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Richard Granger
Western Michigan University

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THE EFFECT OF TEMPERATURE ON REFINING

by

Richard Granger

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ABSTRACT

The results of this work indicate that elevated beating temperature drastically increases beating time and produces detrimental effects on the physical characteristics of the formed sheet as evaluated by wet web strength, tear and tensile.

It is thus indicative of the value of cold temperature refining.

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HISTORICAL BACKGROUND

The effect of temperature on refining of stock is a phenomenon to which all producers of paper are exposed. It would, therefore, seem fitting that an investigation to determine the specific relationship of this parameter should be made. In this way, a technical approach could be analyzed to determine if process control of refining temperature would realize any significant advantage in the manufacture of the final product.

It is very surprising to learn that so little research has been done in this direction as is evidenced by the lack of information normally found in the standard technical references. However, some work has been done and noted. It is this previous work with which the following is concerned.

Generally, it is conceded that increased temperature increases beating time requirement to attain a given freeness. As a result of his mill experience, Hatch (1) noted that a very definite drop in strength occurred in stock beaten at temperatures greater than 75°F., all other factors being equal.

Several years later and across the Atlantic, a French paper mill (2) conducted an experiment in 1924 concerning beating temperature. The mill had noted that on a critically produced grade with exacting specifications, the composite numerical evaluation of the quality of the paper declined 5% to 8% during the warm summer and rose by an equal magnitude during the colder winter. A correlation with the temperature rise of the beater stock was noted (i.e., a winter rise of 10 to 33°C. vs. a summer rise of 20 to 49°C.).

As a result, an experimental beater with a water cooling jacket was constructed so as to minimize temperature changes (i.e., less than 5 to 10°C. per annum). The result was that a uniform grade was produced year round. Subsequently, all beaters were modified as such.

However, owing to the hardness of the water supply, an insulating coating of mineral deposit effectively negated the cooling effect and, when asked in 1946 if the process was still in use, the reply was negative. The removal of said coating would almost certainly have restored the original efficiency but unexplicably was never done.

Based on the result of their published rag half stock studies of 1935, Lewis and Gilbertson (3) made several interesting conclusions concerning beating temperature. Their experiment, based on refining at three distinct temperatures (i.e., 6°C. vs. 25°C. vs. 85°C.) indicated that the fastest rate occurred at 25°C. That is, both lowering or raising the temperature tended to increase beating time as defined by freeness. However, the lower temperature tended to increase physical strengths while the higher temperature tended to decrease them.

An interesting twist in their experiment showed that by using higher temperature in the first half of the beater run and lower temperature in the second half of the beater run, or visa-versa, stock preparation characteristics could be markedly controlled. Specifically, the rate of beating seemed to be controlled by the temperature of the first half cycle period and strength development by the temperature of the second half cycle period. This was ascertained by comparison of stock beaten at either high or low temperature exclusively.

Conclusively, from their data it seems that profit could be made from beating at 25°C. for the first half cycle period to minimize beating time followed by beating at lower temperature for the remainder of the period to develop strength.

Kukolich (4), in his work with rag stock, illustrated dramatically the effect of extreme temperature (i.e., 210°F.) by boiling portions of stock refined to 360 CSF and 515 CSF for five minutes. A subsequent comparison of fold and burst indicated that the stock had reverted to an equivalent of 650 CSF. He attributed this to removal of fibrillae protrusions from the fiber structure and a general reversal of the beating process.

Utilizing a Clark Kollergang employing temperature control, Noll (5) found that either hardwood or softwood pulps in either bleached or unbleached condition showed a decrease in beating rate with an increase in temperature as defined by freeness and strength. He concluded that this naturally resulted in a higher power requirement per unit weight of refined beater stock.

Noll, as did Tolvi (6) later, theorized this as a result of a decrease in water surface tension at higher temperatures with resulting decrease in swelling of the cellulose fiber. This was confirmed by the fact that stock beaten in the Clark Kollergang mixed with a wetting agent to decrease surface tension exhibited a slower beating rate than did 'normal' water (i.e., sans wetting agents). Conversely, use of water containing salts to increase surface tension resulted in accelerated beating rates.

Noll (7) subsequently followed this experimental work up on mill scale using 375 kilograms oven dried soda pulp per beater charge.

