Jan. 5, 1965 G. L. CALEHUFF 3,164,513

DISTRIBUTOR SYSTEM FOR A PAPER MACHINE HEADBOX

Filed Dec. 14, 1961 2 Sheets-Sheet 1

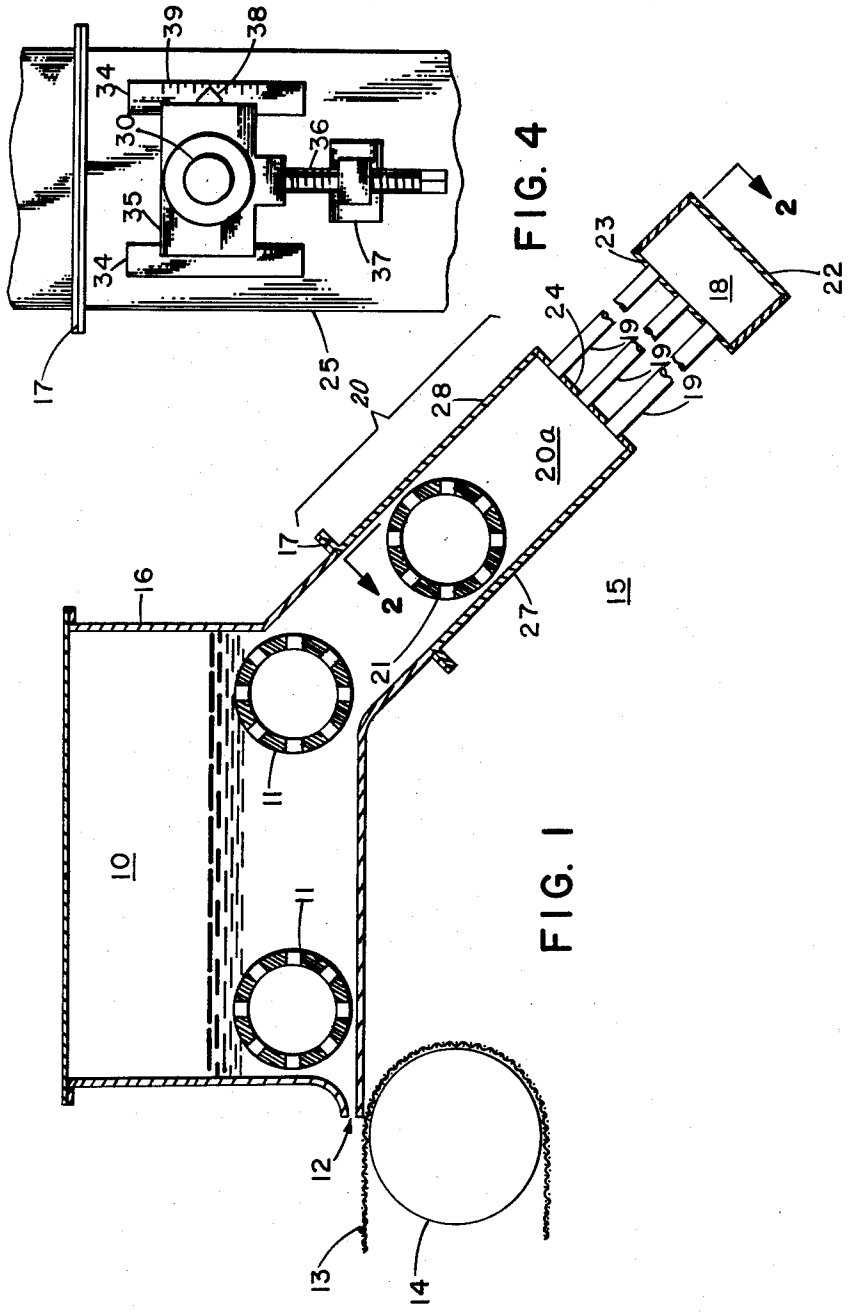


FIG. 4

FIG. 1

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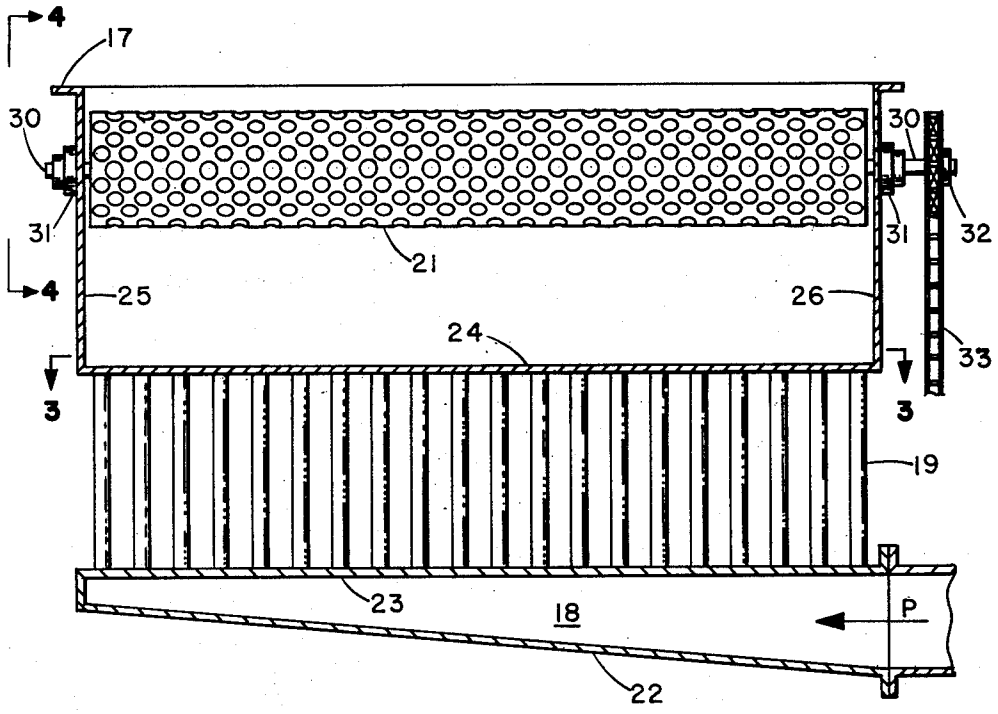


FIG. 2

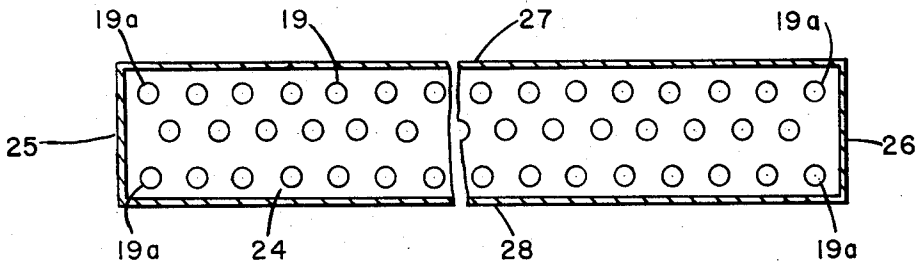


FIG. 3

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DISTRIBUTOR SYSTEM FOR A PAPER MACHINE HEADBOX

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10 Claims. (Cl. 162—212)

This invention relates to new and useful improvements in a method of and an apparatus for distributing a dilute paper stock uniformly across the width of a paper machine headbox.

The function of a distributor system is to convert the flow of dilute paper stock from flow in a round pipe as is the condition of flow approaching the distributor system to a flow in a rectangular passage extending the width of the headbox as is the condition of the flow leaving the distributor system. The velocity and direction flow of the dilute paper stock must be carefully controlled during the conversion by the distributor system so that the fluid velocity leaving the system is essentially uniform and so that the direction of the flow leaving is everywhere parallel (no cross-flows). An ideal distributor system would convert the flow so efficiently that no further flow eveners would be necessary. The dilute paper stock would flow from the distributor directly onto the paper web former.

Even in headboxes having complex flow eveners and flow rectification means, i.e., rectifier roll, large scale velocity differentials will travel from the outlet of the distributor system through the headbox to the slice resulting in unequal slice jet velocities. Regardless of the headbox construction, an efficient conversion of the flow of dilute paper stock is necessary.

