassine. As

mentioned earlier, glassine is manufactured from low freeness fibers, and as they were redispersed and mixed in with the rest of the 50/50 HW/SW fibers, these shorter fibers had the resulting effect of lowering the strength properties of paper. Tear, burst and tensile values are greatly affected by fiber length, especially tear, and so if there are more shorter fibers in the furnish this will have the corresponding effect of lowering strength properties. (Note: In run 6, I forgot to take a 0 minute sample, so all values in the Figures shown at 0 minutes for run 6 were assigned a value of 0 so I could graph the rest of the results. In actuality, however, I have no data to report for run 6 at the 0 minute sample time.)

CONCLUSIONS

The conclusions in my experiment are as follow:

1.) Glassine is recyclable because when glassine, a very low freeness paper, was added to the furnish, freeness values dropped dramatically in comparison to the 0 minute runs with no glassine, indicating that the low freeness fibers in the glassine furnish had been liberated into the overall furnish.

2.) The optimal conditions for recycling glassine included keeping a pH of around 8.5. This pH was a minimal to disperse the glassine and prevent glassine specks, yet low enough so as to not harm strength properties. Keeping temperature at a minimal of 130°F also seemed to be enough to recycle the glassine without compromising strength properties any more than they had to be. Finally, ample defibering of the glassine seemed to occur between a 20 to 30 minute period without further harming strength properties as well as using up increased time and energy (like the 60 minute run would do).

3.) A 20% glassine furnish had lower strength properties than a furnish with no glassine in it. As mentioned above in (1), freenesses were dramatically lower for the 20% glassine papers, indicating the 20% papers were made with shorter fibers. Shorter fibers in turn harm strength properties, especially tear, because strength properties are dependent

upon fiber length in a large way.

RECOMMENDATIONS

Because plastics are non recyclable and glassine is (as I have proved in this report), I would like to see glassine papers make a comeback into products such as envelope window patches, food bags and wrappers. It seems to me that while not everything using plastic should be replaced by glassine (and some things certainly shouldn't be), glassine could certainly be used more than it is currently used, and with its added incentive of recyclability, it should be.

I believe any further work done on the recycling of glassine be done on a full-scale papermill basis to see if similar results to mine are obtained.

