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The Effects of Temperature on Hot Melt Removal

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THE EFFECTS OF TEMPERATURE ON HOT MELT REMOVAL

by

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ABSTRACT

This experiment attempted to reveal the role temperature plays on the removal of hot melt adhesive from corrugated medium.

Three repulping trials were conducted on stock containing a previous applied EVA base hotmelt. The trials were conducted at the following temperatures: 160°F, 100°F and 40°F. The stock was then screened and centrifical cleaned at varying temperatures. Below is the general experimental scheme.

Trial	Repulping Temperature	Finckh Screening Temperature	Bergstrom Centrifical Cleaning Temperature
1A	160°F	160	160
1B	"	100	100
1C	"	40	40
2A	100°F	100	100
2B	"	40	40
3A	40°F	40	40

Handsheets were made before and after each stage, and visually inspected for hot melt content. Trial 2A gave a final sheet with virtually no hot melt content.

Further lab work was conducted. At 160° the hot melt was found to tear into pieces. At 40° it was cold and fractured during repulping but at 100° the hot melt was durable to withstand the hydrapulper action and remained in large pieces, easily removable.

In the decade ahead, recycling of post consumer waste paper and paperboard will become a necessity for several key sectors of the paper industry. Newsprint, linear board, corrugating, printing papers, molded cartons, and boxboard manufacture have all been penetrated by recycling.(1) As these industries grow, along with them the need for recycling climbs.

The capital requirements for a new recycled fiber mill are estimated to be about $50,000 less per daily ton capacity than for a virgin fiber mill. This could be a saving of at least $1 billion in the decade ahead.(2)

Recycling mills have always been operated to cope with unwanted foreign materials but circumstances are changing. The general quality of recyclable post-consumer waste paper is declining as a result of increasing quantities and types of contaminates. These waste paper contaminates are synthetic materials and their use is expected to double by 1985. Thus, the problems with recycling will only continue to grow.

In the years between 1970 and 1975, the paper industry increased the amount of recycled waste paper from 21 percent to 23 percent of the total paper and paperboard production.(3,4) During 1974, the industry recycled fourteen million tons, projected values indicate the recycling to be twenty-three million tons by 1985, this would be approximately twenty-six percent of production.(5)

A list of contaminates reported recently in a nation-wide survey to which approximately one hundred mills responded is below:

Plastics-Films
Wet Strength Additives
Tapes
Asphalt
Hot Melt Adhesives
Waxes
Adhesives (6).

One of the most troublesome contaminants today falls under the general classification of "stickies". These materials stick to mill equipment and to surfaces of the finished paper product. These substances are primarily hot melts, latex, and pressure sensitives, all of which fall under the general title of adhesives. These substances are all sticky under normal mill conditions where the pulp temperature is above 150°F. Stickies plug screens and paper machine wires and felts, thus reducing mill capacity by causing slowdown of the machine or downtime for cleanup purposes. They also adhere to paper machine press rolls and foils. Their densities are very close to that of pulp so that conventional cleaners are reasonably ineffective.

Stickies are most visible in the dryer section due to the fact of the elevated temperature. The temperature generally ranges from 300-350°F. At the dryer section the sticky spots in the paper adhere to the dryers and pull out of the paper sheet. Many mills mount "doctor blades" to scrape the stickies from the dryers. However the problem does not stop at the dryer section. When the paper is wound at the end of

the dryer section the roll is still hot within and the stickies are able to bleed through the roll and reagglomerate. This roll may set in a warehouse for months before it is used. These stickies cause the adjacent layers of the paper to adhere. Sometimes the roll unit can't be unwound, and if it is unwound, many times holes are caused in the sheet from the stickies pulling apart.

The customer receiving most often finds majority of the problems with stickies is the offset printer. He gets a buildup of stickies on his converting and printing equipment, inevitably the loss of money to the customer and paper producer. All these problems are compounded by the fact that just a low concentration of stickies is all that is needed to cause the trouble.

Studying all the materials under the title of "stickies" would be beyond the time alloted range of this project so I will now focus in on one of the chief contaminates for the users of old corrugated containers, hot melt adhesives.

Hot melts are used in a variety of commercial products: corrugated case sealing, book and magazine binding, water resistant coatings on cartons and boxes and manufacturers joints on corrugated containers,(7) all of which lead to waste paper contamination.