The velocity profile must be controlled by the distributor system so that fluctuations or surges in the inlet piping are ineffective in general to the outlet flow and in particular to the slice jet velocity. It is well known in the art of papermaking that flow irregularities remaining in the system after the distributor system in the form of non-uniform velocity profiles, unstable velocity profiles or non-parallel flow conditions cause undesirable deviations in the physical properties of the finished paper such as varying basis weight profiles and sheet strength due primarily to poor fiber distribution. Since the fluid acted upon by the paper machine distributor system is essentially a forced suspension of solids (wood fibers) in a liquid which will settle or flock together in relatively tranquil regions, the distributor system should be a cause of constant mixing and agitation of the dilute paper stock.

Various distributor systems have been set forth in the past to obtain the flow conversion in such a manner that a stable and uniform velocity profile is obtained in the headbox in general and in particular at the slice. Although these distributor systems have improved upon the flow conversion as compared to earlier systems, nevertheless they have retained or added undesirable characteristics. Some of the systems share various modifications of a highly desirable common element in the tapered manifold which in basic form employs the hydrodynamics of a reducing cross-sectional area to subject the dilute paper stock to a substantially constant pressure. The tapered manifold normally extends across a back wall of the headbox and contains a slotted or perforated wall extending the width of the headbox. In operation, the stock is introduced into the larger end of the tapered manifold and is forced through the slotted or perforated wall as the stock travels toward the smaller end. Experience has shown that the perforated wall does not redirect the dilute paper stock into the headbox properly unless each perforation is