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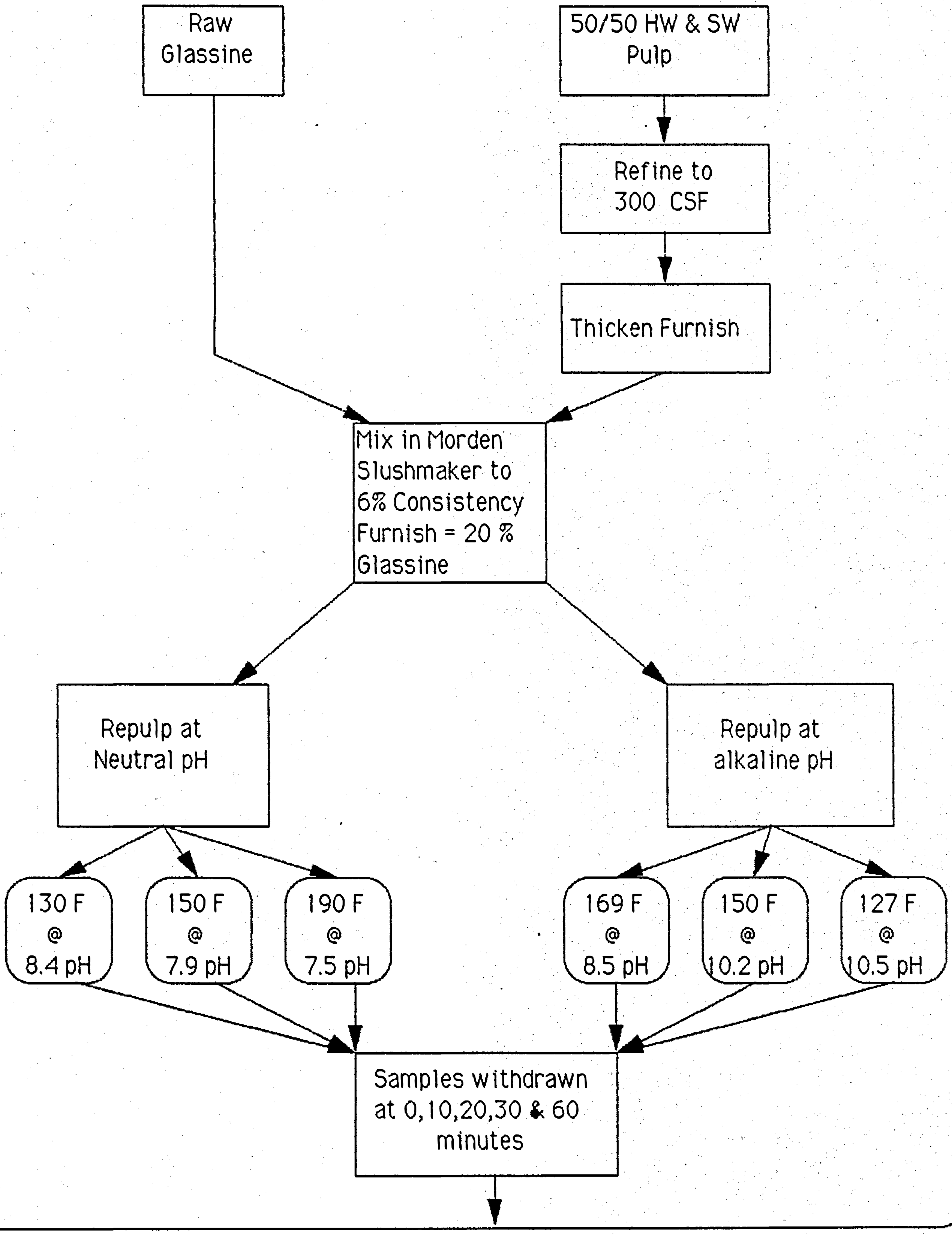
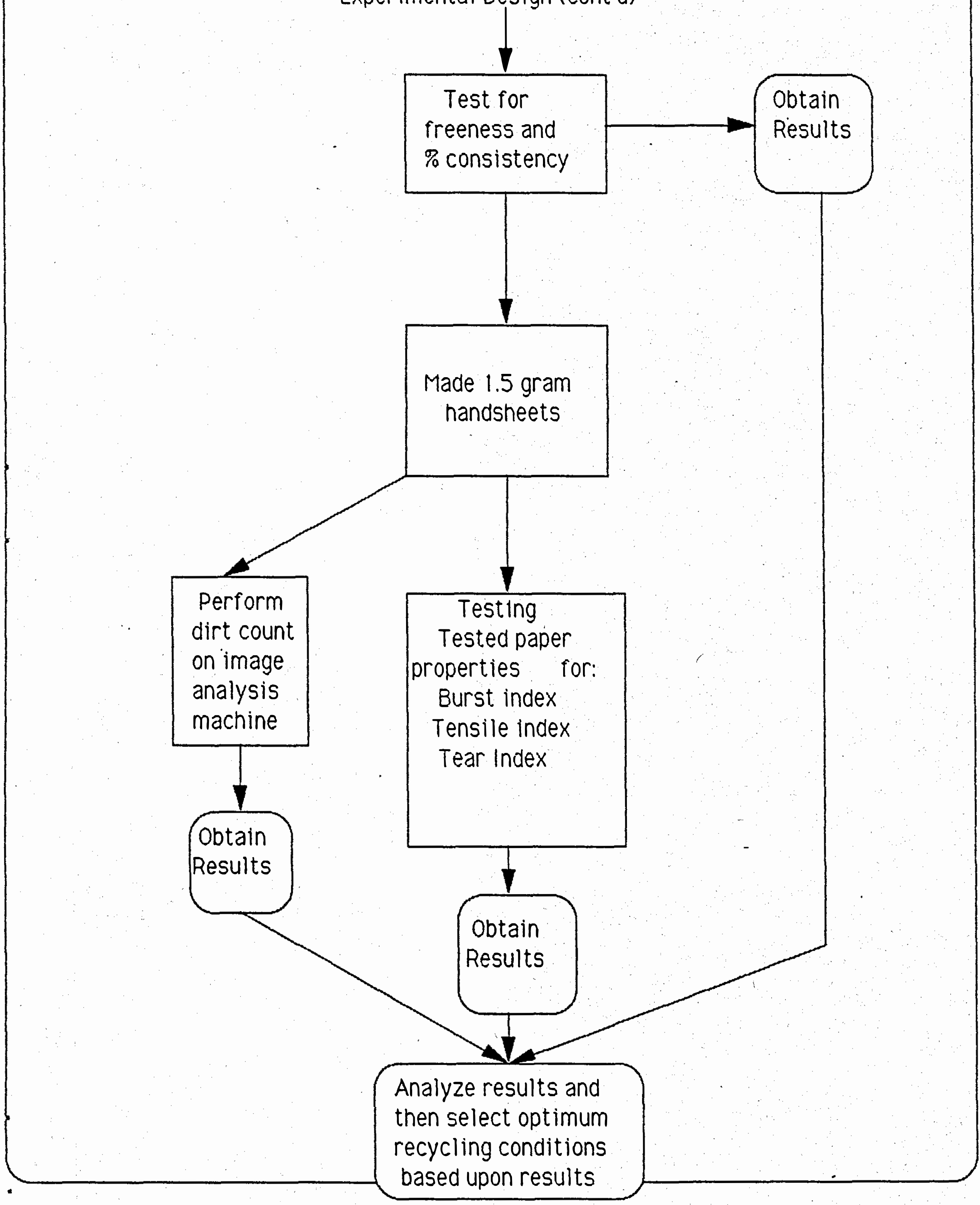
Appendix 1