Hot melt adhesives, also known as thermoplastic adhesives, have in recent years made their entrance into the paper industry. They are a blend of resins with other chemicals and bonding agents which when heated melt to a liquid form and

solidify upon cooling. Hot melts are one hundred percent solid formations of a thermoplastic material. They do not require a solvent as do many other adhesives.(8) Hot melts used for corrugated case sealing and book binding begin to soften significantly in the temperature range of 150°F to 250°F and are applied at operating temperatures of 285°F to 430°F.(9) A wide range of characteristics for hot melt adhesives is obtained by varying the amounts and kinds of chemicals constituating the blends. These materials are insoluble in water or in solutions of acids or alkalies, but are soluble in many organic solvents.

The polymer adhesives used for hot melts are linear macromolecules and usually of very high molecular weights. The polymer is the strength component of the hot melt adhesive. Hot melts use high molecular weight polymers due to their high viscosities, high strength and mechanical properties. There is a direct relationship between molecular weight and adhesive properties.(10)

Elastomeric resins used in the hot melt market are mainly two chemicals: ethylene vinyl acetate (EVA), and polyolefins.

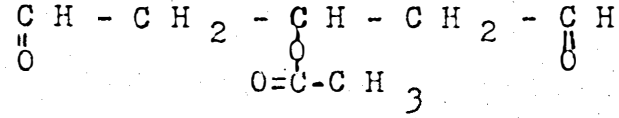
EVA based hot melts have three primary components: EVA, tackifiers, and waxes. Tackifiers are frequently wood or petroleum derivatives which enhance the wetting ability and reduce the viscosity of the adhesive. Waxes are added to adjust the melting temperature of the blend and also act as an extender.

Polyolefin based hot melts consist of a blend of plastic materials mixed with a petroleum derivative tackifier and paraffin. The plastic used is polyethylene, polypropylene, or a blend of the two. Primarily because of their low cost, polyolefin based hot melts have captured one fourth to one half of the hot melt corrugated case sealing market in this country during the past few years.(11) However, EVA blend types are still preferred for bookbinding.

The commonly used adhesives fall in a density range of .92 to .98 with EVA adhesives averaging slightly higher than polyolefin types. Thus, though EVA adhesives float in water, their densities are not significantly different from water.

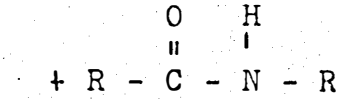
Common types of hot melt adhesives include polyamide resins, petroleum waxes, polyvinyl acetates, bulytmethacrylates, polyethylenes, polystyrenes and ethylene-vinyl-acetate copolymers.(12)

Polyvinyl acetate was one of the first used hot melts. It has a repeating unit of



PVA is made commercially by reacting acetylene and acetic acid in the presence of a catalyst. The catalyst usually being organic peroxides which initiate polymerization by a free radical mechanism thus yielding addition reactions. PVA has fair flexibility and strength. It is used primarily for bookbinding and frozen food packaging.(13)

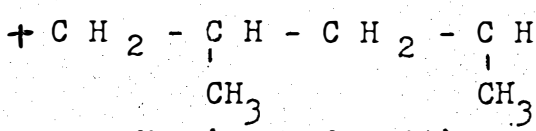
Polyamides are obtained by dimerizing fatty acids and then reacting with diamines. They have a repeating unit of



This group displays good oil resistance and good strength with flexibility due to the linear property of the resin. Polyamides are used to bond aluminum foil paper, packaging or sealing food packages for a quick set bond.

Polystyrene is made by catalytic dehydrogenation of ethyl benzene. They have good resistance to salts, organic acids, and lower alcohols. They are very brittle and show fair adhesiveness.

Polyethylenes have the repeating unit



They have poor adhesion and wetting ability and can be used as a coating on paper for grease or water resistance.(14)

These adhesives mixed with modifiers or copolymers give the properties for the desired hot melt and also the problems associated with recycling.

