Strength Properties of Secondary Fibers Repulped Under Various Conditions

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by

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ABSTRACT

The inability of fibers to swell to their original extent is probably the largest single factor contributing to strength losses of repulped fibers. This lack of swelling lessens the number and strength of fiber to fiber bonds in the sheet formed. It is this fact which leads to the decreased mullen, tensile and stretch of the sheet, and the increased tearing resistance. This paper is a study of the effects of temperature, pH and surfactants on the strength properties of secondary fibers. It was shown that a surfactant is very detrimental to strength properties. While not affecting some strength properties, pH affects mullen and fold strength, with a low pH giving a higher mullen and fold. The effect of temperature is less, affecting only the fold resistance. It is quite possible that other strength properties are affected by temperture and pH, but these differences, if present, are small and could not be detected by this experiment.

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HISTORICAL BACKGROUND AND DEVELOPMENT

Introduction

Reuse of paper which has been printed and has served its purpose and reached the status of waste paper is of early origin. George Balthasar Illy made the first recorded attempt in Denmark in 1695. Matthias Koops was granted a patent on April 28, 1800 by the British Patent Office for a similar process. Although commercial manufacture was never a success, the basic principles have not changed. The recovery of stock has acquired quite a bit of importance as a supply of papermaking fibers and as a means of disposal as well (1).

The basic deinking process uses caustic soda and related alkalies to saponify the resin base of the inks. F. C. Clark suggested that the deinking treatment was a wetting of the paper so that it could be defibered; a softening of the rosin size of the paper and of the ink binder so that the ink pigment could be released; and a washing operation to remove the pigments (1).

Advantages

There are certain advantages which justify the use of deinked stock that should be briefly explored. The first factor is economics. Many mills in a favorable location to secure waste papers find that they can produce pulp at a cost of $25 to $65 per ton below the

price of virgin pulp. The second most valuable advantage of deinked pulp is opacity. Probably no virgin pulp of the same physical strength can give the opacity of deinked stock. In a fifty pound sheet using one-third deinked stock, the opacity would probably be one or two points greater than the opacity of a similar sheet made of 100% virgin fiber. Thirdly, deinked stock is ready to be made into paper. No extra beating or refining is necessary. Some slight brushing is desirable, but expensive hydration is not necessary or desirable. A fourth advantage is that deinked stock is a blend of fibers suitable for use in most paper furnishes. It varies less in physical characteristics than virgin pulps being sold today. Other advantages may exist, but most are debatable. These claims include: a more fuzz-free surface than a sheet made from virgin fibers; less moisture sensitive, and hence, better register on an offset press; and less curling tendency (2).

Repulping

The largest tonnage of paper stock is used with no attempt made to remove ink or lighten the color. In 1958, paperboard mills used 76% of the total paper stock used in the United States. Some of this was unprinted stock which was directly substituted for virgin pulp. Lower grades were largely used in the inner or back plies of paperboard where color is of little importance (3).

As in deinking, pulping is the first step in preparing paper stock in non-deinking mills. This can be done in one of the various types of pulpers which operate on the principle of violent agitation and shearing action in the disintegrating mass of pulp. Hot water at a temperature of 140° to 170° F is usually used, but some mills carry out the repulping at room temperature. Pulping is sometimes completed in a breaker beater. This beater is of the same design as the Hollander beater. The clearance between the cylinder and the shell is close, but there is no metal to metal contact. This completes fiber separation, but does not break up small pieces of cellophane and related materials which may be present. Screening and cleaning generally follow. Since the pulp has already been processed to make the original paper or board, less refining is required than if virgin pulp were used. However, additional refining provides a means of controlling freeness and maintaining uniform pulp characteristics (3).

Most of the investigations carried out relative to pulp and stock preparation have been concerned with virgin pulp. This paper is concerned with properties of fibers and the resulting sheet which have already been exposed to beating, refining, forming, and drying. The literature available on the subject of the repulping of waste paper other than deinking is very limited.

