The Institute of Paper Chemistry

Appleton, Wisconsin

Doctor's Dissertation

A Photographic Method for Hydrodynamic Research and its Application to the Motions of Fibers in Flowing Suspension

by Earle O. Bryant

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A PHOTOGRAPHIC METHOD FOR HYDRODYNAMIC RESEARCH AND ITS
APPLICATION TO THE MOTIONS OF FIBERS IN FLOWING SUSPENSION

A thesis submitted
by
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Historical Introduction

While many advances have been made in the various operations of paper manufacture since the time when the art became essentially a mechanized one, it is interesting to note the relatively minor changes that have occurred at the wet end of the Fourdrinier machine.

Credit is given Nicolas Louis Robert for first successfully attempting the production of an endless web of paper. This development came in 1790 at Lesonnes, France, and the French government granted him a patent on the machine for making sheets of paper up to 12 feet in width and 50 feet in length. Robert's machine used the principle of an endless wire cloth passing over two rolls. In order to place the fiber suspension upon the wire he made use of a revolving fan which threw the pulp against a baffle plate that distributed the suspension onto the slowly moving wire. Drainage of the water through the wire by gravity, and the use of a small set of squeezing rolls removed sufficient water from this suspension so that the resulting wet web could be wound on a roll. A length of about 50 feet of wet sheet was the practical limit for each roll thus made.

This machine did not function with a high degree of satisfaction; but two English paper manufacturers and stationers, Hanry and Sealy Fourdrinier, purchased the
patent rights and with the aid of Bryan Donkin they perfected it to such a practical extent that the machine of the present day bears their name. This machine used a headbox from which stock flowed over a slide onto the wire. Movable deckles, an upper felt on the couching device, and a separate press section using an endless felt were improvements added at this stage. Thus the present Fourdrinier wet end came into existence. The development of the dryer section did not occur until later.

Between the years 1839 and 1867 developments included the use of suction under the wire, addition of a second press, invention of the dryer section, and the addition of a calender stack—the final result being very close to our present Fourdrinier paper machine (1).

Since 1867, when the maximum wire width was 60 inches and the maximum machine speed about 100 feet per minute, the refinement of details of both the Fourdrinier wet end and the dryer section has resulted in an increase in wire width of slightly more than five times and a speed increase of about fourteen times. Until the period of the 1920's this increase had come almost entirely from considerations of what might be called the mechanical factors of design in contrast to hydrodynamic considerations. During the last decade and a half, however, an ever increasing amount of attention has been given to this latter phase. This is shown by an examination of the patent files
of the United States government. In the appendix of this paper is a list of patents pertaining to the machine headbox or flowbox and slice which is based upon a careful examination of U. S. patents issued between January, 1920 and July, 1936 under the heading of Class 292, "Paper Making and Fiber Liberation"; sub class 244, "Fourdrinier Machines".

This period of activity along hydraulic lines did not arise spontaneously but resulted from actual needs. Mechanical improvements, with only slight changes in headbox design, brought paper machine speeds up from the figure of 100 feet per minute in 1867 to about 800 to 900 feet per minute in 1914. The idea of a sloping wire as an aid in forming a proper sheet at high speeds was then introduced, the first mention of the installation of a sloping wire being of that made in 1914 at the mill of the Great Northern Paper Company, Millinocket, Maine (2). Within the next few years this came to be considered an essential for high speed operation; however, today there is considerable difference of opinion on this point, and many machines are now operating at rates faster than 1,000 feet per minute with level wires.

The Wausau Fibre Company at Mosinee, Wisconsin is given credit for first attaining a speed of 1,000 feet per minute. The sheet was a light weight kraft made on a 112-inch machine on October 23, 1920. The first commer-
cial newsprint was made at this speed by Great Northern at Millinocket, Maine in April, 1921, with the first run of Canadian newsprint made at this speed following shortly after in August of that year. This was made at the Laurentide Company mill at Grand Here, Quebec (2).

At the Laurentide mill in 1921, Van de Carr was doing experimental work with the first nozzle-type high-speed slice. The first commercial installation of this type of slice was in 1923 at Kenora, Ontario.

The first Voith inlet was installed in this country in 1923 by Kimberly Clark Corporation in its plant at Niagara Falls, New York.

These two important inventions came at the beginning of the recent period of activity along hydrodynamic lines, and proper consideration of better headbox construction and of slices of the nozzle type has aided very materially in attaining the present high operating speeds of 1200-1400 feet per minute on newsprint. The present record for sustained high speed production is probably held, according to Bennett (1), by the Powell River, British Columbia mill with a rate of 1,360 feet per minute, with the Maine Seaboard Company at Bucksport, Maine a close second.

Present-day economic conditions are driving the paper manufacturer towards continual speed increase, and at the same time the use requirements of papers demand in many
cases not only a maintaining of, but a betterment of, present standards of strength and formation. Undoubtedly mechanical engineering science of the present day can design paper machines that will operate in a mechanically satisfactory manner at a figure 500 feet per minute faster than present operation. But a thorough study must be made of the many hydrodynamic problems connected with the proper placement of the stock suspension on the wire before the paper industry can take full advantage of the services which the mechanical engineer can offer.

Until very recently the attack upon the problems of headbox, slice, and wire factors has been of an extremel, practical and empirical nature; but the need of a thorough understanding of the problems along more fundamental lines is now recognized. The recent papers of Lund (3) and Gough (4) illustrate well the trend toward the use of theoretical hydrodynamics in attacking these problems.
Considerations demanding a new method of attack upon hydrodynamic problems.

An examination of the patents pertaining to headbox and slice construction and accessory equipment shows the lack of a complete understanding of the action and motions of the fiber suspension as it passes through this portion of the paper making operation.

The fact that a small proportion of patents and ideas proved to have a value for commercial operation indicates in itself the difficulties found in the purely empirical method of approach to the problem. It is not surprising that such is the case when the complexities of the problems are realized. Consider the flow of water alone through a system of converging and diverging channels, in some cases with an abrupt and in other cases a gradual change of section, which make up a headbox; through slice openings of sharp or gradual curvatures which may be situated symmetrically or unsymmetrically in relation to the oncoming stream; and then spouting out over an apron into a pond above a moving wire, or spouting directly onto the moving wire surface— all of this is too complex to allow of a successful arbitrary and empirical solution. Then this complex motion occurs with the papermaking stock held in suspension by the fluid, the task of understanding the system is even more difficult. It is, of course, this latter phase of the problem— the
motions of the individual papermaking fibers themselves -
that limit and govern the formation of the final sheet.
Therefore an understanding of the ultimate fiber actions
within this complex fluid motion must be had before a
scientific analysis of the wet end portion of the Four-
drinier or of the cylinder machine can be made.

The opinion generally held by technical men in the
industry is that further improvement and redesign of the
Fourdrinier and cylinder machines is limited at the pres-
ent time by the hydraulic factors that must be considered
rather than by the purely mechanical aspects. This in
itself, then, fully justifies the task of attempting to
secure a more scientific and analytical interpretation
of phenomena associated with the action of fluid flow
and fiber suspensions: the very complexity of the prob-
lems involved requires such an approach, over and above
the purely practical and empirical method, before this
gap between the limit of hydraulic possibilities and of
mechanical possibilities is narrowed.

When the problems are approached from the standpoint
of hydrodynamics and the mechanics of particles, improved
streamline design of headbox and slice results, and some
predictions of the actions of the individual fibers with-
in the fluid can be made. However, a system designed only
from a consideration of most efficient streamlining, for
example, can in itself be no guarantee to success from
the standpoint of practical properties in the final sheet formation produced since this formation depends upon what happens to the suspended fibers within the fluid. On the other hand, while the proper mathematical treatment, with certain assumptions, can predict the action of an individual fiber within the fluid as the fluid motion impresses itself upon the fiber, it cannot successfully by itself handle the problem practically because the degree of fiber dispersion and consistency under normal operating conditions do not allow each individual fiber to act as an agent unaffected by neighboring fibers.

Such considerations as those above show the necessity of developing a new method of approach to these hydrodynamic problems. It has been the purpose of this investigation to produce such a method. By this means one may record the complete actions not only of the fluid but also of the fibers within the fluid under actual conditions of flow.

This direct method discussed below can be used to obtain important information in the field of general hydrodynamics, although it was developed primarily to solve problems of flow of water suspensions of papermaking materials. Thus it may be emphasized here that this method is presented as an advantageous tool for general hydrodynamic problems and not merely as a special appliance limited to papermaking problems alone.
Factors to be considered in developing a direct method of study.

The relatively young science of aerodynamics has made much of its progress because of information gained by photographic studies of airfoils under active conditions. Use has been made of streak trail photographs obtained by time exposures of strongly illuminated oil droplets or small metallic particles carried as a water suspension; of smokes; and of the Toepler striae method. Photographs produced by Prandtl (5) and by Chiba (6) may be mentioned as important examples of such work. In such types of study the investigators desired information about the streamline and vortex systems formed by the relative motion of a body with the surrounding medium. In our particular problem we desire the same type of information; but we also need the very important data on the behavior of the suspended fiber material within the flowing fluid.

Another important difference between the two types of problems is that, whereas a two-dimensional study apparently met most of the needs of investigators in the field of aerodynamics, we cannot be satisfied unless we obtain data allowing us to interpret the action of the fibers in the fluid, and their reactions upon each other, in all three dimensions.

It is also important to know definitely that our method is such that no optical illusion results— in other
words, we must know that any particular fiber records itself as well as any other fiber in the field, no matter what its relative orientation may be.

In this study, as in all other lines of research, care must be taken that errors from the human element are at the absolute minimum; and as the eye is easily deceived in its observations of many phenomena, particularly whenever motion is present, one cannot put faith in visual observation alone. There should be a permanent photographic record of such work. A verbal report or sketch is affected by this element of deceptive seeing. Such a report also has the disadvantage of requiring considerable time to construct, during which time the memory of relative importance of types and magnitudes of motions can become cloudy or modified, even though they were at first correctly observed. But a much stronger reason for demanding a permanent photographic record is the fact that the eye cannot detect and analyze the fundamental movements within a very active system; the eye can at best recognize and interpret only the gross general regions where the over-all effects differ sufficiently to make patterns or outlines visually noticeable.

In spite of these deficiencies of normal vision it is not suggested that a visual study should be avoided. As will be shown later, the sketches made from visually studying the flow of a fiber suspension within a system
help very materially in interpreting photographic data of the same system - in fact, an interpretation based only on such photographic work alone, without aid from the visual study, will be not only exceedingly difficult at times but perhaps actually dangerous from the standpoint of a complete and correct analysis.

Prandtl and Tietjens, in their book "Applied Hydro- and Aeromechanics" (2) show by means of some fine photographs the differences arising on the film when recording the identical phenomenon, in one case, with the camera motionless relative to the object about which the flow occurred and, in the other instance, with the camera motionless relative to the flowing liquid. The method to be described in this paper has eliminated this variable from consideration.

It was realized that if this method was to have use in aiding the solution of questions of practical elements of design, as well as use in theoretical work, it should produce results with a minimum of expense for equipment and with a minimum demand on technique. Therefore, it was decided to develop the method upon a model scale rather than on large scale equipment.

When working on a model scale the first requirement is that the scale of dimensions and types of motion shall be dynamically similar to the full scale system represented. A proper consideration of the factors of
dynamical similarity or dimensional analysis will satisfy this requirement \((7,8,3)\) and allow one to use to advantage this method of approach.

When studying headbox conditions or similar problems with this experimental method, where small scale baffling is used to represent corresponding full scale effects, such principles must be observed; but the equipment developed in this investigation can be used to directly represent the flow conditions of commercial slices. Slice openings can be equivalent to those on commercial machines and sufficient heads can be carried behind the slice to give efflux speeds equal to at least the lower range of speeds used in the mill. In studying the slice, the only alteration made in going from an actual paper machine slice to the model equipment is that of the stream width, and, as the surface friction effects are small, this reduction in width is unimportant. Thus the study of slice action with this equipment need be considered a "model study" only in the limited sense that it is not actual mill equipment and because the stream width is foreshortened for experimental convenience.

It is taken for granted that the small scale model lent itself well to the purpose of the original development of this new method of studying fluid and fiber action. But there are several important reasons why the continuation of work upon models is desirable when compared to
study on actual papermaking equipment. The first obvious, but very important, advantage obtained with a model is that a study of normal operating conditions can be made without affecting or being affected by production requirements. The second advantage is that a study of conditions not within standard operating regions can be made; and the understanding of such regions is usually needed to build up a reasonably complete theoretical interpretation of phenomena associated with the system in question. It is the proper application of this latter type of information which often greatly extends, modifies, or changes completely practical operation. The use of model study also simplifies the electrical, optical, and photographic apparatus and lessens the demands upon their size and costs. A very important feature of the use of a model for this particular type of problem is that the path of light through the water suspension of fibers is kept within reasonable limits.

While the above points mentioned in favor of a model approach are somewhat obvious, it was thought desirable to list them because, in past developmental work on the wet end problems of the paper machine, the approach has been, with very few exceptions, from the standpoint of practical mill operation. It is reasonable to expect that information obtained on fluid and fiber action in model systems can be applied by the paper industry as success-
fully as similar information obtained from model airfoil study has been applied by modern aircraft builders.
Evolution of the method.

The first experimental work leading to the present method was done upon a water suspension of silver crystals. Prandtl (5) and other investigators have made good use of metallic particles in water suspension for studying aerodynamic problems, and this seemed a good starting point on the route to a fiber method. The general technic of Schmieschek (10) was used to produce fine, regular, hexagonal, silver crystals of diameters of 0.01 to 0.015 mm. These crystals had a very high reflectance and were easily recorded upon the photographic film. Such a method was used as a starting point for two reasons: first, to furnish an introduction to the general problem of lighting, selection of photographic film and developing formulas, camera lens, etc., as applied to work on small particles at reasonable high velocities, second, to furnish a reserve method that could be used later if the greater difficulties attendant upon photographing the papermaking fibers made such a move necessary.