Hot melt adhesives are heated until the solid thermoplastic resin becomes fluid. The hot melt is then applied to the material and contact between the two is maintained. As the adhesive cools, it solidifies, giving a bond strength supporting the assembly. This type of bonding is a physical process, but chemical bonding can also be brought about with the use of specific modifiers within the hot melt.(15)

As stated before, hot melts are modified to get desired properties in areas of wetting ability, water resistance, tack, viscosity and heat stability. The molten viscosity is important in that it affects the wetting ability of the adhesive which in turn affects its spreadability and handling ease. Plasticizers are mainly used to modify viscosity characteristics. The total composition of the hot melt affects its heat stability. Each hot melt adhesive has its own heat stability characteristic. Copolymerization is very useful in building up the base polymer for use in hot melts. Copolymerization can extend the chain length, cause a greater linear characteristic of the polymer and even give one polymer heat stability that it didn't have before. A prime example is polyvinylacetate which can be copolymerized with a wide variety of compounds for changes in properties.(16)

The advantages of using hot melts are numerous, the prime one being speed of bond formation and their ability to bond a variety of surfaces. Hot melts show gap filling which is non absorbtion in the substrates due to the increase of viscosity upon cooling making hot melts very advantageous when using porous substrates. Also, water resistance is inherent in all hot melts, making them excellent for frozen food packaging.

The uses for hot melts are continuing to grow and their impact on recycling has become a major concern. The problems associated with these materials are numerous and

the work to find an answer is just beginning.

This study will primarily be concerned with the effect of temperature on the processes of repulping, screening, and centrifical cleaning for "sticky" removal.

EQUIPMENT

- Bunsen Burner
- Trowel (for hot melt application)
- Recycling Plant Equipment
  - Hydrapulper
  - Finckh Screen
  - Bergstrom Centrifical Cleaner
  - Chests

MATERIALS

- EVA base hot melt (#602 - Fuller Company)
- Virgin Kraft Corrugated Stock

EXPERIMENTAL PROCEDURE AND DISCUSSION OF RESULTS

The hot melt used in this experiment was an EVA base type and it was donated by the Fuller Company.

This hot melt was applied to virgin corrugated at a percentage representative of industrial receivables. A 1% level was prepared for 100 lbs. of stock. This amount was kept constant for all trials. The hot melt was melted at approximately 300°F and applied with a trowel. Hopefully this procedure would yield a sample attached to the fibers.

Three temperature trials were selected: 160°F, 100°F and 40°F. The treated samples were repulped in the hydrapulper at 6% consistency, then run through the Finckh screen at approximately .7% consistency and finally sent through the Bergstrom at .4% consistency. Below is how the trials were broken down.

	Repulping Temperature	Finckh Screen	Bergstrom Cleaner
1A	160°F	160	160
1B	"	100	100
1C	"	40	40
2A	100	100	100
2B	40	40	40
3A	40	40	40

Handsheets were made to visually inspect what was happening at each step: initial handsheets, Finckh rejects, Finckh accepts, primary rejects from the Bergstrom along with the secondary accepts and final rejects. Then approximately 20 final handsheets were made at the end of each trial.

This hot melt is visible when held up to light, the hot melt is a noticeable yellow color and shows up as little specs 1/16" to 1/8" in size within the final sheets. These specs were counted in each sheet.

To this data the "Q" test was applied. This test is an aid in deciding whether to retain or reject a measurement. A ratio Q is evaluated, with the difference separating the outlying result and its nearest neighbor in the numerator, and the spread of the measurements in the denominator. This experimental ratio is then compared with rejection values that are critical for a particular degree of confidence.[17] If the ratio is lower than that of the rejection value you save the data. I used critical values of Q at the 90% confidence level.

The averages were then recorded for each trial. These were the basis of the conclusions and further study.

Besides temperature there are other parameters involved somewhat affecting the outcome of this experiment. Although it's beyond the scope of this study to thoroughly examine the effects they have in this experiment they must be noted. Repulping time, pH and the changes of the density and viscosity of water as the temperature changes all play a role in the efficiency of this process.

Initial work was done in a Waring blender to come up with an estimate of the repulping time necessary for each run. The times just came out too long, so it was decided to visually inspect the degree of defibering as we make the runs. This way, instead of having a predetermined time we'd check regularly the degree of defibering. Then we'd run all trials at complete defibering and record the time necessary.