By controlling temperature from 13° to 16°C. using chopped ice (meanwhile keeping consistency constant) it was observed that a time savings of 36% to 57% and a power consumption reduction of 33% to 55% resulted over nonemployment of cooling measures where temperature rise was typically 33 to 34°C. In terms of freeness and strength, the cold refined pulp was essentially indistinguishable from the pulp refined under 'normal' conditions.

During his exposure to mill operations and specifically beaters, Baxter (8) also concluded that temperature has a great deal to do with beating and stock characteristics. Contending that if long and slow stock is desired for production of quality bond, ledgers and manifold then water sources should be from wells with inherently stable temperatures as opposed to lakes or rivers with fluctuating temperatures. Baxter points out that under no circumstances should water be used for stock preparation that has been previously used for cooling steam power plants.

Stephansens' (9) work with the Valley beater at stock temperatures of 4°C. vs. 70°C. with a mean of 40°C. also tended to agree with the work of his predecessor. However, he concluded that since the viscosity of the water was so increased at lower temperature and since the system as a whole would tend toward this lower temperature, any advantage would be nullified by the decreased drainage on the Fourdrinier wire.

Mack and Baumgarten, (10) in one of the most recent studies, compared the effects of refining temperature variation on furnishes of unbleached spruce sulfite vs. bleached straw pulp vs. bleached and unbleached groundwood. The temperature ranges were 3 to 13°C. vs. 18 to 22°C. vs. 50 to 60°C.

Results showed that the spruce sulfite responded most favorably to cold beating in terms of freeness and strength (i.e., 16% vs. 7% for straw pulp). The groundwood did not respond significantly to temperature changes but seemed to be most effectively beaten at intermediate temperatures.

EXPERIMENTAL DESIGN

Preparation

As a result of knowledge obtained through historical data, this experiment will be guided along the lines of evaluation of two distinct pulp types. The basic types are bleached hardwood kraft and bleached softwood sulfite. These two distinct types might be considered to exemplify the most prevalent and versatile products utilized by the fine paper industry today.

The parameter of study of the effects of temperature on refining will not be specifically limited to the classical tests of freeness and assorted physical strengths. This is not to say that consideration will not be given to them. It does, however, mean that the parameters of free shrinkage, initial wet web, Instron tensile and tear will be the mainstays of evaluation.

Concerning temperature of refining, it will be attempted to refine the stock at 2% C. to 400 CSF by use of a laboratory Valley beater at three distinct temperature ranges.

These target ranges will be 15 ± 2°C., 45 ± 2°C.

and 75 ± 2°C. Therefore, this should give a representation in a broad spectrum of the effect of temperature.

In an attempt to maintain the low temperature (i.e., 15 ± 2°C.) use will be made of a 3/8 inch copper coil of ca. 25 foot length immersed in the bottom of the beater. Through this coil will be circulated tap water at a temperature of ca. 11°C.

The high temperature (i.e., 75 ± 2°C.) will be maintained by use of this same coil. However, instead of circulating water, low pressure steam will be fed into the coil with the condensate going to the sewer. Temperature regulation will be simply a matter of control of the volume of cooling water or steam.

In both of the above cases, it will be expedient to provide a cover on the beater to minimize influence of the ambient air.

For the intermediate range (i.e., 45 ± 2°C.) there should be a minimum of control difficulty in temperature regulation. However, any necessary adjustment will be made in one of the above manners, whichever the situation demands.

The refined stock will then be used for handsheet manufacture utilizing the Noble and Wood unit at a basis weight of 25 x 38-80M.

Air drying under controlled temperature and humidity (i.e., 72^{o} and 50% RH respectively) will prepare the sheets for subsequent evaluation. All above procedures will conform to TAPPI standards when applicable.

EVALUATION

Initial Wet Web

Evaluation of initial wet web draws its merit from correspondence to Fourdrinier web consistency in the area intermediate between the wire and the wet presses. Transfer of the web at this point is critical for machine 'runability' and therein lies the value of the initial wet web test.

At the nominal consistency typical of this point (i.e., 20%) the principle force binding the fibers of the web together is surface tension.

Hydrogen bonding, the primary binding force of dry paper, is not of significance until a consistency of greater than 25% is attained. Therefore, the physical condition of the refined pulp has a significant effect on the web strength and thereby invites evaluation of the effect of refining temperature.