As soon as the above purposes were met a change was made to a water suspension of actual pulp fiber. West Coast fractionated unbleached sulfite pulp was used because the higher fiber length values were desirable. The change to pulp fibers was made for two reasons: first, while the thin, hexagonal, plate-like silver particles show well the streamline and vortex regions present in
the system, they can give no idea of the very important
types of motion which fibers in suspension will undergo,
and, also, the way in which fibers react upon one another.
Secondly, the positions of any particle of silver or
particular fiber can be followed if a streak trail is
recorded on the photographic film; but if successive
instantaneous images are formed on the film, the fibers
exhibit enough individuality to permit the successive
positions of any particular one to be easily followed,
whereas the light beams reflected from the silver part-
icles have no such individuality. The first point mentioned
above is of particular importance as the investigation
applies to paper making problems, whereas the second point
is of importance when considering any problem of a gen-
eral hydrodynamic nature.

In fact it might be repeated that the new method in-
volving instantaneous, successive fiber images upon one
plate has applicability to general hydrodynamic problems
and is not limited to problems of the paper industry. As
mentioned before, Prandtl and Tietjens (5) exhibited photo-
graphs showing differences obtained upon photographic
film using short time exposures when the camera motion
is zero relative to the object in one case and then zero
relative to the general flow in the other instance. In
order to avoid ambiguous interpretations which can arise
under such conditions, one should go to a series of in-
stantaneous exposures. For such work the fiber method
allows a much higher accuracy in analyzing the photographic plates, because of the individuality exhibited by the fibers.

If any particles are to be used to indicate the fluid action within a system, one must be sure that their motion and changes of motion correspond very closely with that of the liquid at the points in which they are located. In other words, the inertial effects for the indicating particles must be negligible when compared to the effects of the viscous forces exerted at the solid-liquid interfaces. Small spherical particles, such as have been used in other investigations, meet this requirement satisfactorily from all practical standpoints. But the motions of pulp fibers will correspond more closely to that of the actual stream velocities and accelerations than spherical particles of the same volume, because of the greater surface area per unit of volume; although for practical purposes this theoretical advantage is relatively unimportant at speeds involved in the normal regions of study. However, the greater certainty of interpretation of the photographic plates, when fibers and the new technic of illuminating and photographing are used to indicate flow, is important enough in itself to warrant in many cases a substitution of fibers for the other types of particles previously used in such studies.

Before the actual work of photographing the fiber suspension commenced, a glass trough and a means for cir-
eulating the suspension through the trough were designed and constructed. The experimental arrangement is diagrammed in Figure 4, page 30, and is pictured, along with the electrical portion of the equipment, in Figure 2, page 26. A discussion of all equipment will be given in the following section entitled "Description of equipment and procedure".

The first work with fibers was done by using a short time exposure with a continuous light source to give reflection images of the fiber trails as they were moving in the water suspension down the trough. On the basis of the observed results it seemed that, while this means is satisfactory for the picturing of streamline and eddy regions, it is unsatisfactory for the purpose of securing data where complete three-dimensional detail of fiber action is wanted. While the trails show the direction and speed of the currents in the liquid, there is not enough differentiation in the photographic images of the trails to enable one to know in what manner the fiber is moving; that is, whether it is moving with its long axis uniformly vertical or horizontal or whether it may be spinning or turning irregularly. Also, the effect of preferred orientation of fibers relative to the light source (a point to be discussed later) makes interpretation of the photographic plates unreliable.

Two possible means of remedying the above trouble
presented themselves. One could possibly make use of a directly transmitted polarized light beam with an analyzing prism and thus record fibers oriented in a particular plane in reference to the system; and a record of several such planes in the region being investigated might, with statistical treatment, furnish significant data. A brief trial of this method gave little promise and was abandoned. The other possible method consisted in making a photographic record, by means of the electrical spark technic, of instantaneous images of the fibers as they underwent their various motions. This latter type of attack proved to be the one desired, and its development resulted in the method which is described in the following section.

The electrical wiring diagram used for this spark technic is given in Figure 3, page 27, and is pictured along with the balance of the equipment in Figure 2, page 26.

The use of a high intensity spark of a duration of time of roughly 0.000003 second gave three possible ways of obtaining the exposures. These possibilities were:

1) A shutter speed adjusted to correspond to the frequency of the spark source, which in this case was 120 per second. In this manner, when operating at 120 sparks per second, a shutter speed of 1/100 second would in general produce on the photographic film one instantaneous exposure.

2) Use of a movie camera with the frequency and time
of sparking controlled as a function of camera speed to give one instantaneous exposure per frame, without a mechanical shutter.

3) A method of producing successive instantaneous exposures of fibers so that their paths, and the manner in which they were moving along these paths, could be studied on one photographic plate.

If the first mentioned method were used, it would necessitate the recording of the same phenomena in any particular region of study on a very large number of individual films and a statistical treatment of the assembled results before a conception of the actions could be gained. This would be too costly from the standpoint of both time and materials; so this method was eliminated from consideration.

The second method suggested is used very successfully in the line high speed work of Edgerton (11) and others. But this makes for high cost of equipment which it was desired to avoid.

Therefore it was decided to concentrate attention upon the last-mentioned possibility suggested above, and the multiple instantaneous exposure idea is the basis of the present method.

Such difficulty was met with before a method was developed which showed no apparent orientation of fiber images caused by the position of the light source. The surfaces of pulp fibers in suspension are sufficiently smooth to specularly reflect light. Thus it was found that, with all
possible modifications of the light source, whenever the recording of the fiber images was by means of reflected light, the specularly reflected portion, in contrast to the diffusely reflected portion, was the important factor. Therefore, after many attempts had failed to give an arrangement of one gap, or of two gaps in series, with or without condenser lenses, which would remedy these artificially imposed orientation effects, an entirely different approach was tried. The rather unusual arrangement of aiming the camera directly at the light source was used. The trough was placed between the spark gap and camera, and a condenser lens was placed before the gap in order that the light beam passing through the trough and into the camera lens would consist of approximately parallel rays. In this way the shadow images of the fibers recorded themselves upon the negatives without giving rise to any spurious orientation phenomena.

After the orientation effects had been eliminated the work consisted in finding proper light intensities, film types, development factors, etc., and the application of the technique to some typical demonstrations of possible uses of the method.

The basic idea of producing, say, three successive exposures upon one film can be understood by referring to the typical "E and D" characteristic curve for a photographic negative shown in Figure 1, page 23; to the chart placed immediately below the curve; and to Table I, page
22. The region of correct exposure upon the characteristic curve is between the points A and B; therefore, the spark intensity adjustment must be made so that the sum of the three exposure values falls within this region. A spark so adjusted will affect the negative in the following manner. The first exposure upon the negative is represented by point 1 on the characteristic curve. Hence, for the body of the negative, a density value corresponding to the ordinate of point 1 is created; but the region on the plate hidden by the fiber silhouette (assuming for this discussion that the fiber photographed by this method is completely opaque) is unaffected by the flash. The portion of the plate affected by this first flash is indicated in Figure 1 by vertical cross-hatching. Table I

Table I.

Summary of the Units of Exposure as They Affect the Photographic Negative by the Method of Successive Exposures.

<table>
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<tr>
<th>Area of Negative</th>
<th>Successive Spark Flashes</th>
<th>Total Energy</th>
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<tbody>
<tr>
<td></td>
<td>First</td>
<td>Second</td>
</tr>
<tr>
<td>Main body of plate</td>
<td>1 energy unit</td>
<td>1 energy unit</td>
</tr>
<tr>
<td>Portion of plate occupied by fiber shadow at time of first flash</td>
<td>0 &quot;</td>
<td>1 &quot;</td>
</tr>
<tr>
<td>Portion occupied by fiber at second flash</td>
<td>1 &quot;</td>
<td>0 &quot;</td>
</tr>
<tr>
<td>Portion occupied by fiber at third flash</td>
<td>1 &quot;</td>
<td>1 &quot;</td>
</tr>
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Typical H. and D. Characteristic Curve for a Photographic Emulsion (13)

Hypothetical Negative with one moving fiber in its three successive recorded positions. To illustrate building up of the density of the negative.

Key:
- area affected by 1st flash
- by 2nd flash
- by 3rd flash

Figure 1.
expresses the same idea, showing one energy unit occurring upon all of the negative area except that occupied by the fiber in its position at the time of the first flash. When the second flash occurs, the fiber has moved to its second position as shown in the sketch; the body of the negative is brought to a density value indicated by Point 2 on the characteristic curve. The area that was hidden by the fiber in its first position at the time of the first flash is now energized for the first time and is represented by Point 1, while the area occupied by the fiber in its new position at this second flash time is not energized and so it remains at the value indicated by Point 1 (which value this portion of the negative had already obtained by the first spark flash). When the third spark flash occurs, the general negative area is brought to the density value indicated by Point 3 on the characteristic curve; the portion of the plate hidden by the fiber in its third position corresponding to the time of this third flash is not energized and accordingly remains at its former value indicated by Point 2. The portion of the plate that was covered by the moving fiber at the time of the second flash is exposed to this third flash and accordingly rises from its past value of Point 1 up to Point 2. In the same manner the area which had been shielded from the first spark flash by the moving fiber in its "1 position is now energized another unit to Point 2 on the curve. Accordingly, the negative which has gone
through this series of multiple exposures during one movement of the shutter has its general body area at the density indicated on the characteristic curve by Point 3, while all of the fiber images are at the uniform density value indicated by Point 2.

It will readily be seen that, for maximal contrast, the shape of the "H and C" curve given in Figure 1 should be such that ordinates are small for small exposures, and increase rapidly with exposure in the neighborhood of the exposure corresponding to the third flash. This, as it relates to actual available films, will be discussed at a later point.
Description of equipment and procedure.

The complete equipment, with the exception of the camera, is shown below in Figure 2. This equipment is located in one of the Institute darkrooms, and while absolute darkness is not needed during the actual photographing a low light value in the room is desirable in order to eliminate possible reflections from the glass surfaces of the trough. The glass-lined, horizontal, level trough, A, is seen running lengthwise on the bench. Above and below the entrance and exit ends of the trough are water storage tanks, C and D, connected together by piping; and an elec-
Electrically driven centrifugal pump, $Z$. This portion of the apparatus is diagrammed in detail in Figure 4, page 30. The transformer, $F$; condenser, $G$; and rheostat, $H$ are on the shelf above. The spark gap and condenser lens, $I$, are shown behind the glass trough. The electrical circuit is shown in Figure 3 below.

The Trough and Circulatory System: As the diagram on page 30 indicates, the glass trough is not connected in a closed manner with the circulating system but the line is broken below the tank which furnishes the head of water and above the sump below the trough exit. This is done to prevent the irregularities of the pump flow from disturbing the evenness of flow through the trough. The large area of the head tank evens out the slight variations in flow to it and thus gives a practically constant head of
liquid and a correspondingly regular rate of flow to the trough. This open-type system also prevents the pump vibration from affecting the region where the observations are made.

The galvanized iron entrance to the glass portion of the trough was designed in such a manner as to bring the liquid into the trough proper free of eddies and unevenness of flow.

A standard model Buick automobile water pump connected to a ½ hp. single phase a.c. motor circulates the fiber suspension. Under the operating head imposed upon it, this pump furnishes a maximum flow of about 11 gallons per minute. The flow was determined in the routine work from the Pitot tube and manometer combination tapped into the line above the pump outlet.

Standard ½-inch angle iron, welded at the corners, formed the framework for the trough. Some difficulty was experienced in making the two glass sides and the glass bottom fit in a water-tight manner into this framework, because the rate of flow of the water through the trough did not allow one to use the standard types of aquarium cements. These cements do not harden sufficiently to prevent considerable wearing away under such conditions. Neither did the use of litharge and glycerin cement seem satisfactory. The method that worked satisfactorily is illustrated in the joint detail in Figure 4, page 36. The
two glass side pieces were held to the angle iron frame by DuPont Household Cement, slight continuous pressure holding the pieces in place until the cement had hardened. The top surface of the bottom glass plate had to be flush with or slightly above the upper edge of the lower supporting angle-iron frame piece in order to allow photographing the flow over its entire cross section. This was done by placing small wood blocks of the correct thickness at intervals along the lower inner edge of the angle iron. These took upon themselves the weight of the glass and water and thus kept the position and the level of the glass bottom constant. With these in place, Truscon Caulking Compound was spread heavily along the inside portion of the lower angle irons and the bottom glass was then pressed down into it and onto the supporting wood blocks. After the compound had set several hours the excess was cleaned away leaving flush surfaces as shown in the sketch. As this material remains somewhat tacky and does not harden greatly, the portion of it exposed in the trough between the side glasses and edges of the bottom glass was covered with two or three coats of shellac in order to give a surface that would not be carried away by the water flow. This method of building up the trough proved very satisfactory in that it was entirely waterproof and solid, and, at the same time, because of the non-hardening and tacky nature of the compound, the glass portions could be re-
moved when necessary without breaking them. This same material was used in attaching the streamlined galvanized iron entrance to the glass trough.

The Spark Gap Equipment: The electrical portion of the equipment is diagrammed in Figure 3, page 27, and as indicated there, the primary side of the circuit was connected to the usual 110-volt, 60-cycle, a.c. lighting circuit. A G.E. Luminous Tube Transformer, Model GTQX 241A1, 60 cycle type was used. This transformer had the rating, primary: 110 volts, 900 volt-amperes; secondary: 15,000 volts, 60 milliamperes. In series with the primary side of the transformer was a water-cooled rheostat of 37 ohms maximum resistance with a current rating of 6.2 amperes. This was of sufficient carrying capacity to allow operation of the gap for perhaps 15 to 30 seconds before the resistance winding was dangerously overheated.