Pfaler used a furnish similar to newsprint and found that the sheet made from repulped stock had 16% less bursting strength, 10% less tensile strength, and 6% less tearing resistance. Brecht used a furnish of unbleached kraft and his results showed that, for equal beating time, the repulped stock was always freer, and the sheet made was less dense and more absorptive than the virgin stock sheet. Tensile, fold, and tear were usually quite a bit lower than the values for the virgin stock (4).

The Bonding Theory

In the process of making paper, many physical and chemical phenomena take place which may govern the nature of the fibers. The first major operation is preparing the fiber by beating and refining so that they swell and take up water, become crushed, kinked, twisted, and cut. The second operation is that of forming the prepared fibers into a uniform web so that the inherent strength of the fibers can be fully utilized. Thirdly, drying takes place under tension and at an elevated temperature. In drying we destroy many properties which took so much energy to obtain in the first place--especially the degree of swelling. Each time a fiber is repulped, it is subjected to this swelling and deswelling as the fiber if first separated from the original sheet and then redried. It is possible that this repeated physical change could be responsible for the difference in paper-making characteristics of repulped fibers (4).

Paper made from vegetable fibers such as wood may be considered as consisting of a mass of individual fibers which are meshed together and oriented nearly parallel to the surface of the sheet. The structural members of the sheet, the fibers, are not straight, rather they are twisted, bent, and kinked. From this description of the structure of paper, one can see that the strength of the sheet is dependent of two factors: (1) the strength of the individual fibers, and (2) the strength of the fiber to fiber bonds. Both of these properties are a function of the nature of the fiber. Although fibers vary greatly in size and in chemical composition, the same mechanism of bonding is utilized when a sheet of paper is formed.

Sheet strength is obtained by subjecting the fibers to some type of mechanical action--beating and refining. The purpose of this mechanical action is to open up the structure of the fiber so that water may enter the fiber walls and swell the fiber. The swelling seems to activate the surface of the fiber by partially solubilizing the cellulose at the fiber-water interface which, according to present day theory, is the source of bonding strength between fibers. The swelling which takes place in refining is also accompanied by bruising, crushing, cutting, and fibrillation of the fibers. This tends to make the fiber more pliable so that when the fibers are compressed to form the sheet, many more bonding sites

will be present. As drying takes place, surface tension forces compress the sheet and draw the fibers closer together. When the fibers are brought so close to each other that portions of the fiber can intermingle, they will form a bond when the water between them is removed. During drying the fibers are drawn very close to each other--within molecular distance needed for hydrogen bonding (4).

The average fiber is probably bonded to many other fibers. The failure of the sheet due to a stress applied results from a combination of (1) individual fiber rupture, and (2) a pulling apart of the fibers because the resistance to stress of the bonded area is excelled. The resistance of the bonded area is dependant on the number of bonds and the bond strength.

Paper made from pulp which has never been dried is stronger than paper made from the same virgin pulp in dry form. Furthermore, paper which is air-dried is stronger than paper which is dried at an elevated temperature. Jayme has found that dried fibers lose much of their ability to swell to their original swelling value (4). This decrease in swellability cuts down on the number of bonding sites available, which in turn reduces the strength of the sheet.

Repeated Repulping

McKee (4) performed experiments in which he repeatedly repulped a virgin kraft furnish. The stock was