accurately designed. Even when the perforations are designed to turn the stock, alterations to the total flow through the tapered manifold override the design and result in poor stock turning. The fibers carried in the dilute paper stock tend to build up on the perforated plate. Sometimes the fibers are washed off by the flowing force of the dilute paper stock or build up until some of the perforations are completely clogged. Neither effect is desirable. The flocks of fibers that are washed off are not easily broken up and usually appear in the finished product as a lump or form a thickened area in the paper web which may be picked or removed from the web during passage through various machine components, resulting in a hole in the web and ultimate rejection by the user. Plugging of the perforations by the dilute paper stock obviously reduces the ability of the perforated plate to distribute the dilute paper stock into the headbox evenly thus created a variance in the flow across the headbox and at the slice. The slotted wall does not redirect the dilute paper stock into the headbox in a direction substantially perpendicular to the slice but allows a flow that is angled toward the side of the headbox nearest the smaller end of the tapered manifold and creating large scale velocity differentials and flow eddies. The effect can be easily explained by realizing that the dilute paper stock in the manifold contains a velocity component that is substantially parallel to the original inlet direction. The velocity component cannot be effectively overcome by the slot which creates no resistance to cross flows. Attempts to overcome the turning problem associated with the perforated and slotted walls have been tried by placing baffles that originate at the manifold and extend perpendicularly away therefrom into the headbox. The baffles blocked the velocity component that forces the stock toward the wall of the headbox near the small end of the tapered manifold but did not control the direction of the flow between the baffles; i.e., the flow toward the upper and lower walls of the headbox. The turning problem associated with the above systems can be substantially reduced by using a row of pipes having a length of between 6 to 10 times the internal diameter. However, the pipes, as employed in the prior systems, presented problems in blending or mixing the streams from each pipe into a single rectangular stream bounded by the headbox.

Mixing is an important phase of the distributor system and in the past has been a troublesome feature. Some terminated the pipes in a chamber of appreciably greater width than the diameter of the row of pipes. These chambers, commonly referred to as explosion chambers, contained a solid plate upon which the dilute paper stock issuing from the row of pipes impinged. Theoretically, the impingement converted the kinetic energy present in the dilute paper stock issuing from the pipes to a static pressure that should have existed uniformly throughout the explosion chamber. The static pressure then forced the dilute paper stock through a slot angled relative to the original pipe inlet direction. In actual practice, a portion of the area in the explosion chamber was blocked by standing eddies fromed from the dilute paper stock. The eddies acted as the inner and outer walls of an elbow and in the areas containing the eddies, the dilute paper stock was turned and flowed through the slot with little or no kinetic energy change. The overall effect was a varying cross machine flow velocity that ultimately appeared as a differential slice jet velocity.

Other systems employed diffusers that were attached to the row of pipes at the oulet ends. The dilute paper stock flowing through these diffusers was subjected in some cases to separation and in all cases to very slight deflocculation tendencies.

Still others employed a wall having a series of parallel

slots that were arranged substantially perpendicular to the inlet end of the manifold. This system, while it would redirect the flow in a direction perpendicular to the inlet flow direction, would not control flow conditions within each slot. The resulting flows may or may not have been parallel and were quite similar in effect to the diffusers discussed above.

Striving to overcome the minor pressure variations present in the tapered manifold, still others added flow controlling vanes within the rows of pipes. These systems were not only complex and expensive but required additional maintenance and presented cleaning problems.

Still other manifold systems employed frozen flow conditions where there was little or no turbulence in the dilute paper stock. These systems had inherent cleaning problems and were applied to paper machines of relatively narrow operating speed ranges and relatively constant stock furnishes. The frozen flow distributors were usually expensive and difficult to add to existing headboxes and therefore were not used as improvement additions to existing paper machine headboxes.

Therefore the principal purpose of this invention is to provide an even and stable velocity flow of dilute paper stock to the headbox regardless of the flow conditions of the feed pipes and to redirect the flow in such a manner that the flow streams are parallel.

In addition, this invention overcomes the relative complexities present in some of the earlier distributor systems and thereby is adapted to be used as an improvement modification on existing paper machine headboxes.

The present invention also has overcome the hydrodynamic problems inherent in the headbox distributor system depending upon impingement and redirection theories for evening the flow such as the explosion type distributor systems.

It has removed flocculation problems resulting from low shear fields and large secondary flows.

It contains a novel means for reducing the pressure variations inherent in the tapered manifold without complicating the structure and reduces the effects of pressure surging.

It is constructed to subject the dilute paper stock to continual agitation, preventing stock flocks and breaks up stock flocks formed prior to the distributor systems.

The distributor is applicable to a wide range of machine speeds and stock furnishes.

Further advantages of this invention will hereinafter more fully appear in connection with a detailed description of the drawings in which:

FIGURE 1 is a sectional elevational view of the distributor system according to a preferred embodiment of this invention, and of a conventional-type headbox and breast roll associated therewith.