The condenser was of the parallel plate type having glass separators. Standard 5"x7" photographic plates, cleaned of their emulsion, formed the dielectric plates, upon which were shellacked sheet copper 3.5"x5.0" in size, thus leaving a 0.75-inch margin which was sufficient to prevent sparking around the edges of the glass plates under normal operating conditions. The copper sheet used was 0.005 inches thick. Twenty active plates were built up in this manner and placed in an Eastman Plate Rack as pictured in Figure 2, page 26. These were spaced 1.25
inches apart with an ordinary glass plate placed between each active plate, thus making a rack of twenty dielectric plates and nineteen insulating plates. The latter prevented any sparking across the 1.25-inch gap between the active plates. Wires connecting the condenser plates to the bus bars were 4 inches long and were insulated by pieces of ordinary 0.25-inch glass tubing to prevent sparking from these leads around to the oppositely charged side of the same plate or adjacent plate. The two large plates shown at either end of the racked plates served to support the two bus wires, placed one on each side of the condenser, thus removing any strain from the soldered connections at the plates, lead wires, and bus wires. These two plates were of Masonite, impregnated with paraffin to improve their insulating quality. Operating with normal gap length, which was varied from 0.2 to 0.75 cm., no trouble due to spark-over was encountered. The capacitance of the condenser was approximately 0.01 μF.

Emunicator wire was used to connect the various portions of the secondary circuit. Because of the low current small battery clips were satisfactory for each connection.

To provide an adjustable spark gap, standard brass machine bolts were used. These were ground down to a point at their ends and were threaded through brass strips which in turn were threaded to the binding posts of "stand-off" porcelain insulators. Fastened onto a wood base, this con-
stituted the spark gap unit. (It is known that a magnesium gap gives higher light intensity; but the light intensity from the brass gap was more than ample).

The Optical and Photographic Equipment: Figure 5, page 34 shows the relative positions of the light source, condenser lens, trough, and camera when a horizontal shot is made in one case and then when a vertical shot is made down into the trough.

A double convex lens, of diameter 3.5 inches and focal length 7.25 inches, placed between the spark gap and the trough, furnished an approximately parallel beam of light for illuminating the flowing suspension. The camera on the opposite side of the trough was aimed directly into this beam with its object plane at the center line of the trough. In a vertical shot a plane mirror was placed under the trough so as to produce a beam of light coming vertically up through the body of the trough.

The camera used in this investigation was a 4"x5" Rolmer Graflex "Speed Graphic" fitted with a ground glass removable plate interchangeable with the film holder.

The lens was a Xenar f.3.5, focal length 16.5 cm., fitted with a compound shutter. Thus the camera was fitted with both focal plane and compound shutters. In all of this work the camera was placed and adjusted to give unity magnification upon the negative. Under these conditions the depth of field in which a fiber was not completely out of focus was 0.75 inch.
Alignment of Optical Equipment for Horizontal Shots of Vertical Cross Sections

Alignment of Optical Equipment for Vertical Shots of Horizontal Cross Sections

Figure 5.
Choice of Film Material: Because a series of three successive exposures is used upon one negative, the matter of choosing the proper type of emulsion is viewed quite differently than is normally the case. While the total exposure value from the three sparks may build up an appreciable density upon the negative, the duration of each spark flash is something less than 0.000003 second. (Needless to say, even a rapidly moving fiber moves virtually no distance during this interval, and the image pictures are sharp). The following factors are to be considered in arriving at the proper balance between spark intensity and film characteristics.

It was pointed out on page 25 that, for good contrast, the "H and D" curve of the film should exhibit small values for small exposures, and a sudden rise in the neighborhood of the exposure resulting from the three flashes. The straight line portion of the "H and D" curve is represented by the equation \[ D = \gamma (\log E - \log i) \] (12), where \( E \) is the exposure, and \( \gamma \) and \( i \) are constants of the emulsion. For our purpose, both \( \gamma \) and \( i \) should be relatively large. Inspection of Table II, page 37 shows that Eastman Panchromatic Process film has relatively large \( \gamma \) and \( i \) values. The "H and D" curve for this film is compared with that of Eastman Supersensitive Panchromatic film in Figure 6, page 37. It will be seen that the curve for the Panchromatic Process is considerably steeper than that for
the Supersensitive Panchromatic, and starts rising at a larger exposure value. The intensity of light is empirically adjusted so that the exposure of three flashes is represented by a point somewhere between A and B, on the straight portion of the curve.

General Discussion of Procedure: The necessary plates inserted within the trough proper to form a system of the desired nature were made of photographic glass-plate stock or copper plate of sufficient weight to resist the current flow without buckling. The edge of any copper sheet which directed water flow was given a finished, even knife-edge by using a flat file. The edge of any glass plate which directed flow was made true by polishing with emery and turpentine. These baffles were held in place by small pieces of celluloid cemented to the trough sides with DuPont Household Cement. Usually the pressure of the flowing stream held the plates closely against these celluloid pins; if it did not do so, a drop of cement at the surface of the baffle and pin would keep the contact secure. Celluloid stuck to the glass in such a manner normally held for several hours; but it could be removed easily at any time by forcing a razor blade between the surfaces. Such a method of inserting baffling material put no strain upon the glass sides and bottom of the trough and gave sufficient solidarity, ease of building up and removing the necessary modifications, and in itself obscured only very small
H & D Characteristic Curves for Film Emulsions
Figure 6.

Table II.

Characteristics of Film Emulsions (12)

<table>
<thead>
<tr>
<th>Type of Film</th>
<th>Inertia (i)</th>
<th>10/i</th>
<th>K</th>
<th>Gamma infinity</th>
<th>Time for gamma = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supersensitive</td>
<td>0.011</td>
<td>900</td>
<td>0.37</td>
<td>1.70</td>
<td>3.6 min.</td>
</tr>
<tr>
<td>Panchromatic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Panchromatic</td>
<td>0.017</td>
<td>600</td>
<td>0.22</td>
<td>1.80</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panchromatic Process</td>
<td>0.130</td>
<td>75</td>
<td>0.25</td>
<td>3.00</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>
portions of the field that was studied. The celluloid pins show upon the photographs as dark objects roughly rectangular in shape with dimensions of about 1/4"x3/8".

All photographs made during the developmental period were obtained with a very dilute fiber suspension. About 0.2 gram of West Coast long fibered fractionated unbleached sulphite was used in the system. Such a dilute suspension was used in order that the effects of changing the variables of lighting, flow conditions, etc., might be more clearly recognized.

In the optical and photographic procedures there were several factors which had to be considered, in addition to the adjustment of light intensity or exposure variables, and the development of the negative. The spark source, condenser lens, and camera were set up for a horizontal shot so that an imaginary line passing from the center of the spark gap to the center of the camera also passed through the center of the condenser lens and was at right angles to the sides of the trough. The line-up of spark and condenser relative to the camera was easily checked by the appearance upon the ground glass of the camera. Such a line-up of the apparatus of a common center line was needed to obtain the maximum area of field on the negative. When this center line of the optical system is at right angles to the glass surfaces of the trough, refraction and apparent displacement effects found when
the angle between the light rays and the glass surfaces is not 90 degrees are avoided.

The spark gap as operated normally gave a spark 0.35 cm. in length. The condenser lens was of the ordinary molded type. The finite size of the gap and the lens imperfections necessitated an adjustment of the distance between the gap and lens to produce upon the ground glass of the camera as large and uniform a field of illumination as possible. This adjustment was dependent upon the aperture of the camera lens and the effective aperture of the condenser lens.

The Xenar lens on the camera which had an apparent diameter of 1.75 inches was used at its full aperture, not only to give the fullest available area of observation, but also to limit the depth of field as much as possible. Used in this manner with the camera located in respect to the object at a distance to give unity magnification, the depth of field was, as stated before, less than 3/4 inch, and the area of clear observation, as shown on the negatives, was a circle of approximately 2 1/4 inches diameter.

The object and image distances from the camera lens which gave a clear-cut reproduction at an accurate value of unity magnification were critical. But, with care, the distances could be adjusted with sufficient precision to permit one to obtain distance, velocity, and acceleration values directly from the photographs.
With the particular experimental arrangement used, it was found that spark intervals of 1/120 second, rather than 1/60 second, were best suited for the purpose of following the fiber action, since this time did not result in the fiber images crowding together; and, on the other hand, it allowed a recording of three images of the majority of fibers before they moved from the field.

Where no attempt was made to adjust the shutter speed in accord with the time of sparking, a variation of the number of exposures on the negatives was frequently observed. But a shutter speed of 1/40 second would, in general, produce three exposures per negative. In the same manner a shutter speed of 1/30 second would, in general, allow four of these 0.000003-second flashes per shutter action. Peculiar bar-like effects across the negatives were observed; these were regions where either two or four flashes reproduced instead of the usual three. This arises from the lack of synchronization of the spark flash and shutter action and also to a variation from the theoretical exposure time value. When using this particular camera and its focal plane shutter at the value of 1/40-second shutter speed (which would theoretically be better suited to the spark frequency of 120 per second) it was found that the ratio of the bar regions to the main region of three exposures was higher than when the 1/30-second
setting was used. Therefore, the latter value was used throughout this work.

It is obvious that the shutter speed did not determine the exposure; rather, the exposure was determined by the number and intensity of the spark flashes. Therefore the development time and the spark gap size were balanced empirically to fit the photographic film used. As stated before, Eastman Panchromatic Process cut film was used, the developing agent being Eastman's D-11 formula, a so-called fine grain, contrasty type.

The developed negatives were fixed in 25% "hypo" and hardened in a weak formaldehyde bath in the normal manner.

The printing of positives from the negatives produced in such a study may in many cases be eliminated. The negatives alone, when placed against a well-lighted frosted-glass backing or when placed in a projector and given enlarged reproduction on a screen, allow one to analyze the conditions conveniently. In this manner considerable unnecessary work can be eliminated and only negatives representative of typical conditions need be printed for illustrative purposes.

When a vertical shot of the stream within the trough was desired, the use of a plane mirror, as shown in Figure 5, page 34, was necessary. While the mirror made it unnecessary to place the spark gap and condenser lens beneath the trough, it had a much more important use. The uneven
water surface, particularly noticeable in the rapidly moving effluent from an orifice opening, and also the normal degree of curvature of a free-falling effluent, caused much trouble by refracting portions of the illuminating light beam away from its normal parallel path. This resulted in highly illuminated regions on the negative and, accordingly, a destruction of the normal fiber silhouettes. By properly adjusting the mirror, while viewing the effect on the ground glass plate of the camera, much of this irregularity could be removed and any particular portion of the stream photographed with a minimum loss of plate area. This method of using a plane mirror was the only practical way found among many methods tried of making satisfactory vertical shots through portions of the flowing liquid where there was surface activity and irregularity. Hence, in general, wherever the light beam passed through a free liquid surface exhibiting motion, the slight modification of the direction of the illuminating beam by the proper adjustment of the plane mirror was extremely important.
Some applications of the method.

In this section photographs made from typical negatives are shown and briefly discussed. These are given to indicate the manner in which hydrodynamic data can be obtained for various types of systems.

As mentioned previously, these positives are offered for illustrative purposes only; the negatives themselves may be conveniently used for study, either by observing them against a well-lighted translucent glass background or by projecting them and viewing the enlarged image.

The following order is observed in assembling the photographs and sketches:

1) Action of fiber suspension during free flow within the rectangular trough: Figures 7, 8.

2) Action at a typical slice-like orifice: Figures 9, 10.

3) Action of a typical rectangular orifice having a free-falling effluent and with variations of head of liquid and degree of symmetry of orifice placement relative to the oncoming stream: Figures 11-19.

4) A series showing briefly the significance of changes in path ratios around a simple baffle and orifice system: Figures 20-24.

5) A scale model (1:13 ratio) of a headbox that is in actual operation on a Fourdrinier machine: Figures 25, 26.

With the exception of Figure 26, page 75, which has a magnification of 24 diameters, all the prints have been enlarged from the original negative value of unity magnification to three diameters. In the composite photographs
made from two or more negatives no attempt was made to
remove the lines formed at the point where the negatives
meet, nor has retouching of any sort been done on any of
the illustrations. In the composite photographs the lack
of alignment of the horizontal bars of varying intensities,
which were formed because of the lack of synchronism of
the focal plane shutter and the spark, does not mean a
misalignment of the two negatives as they make up the
completed picture.

The apparent irregularity of the baffling surfaces
noticed in these photographs is due to the opacity of the
small amount of filling material used at the junction of
the baffles with the trough side walls to make a water-
proof joint. The material used in this manner does not
affect the flow, as it is merely a thin surface applica-
tion, and all photographs of vertical sections are taken
at the trough centerline which is 1-1/8 inches away from
any irregularity of surface caused by this material. As
previously mentioned, the baffles themselves are either
3/16-inch glass plates or copper plate, and have true plane
surfaces and ground edges.

These photographs give visible evidence in support of
the previously made claim that the interpretation of stream-
line effects and of velocity and acceleration values can
be made with accuracy, because the appearances of the in-
dividual fibers allow one to know with certainty the suc-
cessive positions of a fiber at the successive time intervals. They also substantiate the assertion that the fibers accurately show the fluid motion by keeping with the fluid; that is, that their inertial effects are negligible. This is brought out by observation of the frequent small spherical particles or air bubbles whose images are caught upon the plate, and which happen to be located very close to some fiber in the fluid.

