(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 936 303 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.08.1999 Bulletin 1999/33

(51) Int Cl.6: **D21F 1/02**, D21F 1/06

(21) Application number: **99630015.8**

(22) Date of filing: **05.02.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **10.02.1998 US 21246**

(71) Applicant: **BELOIT TECHNOLOGIES, INC.**
Wilmington, Delaware 19803 (US)

(72) Inventor: **Neill, Eugene Bruce**
So. Beloit, Illinois 61080 (US)

(74) Representative: **Schmitz, Jean-Marie et al**
Dennemeyer & Associates Sàrl
P.O. Box 1502
1015 Luxembourg (LU)

(54) Expanded flow range edge flow control valve for use in a paper machine headbox

(57) Edge flow control valves located within edge flow tubes of a tube bank in a headbox can be adjusted to optimize fiber orientation of paper produced in a papermaking process. The present invention uses a chamfer at the inlet of edge flow tubes in order to increase maximum flow of pulp through the edge tube and edge valve. The minimum flow range is not changed, therefore, the essential flow range of pulp through the edge flow valve is increased. Laboratory tests have shown at least a 15 percent increase in maximum flow while not changing the minimum flow. Using a chamfer tool with a stop collar to control the depth of the cut, a chamfer is provided at the inlet of each edge flow tube for optimum performance. According to the present invention, paper produced in a papermaking process will have an improved fiber orientation when more flow at the edges of a headbox is needed.

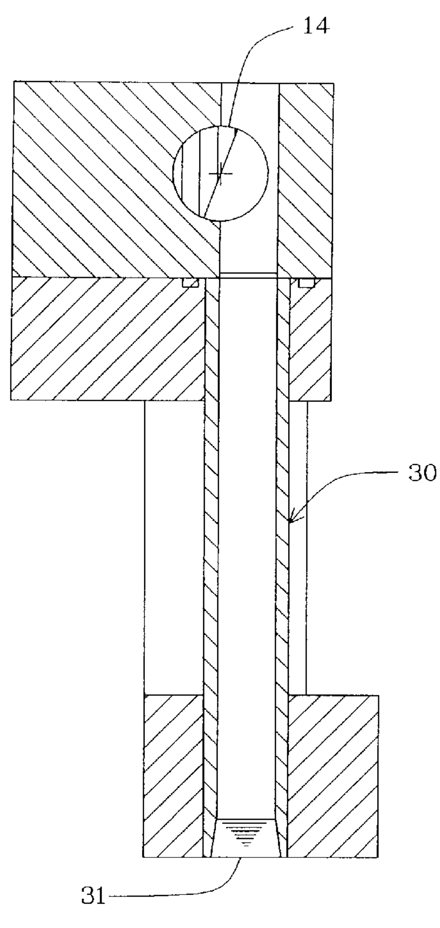

Fig. 8

EP 0 936 303 A2

Description

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates to edge flow tubes and edge flow control valves contained within a tube bank of a paper machine headbox, which edge flow tubes and control valves are used for pulp fiber orientation or pulp fiber angle control; and relates more particularly to expanding the flow range of pulp fibers through edge flow control valves.

DESCRIPTION OF THE PRIOR ART

[0002] A fundamental requirement of any headbox as a part of a paper machine used in the production of paper is to provide cross-directional uniformity in the pulp exiting the headbox. Uniform formation of the pulp leaving the headbox is desired with no fiber flocs and no graininess contained within the pulp flow. The paper machine headbox must also operate in a continuous manner, without substantial build-up of dirt, fibers or chemicals, and it must have the capacity to meet the needs of the high production rates of the modern paper machine.

[0003] Two areas that face increasingly stringent quality demands in the paper produced by a paper machine are uniformity of basis weight profiles on finer and finer scales, and uniformity of fiber orientation profiles. The present invention relates to uniformity of fiber orientation. However, because uniform basis weight profiles are important in having an excellent final paper product, some background is provided with respect to basis weight concerns and applications.

[0004] Cross-directional basis weight variations can be broken down into two categories: wide band and narrow band. The wider band variations are controlled by thermal and mechanical reaction of a headbox structure and by bending of a slice-lip. A typical paper machine headbox slice area, generally known to those skilled in the art, consists of a slice body wall which cooperates with a lower slice wall or apron floor to determine the opening of a slice, where a flow of papermaking stock flows from the headbox and is then delivered onto a forming wire trained about a roll as the flow of stock travels to the next step in a papermaking process. A series of spaced adjusters or actuators are positioned along an upwardly extending body wall from the slice body wall for incremental adjustment of the slice opening. The spaced adjusters or actuators can adjust the slice opening by mechanically manipulating a lower extended body wall or slice-lip of the upwardly extending body wall in movements as small as one ten-thousandths of an inch. In general, control of narrow band variations is not possible if such variations are narrower than twice the actuator spacing. Unless the variations span at least two actuator locations, there are no mechanical control devices available that will level the basis weight profile. Narrow variations are a concern in paper production since they can adversely affect product quality as well as runnability, particularly in coating and supercalendering operations in a papermaking process.

[0005] A historical objective has been to reduce basis weight profile variations on smaller and smaller scales. Over the years, paper machinery manufacturers have been progressively reducing the spacings between slice-lip actuators or jacks used to mechanically control the slice-lip opening in a headbox through which paper pulp flows enroute to the next phase of the production of paper. The earliest systems had adjustments of 300mm centers. A short time later, 150mm centers became the standard. This later dropped to 100mm and, more recently, 75mm centers have been used for all critical paper grades. With these close centers, papermakers or operators have to contend with significant drawbacks: to manually control a large number of actuators is tedious - a move with one actuator causes two or more adjacent slice positions to also change, requiring corrections - and the affected range in basis weight response is multiple actuators wide. Further, slice lips can be permanently distorted if careful monitoring is not provided. Basis weight adjustment with slice-lip bending is complex and inherently difficult to control.

[0006] With advanced computer controls, the job of profiling becomes manageable, but the results in quality are not always better. Saw-tooth profiles are a common occurrence. Mapping and trim measurement are regular issues; and on top of all this, the concept of slice bending for basis weight control is fundamentally flawed.

[0007] Any change to the position of a slice-lip affects not only the local velocity of the slice flow, but also the adjacent velocities, in both magnitude and direction. The velocity in one area can be reduced, but only at the expense of cross-flows to the adjacent areas. As generally known to those skilled in the art, cross-flows of pulp adversely affect fiber orientation. Since uniform fiber orientation is one of the primary goals in the production of paper and a subject of the present invention, a concept discussed more fully below, slice-lip bending is clearly unacceptable. Ideally, an objective of papermakers today is to be able to control basis weight profiles independently and apart from controlling fiber orientation profiles. The Concept IV-MH™ headbox sold and manufactured by Beloit Corporation is capable of independently controlling basis weight and fiber orientation. U.S. Patent Number 5,196,091 describes a headbox apparatus with stock dilution conduits for basis weight control.

[0008] The headbox in the '091 patent incorporates a fundamentally different approach to profile control-flow consistency. Basis weight is a function of both the consistency and slice opening. If, instead of controlling the slice-lip profile, the local consistency is varied, the basis weight profile can also be controlled.

[0009] An approach available in the headbox of the '091 patent is to control local flow consistency as opposed to bending a slice-lip to control cross-directional basis weight. With this approach, the local basis weight is adjusted by increasing or decreasing the local flow consistency. The slice opening can be kept uniform, eliminating headbox cross-flows, complex control algorithms and bending limitations of a conventional slice-lip, thereby, also eliminating adverse affects to fiber orientation.

[0010] The headbox of the '091 patent provides an injection system used to control flowability to control cross-directional basis weight. The headbox of the '091 patent utilizes a uniquely shaped tapered header for receiving pulp stock, followed by a tube bank which consists of distributor tubes whose first and primary function is to turn the flow of pulp stock 90 degrees into the machine direction for cross-directional flow distribution, and a nozzle section consisting of Converflo™ multiple vanes or flexible sheets; the nozzle section being in-line with the tube bank in order to maintain a high velocity without a change in fluid direction which is required for a stable flow delivery and a clean headbox operation.

[0011] In the headbox of the '091 patent, individual injection tubes are added to the tube bank. Typically, there is one injection tube per vertical row of headbox tubes and each individual injection tube is located between adjacent rows of vertical tubes. Each of these injection tubes meter low consistency white water into the header, just upstream from an adjacent headbox tube. The low consistency flow turns and goes directly into the adjacent flow tube. In this way, as a result of the location of the injection tubes and the flow of the low consistency flow, the consistency across the machine can be controlled on centers as small as 35mm; which is generally half the distance between the centers of the adjacent rows of tubes.