FIGURE 2 is an elevational view taken along the line 2—2 of FIGURE 1.

FIGURE 3 is a sectional view taken along the line 3—3 of FIGURE 2.

FIGURE 4 is a sectional elevational view taken along the line 4—4 of FIGURE 2.

Referring to FIGURE 1 of the drawings, the headbox is indicated by the reference 10 and is shown for the purposes of illustration as a pressurized type containing two flow evener rolls 11 for preventing the buildup of minor flow irregularities as the stock travels through the headbox to the slice 12 that feeds the dilute paper stock onto the forming wires 13 at the breast roll 14. The preferred embodiment of the distributor system 15 is angled to the upstream wall 16 of the headbox and extends the width of the headbox. The distributor system 15 is connected to the headbox by the flanges 17 and, in the particular embodiment shown, consists of the tapered manifold 18, three rows of parallel pipes 19, a headbox inlet chamber 20, mixing portion 20*a* of the headbox inlet chamber, and a perforated mixing roll 21. The elements in combination provide a distributor system

that not only overcomes the disadvantages of the prior art systems but also carries out the function of a distributor system in a more economical and efficient manner. In order to obtain a clear understanding of the operation of the distributor system, each component will be discussed thoroughly following a brief detailed description of the preferred embodiment.

Referring to FIGURE 2 of the drawings, the dilute paper stock, as indicated by the reference letter P, flows from a suitable supply (not shown) into the wider end of the tapered manifold 18. The tapered manifold has a lower wall 22 that slopes gently toward a pipe receiving wall 23. The dilute paper stock is subjected to a flow division wherein a portion flows through the three rows of parallel pipes 19 as the dilute paper stock progresses through the manifold internal area from the larger end toward the smaller end. The lower wall 22 is designed to a slope toward the pipe receiving wall 23 so that the dilute paper stock flowing through the internal area will be in a zone of relatively constant pressure.

From FIGURE 2, the three rows of pipes 19 have the outlet ends received by the transition wall 24. From FIGURE 3, the three rows of pipes 19 can be seen terminating in holes in the transition wall 24 in a patterned, systematic manner that extends throughout the cross sectional area of the transition wall. As shown in FIGURE 3, each pipe is preferably equally spaced from the nearest pipe, forming a geometric pattern, wherein each pipe can be imaginarily joined by straight lines extending from pipe center to pipe center to form a system of equilateral triangles. The pipes in middle row are staggered from the pipes in the outer rows so that the equilateral spacing will occur with the outer rows of pipes being terminated with a pipe 19*a* located in proximity of each of the corners. The distance from the pipes nearer the edges of the transition wall 24 is preferably approximately half the distance separating the pipes. The word "distance," when used herein with reference to the space separating a pipe from an edge of a wall or from another pipe, means the "separating" distance, or the distance measured from the closest point on the inside surface of a pipe to the closest point on the edge of a wall or on the inside surface of another pipe, as the case may be. From FIGURE 1 and FIGURE 2, notice that the pipes extend substantially perpendicularly away from the transition wall 24 of the headbox inlet chamber and are mutually parallel and equal in length. As indicated in the drawings, the pipes extend perpendicularly along their entire length away from transition wall 24. While it is not necessary for this relationship to exist over the full length of the pipes, they should extend upstream for at least a portion of their length perpendicularly away from transition wall 24. As a result, the jets of dilute paper stock issuing from the pipes will be substantially perpendicular to the transition wall 24. All pipes have the same diameter and have equal lengths which are considerable as compared to the diameters.

The headbox inlet chamber 20 is defined by transition wall 24 forming its upstream boundary, inlet tending wall 25 and inlet drive wall 26, which are parallel to each other, two parallel inlet sidewalls 27 and 28, and the plane between the flanges 17 connecting the distribution system to the headbox, such plane forming the downstream boundary of headbox inlet chamber 20.

The transition wall 24 forms the upstream boundary of the mixing portion 20*a* of the inlet chamber. Referring to FIGURES 1 and 2, the remaining boundaries of the mixing portion of the headbox inlet chamber are formed by the lower portions of inlet tending wall 25, the inlet drive wall 26, and two inlet sidewalls 27 and 28. The lower or impinging surface of the perforated mixing roll 21 forms the downstream boundary of mixing portion 20*a*. The mixing portion thus defined is the region in which the flow of the dilute paper stock is blended into a single stream covering the cross sectional area of the headbox

inlet chamber. The headbox inlet chamber is preferably constant in cross sectional area substantially equal to the cross sectional area of the transition wall **24**. To be more precise, it can be clearly seen that all cross-sectional areas of the headbox inlet chamber **20**, when measured in any plane therein parallel to the transition wall **24**, are equal to each other and substantially equal to the area outlined by the boundaries of transition wall **24**, and that the mixing portion **20***a* of the headbox inlet chamber has the same cross-sectional area measurements. The dilute paper stock is required to expand only once and that expansion occurs in the mixing portion which can be carefully controlled by the perforated mixing roll **21**.