The tracings covering Figures 9, 11, 14 on pages 61, 62, 64, illustrate a valuable general application of this photographic method. They indicate the relative velocities at points within the system, and also the nature of the streamlines. The segments on the tracings were obtained directly from the photographs by constructing loci of the ends of fibers as they were recorded in their successive positions.

Some of these fibers were in different planes, which accounts for the different directions at the same projected point. While one can easily see the general streamline pattern directly on the negative or prints, this method of tracing from the negative or print or marking directly on the print or upon the projected image of the negative furnishes a convenient and accurate means of obtaining more detailed information.

Figures 7 and 8, page 60, indicate the randomness of fibers under normal or free flow conditions in the rectangular trough. The mean velocity was approximately 3.1 inches
per second. The depth of liquid within the trough was 3-5/8 inches, with the dark dashed line visible in Figure 7 indicating a height of 1-7/8 inches above the trough bottom. This depth of liquid was held by inserting a 3/8-inch rectangular orifice in the trough; but, as this was placed 10 inches below the region being photographed, no velocity and acceleration values were felt at this point. Figure 7 is a vertical section at the trough centerline. Figure 8 is a horizontal section with the plane of focus at the height of 1-7/8 inches above the trough bottom; or in other words, the horizontal section whose edge is indicated by the dashed heavy line in Figure 7. These two shots made at right angles to each other show the randomness of the fiber orientation under this simple type of flow - and this is in decided contrast to the analogy of the alignment of logs carried in a stream, which analogy has frequently been applied to describe fiber action in a free-flowing stream.

Figures 9 and 10, pages 61 and 62, show the fiber orientation in the region of a simple rectangular orifice. The top of the orifice is 3/8 inch above the trough bottom and extends the full width of the trough, or 24 inches. It is therefore depressed on three of its boundaries, the top edge being the only free-flowing portion. Figure 9 is a composite photograph of a vertical section at the trough centerline. Figure 10 is a horizontal cross-section of the effluent stream immediately below the slice. This latter
print illustrates well the use of a mirror to adjust the light beam on order to eliminate the effect of surface ripples over the portion of the stream being photographed; the right half of the picture was cleared up by the mirror, while the left half of the picture, or the downstream direction of the flowing effluent, shows the usual distortion and reflection effects of the light beam which naturally occur because of the ripples at the surface of the rapidly moving water. The head of water behind the slice was 2-5/8 inches, and the streamline effects, as this stream narrows down to pass the 3/8-inch slice, are clearly shown in the photograph and upon the tracing.

A comparison of Figures 9 and 10 shows the degree of orientation imposed upon the fibers as they pass through and beyond the orifice opening. Since the question of degree of orientation of fibers as they leave paper machine slices of various types has long been recognized as of extreme importance, this photographic method should find important use in furnishing information directly applicable to problems of design.

Figures 11 to 17 inclusive, pages 62 to 66, form a brief series showing a rectangular orifice operating under varying heads as its position relative to the vertical transverse cross-section of the oncoming stream varies. Table III, page 48, gives data such as orifice coefficients,
### Table III.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Stream Depth inches</th>
<th>Flow Volume (\text{in}^3/\text{sec.})</th>
<th>Average Velocity of Stream in (\text{in.}/\text{sec.})</th>
<th>Water Head above Orifice Center line inches</th>
<th>Orifice Coefficient</th>
<th>Theoretical Head above Orifice CL (if C = 1)</th>
<th>Ratio: Orifice Cross-section to Stream Cross-section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Series 1. Orifice 3/8 inch deep by 2 1/4 inches wide (full stream width) placed with its lower lip 0.5 inch above trough bottom.</td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>11</td>
<td>1.5</td>
<td>15.7</td>
<td>4.6</td>
<td>18.6</td>
<td>0.8</td>
<td>0.74</td>
<td>0.45</td>
</tr>
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<td>12</td>
<td>2.3</td>
<td>20.8</td>
<td>4.0</td>
<td>24.6</td>
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<td>.70</td>
<td>.78</td>
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<td>3.1</td>
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<td>.68</td>
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<td>14</td>
<td>3.6</td>
<td>26.0</td>
<td>3.2</td>
<td>30.8</td>
<td>2.9</td>
<td>.64</td>
<td>1.23</td>
</tr>
</tbody>
</table>

**Series 2. Orifice 3/8 inch deep by 2 1/4 inches wide with its lower lip 1.8 inches above the trough bottom.**

| 15     | 2.8                 | 15.9                             | 2.5                             | 18.8                            | 0.8             | .75                             | .46                                           | 1:7.56                                      |
| 16     | 3.6                 | 20.8                             | 2.6                             | 24.6                            | 1.5             | .70                             | .78                                           | 1:9.57                                      |
| 17     | 4.5                 | 26.3                             | 2.6                             | 31.1                            | 2.4             | .71                             | 1.25                                          | 1:11.9                                      |
average velocities, etc., calculated for this series. It might be mentioned in passing that the low values for the orifice coefficients, "C", can be accounted for to some extent by the fact that the transverse edges of the orifice are not bevelled on their downstream side away from a sharp lip, and also by the fact that the velocity values, "v", used in calculating the "C" values were taken as the mean velocity through the orifice opening, rather than at the vena contracta.

However, the chief purpose of this series was to determine in what manner, if any, the degree of orientation of the fibers might vary at the orifice and effluent regions during an appreciable change of head conditions and with a change of symmetry of the orifice location in respect to the oncoming stream. These prints clearly show that even at the low heads of 0.8 inch above a 3/8-inch orifice, and even with an unsymmetrically located orifice, a sudden and drastic orientation is forced upon the fibers as they come into the region of rapidly converging streamlines near the orifice. It will be noticed that the direction of orientation of the fibers along the stream persists within the free-falling effluent well beyond the orifice itself. The vertical section shown in Figure 18, page 67, and the horizontal section of Figure 19, page 68, also illustrate this.

The changed contours of the streamlines as the head and orifice location change is interestingly shown in this
series. Tracings of Figures 11 and 14 illustrate the varying velocities and streamline patterns taking place at a particular orifice setting when the orifice is operating under two conditions of head and flow rate.

It will be noted in a few of the photographs taken in this series that the drastic acceleration in the immediate region of the orifice is well shown, in that the second position of some particular fiber is conveniently at the orifice opening, while its position 1/120 second before is on the upstream side, and its final position is in the effluent. Gradually converging streamlines and varying velocity values, as illustrated by the fiber images, show the effect of the orifice as it is felt upstream; but the region of sudden acceleration localized about the actual orifice opening itself is particularly worthy of note.

As all of the pictures taken at low heads show this action of a powerful orienting of the fibers into line at the regions of strongly converging streamlines, it can undoubtedly be safely assumed that, under the much higher heads used for slice operation on actual paper machines, the tendency for an alignment of fibers along the machine direction and along the flow lines of the effluent is very strong where the suspension passes the slice; but, because of the much higher stock consistencies used commercially, and because of apron, wire, and shake effects coming into
play just beyond the slice itself, little more should be said at present. These prints, however, do support the theory of a strong fiber alignment at the slice, in contrast to the alternative theory of a fiber "skin" taking place in this region.

Figures 18 and 19, pages 67 and 68, are additional vertical and horizontal sections of a free-falling effluent similar to the preceding series. In this case, however, the amount of fiber in suspension was twice that used when making the other photographs. This was done so that a larger number of fibers would show in the horizontal section of the effluent. The two horizontal sections which make up Figure 19 include the effluent for a distance beginning one fourth of an inch below the orifice plate and extending for a 7/8-inch segment down the stream - from right to left in the print. The two separate negatives making up this print are two different photographs made of the same region in succession and under the same flow conditions prevailing at the time of photographing the vertical section of Figure 16. The significance of these prints has been discussed along with the series formed by Figures 11-17.

Figures 20 to 24, inclusive, pages 69 to 73, form a series indicating the use of this method in determining flow changes arising with a change in proportions of passages or baffling agents composing a given system. The sketches of Figure 20 were made while visually studying the system, and
therefore supplement Figures 21-24. The prints are com-
posite photographs, having been made up in each case from
two separate negatives. The sketches are natural size,
whereas the prints are enlarged three diameters. By com-
paring the photographic prints with the sketches made from
visual observation one can appreciate the manner in which
these supplement each other.

The presence of vortices within a given system, their
magnitude, location, and degree of activity; and the tendency
of the fluid to "channel" through a portion of a passage,
thus leaving dead spaces or vortex regions, are all of fund-
mental importance in designing systems for fluid flow. All
of these factors can be greatly changed by changes of pas-
sage sizes, curvatures, etc., and at present many of the
changes which can arise are unpredictable. This method is
thus a good general tool for obtaining data to answer prob-
lems of hydrodynamic design.

Visual study of the models and a study of the prints
suggests the possibility that, in many cases, a region
appearing as a smoothly rotating vortex area to the eye
is actually a region containing much random motion or many
small unstable vortices.

Figures 25 and 26, pages 74 and 75, are respectively
a sketch made from careful visual observation of a head-
box model and a composite photograph of the same, the
print being a composite of four negatives. The model is on a scale of 1:13, and represents a headbox in use on a Fourdrinier machine making book papers at production speeds in the neighborhood of 500-700 feet per minute. Both the visual observation and the print clearly show the channelling through the passages, and the adjacent eddy regions. In the last pass immediately before the slice the active portion, as compared to the eddy volume, is small. The reason given for a large passage before the slice, in comparison with the areas of other passes in the box, is that it slows down the more violent rate of flow of the fiber suspensions and allows it to even out, so that the flow under the slice to the table is smooth and even. However, it seems that such a design is not efficiently suited to this purpose because the strong channelling tendency carries completely through the last passage. Also, a large eddy region or "dead spot" in a headbox is credited by paper makers with the formation of fiber lumps. Therefore, this preliminary survey of a commercial headbox indicates the value of this method in possible future studies of more efficient design.
A photographic method for the direct study of hydrodynamic phenomena is presented. This method has interesting applications to the study of the hydrodynamics of fiber suspensions as it concerns the papermaking industry. It can also be used advantageously for the recording of flow data for the science of hydrodynamics in general.

Images of papermaking fibers within the flowing water are recorded upon the photographic negative, thus making visible the action within the system. It is shown that the movement of the fibers is a true indication of the fluid motion, as the inertial effects of the fibers are negligible when compared to the viscous effects at their surfaces. Three successive, instantaneous exposures of the flowing suspension obtained upon one negative give a series of silhouette images that record directly the directions of motion and the velocities of the fluid, and also show the manner in which the individual fibers are influenced by the liquid action.

The apparatus consists of three functional units:

1) The circulatory system
2) The electrical spark-gap circuit
3) The optical system

A rectangular trough having glass sides and bottom is modified by the insertion of baffling plates so as to produce the type of flow desired. The fiber suspension circu-
lates through the trough by gravity flow from a large head tank. After leaving the trough, the suspension is returned to the head tank by means of a small electrically-driven centrifugal pump.

The electric circuit for the spark source contains a transformer, the primary side of which is connected to the ordinary 110-volt, 60-cycle lighting circuit through a variable resistance rheostat, while the secondary side is rated at 15,000 volts and 60 milliamperes. On the secondary side of the circuit and between the transformer and the spark gap is a condenser of approximately 0.01 mf. capacity. By proper adjustment of the rheostat, a spark frequency of 120 sparks per second is obtained, the duration of each spark being roughly 0.000003 second.

The optical system includes the spark source and a condenser lens so placed in relation to the spark as to produce a beam of light of approximately parallel rays. This light beam illuminates the portion of the system being photographed. The light source, condenser lens, and camera lens are so adjusted that, for a photograph of a vertical cross section of the fluid, a common centerline passes between them and through their respective centers. To obtain a horizontal cross section through the system a plane mirror is used to pass the horizontal beam of light from the condenser lens up through the trough into the camera. The plane mirror also has the very important func-
tion of allowing one to eliminate or greatly minimize refraction effects caused by the active water surface through which the beam passes and thus allows photographing below a water surface having a high degree of rippling and curving of the surface.

A 4"x5" Folmer Graflex "Speed Graphic" camera fitted with a Xenar f. 3.5 lens, a focal plane shutter, and a ground glass plate interchangeable with the film holder was used to produce the photographs shown in this paper. The camera was located so as to produce negatives having unity magnification in order to simplify measurements and calculations taken from them. The depth of field under these conditions was somewhat less than 0.75 inch.

With the focal plane shutter speed set at 1/30 second, and the spark operating at a frequency of 120 sparks per second, three exposures are in general produced upon the negative. The proper density of spark, so that the density of the resulting negative remains within the region of correct exposure, is found empirically. The successive silhouette images of the fibers so produced upon the negative all have a uniform density less than the main plate density. As the duration of each spark is about 0.000003 second, the spark is for all practical purposes an instantaneous one, and the images of the rapidly moving fibers are clear-cut and free of blurring.

The developed negative itself, or a projected image
of the negative, can be used directly for analyzing stream-
lines and velocity and acceleration values of the fluid.
Positives need be made only for the purpose of illustration.