beaten in a laboratory Valley beater to a freeness of 350 cc. Canadian Standard. The stock was then made into handsheets which became the raw material for the first repulping. This procedure was followed six times, repulping each time to the same freeness. McKee discovered that the bursting strength decreased rapidly with the number of times the fibers were repulped. After the sixth repulping, the bursting strength had decreased approximately 30%. The rate of change also decreased with the number of repulpings. The apparent density decreased with increasing number of times the fibers were repulped. McKee stated that for a given pulp the density is an indirect indication of the degree of refinement, and therefore, of bonding. Because all repulpings were carried out to the same freeness, these density results indicate a decrease in bonding--either a decrease in the number or strength of the bonds. McKee's results also showed an increase in tearing strength of repulped fibers. The energy used in tearing a sheet of paper is due to breaking individual fibers, and pulling fibers out of the mesh of fibers. More energy is necessary to pull fibers out of the mesh than to break the fibers. The less the bonding strength, the more the fibers which will be pulled out. The increased tearing strength in McKee's experiment indicates that the bonding strength decreases with the number of repulpings. The tensile and stretch also decreased with repeated

repulping. Since tensile is dependent on the strength of the fibers and the number and strength of the bonds, one or all of these identities must decrease. The decrease in stretch points to a lowering of the bond strength, since stretch is dependent on the degree of bonding (4).

The inability of fibers to swell to the same extent when repulped is inherent to the nature of cellulose. Cellulose, and particularly hemicellulose, once dried, will not swell to its original extent, and thus the bonding of the fibers suffers. This is believed to be the main difference between virgin and secondary fibers (4), and it is this decreased bonding ability which leads to the increased tear and the decreased mullen, tensile, and stretch of the sheet made from secondary fibers.

DEVELOPMENT OF THE PROBLEM

Since work had previously been done with repeated repulping of fibers, it was felt that more work could be done in a related area. It was decided to attempt to show the effects on the strength properties of sheets formed from pulp which had been repulped from a paper stock under varying conditions. It was decided to study the effects of temperature, pH, and a surfactant. A 100% softwood kraft furnish was used to eliminate possible problems which could have been caused by a blend of pulps. The writer wishes to express sincere appreciation to the Kalamazoo Paper Division of Georgia-Pacific Corporation for help in procurement of this pulp.