Referring to FIGURE 2, the perforated mixing roll **21** has its shaft **30** rotatably held by the bearings **31** so that the lower or impinging surface is in spaced parallel arrangement with the transition wall **24**. The mixing roll **21** has a ratio of open to closed area of about 35 percent and is driven by any suitable means which is indicated by the sprocket **32** and chain drive **33**. A standard roll used in the industry to even velocity differentials within the headbox performs quite satisfactorily as a mixing roll. By rotating the mixing roll, the possibility of fiber build up on its surfaces is eliminated. A rotative speed of approximately 6 to 10 r.p.m. will prevent fiber build up.

It is highly desirable to have a means for moving the mixing roll toward and away from the transition wall **24**. FIGURE 4 is illustrative of a means for providing this movement. Two angle members **34** are rigidly attached in spaced, parallel relationship on the inlet tending wall **25** and the inlet drive wall **26**. A bearing block **35** spans the distance separating the two angle members and carries the shaft **30** of the perforated mixing roll **21**. It is to be understood that the bearing block **35** is provided with suitable slots that mate with the angle members **34**. The bearing block **35** is held by the slots in such a manner as to limit the movement to a direction of upwardly and downwardly between the angle members **34**. A threaded shaft **36** is attached to but rotatably free of the bearing block **35**. A spacer **37** has internal threading that mates with the threaded shaft **36**. The spacer **37** is rigidly attached to the inlet tending wall **25**. By rotating the threaded shaft **36**, the bearing block **35** will be moved upwardly or downwardly between the angle members **34**. A pointer **38** is rigidly attached to the bearing block **35**. The pointer **38** moves with the bearing block **35** and passes with the bearing block **35** along the graduations **39** that are etched or otherwise placed upon the adjacent angle member **34**. Inlet walls **25** and **26** contain identical units. The position of the mixing roll can be accurately determined by and repositioned by the relation of the graduations **39** with the pointers **38** downstream from the transition wall **24** such that the lower surface of the mixing roll **21** is equally spaced from the pipe outlet ends.

In the tapered manifold **18** the relative slope between the lower wall **22** and the pipe receiving wall **23** can be designed based on hydrodynamic principles so that the dilute paper stock will be subjected to a zone of equal pressure for a certain value of total flow through the internal area. The design results in a lower wall that is curvilinear and in a manifold that will develop pressure differentials within the internal area when the total flow deviates from the design total flow. A popular practice in the paper industry has been to simplify the construction and the design to reduce the cost of the manifold by substituting a series of angularly connected straight segments for the curvilinear lower wall. Deviations from the theoretical curvilinear shape of the lower wall resulting from design deficiencies, manufacturing inaccuracies or from the usage of segmented lower walls will cause corresponding pressure variations in the internal area of the tapered manifold. The pressure variations will appear in the prior art distributor systems as velocity differentials in the inlet sections of the headbox and can ultimately appear as velocity differentials at the slice.

The tapered manifold used with the distributor system preferably employs a lower wall designed to approach constant internal pressure conditions. However, the lower wall **22** when used as a part of the distributor system designed according to the invention could be straight without forming detrimental velocities differentials in the slice, even in the absence of a complex flow evening headbox. It will become evident in the following discussion that the shape of the lower wall **22** is no longer critical when employed in a distributor system designed according to the invention. The underlying reasons for the non-criticality of the heretofore critical shape of the lower wall will be obvious after the important and novel features of the distributor system are explained.

By utilizing a region of high energy loss, the distributor system has incorporated a novel means for removing the velocity differentials that would normally appear in the headbox and at the slice as a result of the pressure deviations developed by the manifold. Those skilled in the art of hydrodynamics can reason that the ability of upstream pressure deviations to effect downstream velocities in a fluid can be substantially removed by passing the fluid through a region of high energy loss. In applying this theory, the present invention employs a multiplicity of rows of long pipes **19** that have a predetermined energy loss in the form of friction losses to overcome the ability of the pressure deviations developed by the manifolds that result from segmented lower walls, from the usage of non-tapered manifolds, or from changes in the total flow through the manifold, to produce downstream velocity differentials in the headbox and at the slice. As a result, the dilute paper stock leaving each pipe is substantially uniform and equal in velocity.