Typical photographs are given to show the application
of this method to problems of the paper industry. From
such a study information can be obtained of the reactions
of the fluid to a particular system; but the important in-
formation on the manner in which the fibers themselves
act within the fluid body is also available. Thus, for
example, the action of fibers as they pass the slice of
a paper machine can be clarified by such a study. Illus-
trations show that, with the dilute fiber suspension used
in this work, a drastic orientation of the fiber in the
direction of flow is obtained as the fibers pass the ori-
face, even with a low fluid head of only 0.8 inch above
a 3/8-inch orifice. This lends support to the theory of
a strong alignment of fibers in the machine direction as
they pass the paper machine slice; however, because of the
effects of increased density of fiber in suspension and
the influence of the apron, shake, etc., factors which
enter into commercial operation, little more should be
said at present. It is also shown that, in a smoothly
flowing stream, the fibers are randomly oriented, this
being in direct contrast to the frequently used analogy
of fiber action to that of a log carried in a stream.
This method is also applicable to hydrodynamic problems in general. The fibers themselves show such an individuality that their successive positions on the negatives can be followed with accuracy. Highly reflecting metallic particles, oil droplets, etc., have been much used for making visible the action within the fluid; but an examination of illustrations produced by the present method indicates that an ultimate analysis of a fluid system can undoubtedly be made with greater ease and accuracy by this latter method. An important disadvantage inherent in the streak-trail method, whereby differing relative motion effects of the camera relative to portions of the system produce photographs having varied appearances, is avoided by the use of successive instantaneous flashes.

A patent survey on the subjects of headbox, slice, and accessories affecting their operating is given. The abstracts listed were obtained from an examination of United States patents in Class 92, "Paper Making and Fiber Liberation", sub-class 44, "Fourdrinier Machines"; and from the patent abstracts of the Paper Trade Journal. The period between January, 1920, and June, 1930, is covered.
Literature Cited


Lund, A. L., Paper Trade J. 103, no. 1: 76, 78, 80, 82 (July 2, 1936).


Figure 10.

Figure 11.
Figure 16.
Pass width 2"
Bottom opening ½"
see Figure 21.

Pass width 1"
Bottom opening ½"
see Figure 23.

Pass width 2"
Bottom opening 1"
see Figure 22.

Pass width 1"
Bottom opening 1"
see Figure 24.

Figure 20.
Sketch of headbox from visual observation

Figure 25.
Patent Survey

The patents listed below are those issued beginning with the year 1920 and up to June 1936 on the subject of slices, headboxes, and their accessories which in their design affect flow characteristics. Both American and foreign patents are included, the patents of each country being grouped chronologically under the name of the issuing country. The United States patents are taken from "Class 92, Paper Making and Fiber Liberation; sub-class 44, Fourdrinier Machines".

Many of these abstracts are from the Paper Trade Journal; references to these are given at the end of the abstract. The pagination used for this purpose is that of the Technical Section and not that of the individual numbers of the Journal. When checking the abstracts obtained from this source back to the patent file, practically every U. S. patent was within the Class 92, sub-class 44; so this points to the conclusion that the following survey based upon a thorough review of only this one classification is, nevertheless, sufficiently complete for all practical purposes.
1,342,655. H. G. van Ornum. Paper making machine. A more detailed and important object with respect to the slice mechanism resides in the provision of an arrangement wherein the ratio of horizontal adjustment to dependent vertical adjustment may be varied to adapt the machine for different type papers.

1,383,363. C. S. Witham, Jr., assignor to Union Bag and Paper Corp. July 5, 1921. Fiber crossing apparatus. The crossing of fibers by means of elements adapted to lie in the stream of stock obliquely to its direction of travel; these elements being of such construction (spiral ridges on the circumference of a cylinder) that they may be applied to the stock to produce a crossing of fibers at a point so near the suction boxes that the fibers will remain permanently in their positions. This eliminates the usual shake and also acts as a stock leveler.

1,421,752. A. Aldrich and A. L. Larson. July 4, 1922. Paper making machine. Includes in the design a combination of headbox and pond associated therewith, said pond having a laterally adjustable wall, and a means whereby the said wall may be adjusted vertically, etc.

1,421,361. A. L. Murray assignor to International Paper Co. July 4, 1922. Method of feeding stock to the Fourdrinier wire. The slice and pond are entirely eliminated, the stock being fed from a headbox onto the wire over a dam and a slightly curved sloping surface extending across the width of the machine. Height of the dam is adjustable. The dam is of flexible metal and irregularities in its height can be adjusted to make it even throughout. The headbox is fitted with an overflow chamber, the front wall of which extends to the top of the box, while the rear wall, which does not extend as high as the level of the stock in the box, is surmounted by a weir plate the height of which determines the level of the stock in the box. Any foam in the headbox rises to the surface at this point and passes over the weir into the overflow chamber. The height of the discharge dam regulates the speed at which the stock discharges to the wire, while the difference between the dam heights and the weir plate controls the amount of stock delivered and the weight of the sheet. This method of feeding is claimed to give more efficient felting of fibers in all directions, resulting in substantially equal strengths of paper in both machine and cross directions. (T.S., 79:76)
1,431,558. G. S. Witham, Jr. Oct. 10, 1922. Slice. The slice is made so that it can be adjusted vertically and also by rotation about a horizontal axis at the top of the slice. It is claimed that this allows finer adjustments, and also that adjustments by rotation about the axis change the area of the pond and can consequently be used to take care of variations in degree of slowness of the stock by introduction of more or less water into the system. (T.S., 79:76)

1,434,033. G. S. Witham. Jr. Oct. 31, 1922. Method of felting fibers on the paper machine. A roll rotates above the wire, in close proximity but out of contact with the wire, and at the same peripheral speed. It is placed between the pond and suction boxes. An air jet is placed just in front of the roll which puddles the water and stock slightly so that in passing between the roll and wire the fibers are forced compactly together and are crowded through a relatively narrow space. The air also serves to break up bubbles and fiber lumps and to eliminate froth. (T.S., 79:76)


1,481,163. C. F. Van de Carr, Jr. Jan. 15, 1924. Pulp sheet levelling attachment. A flexible plate extends across one side of the headbox at a suitable height above the wire, thus forming an orifice for delivering pulp onto the wire. The plate is mounted on a series of brackets supported on a transverse bar, and screws are provided on the brackets for raising and lowering the plate, thereby increasing or decreasing the thickness of the layer of pulp delivered at different points of the wire. (T.S., 79237)

1,492,379. H. L. Kutter. May 29, 1924. Formation table. Below the wire extending from the breast roll to the first table roll is a transverse plate extending across the full width of the wire. This is perforated, preferably in the form of elongated slots placed to form a series of staggered transverse rows. This plate or formation table prevents too rapid draining away of the water from the fibers and prevents distortion of the fibers which very rapid draining tends to produce. (T.S., 81:16)

1,497,403. C. H. Bruner. June 10, 1924. Slice. In order to eliminate or diminish eddies and "boiling"
as the stock passes from under the slice, a lip is provided at the bottom of the slice. The lower face of the slice is inclined downward toward the apron board, and the inner lower edge (towards pond) of lip is rounded instead of sharp. Vertical rods are provided at intervals along the length of the slice, the lower ends of which are seated in bosses on the lip of the slice, while the upper ends are threaded and journalled in a flange at the top of the slice and are each provided with a hand wheel. By manipulating the latter, minor adjustments to the lip can be made in the vertical plane without affecting the angle of inclination of the lip towards the apron board. (T.S., 81:16)

1,519,559. M. E. Stewart. Dec. 16, 1924. Self-clearing silencer for paper machine. A slowly revolving perforated roll in the last pass of the headbox to break up lumps and to even up the rate of flow.

1,519,696. H. Nishina. Dec. 16, 1924. Paper machine. The main feature consists in causing an endless band to travel very rapidly and projecting pulp thereon, by means of an ejector with air under a pressure of several thousand pounds per square inch, at approximately the top point of one of the rolls over which the felt or wire passes.

1,526,193. W. Voith, assignor to American Voith Contact Co. Feb. 16, 1925. Stock inlet. The invention provides a perforated rotating cylinder in the bottom of a Voith high pressure stock inlet. The perforations in the wall of the cylinder are sufficient size to permit free stock flow without danger of choking. This cylinder is claimed to prevent formation of knots, lumps and foam. (T.S., 82:56)

1,532,597. W. E. Metcalf, assignor to Process Engineers, Inc. April 7, 1925. Preventing rooth formation. The stock passes from the screens to the flow box which carries it to a central box; and from there it is pumped to the headbox in which it is delivered by means of a submerged horizontal pipe perforated so as to discharge the rapidly flowing stock in various directions. The individual fibers are thus kept in motion when they reach the wire, and there is no trouble in obtaining a proper formation of fibers without using an emulsion. (T.S., 82:268)

1,534,080. A. F. Russell. April 21, 1925. Flow box. A deflecting member is provided at the delivery end of the flow box and extending across it. The member is adjustable vertically, and also about its horizontal axis; and it is so positioned and formed that it takes two nozzles or
or passages, one between the deflector and the bottom
and the other between the deflector and the front of the
flow box. The stock flow is divided into two streams,
one passing over and the other under the deflector; and
the two streams flow into each other just before being
delivered unto the wire. This results in a thorough mixing
of the stock and a uniform distribution over the wire. (T.S., 82:282)

1,552,629. J. O. Mason and E. B. Wardle, assignors
to Laurentide Co., Ltd. Sept. 6, 1925. Flow box rectifier.
A number of plates are placed within the flowbox adjacent
the spout or outlet of the box. The length of the plate
is in the direction of flow to provide a long surface for
steadying and regulating the flow of stock onto the wire.
Plates made of thin material, and are spaced at even intervals across the box. The edges of the plates nearest the
source of the flow are rounded off to prevent any of the
stock adhering to this edge, and the edges nearest the
delivery end of the box are bevelled to prevent eddying
of the flow. The plates are held in position by means of
concealed attachments and may be attached to the front or
rear of the spout or delivery end. The plates are mounted
on round bars with suitable spacers, the whole being securely fixed to the front or back of the spout so that the
rectifier may be easily removed for cleaning or repairing.
The attaching bars and bolts being concealed allow the
flow to be easy and steady, there being no exposed fixings which will retard the flow, cause eddying, etc.

1,563,025. A. J. Lewthwaite. Nov. 24, 1925. Method
of delivering stock onto paper machine wire. Air is blown
onto the surface of the stock as it emerges from under
the last slice, the air being blown at the same speed
and in the same direction as the stock, and being confined
by a plate parallel to the wire. suction boxes are placed
between the apron and the first table roll, and the plate
confining the air over the wire extends to the last suction box. (T.S., 82:164)

1,563,436. R. E. Putnam. Dec. 1, 1925. Ripple and
bubble eliminator. The principle of leaves riding on the
water surface immediately in front of the slice in order
to break bubbles and ripples.

Provides means whereby the second slice can be adjusted
toward or away from the first slice to change the size
of the pond without affecting the vertical adjustment
of the slices. (T.S., 83:68)

1,568,303. C. W. Horden. Jan. 5, 1926. Slice. The
slice is composed of a main member which is as long as
the narrowest adjustment between the deckle frames and
which has one or more complementary pieces bolted thereto.
It is supported at its ends by deckle frames and has a
flexible bar constituting a lip mounted on its lower
edge which preferably is also made in sections correspond-
ing in length with the main member and complementary
pieces. Means are provided for flexing or adjusting the
bar relative to the apron board so as to counteract un-
even strata in the flow of the stock and thus cause the
flow to become uniform throughout the full width. (T. S.,
82:250)

1,577,897. A. Danninger. Paper making machine. The
use of a wire under the usual fourdrinier wire which runs
over the breast roll and for a short distance along the
table on the table rolls.

1,579,264. L. L. Berry assignor to Beloit Iron Works.
April 6, 1926. Adjustable apron board. The apron comprises
adjustable side walls which rest upon an apron board hav-
ing a downwardly directed integral flange and secured to
a supporting block or beam. The apron board is shorter
than the side walls and is recessed along the front edge
to receive one edge of a projecting flexible metal lip.
Lower front portions of apron side walls are cut away and
rest upon rubber strips which movably rest upon the top
of the lip. Retaining strips are secured to the outer
walls and clamp against flanges formed on rubber strips.
Secured to the bottom of the lip are a number of straps
in the pocket of each of which one end of a fulcrummed
lever is engaged, each lever being pivoted intermediate
of its ends. Means are provided for individual manual ad-
justment of each one of the levers so as to regulate the
flow of pulp to obtain a sheet of uniform thickness across
the entire width of the machine. (T. S., 82:193)

1,581,665. F. N. Monaghan, assignor to Bagley and
Sewall Co. April 26, 1926. Fourdrinier for improved forma-
tion. In a co-pending patent application the inventor
claims a method of forming a sheet at high speeds consist-
ing broadly in the formation and maintenance of a pool
or reservoir above the wire in, to, and thru which the
water and stock is caused to move at approximately the
same speed as the wire, with agitation and inter-mingling
of the fibers of the stock in the pool, the wire taking
the water and stock from this pool to form the web.
According to the present invention this result is obtained
by extending the apron under the slice over the breast
roll a certain distance beyond the slice, and it extends
further in the center of the machine than at the sides.
In order to give a chance to obtain proper loss of water on the remainder of the table, the wire is given an upward inclination by lowering the breast roll or by raising the couch roll. (T.S., 84:251)

1,584,345. A. Aldrich. May 11, 1926. Stock inlet. Inlet is in the form of a nuzzle or spout attached to the headbox so that its open end shall clear the wire at the top of the breast roll and extending across the width of the machine between the deckle strands. A vertically adjustable gate or shutter is arranged to slide vertically on the inside of the headbox wall so as to control flow from the box. In order that flow of material from the spout may be regulated, the outlet of the spout is made adjustable by hinging the upper lip thereof so that it may be swung up or down. (T.S., 84:251)

1,587,699; 1,587,700. R. B. Daniels. June 2, 1926. Method and apparatus for making paper having portions of different thickness. Portions of the sheet are made thinner by securing to the slice one or more obstructions in the form of a U-shaped plate, which is bolted to the slice in such a manner as to provide for longitudinal and vertical adjustments. In order to prevent the stock from flowing from the thicker portions to the thinner portions of the sheet, compressed air is blown on top of the thinner portions of the web from a longitudinal pipe with a number of openings arranged longitudinally along the under side. On both sides of the pipe and extending longitudinally through practically its entire length are side walls or curtains which project slightly into the pulp to form a seal and prevent the escape of air along the sides. (T.S., 84:264)