[0012] An important features of the Beloit Concept IV-MH™ headbox is the tube bank design. The Concept IV-MH™ tube bank includes a series of flow tubes - each with a circular entrance, a sudden expansion to a larger diameter, and a gradual transition to a rectangular exit. This novel tube is described in U.S. Patent Number 5,196,091, and shown in figure 4. The design lets the flow of pulp accelerate through the transition. The designed tubes provide a pressure drop to help achieve uniform cross-directional flow distribution. Ample turbulence is generated for fiber dispersion, and the tube bank establishes a uniform velocity profile into a nozzle section, without cross-flows. In addition, Beloit's Concept IV-MH™ headbox optimizes uniformity of stock consistency by providing the ideal tube length. Tests have shown that longer tubes can produce basis weight streaks. The shorter tubes of the Concept IV-MH™ headbox provide profiles of much more even consistency.

[0013] A headbox such as that described in the '091 patent may also feature a parabolic-shaped tapered header. This shape precisely matches the theoretical shape needed for uniform pressure distribution across the width of a paper machine. The result is more uniform cross-directional flow distribution for better sheet quality.

[0014] Another feature of the Concept IV-MH™ headbox is the in-line flow path from the header, through the tube bank and through the slice opening - while maintaining high nozzle velocities. This provides stable flow delivery and clean headbox operation.

[0015] The nozzle section of the Concept IV-MH™ headbox is divided into multiple channels, each separated by a flexible sheet. These sheets control fine scale turbulence and maintain layer purity. The Concept IV-MH™ delivers exceptionally low turbulence intensity near the discharge of the headbox. This low intensity, with high stability, is important for high speed operation. One nozzle section using such flexible sheets is described in U.S. Patent Number 3,607,625 assigned to Beloit Corporation. Such flexible sheets are sold and marketed by Beloit Corporation as the Converflo™ sheets. The high flow stability of the Concept IV-MH™ headbox tube bank and nozzle combination maintains a discrete flow stream to the slice opening, and the result is a high resolution profile control.

[0016] Still a further feature of the Beloit Concept IV-MH™ headbox injection system is that while consistency is being changed, the flow rate through the headbox tubes is not. This eliminates the potential for cross-flows being generated in the nozzle, and makes it possible to profile basis weight without generating a fiber orientation problem. As mentioned earlier, fiber orientation is the other area that requires stringent quality demands in the production of paper. The basis weight concerns are identified and dealt with through the dilution control system of Beloit's Concept IV-MH™ headbox as described in the '091 patent. The fiber orientation concerns are the subject of the present invention.

[0017] As noted, a second issue in paper production that demands attention in modern paper machines is fiber orientation control. This is a property that is heavily dependent on headbox design and operation, and is critical to many grades of paper. Fiber misalignment can influence twist warp in linearboard, diagonal curl in copy papers, and stack lean in forms bond.

[0018] Fiber orientation profiles are more sensitive to headbox flow conditions than basis weight profiles. Fiber misalignment can exist even with a flat basis weight profile.

[0019] There are many factors that affect fiber orientation profiles. These include approach piping, header pressure distribution, headbox tube patterns (especially at the edges), cross-flow conditions, cleanliness, slice-lip profile, stock spread on the wire and forming activity. The basic mechanisms to control and measure fiber orientation have been available and are well understood to those skilled in the art.

[0020] Beloit's Concept IV-MH™ headbox has been engineered as a totally new approach to profile control. Instead of depending on slice-lip deformation, as described above, the new Concept IV-MH™ provides localized control flow consistency. This, as described, permits easier, more accurate control of basis weight profiles. Additionally, fiber orientation is regulated by opening or closing high-capacity edge flow control valves, a subject of the present invention. Fiber orientation control is totally independent of basis weight profile control.

[0021] Fiber orientation profile is affected by flow at the edges of a tube bank. If there is a deficit of flow or an access of flow at the edges of the tube bank, the fiber orientation is non-uniform. On the other hand, if the flow through the entire width of the headbox is nearly uniform, including at the edges, the fiber orientation profile is nearly uniform. For various grades of paper, it is desirable to control fiber orientation by controlling the flow rate through special edge flow tubes in the tube bank. With controlled edge flow tubes, the papermaker has a tool for direct, active control of fiber orientation.

[0022] One method and apparatus for controlling the distortion of fiber orientation in a paper web is described in U.S. Patent Number 4,687,548. The '548 patent describes an arrangement wherein by-pass flows of pulp suspension are passed through opposite passages lateral of a turbulence generator preceding the slice portion, or discharge channel, of a headbox. The magnitude and/or the mutual relationship of the by-pass flows is adjusted to control the distortion of the fiber orientation in that the by-pass flows produce a transverse flow in the discharge flow of the pulp suspension from the headbox, the speed of which compensates for the distortion of the fiber orientation.

[0023] Another method and apparatus to control fiber orientation has been previously used in the Beloit Concept IV-MH™ headbox. Beloit's Concept IV-MH™ headbox accomplishes edge flow control by providing edge flow control valves to regulate flow in the edge tubes forming a part of the tube bank. The Beloit trailing elements or flexible sheets following the tube bank are like a series of parallel flags in the full flow channel which run from one side of the flow channel to the other, and through which all of the pulp suspension flows.

[0024] It has been found, however, that the present square edge orifice inlets of edge flow tubes in a tube bank of the Concept IV-MH™ headbox limit the total flow to the edge flow control valves thereby limiting the amount of flow which exits the edge tubes. In many field operating experiences, the present range of the flow of pulp through an edge flow control valve is not adequate to control fiber orientation or angle. The present square edge orifice inlets and the problems associated therewith will be more fully discussed and described below in conjunction with the description of the preferred embodiments of the present invention.

[0025] Poor pulp fiber alignment or fiber orientation in a headbox affects the characteristics of the final paper produced. Edge flow tubes and edge flow control valves are used to control fiber orientation. However, under current designs, in some circumstances, not enough flow through the edge flow tubes and edge flow control valves is provided to compensate for poor fiber alignment. What is needed is a new edge flow tube and edge flow control valve design which can be used in modern headboxes to increase flow through the edges of a tube bank in a headbox which will allow for improved fiber orientation when more flow is needed in order to correct poor fiber orientation.

SUMMARY OF THE INVENTION

[0026] The solution to increasing flow of pulp through edge flow control valves of a tube bank in a headbox thereby increasing the amount of flow exiting edge flow tubes, resides in using a chamfer at each inlet of the edge flow tubes. The present invention increases maximum flow through edge flow control valves by at least 15%, while not changing the minimum flow through the edge flow control valves. Thus, the present invention expands the flow range through edge flow control valves in a headbox to improve fiber orientation in those situations where more flow is necessary.

[0027] Slice flow control is a key to good profiling in a paper machine headbox. The goal is to adjust the headbox to produce a uniform machine direction discharge which retains this character on a wire following the headbox without table disruption. A flat fiber orientation profile indicates that no cross-flows exist.

[0028] The Beloit Concept IV-MH™ headbox incorporates edge flow control valves. These valves can increase or decrease stock flow in a column of tubes in a tube bank nearest the pondsides, or sides of the headbox.

[0029] It has been found that control of the flow in the end-most tubes can have an immediate effect on fiber orientation, without upsetting the basis weight profile. The edge flow control valves allow papermakers to control fiber orientation by adjusting a stem of the valve located on top of the headbox, front and back. However, at times, wide open flow through the edge flow control valves does not provide enough flow to correct fiber misalignment problems.

[0030] Accordingly, it is a feature of this invention to increase the flow range of edge flow control valves to allow for improved fiber orientation of paper produced by a paper machine.

[0031] Another feature of the invention is to improve uniform fiber orientation, without adversely affecting uniform basis weight profiles.

[0032] A further feature of the invention is to provide a flat fiber orientation profile, thereby eliminating or substantially reducing cross-flow of fiber.

[0033] These and other objects, features and advantages of the invention will become apparent to those skilled in the art upon reading the description of the preferred embodiments, in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Figure 1 is a schematic side view of a typical Beloit Concept IV-MH™ paper machine headbox with a side panel removed to reveal the inside of the headbox.

[0035] Figure 2 is a cross-sectional view taken along line II-II of Figure 1, showing a tube sheet of a tube bank.