EXPERIMENTAL DESIGN

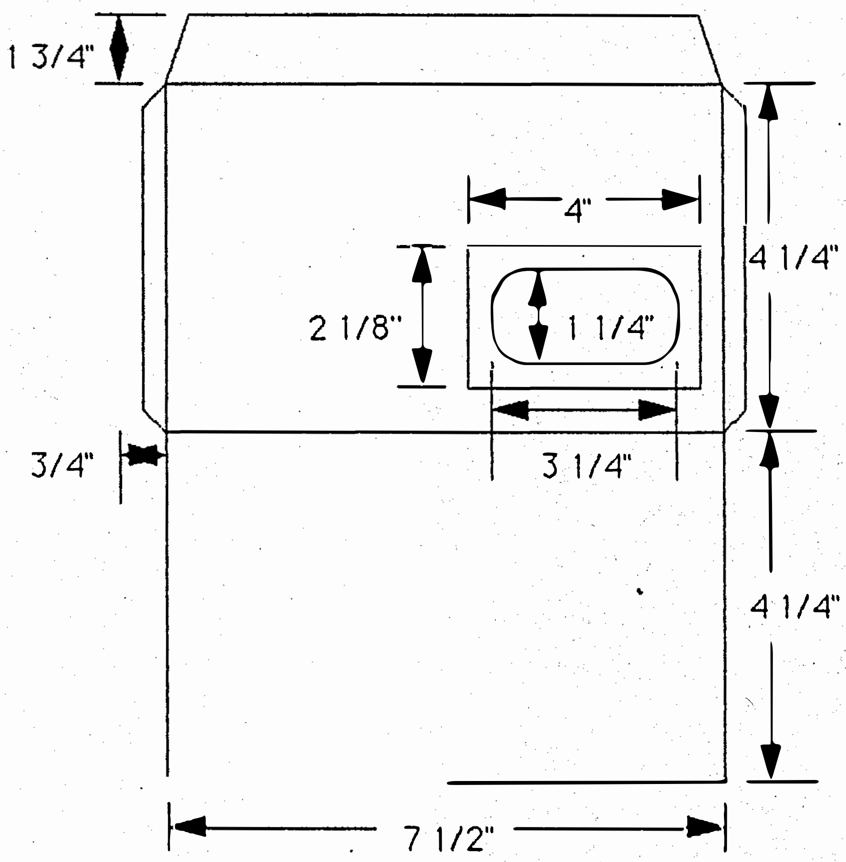


Appendix 2
Experimental Design (cont'd)



Appendix 3

Area of Envelope and Glassine Window Patch



Approximate area of envelope:

7 1/2 x 81/2"	=+63.75
3 1/4 x 1 1/4"=	-4.0625
1 3/4 x 7 1/2"=	+13.125
2(3/4 x 4 1/4") =	+6.375

Total area = 79.1875 in^2

Area of Glassine Patch: 2 1/8 x 4"= 8.5 in^2

Percent area of envelope that is window patch: 8.5/79.1875 x 100 = 10.7%

Appendix 4

Sample Calculations

Tear Index: $\frac{156.96\ (\text{reading})}{(\#\ \text{of plies})\ \text{grammage}\ (g/m^2)} = \text{value}\ (mNm^2/g)$

eg. $\frac{156.96\ (13.4)}{(6\ \text{plies})(43.3 g/m^2)} = 8.1\ mNm^2/g$

Burst Index: $\frac{(6.89\ KPa/psi)\ [\text{reading(psi)}]}{\text{grammage}} = \text{value}\ (KPam^2/g)$

eg. $\frac{6.89 KPa/psi\ (18.83\ psi)}{36.87\ g/m^2} = 3.52\ KPam^2/g$

Tensile Index: $\frac{653.8\ (\text{reading})}{\text{grammage}\ (g/m^2)} = \text{value}\ (Nm/g)$

eg. $\frac{653.8\ (5.76\ \text{kg force})}{75.67\ g/m^2} = 49.8\ Nm/g$