1,610,742. C. Bucking. Dec. 14, 1926. Delivering stock to paper machine. The stock is delivered onto the apron by admitting from below through a number of small vertical conduits in such a manner as to cause a number of small eddies in the pulp as it reaches the apron. (T.S., 85:251)

1,617,767. T. T. Rogan and L. B. Wright. Feb. 15, 1927. Improving formation on the Fourdrinier. An agitator shaft with a series of parallel screw blades is provided in the pond, preferably between the two slices or just inside the opening when only one slice is used. The agitator is driven from some part of the machine, e.g., the breast roll shaft so that its action will vary according to the machine speed. (T.S., 86:62)

1,619,168. C. T. Valentine, assignor to Bagley and Dewell Co. March 1, 1927. Slice. The bottom or lip of the
slice consists of a plate which is rendered flexible by channeling it both longitudinally and crosswise. Adjusting means are provided at intervals along the slice edge, and independently of these provision is also made for raising or lowering the slice as a whole. To adjust the slice, the plate is aligned against the apron board so that any deformation, either of plate or board, is taken care of, as well as any deflection in either of them; and a perfect alignment or paralleling of the two members is effected. The adjusting means are then locked in position and the plate raised as a unit to provide the required opening between the plate and apron board. (T.S., 86:62)

1,623,096. B. D. Davies and G. J. Thomas. April 5, 1927. Slice. The lower edge of the slice is provided with spaced recesses or orifices, substantially semi-circular in shape, and between adjacent recesses there is a straight-edged portion. Means are provided for locally adjusting the height of the recesses across the length of slice. It is claimed that turbulence set up in the stock as it passes under the slice is sufficient to prevent fibers from settling too rapidly, but does not result in formation of an uneven sheet. The currents formed cause the stock to travel further down the wire before sufficient water is extracted to set the fibers, resulting in more criss-crossing and a better rolling. In order to prevent foam from being carried onto the wire and marring formation, and also to complete the flattening of the ridges of stock due to the recesses in the bottom of the slice, a strip of fabric is provided some distance beyond the slice and is adjusted so that its lower edge just draws on the surface of the sheet of stock. (T.S., 86:63)

1,623,157. E. L. Berry, assignor to Beloit Iron Works. April 5, 1927. Paper Machine. An impermeable endless apron extending a substantial distance beyond the slices to form a pond of stock subject to shaking action passes around the breast roll and a number of table rolls. (T.S., 86:254)

1,623,688. A. Alrich, assignor to Beloit Iron Works. May 17, 1927. Mixer for Fourdrinier flow boxes. The mixer consists essentially of a number of plates with fairly large circular perforations, mounted radially in a number of supporting spiders and adapted to be rotated. One of these mixers is preferably located just in advance of and in close proximity to the discharge orifice at the delivery end of the flow box, and others may be located in different channels or passages of the flow box. It is claimed that this mixer breaks up lumps and takes for a uniform consistency of stock and aids in regulating and controlling the flow of stock just before it is discharged through the orifice. (T.S., 86:63)
1,634,344. R. A. Steffen. July 5, 1927. Paper formation and weight indicator. In order to obtain proper formation and weight of the sheet it is necessary that the relation between the speed of the wire on one hand and the velocity and consistency of stock on the other hand remain constant. The instrument is essentially two tachometers mounted together, one of which is driven by the wire and indicates its speed, the other being driven by the layer of liquid stock on the wire near the breast roll. The instrument is applied at frequent intervals to the wire and any variations between the two speeds is read directly and can be corrected by adjustment of the machine. (T.S., 86:266)


1,641,986. N. J. Niks. Sept. 13, 1927. Paper machine apron. In order to prevent formation of streaks in the paper, the apron is constructed and mounted so as to vibrate with the wire. This prevents formation of ripples and allows using the same machine for making different kinds and weights of paper. (T.S., 86:266)

1,641,987. N. J. Niks. Sept. 13, 1927. Slice. The free end of the slice is located beyond the breast roll center and beyond the end of the apron so as to provide a space between end of the apron and end of the slice on the wire in which stock can accumulate, so that the water can drain off thru the wire prior to the stock making its exit on the wire beyond the slice. A second slice is provided back of center of the breast roll and over the apron. The apron is constructed and mounted so as to vibrate with the wire. This arrangement allows of using more water with the stock, which is desirable when working with long-fibered stock; it also results in the production of paper having the same appearance on both sides and eliminates the condition known as "flowering", consisting in the production of groups of mottled marks which mar the under side of the paper. (T.S., 86:266)

1,643,657. R. E. Reisel, assignor to Mead Paper Co. Sept. 27, 1927. Stock inlet. A block member is provided for closing ends of a Voith-type inlet, and construction and arrangement are such that it may be adjusted to vary the width of the inlet opening without necessitating disassembling or rearrangement of the parts of the inlet. (T.S., 86:266)
1,645,766. C. W. Valentine, assignor to Bagley and Swell Co. Jan. 17, 1928. Wiper roll. A wiper roll, preferably of rubber, is mounted over the wire near the breast roll and is provided with a large number of radial fins. These are so placed that several fins simultaneously dip into the stock on the wire, but without coming into contact with the latter. It is driven so that the fins dipping in the stock travel in the same direction as but at a slower velocity than the wire. As each fin leaves the stock, the surface of this fin has a wiping action on the stock surface, thus breaking down bubbles that may be on the stock surface. As the fins move at a slightly lower velocity than the stock there is a tendency for the latter to pile up behind the fins causing intermingling of the fibers which overcomes their tendency to distribute themselves lengthwise and improves the sheet formation. (T.S., 88:227)

1,648,229. E. R. Reisel, assignor to Mead Pulp and Paper Co. Nov. 6, 1927. Fourdrinier slice. The slice comprises an upper plate provided along its rear edge with an enlargement substantially circular in cross section and provided at its ends with extensions in the nature of stub shafts journaled in the side walls of the flow box mounted within the outlet opening of the flow box is a curved plate, the front edge of which is recessed to receive the enlargement of the lip plate, and a retaining plate holds the enlargement in position. Below the upper lip plate is mounted a thin flexible plate (e.g. of brass), and means are provided for adjusting its position relative to the apron at numerous points along its length so as to obtain uniform layer of stock across the whole width of the machine. The position of the lip as a whole can also be adjusted and the lip can be raised out of the operating position, together with the apron, to allow removing the breast roll when changing the wire. (T.S., 88:21)

1,660,274. A. H. Russell. Feb. 21, 1928. Stock deflector. There is provided a pond plate which is adjustable in the lateral direction of the wire and is positioned between the flow box orifice and the deckle straps. The edge of the plate in proximity to the flow box is tempered to a knife edge so that it will cut into the stock without disturbing its direction of flow onto the wire. Secured to and moveable with the pond plate is the deflector pipe which carries the surplus stock clear of the wire and this pipe may be led to a storage tank or back to the stock pond or flow box. (T.S., 30:69)

1,662,226. C. S. Latham, Jr. March 15, 1928. Head box and stock inlet. The head box is divided into a number
of communicating compartments and the flow of stock through the compartments is controlled by adjustable gates and baffles to prevent formation of cross currents and the building of stock on the wire. The head box is provided with a compartment serving as a quiet storage space at the front to maintain the desired head of stock for high speeds, the walls of this compartment extending to considerable height above the wire. At the top of this compartment means are provided for removing foam which may accumulate; it comprises a header to which are connected a number of spray pipes which direct fresh or white water onto the surface of the stock so as to force foam over an adjustable skimming plate at the back of the machine. To diffuse the stock and deliver it at all angles to the wire a perforated board is provided in the opening through which stock passes from the head box into the stock inlet or nozzle, this board being preferably set at an angle across the head box opening. Inlet consists of a nozzle and apron board formed as a unit together with a one-piece slice for maintaining uniformity of thickness across the entire width of the sheet. Inlet is mounted so as to be vertically adjustable, and a secondary adjustable one-piece slice may be provided if wanted. In order to adjust the thickness of the sheet across the width of the machine, a number of vertical nozzles are provided which project into theinside of the stock inlet, and the amount of water is increased at points where the sheet is running too heavy. (T.S., 96:69)

1,667,755. C. V. Valentine, assignor to Bagley and Sewall Co. May 1, 1928. Instead of using a hollow perforated roll across the slice or inlet, as to provide more even flow of stock onto the wire, the roll is constructed of a number of spaced radially-fluted disks which are mounted on a number of smooth rods. The roll is rotated at the proper speed, and the height above the bottom of the head box may be adjusted. (T.S., 98:69)

1,682,460. A. Aldrich. Aug. 28, 1928. Mechanism for uniformly intertwining fibers delivered to paper machine wires. To obtain the proper intertwining on the machine wire the pulp is agitated just inside the feed box or pond. To this end two bars are mounted across the inlet just inside the slice. Each bar is provided with prongs or fingers extending downwards so that their lower ends are well in front of the stock outlet. The bars are given a reciprocating motion across the front of the outlet, the motion of the two bars at any instant being always in opposite directions. (T.S., 99:220)

1,687,447. R. L. Heisel, assignor to Lead Pulp and Paper Co. Oct. 3, 1928. Stock inlet. The inlet is provided
with a lip plate extending across the full width of the
machine, and which can be adjusted to allow of regulating
the amount of stock delivered to the wire. Under the
main lip plate is an auxiliary flexible plate which can
be adjusted at various points to compensate for minor
variations in sheet thickness. Sides of inlet are closed
by means of two vertical plates. At each end of the inlet
is a plate which can be slid sideways to restrain the
stock when the deckle is altered. The apron, lip plates,
side plates, and deckle pulleys are mounted so that they
can be lowered and raised as a unit without disturbing
their relative adjustments. (T.S., 59:226)

1,690,203. A. J. Nikes. Nov. 6, 1928. Adjustable
slice. The object of the invention is to provide a slice
and support therefore which are adjustable in varying
positions in order to permit of an adjustment of quanti-
ty of stock behind the slice to prevent the stock being
forced out under the slice if the stock in the stock box
accumulates to too great a height. The outlet opening of
the stock box is adjustable by means of a vertically ad-
justable gate, the bottom of which carries a block to
which is pivoted a forwardly extending stock-retaining
board supported at its forward end by a series of verti-
cal links to adjust its position. The forward end of the
board is pivoted to the slice, and the front end of the
slice is supported by means of a series of vertical links
similar to those supporting the forward end of the stock
retaining board. (T.S., 90:300)

1,698,028. F. B. Clements, assignor to Bryant Paper
Co. July 31, 1934. Slice. The ordinary slice wall is re-
placed by a rubber covered perforated roll built in sec-
tions, each of which is expandible independently of the
others. The roll is mounted close to a dam and is adjust-
able relative to the dam so as to regulate the amount
of stock flowing from the head box to the wire. (T.S., 100:
265)

1,712,852. E. H. Streeter, assignor to Wood Conver-
sion Co. May 14, 1929. Stock spreading box. A board machine
having an intermittent movement of the wire correlated
to the pressing time has a flow box moving transversely
in the CD correlating with the wire movement.

Slice consists of a vertical plate extending across the
width and near the bottom of the flow box which can be
adjusted vertically. Attached to the lower end of the
plate is the slice-lip which extends down and forward.
Adjusting means for the lip plate are provided at inter-
vals across its width. (T.S., 31:217)
1,727,928. E. E. Berry, assignor to Saloit Iron Works. Sept. 10, 1929. Flow control for flow boxes of paper machines. The walls of the flow box and the baffles are preferably inclined upward and forwardly toward the delivery end, providing circuitous up and down passages, the walls of which at the bottom turns are curved so as to eliminate dead corners. In the last passage before reaching the discharge outlet, stock travels vertically downward, which construction insures against a quiescent condition of stock in the region contiguous to the slice. One or more rotating mixers (preferably of the form described in U.S. patent 1,629,088, May 17, 1927) are provided in the last downward pass before the stock reaches the slice, and additional mixers may also be provided in some of the other passages. In order to prevent formation of eddies and cross currents in the stock as it flows onto the wire, a series of thin flat plates parallel to the direction of wire travel are mounted in the space between the last mixer and discharge orifice. The slice plate is equipped at its lower end with a flexible lip, preferably a strip of rubber having parallel front and back faces and a curved rear-bottom face which defines, with the top surface of the apron, a converging mouth leading to the discharge orifice. Lip body is held against the front wall of the slice plate by a series of guide plates or brackets which allow vertical adjustment of the lip on the slice plate. The lip body is adjustably connected at spaced points throughout its length to the slice plate by a series of screw connections, preferably arranged in alternation with the guide plates. This enables extremely accurate regulation of the discharge orifice and permits setting the lip to vary the stream depth at different points. (T.S., 31:216)

1,751,359. E. J. Trimbley and G. R. Walker. March 25, 1930. Flow box. In order to obtain a more uniform stock flow onto the wire across the width of the machine, the usual type of headbox is replaced by a short shallow spout containing a rotatable blade-carrying member extending horizontally across the width of the spout. Blades dip successively into the flowing pulp as they are moved forward by the pulp stream, and in their passage extend across the path of flow. In this way the greater portion of the slime-accumulating surfaces in the headbox are eliminated thus reducing breaks. (T.S., 31:166)

1,771,606. A. E. Yoder. July 29, 1930. Adjustable making board and flow deflector for paper making machine. The invention, while applicable to the Fourdrinier, is particularly adapted for cylinder machines to guide and equalize stock flow to the cylinder mold. A vertically adjustable making board is mounted at the upper part of the baffles over which stock flows into the vat proper. A series of closely spaced deflector plates are mounted
on the making board; they are arranged in groups, each of which is independently adjustable as regards its angular position relative to the making board. (T.S., 93:10)