EXPERIMENTAL PROCEDURE

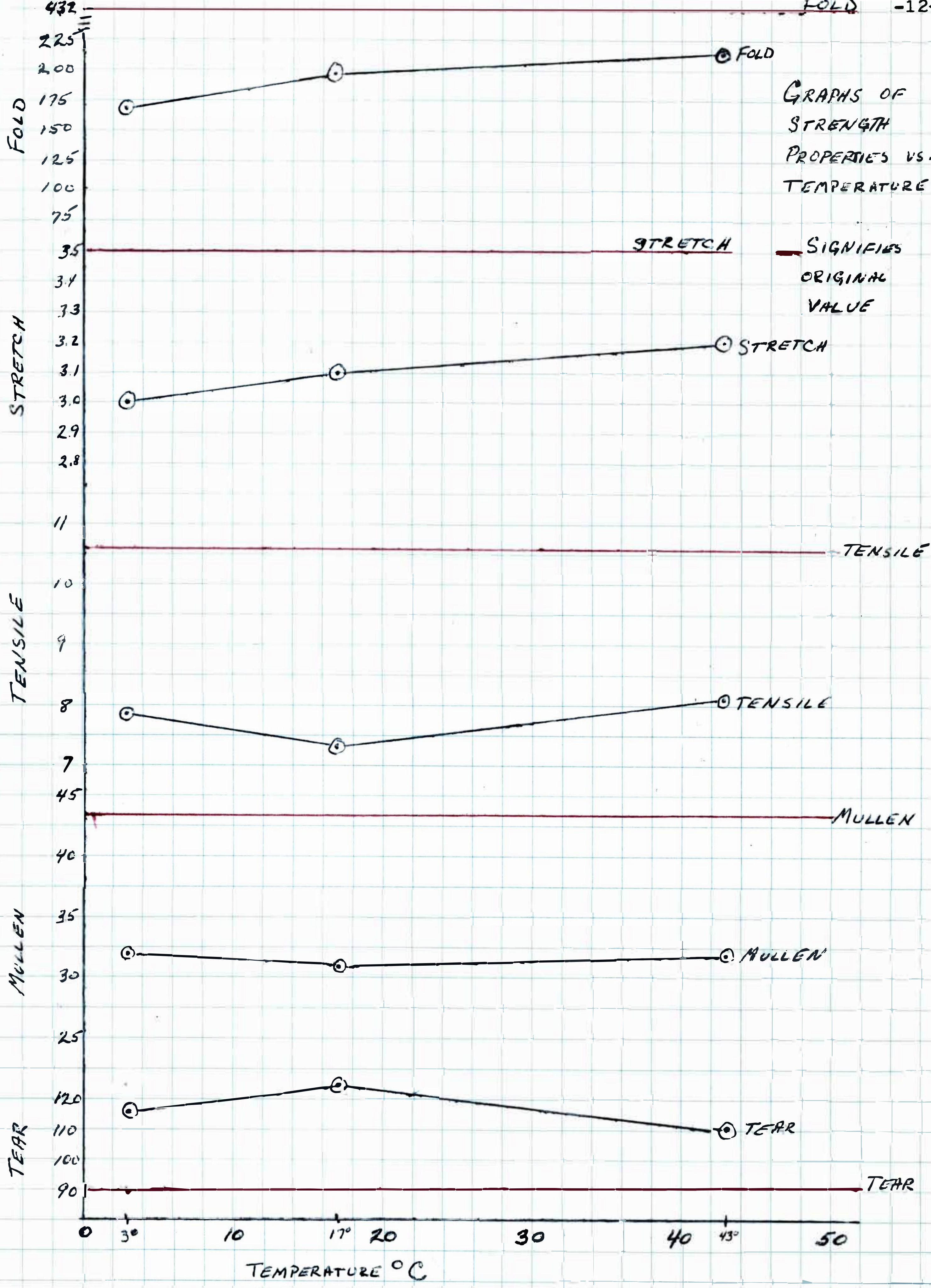
A 100% softwood kraft furnish was used. This pulp was obtained from the Kalamazoo Paper Division of Georgia-Pacific Corporation. The pulp was obtained at a high freeness and beater according to Tappi Standard T-200 ts 66 to a freeness of approximately 475 CFS. This was the freeness of the stock as it went to the paper machine. Paper made on the machine was used for the repulping runs. Handsheets were made from the original stock to be used as a standard for comparison. In each repulping, the stock was rebeaten to the same freeness, 475 CFS. Temperature conditions of 3°C and 43°C were attained using ice and hot water respectively. Sulfuric acid was used to reach the 1.5 pH level of the low pH run. Calcium carbonate was used for the 10.6 pH beater. One-tenth of one per cent Triton x-100 was used as a surfactant in the final beater. Excessive foam occurred in this beater, so a higher level of surfactant was not attempted. The handsheets made from the before-mentioned beater runs were formed using the British sheet mold according to Tappi Standard T-205 m 58. The sheets were then conditioned and tested for fold, tear, and mullen according to the respective Tappi Standards. Tensile and stretch were tested with the Instron Testing Instrument. All test results of above tests as recorded in this report are corrected to a basis weight of 65 g.s.m.