[0036] Figure 3 is a cross-sectional view taken along line III-III of Figure 1, showing trailing elements of the headbox shown in Figure 1.

[0037] Figure 4 is a cross-sectional view taken along line IV-IV of Figure 2, showing part of a top view of the headbox shown in Figure 1.

[0038] Figure 5 is a partial top view of the headbox shown in Figure 1 with a top panel of the headbox removed to show the inside of the headbox.

[0039] Figure 6 is an enlarged view of tubes C and M of Figure 4.

[0040] Figure 6a is an enlarged perspective view of one of the tubes shown in Figures 1-6.

[0041] Figure 7 is a graph showing the effect of edge flow as edge flow pertains to fiber orientation.

[0042] Figure 8 is a partial cross-sectional view of an edge flow tube and an edge flow control valve according to the present invention.

[0043] Figure 9 is a schematic representation of the desired fiber orientation of perfectly aligned paper.

[0044] Figure 9a is a schematic representation of fiber alignment when too much flow is exiting the edge tubes of a headbox such as the headbox of Figure 1.

[0045] Figure 9b is a schematic representation of fiber alignment when not enough flow is exiting the edge tubes of a headbox such as the headbox of Figure 1.

[0046] Figure 10 is a partial cross-sectional view of an edge flow tube such as that shown in Figure 8 with a chamfer tool which is used to create the chamfered inlet of the present invention.

[0047] Figure 11 is a graph showing flow as a function of valve position using a square edge orifice inlet for an edge flow tube.

[0048] Figure 12 is a graph showing flow as a function of valve position using a .040 inch chamfered edge orifice inlet for an edge flow tube.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0049] A chamfered edge orifice inlet to an in-line edge flow tube, according to the present invention, is shown in Figure 8. The edge flow tube with the chamfered edge orifice inlet increases the maximum flow of pulp traveling through an edge flow control valve, when necessary, thereby allowing for improved fiber orientation of pulp flowing through a headbox.

[0050] Beloit's Concept IV-MH™ headbox structure with edge flow control valves is illustrated schematically and described in Figures 1-6a.

[0051] Referring to Figure 1, shown is a schematic view of a Beloit Concept IV-MH™ headbox (1). The headbox (1) is divided into four sections. Looking from left to right in the drawing, the headbox (1) consists of a header (2) followed by a tube bank (3) and trailing elements (4) leading into a slice opening (5), which directs a jet of pulp from the headbox to the next step of a papermaking process. A pulp suspension travels through the headbox (1) from the header (2) to the slice opening (5) and is represented by way of arrows (6). The headbox (1) directs the flow of the pulp suspension from a pulp suspension tank (7) shown schematically at the lower left of Figure 1, through the header (2), then from left to right, as shown by the arrows (6) in Figure 1. The pulp suspension flows through tubes (8) of the tube bank (3), then between the trailing elements (4), before exiting to the right through the slice opening (5). The outline of the pulp suspension flow passage of the headbox is shown as edges (9) of the headbox (1).

[0052] Figures 2, 3, and 4 are sectional views showing the interior of the headbox (1) along different cross-sectional lines.

[0053] Figure 2 is a section taken along line II-II of Figure 1, passing through the tube bank (3) to show a tube sheet (10) of the tube bank (3). The tube sheet (10) of Figure 2 is a flat solid sheet of material having a series of holes positioned in rows and columns. Some of the holes of the tube sheet (10) in Figure 2 are given identifying letters C,D,E,F,G,H,I,J,K,L,M,N and O to assist in explaining the operation of the headbox (1) of Figure 1. In Figure 2, the structure in the center of the headbox (1) is omitted, as shown by the break lines found in Figure 2; there are actually far more holes from left to right, and the headbox (1) is actually far wider in relation to its height, than Figure 2 directly shows.

[0054] Figure 3 is taken along section line III-III of Figure 1, passing through trailing elements P,Q,R and S. Again, the structure in the center of the headbox (1) is omitted, and the actual headbox (1) would be far wider in relation to its height.

[0055] Figure 4 is a section taken along section line IV-IV of Figure 2.

[0056] Returning to Figure 2, each hole C,D,E,F,G,H, I,J,K,L,M,N,O and others is the entrance of a separate metal tube (8). The tubes (8) are shown lengthwise in the tube bank (3) in Figures 1 and 4. The same letters refer to the same tubes and/or holes in Figures 1-6. The pulp suspension flows through the tubes (8) in the tube bank (3), and does not flow in the region between the tubes (8), which represents the solid structure of the tube bank (3). The entire pulp suspension flows through these tubes (8).

[0057] The primary purpose of the tube bank (3) is to cause the pulp suspension to turn 90 degrees where the header (2) connects with the tubes (8), and to cause the pulp to run in the same direction (left to right).

[0058] In Figure 2, the tubes C,D,E,F and G on the left side of the tube bank (3) consist of a set (12) of left edge flow tubes (8), which are not visible in Figure 1; the tubes H,I,J,K, and L on the right side of the tube bank (3) in Figures 1 and 2 consist of a set (13) of right edge flow tubes (8). The tube bank (3) is equipped to control the flow of the pulp suspension in the edge flow tubes (C-G) and (H-L) of the tube bank (3). Each set (12) and (13) of edge flow tubes has an individual edge flow control valve (14).

[0059] Refer now to Figure 4 to more clearly see the edge flow tubes. One left edge flow tube (C), one right edge flow tube (H), the non-edge flow tubes (M) and (O), the edge flow control valves (14) for both sets (12) and (13) of edge flow tubes (C-G) and (H-L), the outside flow channel (9), the tube bank (3) and the pulp suspension flowing from a distribution beam (not shown) of the header (2) through the tubes (8) are shown. Only a few of the tubes (8) between the edges (9) of the tube bank (3) are shown in Figure 4 as being representative of the tube bank (3). Figure 4 shows that the valve elements (14), which control flow through the edge flow tubes (C-G) and (H-L) are semi-cylindrical (or half-moon shaped in cross-section) rods.

[0060] In Figures 2 and 4, the left valve element (14) of Figure 2, which is the same as the top, as viewed with respect to Figure 4, element (14) of Figure 4, has been rotated so it extends part way across the left set (12) of edge flow tubes (C-G), partially blocking and thus reducing the flow of the pulp suspension through the left set (12) of edge flow tubes (C-G). The valve element (14) on the right side of Figure 2 and the bottom of Figure 4, as viewed with respect to Figure 4, is turned so its half-moon cross section is completely outside the right set (13) of edge flow tubes (H-L) and, thus, allows full flow of the pulp suspension through the right set (13) of edge flow tubes (H-L). Either valve element (14) can be closed or opened to independently throttle flow through the sets (12) and (13) of edge flow tubes (C-G) or (H-L), respectively. The valves (14) can be reset so either valve (14) obstructs or is clear of the flow of pulp suspension. The valves (14) are controlled by control boxes (15) outside the flow channel (9) shown in Figure 4.

[0061] Now consider Figures 1 and 3, showing the trailing elements (4). The trailing elements (4) are a series of generally parallel but converging individual trailing elements P,Q,R and S -- flexible sheets which are mounted somewhat like flags to a flagpole (though more rigidly), so their right ends as shown in Figure 1 are free to deflect, and their left ends are supported by the tube bank (3). The function of the trailing elements has been set forth in the Background section of this application and is further explained, for example, in U.S. Patent 3,607,625, hereby incorporated by reference, at column 5, lines 52-75.

[0062] The headbox (1) shown and described in Figures 1-6 accomplishes edge flow control by providing valves (14) to regulate flow in the edge flow tubes (C-G) and (H-L) forming a part of the tube bank (3). The trailing elements (4) are like a series of parallel flags in the full flow channel between edges (9) located after the tube bank (3) which run from one side of the flow channel to the other, and past which all of the pulp suspension flows.

[0063] The respective edge flow tubes (C-G) and (H-L) of the headbox tube bank (3) are virtually the same size as the interior tubes (M-O) and, if desired, can be the same size. The respective edge flow tubes (C-G) and (H-L), and non-edge flow tubes (M-O) have nearly the same, or exactly the same, diameters and lengths, and thus present substantially the same resistance to flow.