The pipes are employed to overcome another pressure variation that is present in the flow of dilute paper stock, pressure surging. Fluctuations or surges in the pressure of the dilute paper stock delivered to the tapered manifold caused by apparatus located upstream from the manifold, such as a pump, develop random velocity differentials within the headbox and at the slice that vary directly with the square root of the pressure fluctuation or surge. Pipes having relatively small diameters and having considerable lengths as compared with the diameters, effectively control the effect of the pressure surges by decreasing the associated random velocity differentials within the headbox and at the slice. In addition, the ability of the pipes to dampen fractional velocity differentials resulting from pressure surges can be increased within limits proportionately with an increase in velocity of the dilute paper stock within the pipes. This follows because a pressure surge of a given magnitude in a given pipe, changes the fluid velocity by a fixed absolute amount independent of the mean velocity so that the ratio of the velocity change to the mean velocity decreases with increasing mean velocity. A velocity of approximately 5–30 ft./sec. will effectively dampen most of the pressure surges developed before the manifold and overcome the tendency of the pressure surges to develop random velocity differentials within the headbox and at the slice. When the pipes are long enough to substantially reduce the effect of pressure deviations and pressure surges, the flow of dilute paper stock is completely redirected and the turning difficulties associated with some of the prior manifold systems having slotted or perforated walls are overcome.

In the preferred embodiment of the distributor system the pipe length is, within limits, varied directly with the pressure surges developed upstream from the manifold; i.e., the pipe length necessary to remove the random velocity differentials within the headbox increases with the amplitude of the pressure surge for constant values

of velocity through the pipes. In a similar manner the pipe length is varied, within limits, directly with the pressure deviations in the manifold; i.e., the pipe length necesary to remove the velocity differentials within the headbox increases with increases in the pressure deviation. Both effects can usually be rendered ineffective in ability to produce velocity differentials in the headbox by employing pipes having a length of about 3–10 ft. and a diameter of about ½ to 3 inches or a length-to-diameter ratio of from 40 to 1 to 72 to 1. The controlling factor, as discussed earlier, is not the exact physical dimensions of the pipes but the energy loss through the pipes. The physicald imensions given are those that will yield an energy loss in the range of approximately 2–5 ft. of water.

Flow of dilute paper stock can be broken down into three relatively distinct flow regimes which for round pipes seem to be characterized by: (1) Reynolds number $=DV/\nu$ where D is pipe diameter, V is average velocity and ν is a kinematic viscosity, usually the kinematic viscosity of water at the prevailing fluid temperature, (2) Pipe diameter and (3) Fiber characteristics such as flexibility, length, stock consistency, etc. In the first regime the fibers form a coherent network (fiber plug) in the center of the pipe so that all the change in fluid velocity from average velocity to zero at the pipe wall takes place in an annulus adjacent to the pipe wall. This annulus is usually of very low consistency. This so called plug flow does not allow fiber flocs to be broken up, and hence should be avoided in paper machines.

The second regime is obtained by increasing the velocity (V) above that required in the first regime. In this type of flow the annulus becomes turbulent and begins to destroy the center plug and is often referred to as mixed flow because it consists partly of a fiber plug in the center of the pipe and a turbulent annulus. The presence of the fiber plug infers poor mixing and large flocs both of which are undesirable for the paper maker.

The third regime consists of a fully turbulent flow and hence has the greatest mixing and deflocculation action. Present experience in the industry indicates that for the usual papermaking consistencies and for pipes having relatively small diameters, the turbulent flow regime occurs for Reynolds numbers above about 10^5. The flow through the multiple pipes should be such that the turbulent regime is obtained. The minimum velocity required may not be defined by a Reynolds number of 10^5 because of the influence of consistency and fiber properties, etc., however if precise data is not available DV/ν should be at least 10^5 for a multiple pipe manifold.

Experience has indicated that the functions of the pipes can be carried out with pipes having diameters in the range of ½ to 3 inches. Pipe diameters below ½ an an inch have tendencies to become clogged with the fibers carried by the dilute paper stock. As explained above, the pipes will overcome the pressure deviations more efficiently as the length is increased, therefore maximum limits on pipe length cannot be given based on desirable operation alone. Space limitations, available pump head and economic considerations decide practical maximum pipe lengths. Keeping these facts in mind, the pipes will ordinarily have a length of less than 20 feet, and will perform in the range of 3–10 feet, which under normal conditions, if the velocity of the dilute paper stock through each pipe is in the range of 5–30 ft./sec., will have sufficient pressure drop (energy loss) to overcome both random and steady state pressure deviations. Commercially clean stainless steel pipes are preferred because there is a minimum tendency of the stock to adhere to the walls. Equal diameter pipes having an equal length are preferred which results in an equal pressure drop (energy loss) and velocity through each pipe.

The jets of dilute paper stock must now be mixed or blended into a single stream of essentially uniform velocity extending the width of the paper machine headbox. Referring to FIGURE 3 of the drawings, notice that the pipe outlet ends terminate in a transition wall 24 in a patterned, systematic manner that covers the cross sectional area of the mixing portion with high energy jets, destroying any tendencies of the formation of large scale counter current or standing eddies. By spacing the outlet ends of the pipes substantially as shown in FIGURE 3, the stock issuing from each pipe is required to expand only one half of the separating distance. As stated earlier, over-expansion of the dilute paper stock in the distributor system is detrimental to the formation of the paper web. By keeping the separating distance of the pipes below approximately five times the diameter of the pipes, over-expansion is no problem. Further, by locating the outlet of a pipe in each corner and by locating the pipes relatively close to the walls, the corners and the walls of the mixing portion of the system are purged by high energy jets which prevent the formation of standing eddies and fiber build up on the walls. Optimum mixing conditions are realized when the pipes are separated by approximately one to two times the internal diameter. Odd numbers of rows of pipes are preferred over an even number because the pattern of the outlet ends can be deployed as explained above.