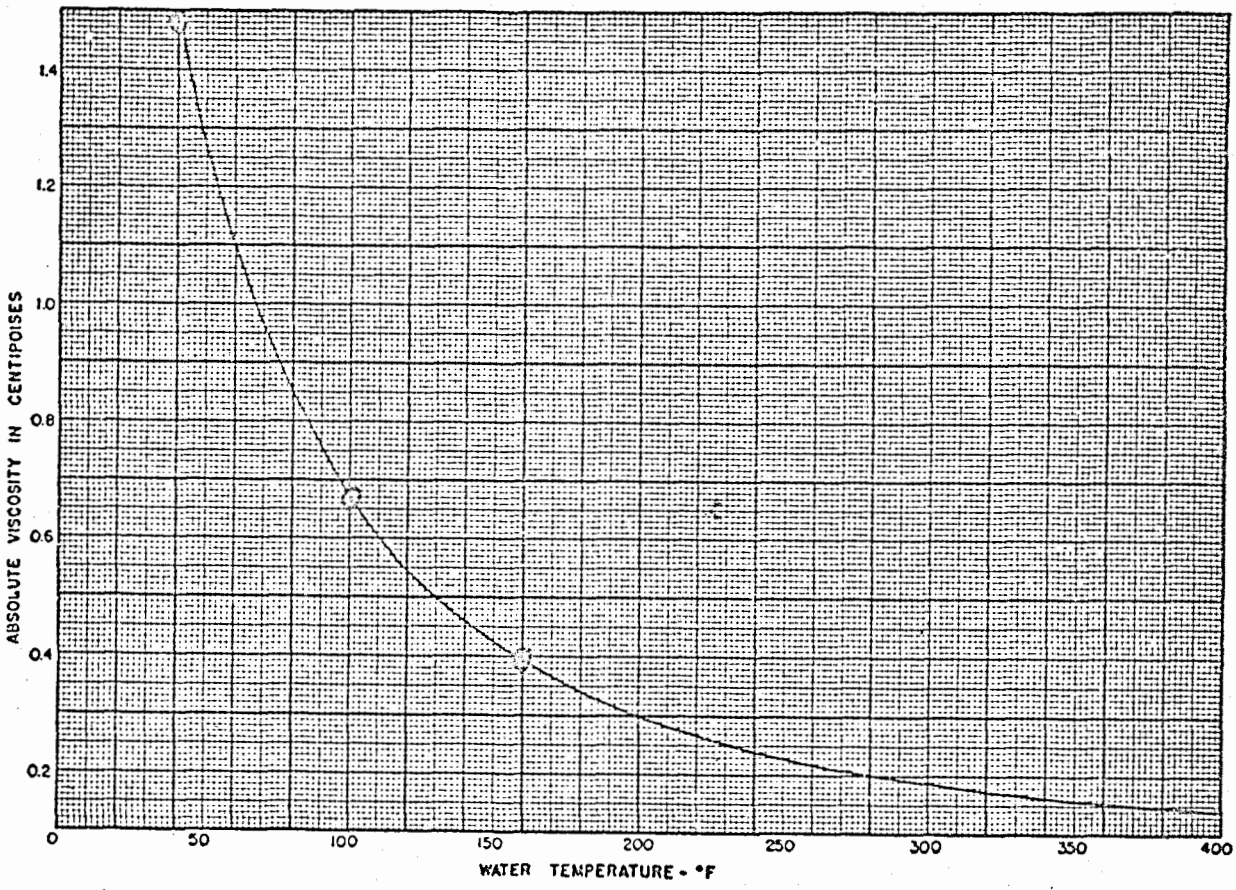
The pH of each sample was recorded after repulping. Nothing was added to help the defibering process. Hopefully if there was a drastic change this would be noted and taken into account.

The density of water decreases with the increasing temperature. At $40^{o}F$, $100^{o}F$ and $160^{o}F$ the densities are 62.42, 62.02 and 60.98 lbs/ft^3 respectively. This means that at the higher temperatures you'd be using more water to change the consistency. In this large of a process we're speaking about 5 extra gallons compared to the 200 used at $40^{o}C$. This change is slight and won't vary the results much. How this may effect the efficiency of the process seems small when compared to the other parameters such as application of the hotmelt.

Viscosity is an important variable primarily in the screening operations. As can be seen on the table below, the viscosity is lower at higher temperatures. This would give the particles less resistance through the water and make it possible to be removed easier. How this affects the internal structure of the hot melt itself is ~~undetermined~~ undetermined. Also what part it plays

in this overall experiment can just be speculated. But seemingly the cleaners would operate more efficiently at the higher temperatures of this experiment.

Viscosity of Water



Flow Meter Engineering Handbook—The Brown Instrument Co.

The primary results of how the handsheets faired for each trial are on chart #1.

2A as can be seen from chart #1 resulted with virtually no specs in the final sheet. Large pieces of hot melt were found in the hydrapulper. See Appendix 2. Initially I felt that I must have applied this trial slightly differently to give this result. Time did not permit another pilot plant run so a lab trial was run in a Waring blender with the same stock.