1,774,363. Harry Fletcher. Aug. 26, 1930. Stock conduit. Purpose of the invention is to provide a stock conduit for delivery of the stock directly onto the wire of the Fourdrinier with the elimination of screens, head boxes, agitation, etc., which is obtained by the shape of the conduit. It is constructed to deliver definite volumes of stock and to reduce the velocity gradually and smoothly. Enlargement in cross sectional area for reducing the velocity of flow is brought about by gradually increasing the width until it is substantially equal to that of the flow box at its point of communication with the latter; the depth of the conduit is decreased at a considerably smaller rate than the increase in width. It is claimed that with this stock conduit the speed of the machine can be increased without detriment to delivery of the stock to the wire. (T.S., 93:10)

1,775,965. R. T. Lang, assignor to American Voith Contract Co. Inc. Sept. 16, 1930. Stock inlet. Bottom of the stock box has a longitudinal groove, back of and parallel to the outlet through which stock flows onto the wire. A perforated roll mounted in the recess and a vertical baffle plate mounted over and parallel to the roll, are so placed that the stock must pass through the roll just before it is delivered to the wire. (T.S., 93:11)

1,803,044. C. W. Valentine, assignor to The Bagley and Sewall Co. April 28, 1931. Slice. A secondary slice is placed in the head box behind a slice constructed according to U.S. patent 1,619,168 of March 1, 1927. The secondary slice is constructed and mounted so that it can be adjusted toward and away from the apron board independently of the main slice. The secondary slice is particularly valuable in obtaining the proper formation in the manufacture of fine papers on high speed machines. (T.S., 93:262)

1,809,937. F. Hilsheimer. June 16, 1931. Inlet. The inlet or slice mechanism, particularly adaptable to the Fourdrinier, includes a plate which forms the top of the outlet or headbox. The plate is mounted on a shaft extending across the machine so that by turning the shaft by means of a suitable worm gear the plate and inlet mechanism may be swung upward to an inactive position or downward to an active position, this providing a rough or quick adjustment for the inlet as a whole. The forward end of the plate carries a bearing rod on the forward position of which projects a longitudinally extending bar
which projects across the machine width and supports the slice. By rocking the bar about the rod, a fine adjustment is provided for the space between the lower edge of the slice blade and the wire, which constitutes the space through which stock flows. The blade is supported by means of a number of spaced brackets provided with adjustable screws by which the blade may be flexed or distorted in the vertical plane so that the feeding space may be varied in height throughout the length of the slice. (T.S., 93:369)

1,812,276. G. S. Witham, Sr. June 30, 1931. Paper making machine. In order to cross the fibers after the pulp has passed the slice, a rotary agitator is provided at a point just after the stock has flowed under the slice and onto the wire. (T.S., 93:368)

1,818,667. H. J. Niles. Aug. 11, 1931. Slice. The invention provides a self-adjusting slice which compensates for the inequalities of adjustment of the slice to provide accurate determination of the thickness of the paper. The slice is arranged with respect to the center of the breast roll so that it is of the minimum distance from the center thereof, so that both sides of the sheet will be made the same without streaks or mottling as a result of perfect distribution over the wire. A yielding seal is provided between the wire and the stuff box so as to provide an enlarged pool of stock to provide an even distribution of stock over the wire. In order to prevent, as much as possible, the fibers from issuing under the slice parallel to the flow direction, a number of disks are mounted on a rotating shaft as close as possible to the outlet of the stuff box, the disks being in two sets inclined in opposite directions. (T.S., 94:253)

1,818,668. E. H. Berry, assignor to Beloit Iron Works. Aug. 11, 1931. Regulating flow of stock on Fourdrinier paper machine. This covers improvements to the U.S. Patent 1,618,777. It provides a simplified and improved construction for facilitating the making of changes in deckle width and at the same time affords a greater range of adjustment of the slice or slices. The change of the deckle width is made with the machine at rest; but the fine adjustments for controlling flow of stock and the deposit of fibers may be made while the machine is running. Provision is made for a sectional slice having a single lip which is interchangeable with lips of different lengths corresponding with the slices for different deckle widths. (T.S., 94:253)

1,816,777. A. Aldrich and E. H. Berry, assignors to Beloit Iron Works. August 11, 1931. Regulating flow of
stock on Fourdrinier paper machines. The invention provides various novel features of construction of Fourdrinier paper machines which permit of making various adjustments in the slices either individually or collectively while the machine is in operation. (T.S., 94:283)

1,622,023. Sieberer. Sept. 8, 1931. Paper machine. The use of a series of hydraulic boxes under the wire both before and after the slices to give regulation to the drainage rate and the rate of settling of fibers to offset the tendency of the fibers to assume the machine direction.

1,633,351. E. E. Berry. Nov. 24, 1931. Paper machine. The use of suction elements under the slice region with additional support for the wire in order to give continuous suction action from the time the stock is delivered to the wire until the sheet is formed and sufficient water has been extracted to allow its removal from the wire.

1,841,933. A. Aldrich and E. E. Berry, assignors to Beloit Iron Works. Jan. 19, 1932. Stock flow device. A plurality of concentric perforated cylinders that may or may not be relatively rotated and through which the stock flows and then through the slice. Its distributing and evening effect make a long pass headbox unnecessary and also discourage the machine direction alignment of fibers.

1,847,426. N. H. Bergstrom. March 1, 1932. pulp distributor. Use is made of horizontal vanes whose general direction is that of the machine, placed above the wire and dipping into the stock, beginning in front of the slice and extending an appreciable distance down the table; their function being to keep an even distribution of pulp over the wire surface.

1,856,347. E. J. McDonnell. Fourdrinier machine. Use is made of a forming table of transversely placed boards under the wire to retard drainage in order to utilize the influence of the shake over a longer period.

1,866,607. F. Wood, assignor to Scott Paper Co. July 12, 1932. Slice and headbox. A gradually tapered passage or throat from the headbox to the slice nozzle, whereby the stock is given an accelerating speed of flow and velocity of discharge with a minimum of agitation. The slice is constructed to permit thickness of the sheet of stock flowing onto the wire to be adjusted at various spaced points transversely across the machine, and also for modifying the thickness of the stock as a whole without disturbing the local adjustments. (T.S., 35:288)
1,873,111. W. H. Cannard. Aug. 23, 1932. Fourdriner paper machine. The stock is delivered on the wire from a cylindrical container located above the wire near the breast roll and extending transversely across the machine. The bottom of the container is provided with a slot extending for its full length. The length and width of the slot, and the height of the container can be regulated in order to regulate the sheet width and amount of stock flowing to the wire. A suction box is provided under the wire directly under the slot through which the stock is delivered. (T.S., 96:233)

1,880,057. J. S. Sherman, assignor to Brown Co. Sept. 27, 1932. Method and machine for making paper. The flowing stream of stock is given a lateral component of motion by causing a wide belt to move directly under the stream in a direction substantially perpendicular to the flow direction immediately before the stock reaches the wire. Suction is provided under the wire at the point where the stock reaches it.

1,880,686, 1,884,688. E. E. Berry, assignor to Beloit Iron Works. Oct. 4, 1932. The first is an improvement on Berry’s U.S. patent 1,833,551 of July 15, 1929. The stock is delivered to the wire directly above the first one or two sections of the suction device through a pipe extending across the full width of the machine and having a longitudinal slit along the upper side and a number of downwardly directed holes on its lower side. Before coming on the wire the stock passes through a rotating perforated cylinder which totally surrounds the feed pipe. Uniform flow and distribution of stock is further assisted by providing a number of oscillating agitating bars, with transversely extending blades, mounted a slight distance above the forming wire. 1,880,688 deals more particularly with the oscillating agitating bars having transversely extending blades.

1,881,985. F. C. Hazmmburg, assignor to Scott Paper Co. Oct. 11, 1932. Method of preventing pitch formation on paper machine. Two plates or grids, or two series of plates or grids, are mounted at some point in the path of the stock, preferably in the headbox, and are charged with opposite polarities; e.g., b, means of a d.c. dynamo, suitably at approximately 115 volts. (T.S., 97:195)

1,885,334. W. A. Darrah. Nov. 1, 1932. Process and equipment for forming sheets. Stock is fed onto and endless wire, the path of which is in the form of a circular loop, the sheet being inside. A speed of 2,000-3,000 feet per minute is used; centrifugal force aiding water removal. (T.S., 97:283)
1,889,819. E. L. Berry, assignor to Beloit Iron Works. Dec. 6, 1932. Method and means for delivering stock to the Fourdrinier wire. The customary flow box and accessory devices are eliminated. The stock is fed directly from screens into both ends of a rotating stock delivery cylinder, form which it passes outwardly through small delivery orifices and flows onto the wire. (T.S., 97:283)

1,890,634. L. Wenzel. Flow rectifier. Dec. 13, 1932. Rotating shaft carrying a number of smooth surfaced disks is mounted across the head box, as closely as possible to outlet, and a number of flow-obstructing elements (pins, plates, etc.) are between the plates in order to restrict stock flow and so avoid formation of uneven flow and turbulence. (T.S., 97:283)

1,903,678. E. Poirier, assignor of 25/100th to J. A. Stobie. Jan. 10, 1933. Paper making process and machine. The head box is designed so that variations in stock consistency are utilized to control the rate of delivery and maintain an approximately constant rate of delivery of dry fiber. (T.S., 97:283)

1,938,372. W. H. Hyde, assignor to Northwest Paper Co. Feb. 21, 1933. Stock inlet. The apron over which the stock flows from the head box onto the wire is provided with a hill-like obstruction formed by a roll eccentrically mounted on a shaft under the apron and just back of the breast roll, so that the height of the obstruction can be adjusted while the machine is running.

1,902,798. W. H. Cape, assignor to S. D. Warren Co. March 21, 1933. Slice. The patent covers various mechanical features in design and construction of an extensible, flexible slice built up of a series of overlapping plates. The latter are mounted so as to be individually adjustable toward or away from the wire; and the slice as a whole is pivotally supported so it may be adjusted without disturbing adjustments of individual plates.

1,904,780. A. E. Goflin. April 18, 1933. Smoothing stock on the wire. A driven roll between the breast roll and table rolls to smooth the ripples, etc.

1,906,355. F. C. Bagley and F. P. Silver, assignors to Maine Seaboard Paper Co. May 2, 1933. Stock inlet. The inlet comprises a bottom apron, side plates and a top apron assembled as a unitary structure. Means accessible from the exterior are provided for bodily adjusting the inlet in a vertical direction.
1,989,156. W. Bell-Irving and R. Sandwell. May 16, 1933. Fourdrinier head box and nozzle assembly. The nozzle presents an upwardly inclined flow passage for delivering the stock on the wire, and a rectifier is mounted in this passage.

1,918,514. R. E. Berry, assignor to Beloit Iron Works. July 13, 1933. Screen type flow evener. This aims to combine the functions of screens, flow evener, and head box and thereby completely eliminate the headbox as a unit of the machine - device is of such structure that stock emerging is in conditions to be passed directly to the wire.

1,928,107. T. T. Lang, assignor to American Voith Contact Co. Sept. 26, 1933. Method and apparatus for bringing paper stock onto the wire. The angle of discharge flow of the stock relative to the wire is adjustable according to the operating conditions.

1,936,603. B. E. Teale. Nov. 28, 1933. Slice. The invention provides a unitary structure of a slice that can be readily attached to or removed from a Fourdrinier machine. Construction permits adjusting or deforming the lower edge to conform to irregularities across the wire. (T.S., 99:39)


1,957,913. C. S. Smith. May 8, 1934. Process for making paper. A portion of the disclosure reads: "slice is provided at the stock discharge and with lip concave towards the apron. It is claimed to produce better felting action by reducing parallelism of the fibers". (T.S., 99:227)

1,961,771. B. A. Zalkin, assignor to Dominion Engrg. Works, Ltd. June 5, 1934. Slice assembly. A flat slice plate is supported in a vertically inclined position by a pair of laterally adjustable pond sides. Plate is mounted on and fastened to the pond sides so that it can be bodily adjusted in the plane of its inclination, and is equipped for locally flexing the lower edge at various points between the pond sides. (T.S., 99:236)
1,968,028. W. B. Clements, assignor to Bryant Paper Co. July 31, 1934. Slice. Use is made of a roll with an expandable surface in place of the wall common in slice construction, and provision of a dam behind the roll and means for adjusting the relative positions of the dam and roll and to regulate stock flow from headbox to wire.

1,974,103. J. C. Corcoran, assignor to Superior Tool and Mfg. Co. Sept. 16, 1934. Manufacture of paper. An apron is formed with two sets of raised ribs extending at an angle to the direction of wire travel. Above the apron is a formation slice in the form of a bar with its under surface provided with sets of raised ribs inclined oppositely to the corresponding sets of ribs on the apron. (T.S., 106:285)

1,984,484. G. K. Filberry. Dec. 16, 1934. Apparatus for feeding Fourdrinier machines. Object of the invention is to cause the stock to flow evenly onto the wire and to form itself, before draining starts, into a sheet of the desired width and thickness moving in a quiescent state at the same speed as the wire. This is obtained by running a non-porous band around the breast roll and under the wire for a considerable distance. For certain grades of paper a series of transverse parallel "equalizer blades" dip into the travelling pond of stock on the wire, and are driven at a speed that is preferably slightly slower than that of the wire. A weir-like head box instead of the typical slice is also included. (T.S., 101:155)

1,988,447. H. L. Rutter. Jan. 15, 1935. Paper making machine. Included in the wet end construction is "a first slice located substantially over the breast roll, a forming table, a forming board spaced from the breast roll to provide an initial free drainage portion of the wire, the forming board approaching the breast roll beneath the wire to form a throttling pathway to limit the rate of drainage through said initial portion to a predetermined amount, and a second slice located over said forming board".