Referring to FIGURE 2 of the drawing, notice that the pipe outlet ends are positioned upstream from the mixing roll 21 so that the jets impinge upon the lower surface of the mixing roll. The surface impingement when interrelated with the spacing of the pipes completely mixes and blends the streams into a rectangular flow of substantially equal velocity. The outlet ends of the pipes are positioned relative to one another and to the mixing roll so that the jets of dilute paper stock issuing therefrom will physically and violently interact with one another and form a condition which is preferably described as controlled jet mixing. Optimum impingement conditions are realized when the mixing roll has a ratio of open to closed area in the range of 20–50%. A ratio of approximately 35% will perform the jet blending quite satisfactorily. Experimental results indicate that the velocity of the jets when leaving the outlet ends of the pipes should be in the range of 5–30 ft./sec. with optimum controlled mixing occurring in the range of 10–20 ft./sec. Omission of the mixing roll can result in substantial pressure variations, large scale secondary flows and uncontrollable turbulence remaining in the headbox inlet chamber. Controlled jet mixing vanishes when the mixing roll is improperly positioned, and the jets no longer interact and blend but become separated jets of high energy that have a tendency to set up large scale eddies and uneven flow patterns (non-parallel flow).

The mixing roll has three distinct and important functions. First, the mixing roll provides a surface which forces the jets of dilute paper stock to blend in a controlled uniform manner before they have an opportunity to establish an uneven flow pattern. Second, the energy conversion is obtained without subjecting the dilute paper stock to over-expansion and redirectional flow paths, removing the possibility of forming uncontrollable turbulence that is inherent in systems containing redirecting chambers. Third, the mixing roll subjects the stock to an additional velocity evening zone which is contained within the internal area of the mixing roll further equalizing the velocity profiles in the distributor system. Referring to FIGURE 1 of the drawings, notice that the flow of dilute paper stock in the distributor system is subjected to only one turning which occurs at the entrance ends of the pipes. The flows of dilute paper stock is thereafter substantially straight and is contained within the headbox inlet chamber which is preferably constant in cross sectional area. As a result, the distributor system has completely removed the possibility of any uncontrollable, unpredictable, or unpredeterminable turbulence, secondary eddies, or velocity differentials that are present in distributor systems subjecting the flow to multiple turning con-

ditions, and has removed the possibiblity of over-expanding the dilute paper stock after mixing and blending.

The mixing roll should be separated from the outlet ends of the pipes by approximately five inches and not more than approximately 20 inches. Experience has shown that 12 inches is workable in most cases. The exact location is best determined by adjusting the position of the mixing roll and observing the reaction of the slice jet velocity. FIGURE 4 of the drawings is indicative of an adjusting device.

A distributor system of the type described herein is necessarily complex to design properly because of the number of factors that must be taken into account, all of which are decidedly important but some of which are necessarily dependent upon more controlling factors. The following discussion deals with a design procedure which is felt to be desirable. The design procedure can be affected by conditions that vary from paper machine to paper machine. As an example, adding the distributor system to existing paper machines sometimes develops space limitations, and requires increasing the available pumping head.

Under ordinary conditions the design can be determined by knowing the flow at which the paper machine will be running the majority of the time. The width of the paper machine is related to the total flow of dilute paper stock to determine the size of the manifold. A flow velocity and a pipe diameter for each pipe is chosen so that the flow through each pipe is fully turbulent (has a Reynolds number of at least 10^5), thus creating deflocculation conditions within the pipe. Pipe diameter and velocity are divided into the total flow to determine the number of pipes necessary. The number of pipes are physically deployed to obtain proper mixing and to prevent over-expansion. The number of rows of pipes is decided upon, usually an odd number is preferred so that the deployment is as described earlier. The size of the transition wall **24** is determined by the pipe deployment, with the exception of the length which is determined by the width of the paper machine. The length of the pipes is determined based on the aforesaid principles that the ability of pressure deviations to cause velocity differentials is inversely proportional to the energy loss. An energy loss of 2–5 ft. of water in the pipes will usually overcome the pressure deviations. Finally, the position of the mixing roll is determined. The mixing roll should have an outside diameter just slightly less than the depth of the mixing portion of the headbox inlet chamber and a length substantially equal to the width of the headbox inlet chamber. This removes the possibility of developing large scale flows of dilute paper stock between the surface of the mixing roll and the walls of the mixing portion of the headbox inlet chamber which would be detrimental to the mixing effectiveness of the mixing roll; i.e., the third function of the mixing roll will be efficiently carried out. The dilute paper stock will be subjected to an additional evening zone during passage through the internal area of the mixing roll. Provisions should be incorporated in the design so that the mixing roll can be rotated to prevent build up of fibers carried in the dilute paper stock on the roll surfaces. The flow of the dilute paper stock can further be subjected to minor corrections by flow evener rolls, reference **11**, FIGURE 1, as the stock progresses from the mixing portion of the headbox inlet chamber to the slice. The usage of the flow evener rolls **11** is well known in the paper making industry and no additional comment is necessary.

