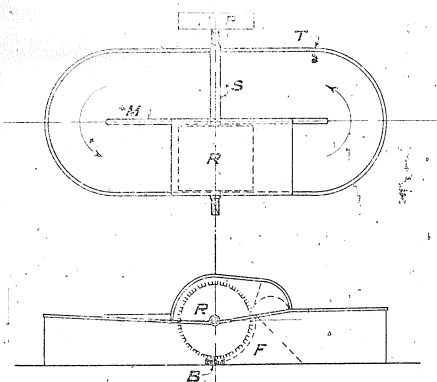


plate B. The fly-bars of the roll R, slap the pulp as paddle-wheel blades slap the water; they pound and cut and mangle the fibre between themselves and the bars of the bed-plate, causing some of the effects which it is desirable to produce. The action serves to raise a rapidly travelling film of pulp from under the roll R up over a backfall F, which assists in



creating the difference of head back of the roll from that before it which keeps the mass of pulp in circulation. Roll R ought to be driven at constant speed.

The beater is furnished in batches, the composition of which is prescribed by formula. Once furnished, the wetness of the mass being once determined, the only further adjustment that can be made by way of governing the results obtained is the vertical adjustment of the roll R. This and its spindle S and pulley P ride by their own weight on their bearings, which can be raised and lowered through a very small range by hand. As the roll is lowered the distance is lessened between its fly-bars and the bars of bed-plate B, and more of the weight of roll, spindle, and pulley is brought to bear in acting upon the pulp passing through. The entire result is determined for a given batch by this one manipulation. The entire skill of the process is shown in the manner of making successive roll settings while the beating is in process.

There are, of course, other types and designs of beaters, but the Hollander is the most common, and the action of the Hollander is typical of the action of all. Our study as applied to the Hollander is therefore applicable to practically all types of beater.

Simple as is the mechanical principle of the beater, however, and simple also as is the adjustment of which it is capable, nevertheless, the technical discussion of paper-makers is full of speculation as to what happens to the pulp in the process of beating, or what ought to happen to it to produce a given result. The matter is extremely complex and obscure. It is not

subject to entire solution without recourse to chemistry, and physical chemistry; and the field is one in which a vast amount of difficult work has already been done with scarcely any profit. In practice, the beater man judges of the condition of his stock by feeling it. His experience enables him to obtain from sensations that which would convey nothing to a new man, a meaning which is clear enough for him to predict pretty well how the pulp will behave when made into paper, and about what quality of paper it will produce. And it is upon this faculty on the part of the skilled beater man that the management depends for the character and uniformity of the paper which it has agreed to furnish. Moreover, paper mills are twenty-four-hour plants; and for every order for paper on each paper machine in the establishment, the management must rely upon the judgment of two or three different beater men and upon their interest in their work.

It is therefore the duty of the management to obtain the knowledge and skill necessary to do what the beater man can do by using his sense of feeling as a guide. That was the object of our work. We had to develop means whereby the management could give to the beater men and their helpers definite duties to perform which could be understood and measured by a competent person not himself doing the work, the result of which would be greater uniformity in the treatment of the stock.

The problem is open to attack in two ways. Study might be made of the various paper-making qualifications of the various kinds of fibres which are combined in the sheet, and of the physical and chemical changes produced in the different fibres under different conditions by different manners of treatment in the beater. It has already been indicated that this course of study has been found altogether too involved to lead to a practical or economical result. The point may be illustrated. During the process of beating, the fibres being of cellulose, there is formed in the mass of pulp a new substance which the beater men call "grease" or "slime". It is an important factor in the quality of the paper, in the expense of making the paper, and in the proportion lost in waste. For hard papers, with high finish, grease is desirable; for blotting papers and "antique" finish, grease is to be avoided. Yet there is no agreement among paper chemists as to what this grease is, where it comes from, or what the action is which produces it; and the research on this point is well nigh continual.

But the mass of pulp making up the batch in the beater has physical properties as well as chemical. The beating action produces physical changes. The minute fibres are altered physically, on the one hand, and the mass itself, considered as a mass, is a semi-fluid, the fluid properties of which change. The

nature and extent of these changes are easily measured, and it remains to correlate them with what is desirable or undesirable in the result. This is the second line of attack, the one which we adopted.