1,989,435. I. Wallquist. Jan. 29, 1935. Method and device for making paper. Fluid jets are directed against the stock on the Fourdrinier wire while it is still in fluent condition, in a direction such that currents are set up in the stock substantially perpendicular to the direction of wire travel. (T.S., 101:244)

1,998,381. E. J. Hellentine. April 16, 1935. Paper making machine. Stock is delivered to the breast roll at constant flow through a specially designed stock-feeding nozzle which has a spread equal to the width of the breast roll and wire web, and has a narrow opening which is
adjustable at intervals along its width to insure micro-meter metering of the flow therefrom. (T.S., 103:315)

2,006,066. S. Amantea. May 7, 1935. Paper making machine. The outlet or flow box is movably connected to the head box in such a way that it can be telescoped into the head box when changing the wire. Deckles consist of an angle iron on each side of the flow box, with a strip of flexible material extending downward from the lower edge of the angle iron to the wire. (T.S., 103:315)

2,022,298. A. O. Neilson. Nov. 26, 1935. Slice paper machine slice has thin, flexible, rubber lip, built in overlapping sections that are individually adjustable vertically. Outer sections are flat across the bottom and the inner one has a tapered edge. Laterally adjustable deckles are provided, the inner edges of which engage the slice lip. (T.S., 103:218)

2,027,611. N. J. Nika. Paper making machine. Jan. 14, 1936. The stock box is constructed in such a manner that the breast roll projects into one corner of the box and forms a part thereof. Rotary drum stirrers behind the breast roll are also included. (T.S., 103:215)

2,028,673. R. T. Lang, assignor to American Voith Co., Inc. Jan. 21, 1936. The upper portion or lip of the stock inlet is provided with an adjusting board which extends over the width of the box and is connected between two flexible parts, one of which is connected with the inlet structure and the other which is supported from the adjusting board itself. The parts are adjustable in their direction of their width and relative to the adjusting board. (T.S., 103:215)

2,028,952. J. J. Reimer. Jan. 26, 1936. Apparatus for and method of making paper. A combination drain and float box device is mounted under the Fourdriner wire close to the breast roll. It consists essentially of a box, divided into suitable number of compartments extending transversely of the machine, each compartment open at the top and provided at the bottom with means for feeding liquid at a regulated rate. By feeding water to the box at a suitable rate, the formation of the sheet may be controlled as desired, and by supplying a suspension of filler, the latter may be incorporated into the sheet and through the wire, and two-sidedness eliminated. (T.S., 103:215)
2,034,402. E. A. Leloff. March 17, 1936. Headbox construction. In a papermaking machine having a headbox, the combination with the front wall of the headbox which forms an opening for the discharge of pulp slurry, of a horizontal elongated member mounted to lie inside the headbox, said member presenting a surface extending upwardly and rearwardly from the opening.
Foreign Patents

Austria

127,198. Firma J. K. Voith, Heidenheim. Nov. 15, 1931. Stock outlet for Fourdrinier and similar machines by which fibrous material can be blown out by means of compressed air on a de-watering wire or felt. The amount of stock of desired consistency which can be deposited onto the de-watering wire or felt is regulated by the pressure or by the speed of the current of air. (T.S., 97:193)

134,537. Firma J. K. Voith, St. Polten. April 15, 1933. Inlet for stock for a Fourdrinier or carton machine.

Belgium


England

181,146. F. H. Lonaghan. March 16, 1921. Feeding fibers on the machine at high speeds. (Canadian Patent 213,368. Oct. 25, 1921) A strong and satisfactory web can be made at high speed (1,000 feet per minute) on a Fourdrinier or similar type machine by feeding water and stock onto the machine under pressure, and providing means whereby stock, after passing under the slice, accumulates in a pool through which the rate of flow of stock is approximately equal to the wire speed. The desired velocity is given the stock by using more water than usual, and by suitably adjusting the pressure head in the flow box. Pool may be formed by extending the apron over the machine wire for a short distance or by placing the apron behind the axis of the breast roll. In the case of difficulty in removing water from the web at high speed the suction box end of the wire is raised. The main feature of this process is that by maintaining a pool of stock above the wire, the fibers become well mixed and give a well felted sheet. (T.S., 97:132)

229,530. F. Voith. Stock inlet. The depth of stock flowing onto the wire is regulated by means of an adjustable and flexible gate, and the delivery of uniform stock is insured by means of a rotary perforated drum situated at the discharge port and capable of being driven at
different speeds. The gate is supported by adjustable links by which it may be levelled, and can be raised and lowered by the rotation of a shaft carrying eccentric from which the links are hung. (T.S., 82:59)

235,864. F. Voith. Feed box. The bottom of the feed box is arranged in the same plane as the wire on which stock is fed, so that the flow of the lowest stratum of stock from the tank onto the wire is horizontal and a perfectly even web of good surface is produced. (T.S., 82:282)

237,598. C. Bucking. In the production of paper of substantially uniform strength in all directions, the stock is caused to eddy before or during its settling onto the wire. Eddies are formed by delivering the stock onto the wire through vertical pipes having guide surfaces or worms therein, the pulp being fed from the bottom portion of the box upward through the pipes. (T.S., 82:272)

249,071. Lead Pulp and Paper Co. Controlling the flow of stock to the wire. The flow of stock to the wire is controlled by a flexible plate, extending across the width of the machine and over the apron. The plate is pivoted to a slip member, which in turn is pivoted to a curved plate member, the pivot being extended at its ends to form a stub shaft carrying a worm wheel engaged by a worm by the rotation of which the lip member may be raised or lowered. The flexible plate can be adjusted throughout its length by a number of screws provided with locking nuts. A graduated disk and a fixed pointer facilitate adjustment. When it is desired to lift the breast roll in order to change the wire, the stub shaft is rotated to lift the lip member. The apron, which is conveniently hinged, may be connected by a chain to the lip member. (T.S., 82:250)

254,381. F. Voith. Fourdrinier stock inlet. The lip which controls the flow of pulp in this improved Fourdrinier is divided and provided with a movable end piece which can be displaced relative to a main part so that panels of different width can be introduced or removed for the purpose of varying the transverse extent of the lip, and consequently varying the quantity and thickness of pulp delivered according to the width of the web it is desired to produce. (T.S., 84:296)

285,311. F. Offenheimer, C. Block, E. Offenheimer, trading as Cellulose Fabrik Okritlet a. E. Offenke imper. Regulating and gauging the thickness of paper. The thickness of paper is regulated by a latch placed behind the
usual froth ledges and mounted on a lath carrier vertically adjusted by means of a screw spindle fitted in recesses in end plates rotatable by a worm and sector in side cheeks. Local adjustment through the length of the lath is made by regulating screws. Jets of liquid, steam or gas act on the gap between the cheeks and wire cloth to prevent leakage of pulp. (T.S., 82:227)

380,599. Beloit Iron Works. Sept. 12, 1932. Paper making machine. The stock which is supplied to the interior of a revolving perforated drum flows directly onto the wire of the paper machine; the wire and a suction device are beneath the drum.

419,369. I. Gallquist. Nov. 12, 1934. Fourdrinier paper making machine. pulp at or near the flow box of the machine is subjected to water, steam, gas, air, vapor, etc. supplied from an outside source to produce transverse currents which are evenly distributed across the wire and tend to lay the fibers transversely of the wire. (T.S., 101:316)

France

601,120. J. C. Bucking. July 21, 1925. Feeding stock onto the wire. In order to obtain as uniform felting as possible in all directions, the stock is agitated immediately before and as it is being fed onto the wire. Preferable to do this by producing a large number of relatively small eddies. The method consists of feeding stock vertically upward through a large number of relatively small tubes just back of the apron, each tube being provided with a screw or spiral to impart a rotary motion to the stock as it is discharged onto the table. (T.S., 82:164)

607,737. Buda Ligno and Paper Co. July 7, 1926. Stock inlet. The top of the stock inlet is in the form of a hinged lip, and by adjusting the position of the lip the thickness of flow of stock can be regulated according to the thickness and weight of the paper. The lip is adjustable across its width in order to make up for any irregularities in the thickness across the width of the sheet. (T.S., 84:289)

620,299. J. ... Voith Maschinenfabrik. High pressure stock inlet for Fourdrinier. The front wall of the stock inlet is sloping so as to form an acute angle with the bottom of the inlet, and in the acute angle thus formed is placed either a rotating, perforated roll or a rotating shaft fitted with a paddle, so as to effect a thorough mixing of the stock as it is delivered onto the wire.
Back of the distributing and mixing roll is a deflector or baffle which divided the stock into two streams which combine again after passing the baffle, thereby further improving the mixing. (T.S., 86:56)

658,370. A. Renard and Papeteries Malauence. July 25, 1926. Elastic slice for boradratic. The slice, instead of being of rigid copper or brass bars, telescoping into one another, are made of a suitable soft, elastic, and plastic material, such as ebonite, mounted on a rigid horizontal bar which is vertically adjustable. (T.S., 90:232)

669,712. J. L. Voith Co. Feb. 15, 1929. Method and apparatus for feeding stock to paper machine at low speeds. A perforated roll is mounted across the flow box near the apron at such a height that it is always submerged completely. Above and ahead of this roll are vertical plates or "froth dams" which when the level of the stock is above the top or roll forces all the stock to pass through the roll to agitate it and insure uniform distribution across the full width of the wire and to remove entrained air.

697,157. J. L. Voith Co. October 21, 1930. Stock inlet. Instead of letting the stock flow onto the wire by gravity, it is delivered to and uniformly distributed onto the wire by means of compressed air. If desired, a number of nozzles may be provided to deliver stock or fillers at several points along the length of the wire. (T.S., 33:117)

742,382. J. L. Voith Co. Flow box and nozzle for delivering stock to the paper machine. The flow box and nozzle are mounted so as to be bodily adjustable in a vertical direction, in a horizontal direction toward or away from the breast roll, and angularly so as to vary the direction of delivery of the stock relative to the wire.

768,222. J. L. Voith Co. Feb. 6, 1934. Production of sheets of uniform formation. To make the AD and CD nearly equal stock is delivered so that it is vigorously agitated at the moment it reaches the wire. This may be done by delivering the stock to the wire in a relatively thin sheet directed diagonally downward at 40 deg. The apron may be eliminated, the stock being delivered directly to the breast roll. (T.S., 106:135)

772,395. I. Allquist. (T.S., 101:314)
765,436. R. W. Lillspaugh. Feb. 8, 1935. Paper machine. In a sheet of paper formed directly on an endless wire passing around a suction roll that is in contact with stuff in the head box, agitators (preferably consisting of parallel blades that are reciprocated transversely of the length of the suction roll) are provided in the stock close to the roll, so as to deflect the fibers transversely of the direction of wire travel and thus produce a sheet having increased transverse strength. (T.S., 103:215)

Germany

376,422. L. Benz. April 1, 1923. Mixing stock. Screens are so arranged as to give a thorough mixing of paper stock just before it flows onto the wire, also permitting more fibers to be deposited perpendicularly to the machine direction. (Papierefabr. 21; 186)

521,502. M. Colombo and Firma. 1anger. Heutlingen. Jan. 7, 1926. Fourdrinier machine with an endless wire laid over a suction cylinder. The machine has a suction cylinder instead of the breast roll and table rolls. An endless wire runs over the suction cylinder, which revolves in a stock solution and takes it up by means of the suction in the lower part of the cylinder. (T.S., 94:152)

527,129. J. M. Voith Maschinenfabrik, Heidenheim. May 30, 1928. Stock inlet for paper, board and carton machines. The invention concerns a device which brings the stream of stock in its entire width onto the wire in a direction oblique to the wire direction. In this manner the tendency for fibers to mat in the wire direction is eliminated. (T.S., 94:254)

535,589. G. Knopp, Berlin. October 3, 1929. High pressure stock inlet. An endless moving band is used as the side or front of the head box facing the wire. The thickness of the paper is regulated by the distance of the lower roll above the wire. (T.S., 95:91)

537,059. October 15, 1929. An addition to the preceding patent. (T.S., 95:91)


583,291. Firma J. M. Voith, Heidenheim. Oct. 4, 1931. Arrangement for bringing stock onto the paper machine wire. Stock is brought onto the wire by regulation of three things, namely, the distance from the breast roll, the direction, and height.

585,147. G. Knupp, Berlin. Oct. 17, 1931. Fourdrinier paper machine. With the ordinary stock inlet there is too much MD orientation; so the idea is to offset this. The stock inlet chest extends onto the wire, there being an agitator in the chest and three dams; and to hold the stock at the other end a large roll rotates directly above the breast roll.


611,585. O. Schmidt. July 28, 1931. Stock inlet for Fourdrinier. The lip of the inlet is curved so that the stock comes onto the wire tangentially to the breast roll. (T.S., 103:57)


Norway

47,349. S. Caspersen, Trondheim. June 19, 1926. Automatic regulator for stock inlet on a board machine. Regulation of the stock inlet is carried out through a sliding gate which is influenced by one or more floats submerged in a stock trough, the motion being transmitted by gears and a rod. (T.S., 92:12)

tator lies completely in the stock at the lowest level.
(T.C., 33:34)

Sweden

63,936. E. Hendel, Stockholm. Oct. 6, 1926. Process and arrangement for production of paper on a Fourdrinier. In order to hasten the dewatering process on the wire, stock is forced into a swirling motion just after its entrance in the wire by means of a special eccentric.
(T.C., 32:12)