[0064] To further explain the components of the tube bank (3), reference is made to Figures 5 and 6. Figure 5 is a partial top view with the top panel of the headbox removed showing the inside of the headbox (1) shown in Figure 1. The pulp suspension flows through the header (2) into the tubes (8) and the edge flow tubes represented by tube (C). The flow channel is defined by a left pondside (16) and a right pondside (not shown) of the headbox (1). Some of the pulp flows through the left end of the header (2) and is recirculated via pipes (not shown) to the right end of the header (2). The left edge flow tube is shown with left edge flow control valve (14). Also shown in Figure 5, the control valve (14) is partially closed, thereby inhibiting the total flow through the tube (C).

[0065] Figure 6 is an enlarged view of tubes C and M of Figure 4. As can be more clearly seen, Figure 6a shows the unique tube design of the Beloit Concept IV-MH™ headbox. The tube shown in Figure 6a shows a circular entrance (17), a sudden expansion to a larger diameter (18), and a gradual transition to a rectangular exit (19). The tube design is more further described in U.S. Patent No. 5,196,091, hereby incorporated by reference. As noted, this unique configuration lets the flow accelerate through the transition. The tubes (8) of the tube bank (3) establish a uniform velocity profile into a nozzle section (4), without cross flows of pulp. As shown in Figure 6, left edge flow tube (C) of the set (12) of left edge flow tubes (C-G) is shown with edge flow control valve (14). As shown in Figure 6, the control valve (14) is partially closed, thereby reducing the total flow through the edge flow control valve (14). If the control valve (14) is opened all the way, full flow of the pulp is provided through the edge flow control valve (14). An inlet (22) of the prior art edge flow tubes is best shown in Figure 6a. As can be seen, the inlet (22) is of a square edge design. As set forth in the Background section of this application, the square edge orifice inlet limits the amount of flow traveling through the edge tubes and, as a result, cannot always correct fiber misalignment problems.

[0066] To help illustrate the effect of edge flow on fiber orientation, Figure 7 is provided. Figure 7 is a graph of fiber orientation profiles for two similar headboxes, such as described in Figures 1-6. Line (20) shows fiber angle with respect to cross-machine position of a headbox in a headbox with an edge flow deficit. Line (21) shows fiber angle for a headbox with more uniform flow at the edges. The difference in these profiles illustrates that flow rate at the edges can effect fiber orientation. By controlling the flow rate through special edge flow tubes, the papermaker has active control over fiber orientation.

[0067] Figure 8 is a cross-sectional view of an edge flow tube (30) and an edge flow control valve (14) according to the present invention. As shown in Figure 8, the difference in the edge flow tube (30) shown in Figure 8 as compared to the edge flow tubes described in Figures 1-6 is the inlet to the edge flow tube. The chamfered inlet (31) of the edge flow tube (30) results in increased flow through the edge flow control valve (14) as compared to the square edge orifice inlets of the present edge flow tubes described in Figures 1-6.

[0068] A Concept IV-MH™ headbox, like that shown and described in Figures 1-6, was built and installed recently on a paper machine for a paper mill on the West coast of the United States. Various measuring techniques known to those skilled in the art were employed to measure the fiber orientation of the paper produced on the paper machine. It was determined that there was not enough flow coming out of the edge flow tubes of the headbox because the fiber orientation of the paper was angled out. Shown in Figure 9 is a schematic representation of the desired fiber orientation of paper produced. Figure 9a is a schematic representation of fiber alignment when too much flow is provided through edge tubes of a tube bank in a headbox. Figure 9b is a schematic representation of what happens when not enough flow is provided through edge tubes of a tube bank in a headbox. As generally known, fluid will follow the path of least resistance. Too much fluid on the edges will force the flow of fluid towards the center of the machine as illustrated in Figure 9a. This phenomenon is referred to as an inflow condition. Not enough fluid on the edges will allow the flow of fluid to flow towards the edges of the machine as illustrated in Figure 9b. This phenomenon is referred to as an outflow condition. To help visualize how pulp should exit a headbox, think of a free flowing river. Without any outside influence, the top surface flow of the river will be quite uniform and uninterrupted. If wind travels over the water or a boat travels on the river, waves will be created in the surface of the water thereby affecting the uniform straight flow of the river surface. The waves create a cross-flow condition in the river surface which results in the river surface flowing in a non-uniform, non-linear fashion. A similar flow pattern can be seen in a flow of pulp leaving a headbox if there is too much or too little flow at the edges of the headbox.

[0069] For the particular Concept IV-MH™ headbox installed and tested at the above-mentioned paper mill, the fiber orientation was representative of that shown in Figure 9b; namely, an outflow condition was observed. When the edge flow control valves were fully opened, not enough flow was being provided at the edges to result in the desired fiber orientation as shown in Figure 9. Thus, more flow was needed through the edge flow control valves in the tube bank of this particular Concept IV-MH™ headbox.

[0070] The problems encountered with respect to the above-mentioned Concept IV-MH™ headbox resulted in the invention of the subject application. Previously, in other prior art headboxes developed and used before the invention of the Concept IV-MH™, attempts were continually made to increase flow through tubes in a tube bank. One concept used to increase flow resulted in providing chamfered inlets to standard tubes. However, although chamfering tubes did increase flow, chamfering is not reversible. In other words, there was no control of the flow through the tubes of these prior art headboxes. The edge flow control valves of the Concept IV-MH™ headbox are capable of controlling the flow through the edge flow tubes. However, the square edge orifice inlets of the edge flow control valves do not always provide enough flow at the edges to correct for fiber misalignment. According to the present invention, the combination of edge flow control valves and adding chamfered inlets to edge flow tubes in a tube bank increases the range of flow through the tube while still allowing for the ability to control the amount of flow through the tube.

[0071] The total flow through the edge flow control valves of the current invention is controlled by the edge control valves (14). By providing a chamfered inlet (31) to the edge flow tubes, the flow through the edge flow control valve with the control valve fully opened is increased by at least 15 percent. Reference to Figures 11 and 12 shows this result. The inlet orifices of the edge flow tubes of the troubled Concept IV-MH™ headbox described above were chamfered in order to increase the flow through the edge flow control valves. As the flow increased through the tubes, the outflow fiber orientation shown in Figure 9b was corrected and resulted in fiber orientation as shown in Figure 9.

[0072] Figures 11 and 12, briefly mentioned earlier, show Cv curves for a nonchamfered edge flow tube and edge flow control valve and a Cv curve for a chamfered edge flow tube and edge flow control valve, respectively. Cv is the flow coefficient, for example, a Cv = 1 if it will pass one gallon per minute of water with a pressure drop of 1 psi. As can be seen, at full open, the flow through the edge flow tube and edge flow control valve with a chamfered edge orifice inlet is 15-18 percent greater than the flow through the edge flow tube and edge flow control valve with a standard square edge orifice inlet.

[0073] The inlet to any tube in a tube bank arrangement is a very large contributor to the total head loss or restriction of flow through the tube bank. Adding a chamfer at the inlet of edge flow tubes of the tube bank greatly increases the maximum flow capability through edge flow control valves. If the edge flow control valve is set below 50 degrees, the control valve is the controlling factor in setting the flow, thus, the chamfer, although it increases the flow, does not adversely effect the minimum flow range. As explained above, sometimes it is necessary to reduce the flow at the edges to correct an inflow condition as shown in Figure 9a. However, above 50 degrees, the control valve is no longer the controlling factor in setting the flow. Rather, the controlling factor is the amount of flow traveling through the tube or past the edge flow control valve. A chamfered inlet captures more pulp as it flows from a header to a tube bank which, as a result, increases the amount of pulp flowing through an edge tube.

[0074] As noted, a large influence on fiber angle is caused by flow deficiencies or flow access at the edges of a headbox. An example of a flow deficiency would be, if there was a low flow condition at an edge, the flow from the headbox would flow towards the low flow area (the path of least resistance) and fill it in (like that shown in Figure 9b). This would create a cross-flow that would cause the fiber to align in acute angles towards the center of the flow in the machine direction, this can be corrected by using the edge flow control valve, by simply opening the valve to add more flow at the edge. The edge flow control valve can also be throttled back to decrease flow at the edge, if testing shows a flow access at the edge resulting in a configuration like that shown in Figure 9a. Although there are many components and factors on a paper machine that can influence fiber angle, the edge flow control valve is a very effective tool for adjusting fiber angle as needed to produce a perfectly aligned piece of paper. Having a proper flow-range through the edge flow control valve will allow the papermaker to correct the inflow and/or outflow conditions shown in Figures 9a and 9b, respectively.