DATA

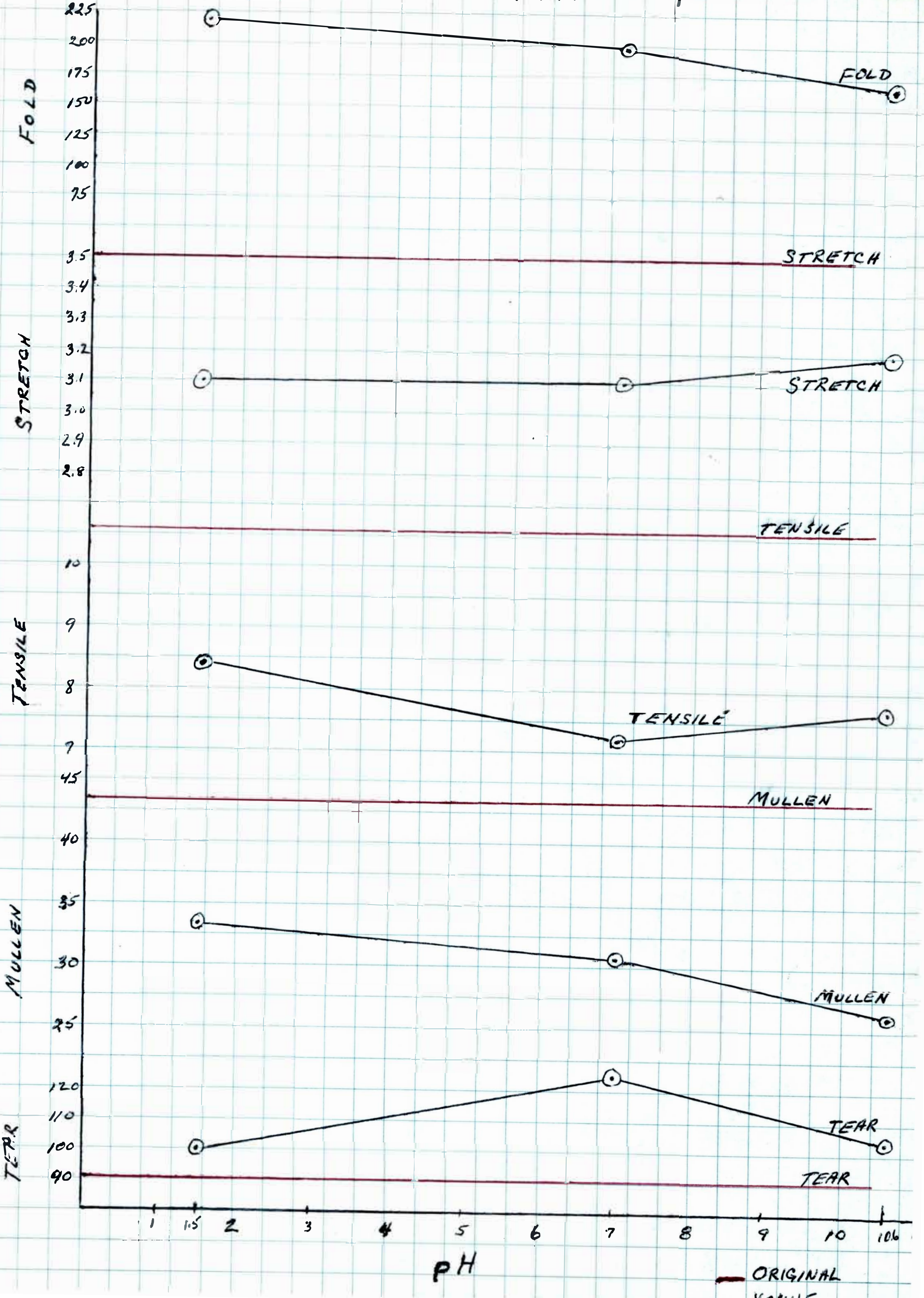
Beater Number	1	2	3	4	5	6	7*
Freeness (Orig.)	718	514	568	569	625	575	530
Time (Min.)**	25	2	4.5	4	6	3.5	3
Temperature	17°C	17°C	43°C	3°C	23°C	17°C	17°C
pH	7.0	7.0	7.0	7.0	1.5	10.6	7.0
Freeness (Final)	478	478	469	475	483	490	479
Tear	90	125	110	116	100	104	104
Mullen	43	31	32	32	33	26	28
Tensile	10.6	7.3	8.1	7.9	8.4	7.7	8.0
Stretch (%)	3.5	3.1	3.2	3.0	3.1	3.2	2.8
Fold	432	197	214	168	219	168	83

* 1/10% Triton added to beater.