We treated the batch of pulp as a fluid mass and studied first of all the physical variables which are set up by the beating action. The mass is stiff at the beginning and becomes more fluid as the beating goes on. Greater fluidity means less viscosity. We therefore applied to the mass a device of our own which we call the "drag" but which the physicist would recognize as a viscosimeter. We arranged this so that it automatically makes a record of every reading at which it stands. Viscosity is composed of two things: the internal friction of the mass which arises from the particles rubbing on each other when the mass is in motion, and the skin friction which arises from the particles of the mass rubbing against a solid body which opposes the movement of the mass. As a result of some careful experiments we established the greater importance of internal over skin friction as a variable to serve as our guide, and accordingly we built our drag or viscosimeter to emphasize the measurement of internal friction. In order to enable ourselves to draw correct conclusions from our work, irrespective of what may happen to the pulp subsequent to beating, we developed some methods of measuring the paper-making qualifications of the pulp at successive stages throughout the beating process, and at its close.

Very important for the character of treatment which it is proposed to give the stock in the beater, is the thickness, or density of the mixture. Our work emphasized this fact and gave us a measure of it. We found that the drag offered a very convenient way of testing this density, and of getting it uniform in one batch after another.

Again, as the beating proceeds, the drag makes a descending curve of readings. We developed the fact that the shape of this curve, rather than the total change in reading, is the important point for determining the quality of the result. By comparison through a long series of tests, we became satisfied that the drag, with its proper shape of curve, would be a safer and more promising thing to use as a guide than any other device or principle yet in view which deals with the variables that take place.

We have had the drag now in successful use for more than two years in two capacities,—first, as a gage of density for the batch, secondly, as a guide to the manner of treatment. For each order for paper a thickening point is set to govern the density. For each order, and for each beater of the set which is to prepare that order, a standard beating curve is set, by prescribing a series of readings to be reached at definite intervals of time. The kind of skill and judgment employed by the experienced beater man

in interpreting the "feel" of the stock is now exercised by the man who sets these curves, and he is on the management side. By these means we have satisfied ourselves that a degree of uniformity in density can be maintained nice enough to govern the ream-weight of the finished paper from the beater room, and a degree of uniformity in quality of paper can be maintained which allows of standardization of grade without confining a large plant to one or two grades. We on the management side have the means of directing in detail the treatment of every batch of stock in every beater day and night, and of taking the full responsibility which belongs to us for results.

Experience has taught us another thing incidentally. While we have been transferring the skill necessary to direct the work, to control the results, and to accept the responsibility, from the skilled workman to the management, we have by no means rendered the beater man's job less skilled or less interesting. We have simply made it precise. We have given him a guide. There is skill in following that guide, of even a higher grade than the skill of going without it, and the beater man always has the advantage of knowing where he stands and how he is coming out. He is protected from unfair blame. He makes much more frequent visits to his beaters, each time to settle a definite question in his mind, each time with a real point of interest before him. Instead of detracting from the fascination of the work, we believe we have added fascination to it.

Again, please notice that since there is skill in following the guide, the guide is not fool-proof. Our instructions are written in precise language; our instruments are instruments of precision; yet anybody who chooses may follow all of our instructions, and still spoil the job. The more a man may know about beating, the more thoroughly can he spoil the job and still produce a perfect record. We were aware of this from the beginning because we had tried it ourselves. We are not interested, however, in devising a fool-proof scheme, because it is not fools or mischief-makers that we or any one else want on the job. If a man is with us, and we are with him, he can do infinitely better work and enjoy it far more by doing it right, than he could without the aid which we have placed in his hands; and if he is with us, and we are with him, (it must be stated both ways), he is not tempted to try to beat the game. In short, we have rubbed against another old law, that efficient work comes from within the worker.

It will be noticed at once, that we have made no changes in the design of our beaters; that we have developed no step toward the ideal beating equipment; and that we have not formulated analytically the elements, and how they should be combined theoretically to produce any desired result. To be sure, we think we have some data that would be use-