The distributor system when designed according to this invention will effectively block upstream disturbances including manifold inaccuracies resulting in stable and uniform flows of dilute paper stock through the headbox. It should be realized that many modifications and variations are possible that are still within the scope of this invention.

I claim:

1. A distributor system for delivering dilute paper stock uniformly to a paper machine headbox comprising:

(*a*) a headbox inlet chamber extending the width of the headbox and opening into the headbox along the full width thereof, and having a transition wall extending the width of the headbox and forming the upstream boundary of said headbox inlet chamber opposite said opening, all cross-sectional areas of said headbox inlet chamber measured in any plane therein parallel to the said transition wall and perpendicular to the direction of flow of dilute paper stock therethrough being substantially equal to each other and substantially equal to the area outlined by the boundaries of said transition wall,

(*b*) a perforated mixing roll mounted within said headbox inlet chamber in spaced parallel relationship to said transition wall,

(*c*) a mixing portion of said headbox inlet chamber defined by the upstream surface of said perforated mixing roll as its downstream boundary and the said transition wall as its upstream boundary, said mixing portion having the same cross-sectional area measurements as defined above for the said headbox inlet chamber,

(*d*) a multiplicity of rows of pipes of equal diameter and of considerable length compared to diameter, having their outlet ends received by said transition wall in a patterned systematic manner throughout the area of said transition wall, said pipe outlet ends being spaced equally apart from each other by a separating distance of at least one times and not more than five times the internal diameter of one of said pipes, said pipes extending upstream for at least a portion of their length perpendicularly away from the said transition wall, and

(*e*) a tapered manifold extending the full length of the said headbox inlet chamber and having a wall receiving the inlet ends of said pipes and an opening at its wider end for receiving the dilute paper stock.

2. The distribution system of claim 1 in which the opposing walls of the headbox inlet chamber are substantially parallel to each other.

3. The distributor system of claim 2 in which the perforated mixing roll is rotatably mounted within said headbox inlet chamber and has an outside diameter slightly less than the depth, and a length along its axis slightly less than the width, of said headbox inlet chamber.

4. The distributor system of claim 3 wherein means are included for moving the said perforated mixing roll toward and away from said transition wall.

5. The distributor system of claim 4 in which the separating distance between the outlet ends of the pipes nearer the edges of the said transition wall and said edges is about one-half the separating distance between the pipes.

6. The distribution system of claim 4 in which the pipes have a length-to-diameter ratio in excess of 25 to 1.

7. The distribution system of claim 4 in which the pipes have a length-to-diameter ratio of from 40 to 1 to 72 to 1.

8. The method of obtaining a uniform flow of dilute paper stock across the width of a paper machine headbox which comprises the steps of:

(*a*) flowing a single stream of dilute paper stock in a path toward the headbox and parallel to the width thereof into an area of gradually reducing size causing the dilute paper stock to be subjected to a relatively constant pressure,

(*b*) dividing and simultaneously redirecting the flow of the single stream of dilute paper stock into a multiplicity of rows of separate and parallel streams flowing substantially perpendicularly to the direction of flow of the single stream,

(*c*) flowing said streams through resistance elements while still in separate and parallel relationship at such velocity of turbulent flow that an energy loss of about 2 to 5 feet of water occurs so that pressure surges and deviations are reduced, the velocity of the flow of the streams is substantially equalized, and the dilute paper stock in the streams is deflocculated by the fully turbulent conditions existing,

(*d*) impinging the streams after they have issued from the said resistance elements in the form of individual jets immediately after the jets have begun to merge together against a flow restricting non-continuous surface in a mixing zone to blend the streams without causing any substantial redirection of the total flow and without causing any expansion of the flow except that resulting from a blending of the individual jets,

(*e*) flowing the blended streams through the flow restricting non-continuous surface to blend them further into one stream of substantially constant velocity, again without causing any substantial redirection of the total flow and without causing any further expansion of the flow, as the stream approaches the inlet opening of the headbox.

9. The method of claim 8 in which the said single stream is divided into a multiplicity of rows of separate, equal-sized, and parallel streams with the streams being separated from each other by a separating distance of at least one times and no more than five times the diameter of each stream.

10. The method of claim 9 wherein the velocity of said individual jets in the mixing zone is in the range of from about 5 to 30 feet per second.

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