[0075] The square edge orifice inlet of the prior art edge tubes does not provide a wide-enough flow range to correct fiber orientation when more flow is needed at the edges. The chamfer, according to the present invention, increases flow by making the inlet orifice of an edge flow tube appear larger than it is. The tube orifice inlet is responsible for a large portion of the resistance through the valve, and the chamfer lessens that resistance and adds to the maximum flow allowable through the edge flow control valve, while still allowing the valve internals to control the minimum flow rate.

[0076] Figure 10 shows part of the edge flow tube of Figure 8 with a chamfer tool which is used to create the chamfer in the edge flow tube. The chamfered inlet of the present invention is produced as follows.

[0077] A .04 inch chamfer is the optimum chamfer because typical edge flow tubes have a tube wall (32) thickness of only .065 inches. Also, typical edge flow tubes are laser welded to a tube bank plate or sheet of a tube bank. The optimum chamfer would not effect the laser weld. The .04 inch chamfer leaves a good margin of safety for structural strength in the tube bank plate and laser weld.

[0078] The chamfering tool (40) has a .25 inch diameter shank (41) so it can be used with a right angle air tool (not shown). Considering the material used for edge tubes, ideal cutting speed is 400 to 600 rpm. The depth of the cut is controlled by using a stop collar (42). The bottom of the stop collar (42) has a Teflon washer (45) attached to protect the surface of the tube bank (3). A cutter (44) pulls chips to the surface and must be cleaned after each tube is completed.

[0079] The chamfered cutter tool (40) is self-centering and doesn't damage the interior surface of edge flow tubes. The cutter (44) may leave a raised edge at the top of the tube, that can be removed with 120 grit green silica carbide stone and emery paper. Any burr or knife edge left from the cutter (44) can be removed with a fine one inch scotchbrite drum. Any chatter marks left from the chamfer tool (40) can be removed with a one inch diameter grinding stone ground at an 82 degree angle.

[0080] The chamfered inlets to the edge flow tubes are generally not cut more than .04 inches wide. Various cutter depths can be set depending on the chamfer width. The procedure is to place a shim (45) over the cutter (44) and set the cutter (44) into a tube to be chamfered, so that point contact is made. The collar (42) is pushed tight against the shim (45) and two set screws (not shown) on the collar (42) are tightened. A spot check should be made before chamfering each tube to insure that the collar (42) has not slipped. The shim thickness will vary depending upon the size of the chamfer required. A 5/8 stainless steel washer cut down to the correct thickness makes an excellent shim.

[0081] In order to provide the most flow through the edge flow control valves as possible, a chamfer should be provided in all edge flow tubes within a set of edge flow tubes located at the edges of a tube bank of a headbox.

[0082] While an apparatus for expanding the flow range of edge flow control valves in a tube bank contained within a headbox has been shown and described in detail herein, various changes may be made without departing from the scope of the present invention.

Claims

1. A headbox assembly for expanding a flow range of pulp traveling through edge flow tubes of a tube bank within the headbox, said headbox assembly comprising:

    a header for receiving a flow of pulp suspension;
    a tube bank following the header, the tube bank containing a plurality of tubes through which the pulp suspension flows;
    a nozzle section located after the tube bank, the nozzle section containing flexible sheets along which the pulp suspension flows;
    a slice opening downstream from the nozzle section which directs a jet of the pulp suspen-

sion from a headbox to a further papermaking process;

an edge flow tube making up a portion of the plurality of tubes of the tube bank, said edge flow tube being located at an outermost edge region of the tube bank;

an edge flow control valve interconnected with said edge flow tube for controlling the amount of pulp suspension that travels through said edge flow tube;

a chamfered edge orifice inlet being a part of said edge flow tube, whereby the combination of said chamfered edge orifice inlet, said edge flow tube and said edge flow control valve expands the flow range of pulp traveling through said edge flow tube in order to improve fiber orientation within a paper product produced in a papermaking process.

2. A headbox assembly as set forth in Claim 1, further comprising:

a second edge flow tube making up a portion of the plurality of tubes of the tube bank, said second edge flow tube being located at an opposite furthermost edge region of the tube bank then said first edge flow tube;

a second edge flow control valve interconnected with said second flow control valve for controlling the amount of pulp suspension that travels through said second edge flow tube;

and

a second chamfered edge orifice inlet being a part of said second edge flow tube, whereby the combination of said second chamfered edge orifice inlet, said second edge flow tube and the second edge flow control valve expands the flow range of pulp traveling through said second edge flow tube in order to improve fiber orientation within a paper product produced in a papermaking process.

3. A headbox assembly as set forth in Claim 2, wherein said edge flow tube and second edge flow tube are each individually a part of a set of edge flow tubes and, wherein one of said edge flow control valves controls the amount of pulp suspension traveling through one set of edge flow tubes and said other edge flow control valve controls the amount of pulp suspension traveling through said other set of edge flow tubes, and, wherein each additional edge flow tube contains a chamfered edge orifice inlet, whereby the combination of said chamfered edge orifice inlets, said sets of edge flow tubes and said edge flow control valves expands the flow range of pulp traveling through said sets of edge flow tubes in order to improve fiber orientation within a paper product produced in a papermaking process.

4. A method of manufacturing a chamfered edge orifice inlet in an edge flow tube, the edge flow tube being one of a plurality of tubes found within a tube bank of a headbox of a papermaking machine through which pulp suspension flows, the edge flow tube being used to control fiber orientation within a paper product produced in a papermaking process; said method comprising the steps of:

placing a shim over a cutter surface of a self-centering chamfer tool;

setting said cutter of said chamfering tool into an edge flow tube to be chamfered so that contact is made between said cutter and the edge flow tube;

pushing a collar of said chamfering tool firmly against said shim; tightening said collar against said shim;

rotating a shank of the chamfer tool thereby activating said cutter which enables said cutter to chamfer the edge of the edge flow tube, said collar controlling depth of the cut.

5. The method of manufacturing a chamfered edge orifice inlet in an edge flow tube as set forth in claim 4, wherein said shank is rotated at a speed of between about 400 to 600 revolutions per minute.

6. The method of manufacturing a chamfered edge orifice inlet in an edge flow tube as set forth in claim 4, further comprising the step of removing a raised edge at the top of the edge flow tube created as a result of the cutting of said chamfer.

7. The method of manufacturing a chamfered edge orifice inlet in an edge flow tube as set forth in claim 4, further comprising the step of deburring any sharp edges left on the edge flow tube as a result of the cutting of said chamfer.

8. The method of manufacturing a chamfered edge orifice inlet in an edge flow tube as set forth in claim 4, further comprising the step of removing any chatter marks created by the chamfering tool during the cutting of said chamfer.

9. The method of manufacturing a chamfered edge orifice inlet in an edge flow tube as set forth in claim 6, wherein said removing step is performed with 120 grit green silica carbide stone and emery paper.

10. The method of manufacturing a chamfered edge orifice inlet in an edge flow tube as set forth in claim 7, wherein said deburring step is performed with a fine 1 inch scotchbrite drum.

11. The method of manufacturing a chamfered edge orifice inlet in an edge flow tube as set forth in claim 8, wherein said removing step is performed with a 1 inch diameter grinding stone ground at an 82 degree angle.