1% hot melt was applied as before but only 2 liters at 3% consistency were used. Repulping runs again were made at 160°F, 100°F and 40°F. Each was repulped for ½ hour. With the blender at medium speed and a rheostat set between 25 and 30, repulping was controlled.

This time it was visually examined every few minutes to see the extent of the hydrapulper action.

See Appendixes. At 160° the hot melt was ripped and torn into pieces. At 40° the hot melt ftactured into many small pieces but again the 100° samples were in large pieces.

Chart #2 contains the entire data of this experiment. Some trends can be viewed but it is difficult to draw definite conclusions how temperature is afftecting the Finckh and Bergstrom Cleaners. Handsheets were made after each step but again it was the action of the hydrapulper that was the major factor determining the size of the specs. The Finckh screen took out the large pieces where the Bergstrom removed the fines.

Repulping time for 40° was more than twice that of the 160° trial. This also may have an effect on the size and degree of the specs.

When this stock was pumped from the hydrapulper, 1/3 at a time was pumped into each chest. This procedure should be changed to give more similarity to each sample. This is crucial when trying to draw conclusions for the effect temperature has on the Finckh and Bergstrom.

	Repulping Temperature °F	Finckh Screening Temperature	Bergstrom Centrifical Cleaning Temperature	Final : Handsheet specs / Handsheet ($\frac{1}{16}$"-$\frac{1}{8}$") $\bar{x}$
1A	160°F	160	160	13.5
1B	"	100	100	10.4
1C	"	40	40	6.9
2A	100°F	100	100	~0
2B	"	40	40	3.6
2n	40°F	40	40	19.4

Handsheets Bergstrom Primary Rejects	Handsheets Bergstrom Secondary Accepts	Handsheets Bergstrom Final Rejects	Handsheets Final Accepts $\frac{1}{4}$-$\frac{1}{3}$" spec/sheet	Density of water at That Temp.	Viscosity of water at That TEMP
—	—	—	13.5	62.42 $\frac{lbs}{ft^3}$	~.4 centipoise
(3) 5-10 specs/sheet	(4) over 30 specs for each sheet	(2) Very fine specs Hundreds	10.4	"	"
(4) Many	(5) Many	(2) Very fine Specs Hundreds	6.9	"	"
(1) few specs good Handsheets	(1) Very few 0-5 good Handsheets	(1) Very few	0	62.02 $\frac{lbs}{ft^3}$	~.65 centipoise
(2) 15 spes/sheet	(2) 5-10/sheet good Handsheets	(3) Hundreds	3.6	"	"
(5) 200/sheet	(3) 10-30 fair	(5) Thousands	19.4	60.98 $\frac{lbs}{ft^3}$	1.5 centipoise

Finck Screening Temperature °F	Consistency Through Finckh	Finckh Screen Rejects (1-5 ranking 1-good 5-poor)	Finckh Screen Accepts	Bergstrom Cleaning Temperature	Consistency Through
~160°F	.85%	(1) Many Small specs 1/4"	——— Not enough sample was obtained	160°F	.4%
~100°F	1% Due To plugging modifications were made and we ran at lower cons.	(4) Bad - Many Small specs	(3) ~25 spec/sheet Slightly Better Than 1C↓	100°F	.3%
~40°F	.7%	(1) Similar To Trial 1A	(4) ~30 specs per Handsheet	40°F	.4%
~100°F	.6%	(4) Large Spots 1/8-1/2" ~10/sheet few small specs	(1) Very few small specs	100°F	.4%
~40°	.6%	(4) Similar To 3A But not quite as bad	(2) Slightly more Than Above	40°F	.4%
~40°	.7%	(5) BAD - Large spot 1/8-1/2" #25/sheet	(5) Very Many fine Specs	40°F	.3%

Trial Number	Repulping Temperature °F	Repulping Consistency	Repulping Time	Hot Melt Specs in Initial Hand Sheets After Repuling	pH After Repulping
1A	160°	6%	½ hr.	25	—
1B	160°	"	"	"	
1C	160°	"	"	"	—
2A	100	"	45 min.	4	7.6
2B	100	"	"	"	"
3A	40	"	1 hr 10 min.	44	7.4

1st Trial pH was not measured - estimating - it should be similar to other Trials

CONCLUSIONS

The mechanisms at work within the sheet during repulping are critical. The strength of the film, including brittleness and regidity, along with the bonding adhesiveness of the film to the fibers are the primary mechanisms to be contended with.