** Time for beating after defibering was complete.


GRAPHS OF STRENGTH PROPERTIES VS. TEMPERATURE
— SIGNIFIES ORIGINAL VALUE
FOLD
STRETCH
TENSILE
MULLEN
TEAR
432
225
200
175
150
125
100
75
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
11
10
9
8
7
45
40
35
30
25
120
110
100
90
0
3°
10
17°
20
30
40
43°
50
TEMPERATURE °C

GRAPHS OF STRENGTH PROPERTIES VS. pH



EFFECTS OF TEMPERATURE ON REPULPING

The effects of temperature on the strength of repulped fibers are quite interesting.

From the data table it would appear that the high temperature beater took longer to process than the low temperature beater. However, this is not the case. The high temperature beater defibered very quickly, whereas the low temperature beater defibered very slowly. The times indicated also may not be accurate, as a visual observation of defibering was the only means available. From this, one can conclude that the higher temperature is desirable for quickness of defibering and refining.

From the tear data, it appears that there is little or no relationship between temperature and tear resistance. This is also true of the mullen and tensile strength.

There is a general relationship of stretch versus temperature. The higher the temperature, the higher the stretch value.

Fold also has a definite relationship to temperature, according to the data of this experiment. It would seem that lower temperature should give a higher fold. However, this was not the case in this experiment. It is possible that the long time necessary to defiber and refine the fibers in some way was harmful to the fibers. In the low temperature range, swelling of the fibers does not occur readily and the fibers are not "broomed and brushed" as much as they probably would be at higher

temperature. Therefore, in order to reach the desired freeness, much cutting of fibers was necessary. This accounts for the low fold values at low temperatures.

EFFECTS OF pH ON REPULPING

The effects of pH on the strength properties of repulped stock are also quite remarkable.

Here again, as with temperature effects, the refining times are misleading. The low pH beater was the hardest to defiber, and took the longest to refine. The high pH beater was the easiest to defiber, and took the shortest over-all time to defiber and refine.

As with the study of effects of temperature, the tear, and tensile showed no definite trends which could be attributed to pH.

The data indicates that a higher pH gives a higher stretch, although the difference is so slight that it is probably insignificant.

The fold values indicate that a lower pH will give a higher fold resistance. This is not what would be expected, and no reason for this behaviour has been established.

The most marked strength difference is the bursting strength. The data indicates a trend of higher burst with lower pH. This factor, along with the fact that the tear resistance of the low pH beater was low, indicates that more bonding is present at the lower pH. This fact could partially explain the high fold value at the low pH.

EFFECTS OF A SURFACTANT ON REPULPING

The effect of even a very small amount of a surfactant is astounding. Strength values in almost every case were much lower than the comparable beater to which no surfactant was added.

Tear and mullen were lower with the surfactant present, and the stretch value was the lowest value of any beater run made. Fold values were much lower also.

CONCLUSIONS

The repulping of paper stock is detrimental to most paper strength properties. In every case in this experiment, bursting strength decreased. At a 10.6 pH, the mullen decreased 40% with one repulping. The tensile also decreased in every case, as did the fold.

On the good side however, certain things are evident. The tear increased in every case, and the per cent stretch decreased in every case.

As for the effects of temperature, pH, and surfactants, some problems were shown by this experiment. It is possible that the differences in strength were too small to be determined. Also, experimental methods, in some cases, were rather crude. These two factors are porbably the reason more definite conclusions could not be drawn from this experiment. However, certain conclusions are still evident. The temperature seems to affect the fold values the most. The effects of pH effects are more noticeable, with low pH giving a stronger sheet as to fold and bursting strength. The surfactant has a very destructive nature on all strength properties.

The inability of fibers to swell to their original extent when repulped is probably the biggest single factor in the strength losses of repulped fibers. This inability to re-swell lessens the number and strength of

the fiber to fiber bonds. This is the main difference between virgin and secondary fibers, and it is this decreased bonding that affects the strength of the sheet made from these secondary fibers.

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