In the actual test, use is made of the Brecht Tester. The test web, formed and pressed on a 100 mesh wire screen in the Noble and Wood, is sized by use of a template to a dimension of 30 x 90 mm. The specimen is then clamped in the tester and the breaking strength determined.

In practice, care is taken to insure as close a proximity to 20% solids as is possible by manipulation of pressing nip pressure so that a consistent pressure will yield a near consistent per cent solids. Values are corrected to an equivalent of 20% solids if this precise value is not attained.

INSTRON TENSILE

Evaluation of the handsheets in regard to tensile strength is accomplished by use of the Instron unit. Actually, the Instron is capable of several simultaneous evaluations, all related to tensile strength.

They are: 1) per cent elongation; 2) stress-strain relationship, commonly referred to as tensile energy absorbtion (TEA) and, of course, 3) ultimate tensile or breaking strength. All values are conveniently recorded graphically by the machine.

In the actual test, use is made of an air dried specimen at one inch width. Loading rate is equal to 15.15% per minute.

Breaking strength is evident from the graph as is per cent elongations (i.e., width of the curve base generated by the breakage of the specimen). Values for TEA are readily found by multiplying the area under the curve (per machine integrater) by 0.666×10^{-4} and by full scale load in kilograms.

FREE SHRINKAGE

Free shrinkage evaluation is perhaps one of the best ways to estimate performance of refining in that the more effectively the stock is hydrated, the greater is the tendency for shrinkage upon drying. This is most evidenced when the web is dryed under no dimensional stress such as those resulting from draw tension on a paper machine.

The test procedure consists of producing a handsheet and marking an exact dimension on the web prior to drying.

The web is then removed from the wire to eliminate dimensional stress and allowed to air-dry in an unhindered manner. The known dimension is then rechecked and the difference (i.e., shrinkage) converted to a percentage of the original dimension. Thus the free shrinkage value results.

TEAR

Tear values are determined according to TAPPI standards and are corrected to a 16 sheet basis utilizing the Elmendorf Tear Tester.

EXPERIMENTAL RESULTS AND CONCLUSIONS

Concerning the effect of beating time vs. the temperature of the stock, it is quite evident from the data gathered that temperature has a very significant effect on beating rate. This seems to be especially true of SW furnishes as compared to HW. Specifically the derivative of beating rate with respect to temperature for SW is 0.0402 vs. 0.0233 for HW. This is approximately a factor of 1.72 times that of the HW. Therefore, it would seem logical that the most gains to be made from low temperature refining would be gleaned from furnishes predominately SW in content.

Needless to say, there is a significant absolute savings in time in either case (i.e., ca. 28% for HW at 15°C. vs. 45°C. and ca. 35% for SW at 15°C. vs. 45°C.).

Interestly enough, when a very high temperature was attained during beating (i.e., 75°C.), HW did not show an increase in beating time while SW continued to require longer beating time (i.e., ca. 135% of the time necessary at 45°C.).

Concerning wet web evaluation, it can be seen from the data that SW yields a somewhat higher wet web strength than HW. This difference is in the magnitude of approximately a 15% increase. It was also determined that there occurred a general decline in wet web strength for both furnishes as beating temperatures increased. Thus, further credence is given to the advantage of low temperature refining as defined by increasing machine runability, especially in the case of SW furnishes.

Free shrinkage evaluation indicates the more sensitive nature of SW to dimensionally unrestricted drying as opposed to HW. Specifically, SW averaged a free shrinkage of 4.3% over the temperature range vs. 3.0% for HW. This is almost certainly a result of the degree of fibrillation occurring in SW during refining as comparing to cutting occurring in HW during refining. Again, both furnishes showed a general decrease in free shrinkage and, hence, hydration and bonding, with an increase in beating temperature.

Tear values for HW furnishes are somewhat higher than those of SW (i.e., 62 vs. 58 respectively at lower temperatures) which is inverse to what would be expected owing to the inherently longer SW fibers and their superior fibrillation characteristics. However, as the temperature increased to 75 C. in both cases, the absolute value of tear decreased in both by a similar magnitude (i.e., 10 pts.). This again is probably a reflection of decreasing fiber length as beating progresses. At this high temperature, the freeness attained is probably much more a function of production of fines as opposed to fibrillation.