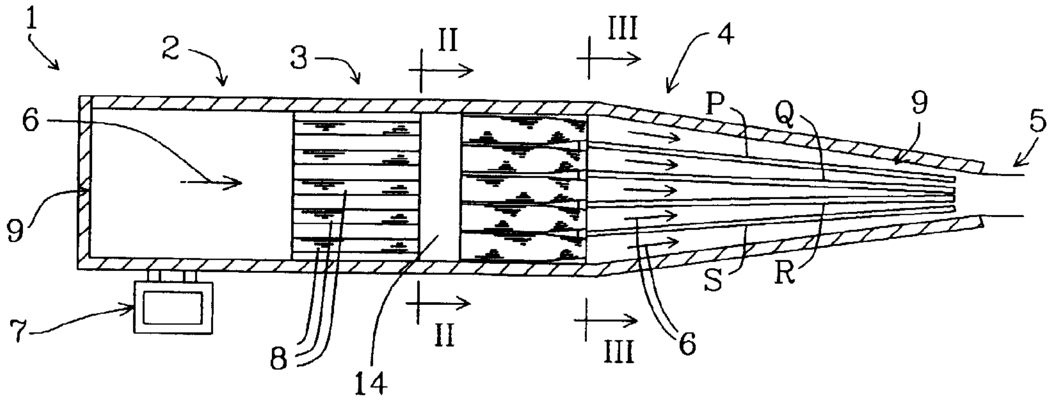

Fig. 1

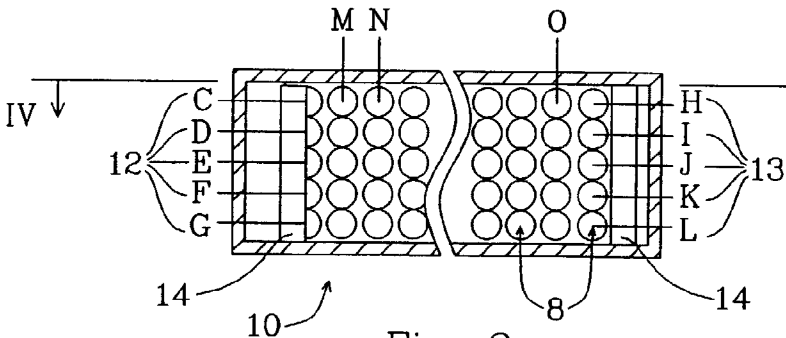

Fig. 2

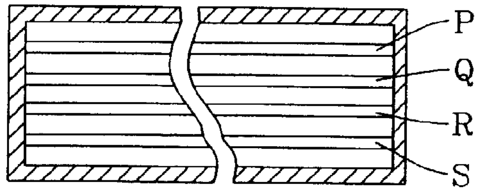

Fig. 3

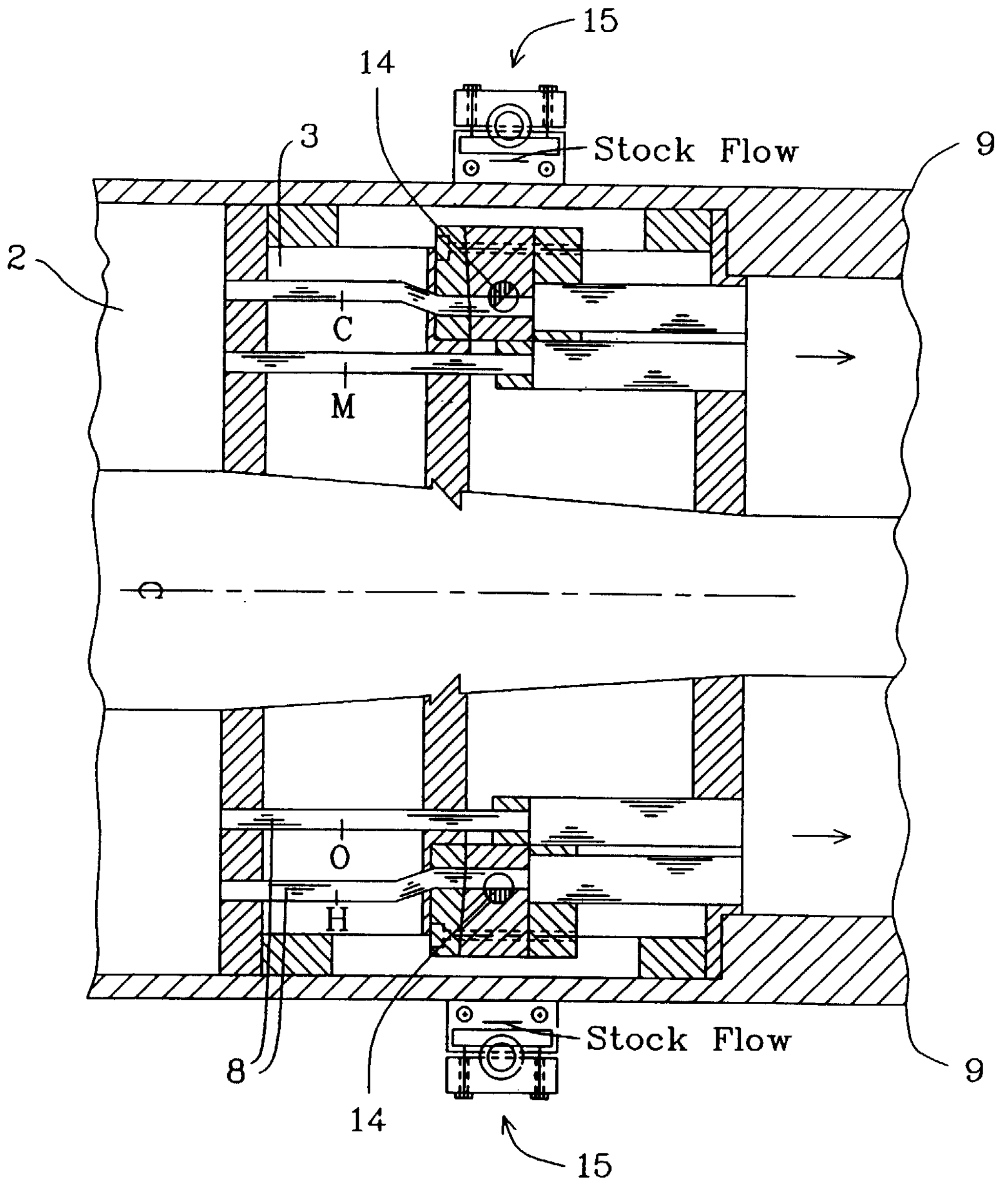

Fig. 4

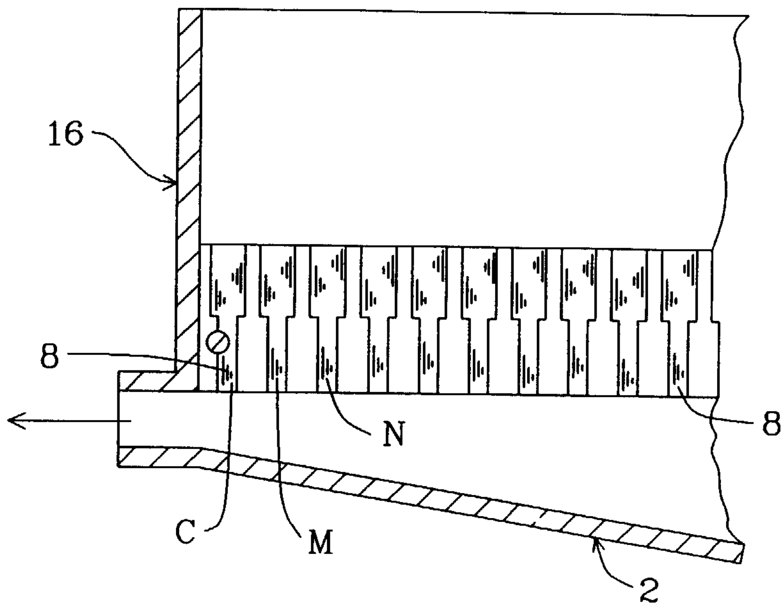

Fig. 5

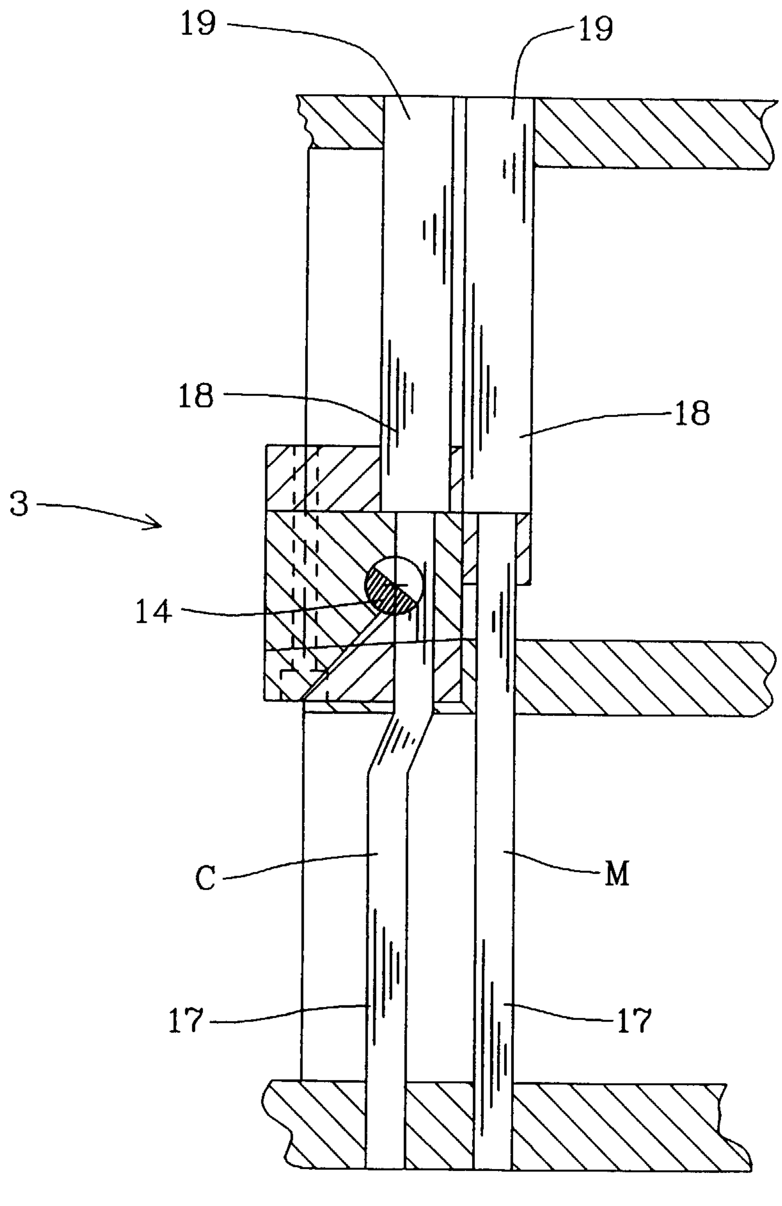

Fig. 6

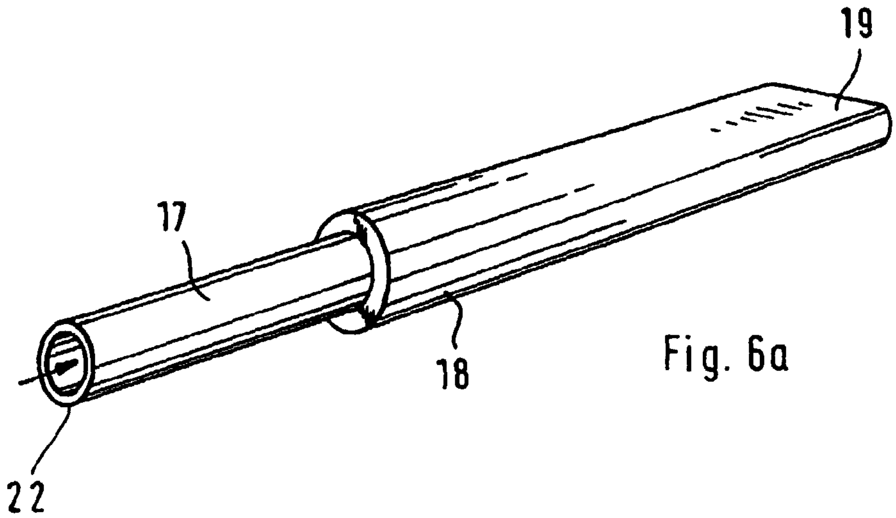