At colder temperatures (40°F trial) this hot melt film is very brittle and fractures into small pieces when struck by the hydrapulper blades. This action caused the high degree of visible specs in the final handsheets of the 40°F trial. See Appendix #3.

At higher temperatures (160°F trial) the hot melt structure is less rigid and more pliable. The hydrapulper blades are able to rip the film into pieces. The toren structure can be viewed in Appendix #1.

At 100°F the hot melt is very strong and flexible. It doesn't rip or fracture but remains a flexible durable plastic. The hydrapulper is unable to tear or fracture this structure. The hot melt bounces off the blades, it tears away from the fibers and remains in its solid state. See Appendix #2.

The governing factor for the performance of the Finckh and Bergstrom cleaners can be tied to what is happening in the repulping stage. This is the crucial stage and it is here where the degree of efficiency of the cleaners can be controlled.

The final results of this experiment may be from my application of the hot melt. This film may be thicker than that of industrial paper. I realize that hot melts behave differently depending on their blends but it may be possible

that every hot melt has a temperature where it is durable enough to withstand the hydrapulper action. For this hot melt, 100°F seems to be the optimum temperature for removal.

More work definitely needs to be done along these lines but this was an initial start. Temperature does have an effect on hot melt removal.

RECOMMENDATIONS

Foremost on the list is the application of the hot melt. A better system to yield a more uniform sample is needed. The trowel apparatus needs modification to give a more representative sheet of industrial paper. A suggestion is that once the hot melt is applied a virgin sheet of paper be ironed upon the sample. This would give a sheet with fiber hot melt contact on two sides.

Another point of mention that is extremely important is the fact that all the sample should be prepared at once for the entirity of the runs. This would limit the deviations from day to day preparation that were present in my experiment. Also application temperature should be regulated, too hot or cold application may lead to a source of nonuniformity.

For continuing work at 40°F it is suggested to run in the winter when snow is available, it is very difficult to hold the temperature. Dry ice might be an alternative.

Once the stock is defibered a better method should be initiated for separating the stock into equal portions. This separation is important to provide uniform samples. Agitation must be kept at all times (I failed to do this in my second run.)

More lab work should be done if possible. Pilot Plant trials are fine primarily for the experience and the other obvious benefits but the time aspect involved is critical as I discovered. Time can be saved if done first in the lab.

Also a better method should be designed to make handsheets from the Bergstrom final rejects. Large quantities are required to make a fairly decent sheet, making the sheets with a vacuum

below the screen would help.

Further work should be done along the lines of the effects of viscosity, density and pH in this process. Also chemical addition for more efficient defibering may also be a method of study.

LITERATURE CITED

1. Paper Recycling - The Impacts of Contaminants 1973-1985 Midwest Research Institute and Franklin Associates 1975 American Paper Institute Inc.

2. National Industrial Pollution Control Council, Sub-Council Report. "Paper and Wood Packaging in Solid Waste." 1972

3. Same as above #2

4. Paper Stock Conservation Committee "1975 Guidelines for Determining Recyclability of Paper Stick." American Paper Institute Inc.

5. Same as above #1

6. Lowe, Kenneth E. "Contaminants, Supply Problems Hinder Secondary Fiber Usage." Pulp and Paper, December 1973.

7. Trout, P.E. "Plastic Contaminants: Bad News for the Paper Recycler," TAPPI Vol55, No. 5, June 1972, pp. 956-958

8. Bikales, Norbert. Adhesion and Bonding, New York Wiley Inter. Science, 1971

9. Beaumont, F.H., "Hot Melt Adhesives in Packaging; Over Rated or Under Stated?" Paperboard Packaging, February 1973, pp. 27-33

10. Cagle, Charles. Handbook of Adhesive Bonding. New York McGraw Hill Book Co., 1973

11. Same as above #1

12. Kouwink, R. and Salomon, G.,."Adhesion and Adhesives" New York, Elsevier Publishing Co., 1975

13. Buck, R., "Hot Melt Adhesives" Report for Polymer Chemistry Dr. R. Janes, December 1976

14. Same as above #13

15. Same as above #8

16. Smith, R., Adhesives In Modern Manufacturing, Dearborn, Society of Manufacturing Engineers, 1970

17. Skoog, D.A. and West, D.M., Analytical Chemistry - An Introduction, 2nd Edition, Holt Rinehart Winston