Again the detrimental affects of higher temperature refining are evident.

Concerning tensile strengths, it is evident from the data that nearly all the furnishes exhibit similar tensile strengths of ca. 7.4 kg. The exception is the SW beaten at 15°C. It has a tensile of 8.6 kg. This particular furnish also has the highest TEA value of any runs made, the closest being SW at 45°C. (i.e., 0.232 in.-lb./in. vs. 0.136 in.-lb./in. respectively). This is a whooping 71% increase over the stock beaten at 45°C. This evaluation is especially indicative of the superior refining attained at lower temperatures.

In final conclusion, the results have emphatically highlighted the value of low temperature beating especially in regard to time and power requirement, tear and TEA. The value of this practice in a production situation would have to be determined from a practical and economic viewpoint in order to ascertain its overall benefit. Several such endeavors have been made, the most notable the afore mentioned French mill in the 1920's. Perhaps today's technology could enhance the benefit and render it an even more lucrative innovation.

FIGURE 1

Beating Time vs. Freeness for Hardwood (400 CSF)

HW at 15°C.	Minutes	0	10	20	30	40	50
	Freeness	646	628	587	524	463	394

HW at 45°C.	Minutes	0	10	20	30	40	50	60	68
	Freeness	646	628	610	593	512	470	429	400

HW at 75°C.	Minutes	0	10	20	30	40	50	60	70
	Freeness	649	638	598	576	532	484	441	394

FIGURE 2

Beating Time vs. Freeness for Softwood (400 CSF)

SW at 15°C.

Minutes	0	10	20	30	40	48
Freeness	658	619	560	514	446	402

SW at 45°C.

Minutes	0	10	20	30	40	50	60
Freeness	627	620	596	556	513	443	391

SW at 75°C.

Minutes	0	10	20	30	40	50	60	70	80
Freeness	645	629	604	574	554	528	488	454	410

FIGURE 3

Hand Sheet Evaluation (400 CSF)

FURNISH	WET WEB (g)	FREE SHRINKAGE (%)	TEAR (g)	TENSILE (kg)	ELONGATION (%)	TEA ($\frac{\text{inch-pound}}{\text{inch}}$
HW at 15°C	165	3.2	63.0	6.5	3.1	0.134
HW at 45°C	172	3.1	60.0	7.4	2.4	0.118
HW at 75°C	170	2.7	50.5	7.4	1.8	0.112
SW at 15°C	208	4.4	57.0	8.6	2.7	0.232
SW at 45°C	197	4.7	58.0	7.7	2.3	0.136
SW at 75°C	189	3.9	48.2	7.4	1.9	0.118

BIBLIOGRAPHY

1. Hatch, R. S. "Beating Conditions as Effected by Temperature of Water," Paper, 20:18-19.

2. "Cooling of Pulp During Beating," Abstract Bulletin Institute of Paper Chemistry, 19:754.

3. Lewis, H. F. and Gilbertson, L. A. "The Effect of Temperature on Beating of Rag Stock," Paper Trade Journal, 15:37-43.

4. Kukolich, S. "A New Process for Manufacture of Rag Half Stock," Thesis, Institute of Paper Chemistry, 1935.

5. Noll, August "The Thermal Behavior of Pulps During the Beating Process," Abstract Bulletin Institute of Paper Chemistry, 8:129.

6. Tolvi, E. K. "The Beating of Kraft Paper," Paper and Timber (Finland), March, 1950.

7. Noll, August "The Influence of Temperature on the Beating Behavior of Pulps," Abstract Bulletin Institute of Paper Chemistry, 18:653.

8. Baxter, B. M. "Notes and Observations on Beaters," Paper Industry, December, 1946.

9. Stephansens, E. "The Beating of Pulp at Different Temperatures," Abstract Bulletin Institute of Paper Chemistry, 21:381.

10. Mack, H. and Baumgarten, H. L. "Comparative Studies Concerning the Effect of Cold and Hot Beating," Abstract Bulletin Institute of Paper Chemistry, 34:1336.

Ronning, O. and Libbey, C. "The Influence of Temperature During the Beating Process," Paper Mill News, May, 1951.