Fig. 6a

FIBER ORIENTATION
Effect of Edge Flow

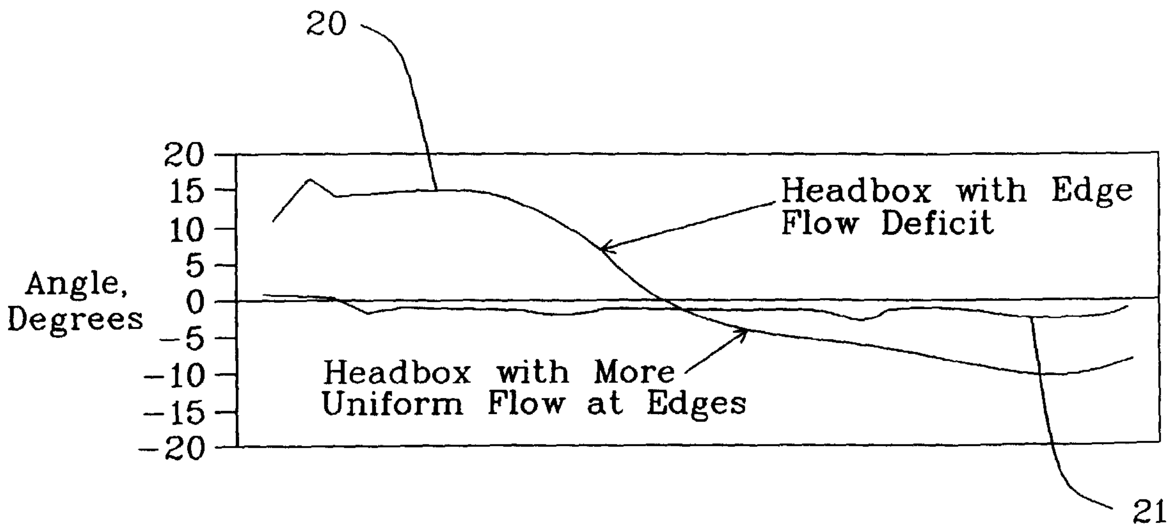

Fig. 7

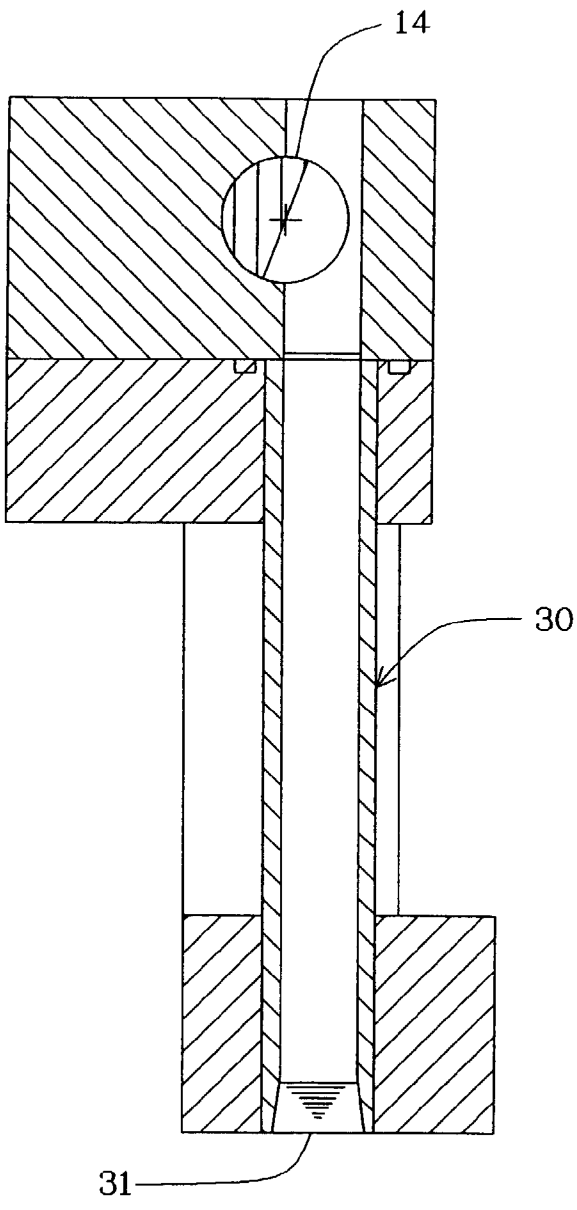

Fig. 8

Aligned Flow

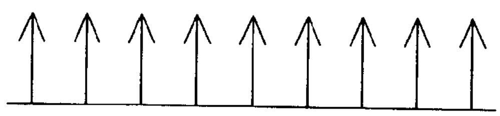

Fig. 9

Inflow

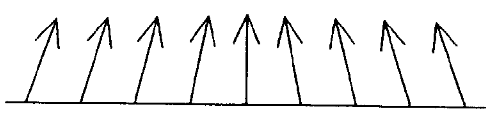

Fig. 9a

Outflow

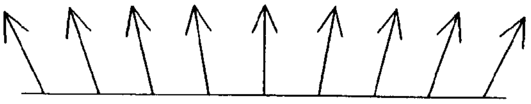

Fig. 9b

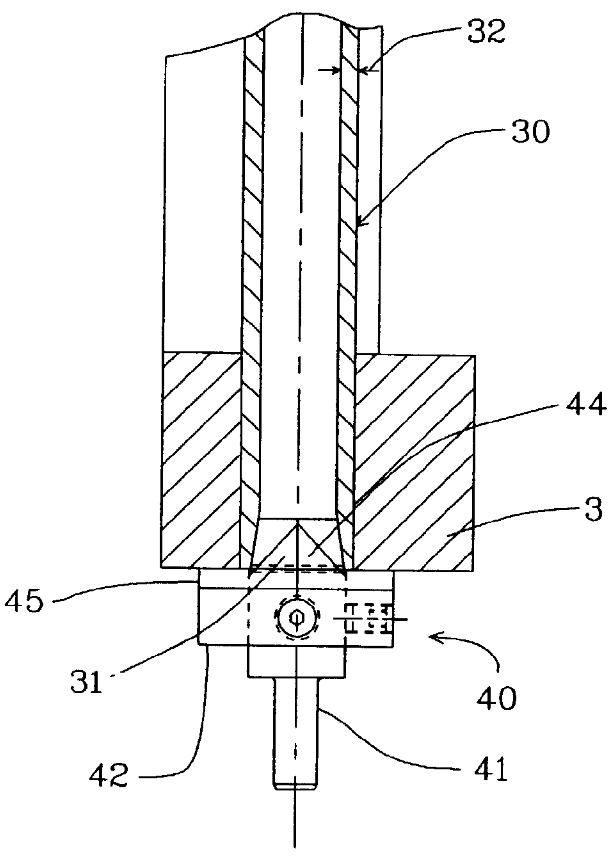

Fig. 10

Edge Flow Tube and Edge Flow Control Valve
with Square Edge Orifice Inlet

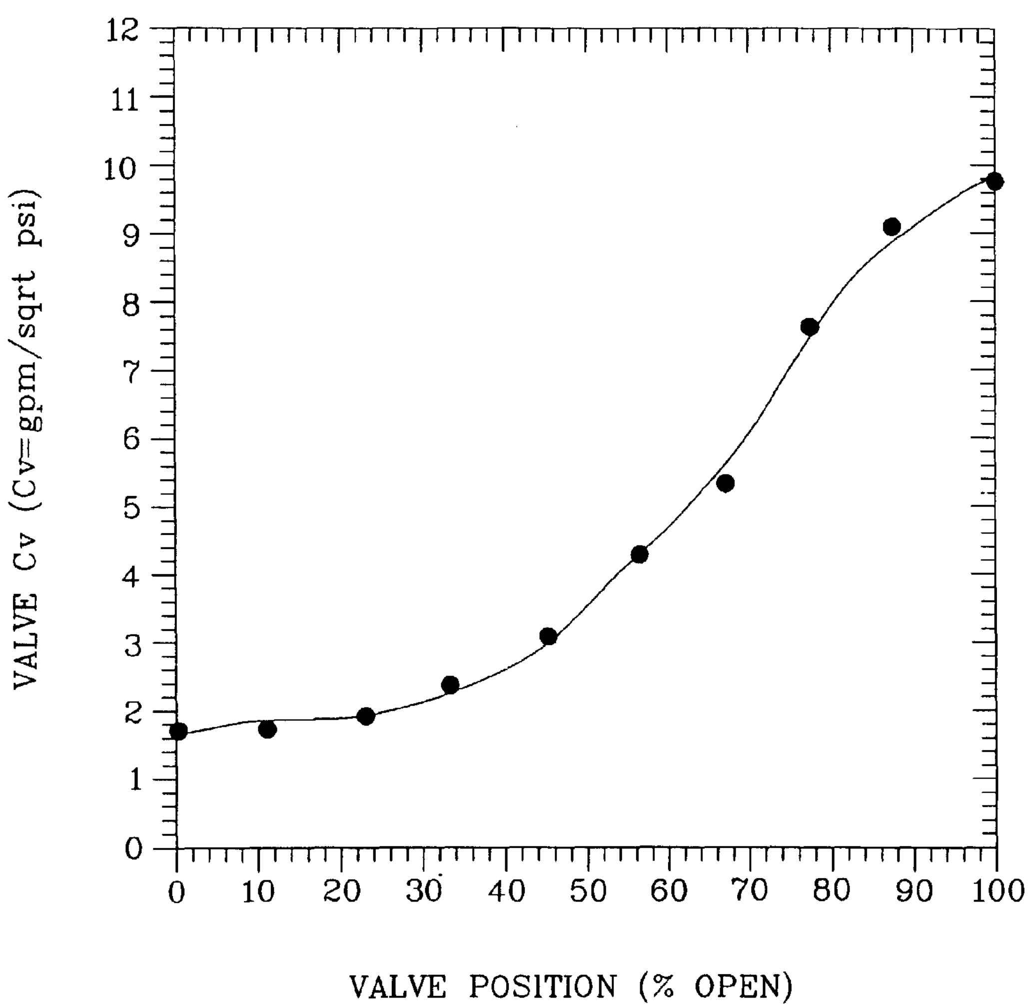

Fig. 11

Edge Flow Tube and Edge Flow Control Valve
with .040" Chamfer on Tube Inlet

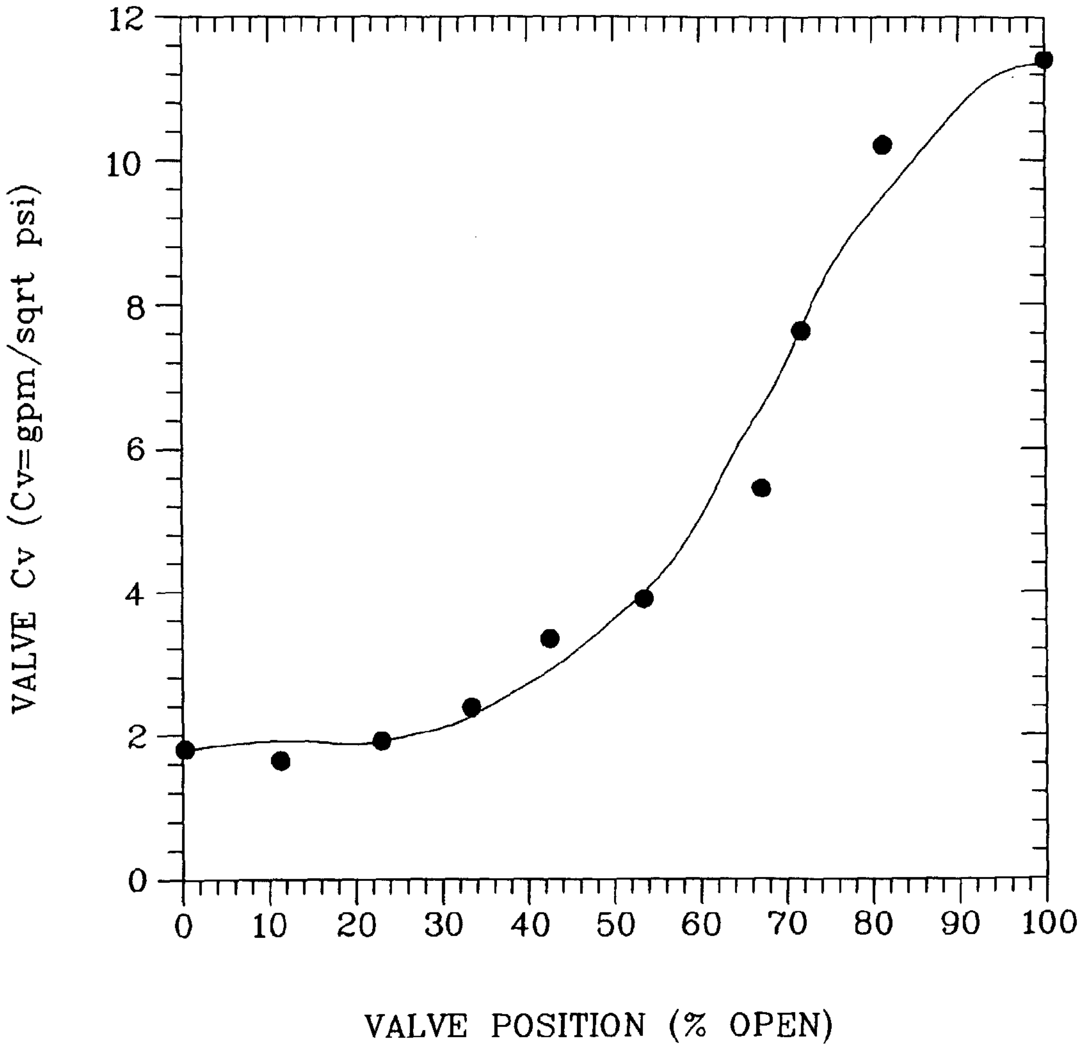

Fig. 12