Sept. 3, 1968 E. J. JUSTUS 3,400,044

HEADBOX FLOW CONTROL APPARATUS

Filed May 27, 1965 2 Sheets-Sheet 1

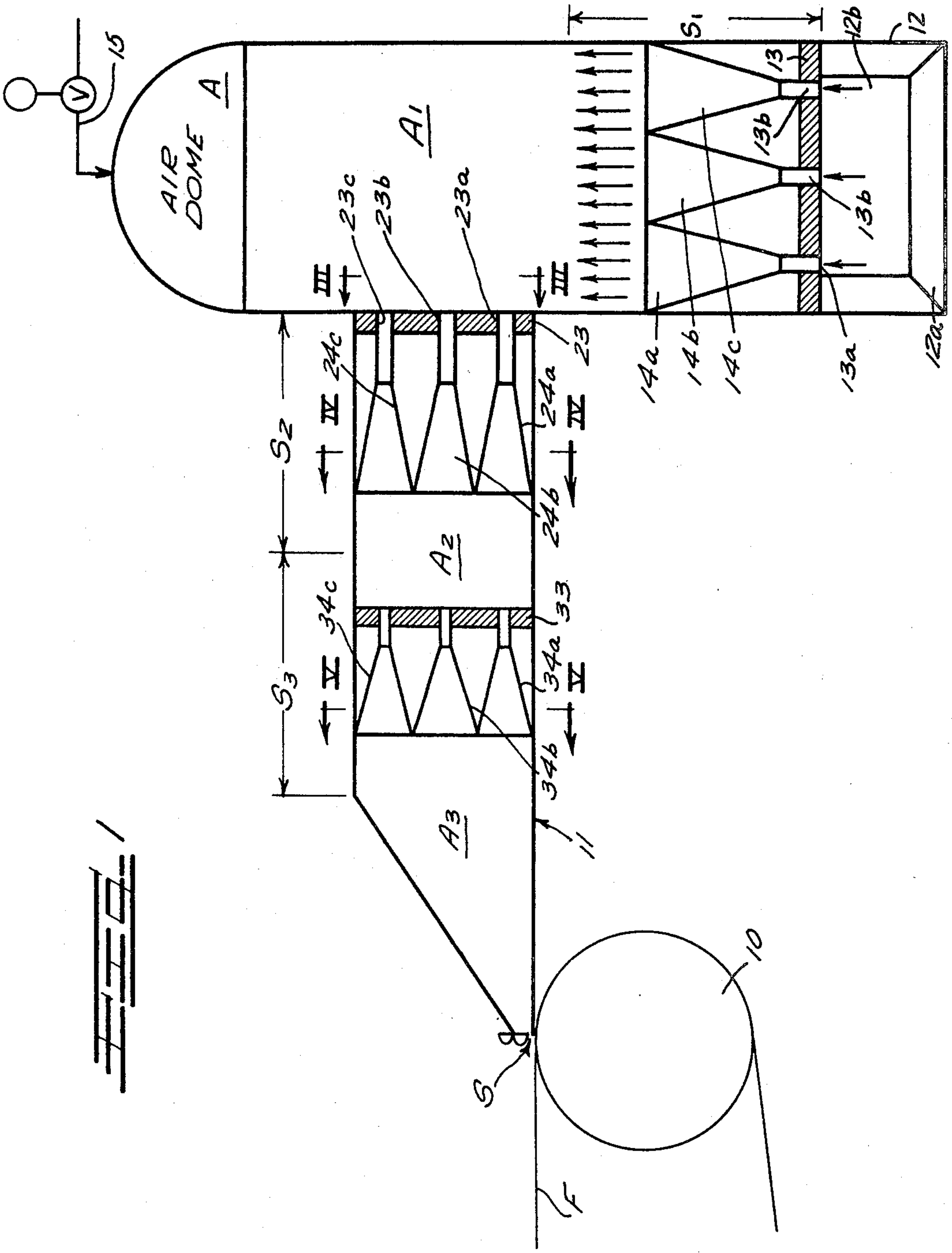

FIG. 1

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FIG. 2

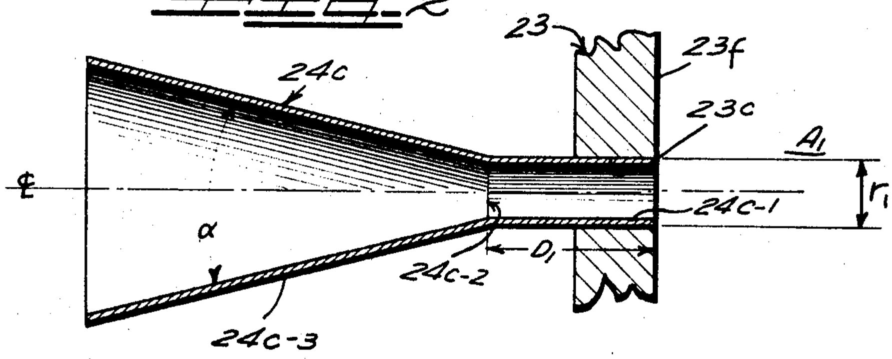


FIG. 3

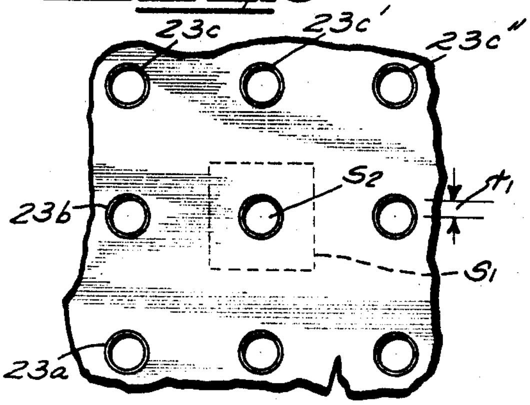


FIG. 2A

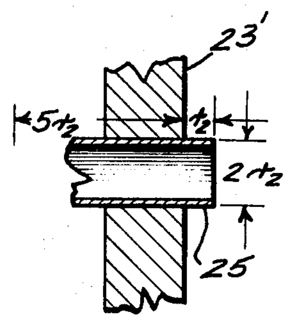


FIG. 4

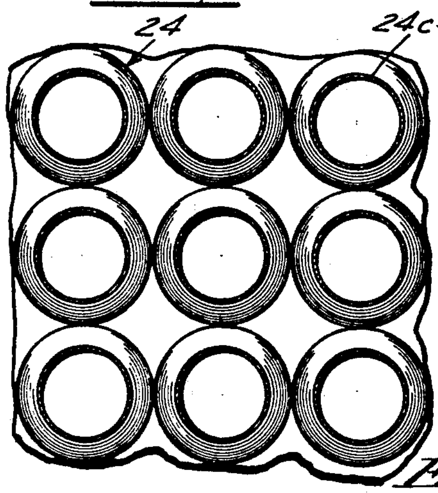
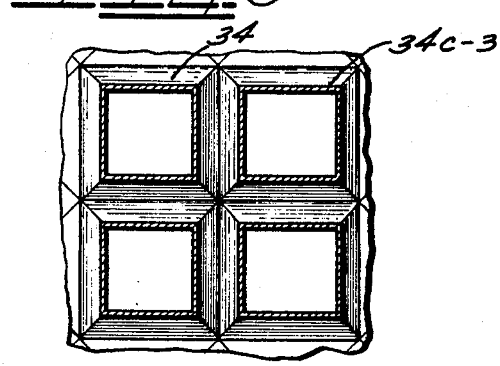


FIG. 5



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HEADBOX FLOW CONTROL APPARATUS

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ABSTRACT OF THE DISCLOSURE

This invention relates to a paper making machine headbox wherein certain flow control devices are included in the headbox. These flow control devices comprise a transversely extending bank of diffuser nozzles mounted with the large end downstream and the smaller intake end secured to an upstream stock flow barrier, in order to effect an abrupt pressure loss with generation of generally parallel velocity components in the stock flowing to the slice.

This invention relates to the handling of fluid slurries, and more particularly, to the maintenance of desired fiber dispersions in stock slurries for paper making and the like processes.

Prior attempts to establish uniform distribution of fibers in the stock slurry and to maintain fiber distribution, once established, along the flow path or stream in the headbox in the so-called pre-slice area prior to deposition of the stock on the forming surface have involved employment of such complicated auxiliary equipment as perforated rotary rolls, commonly referred to as rectifier rolls, holey rolls, or silencing rolls, and other mechanical vibrating, shaking and stirring devices, all of which induce turbulent flow currents of large amplitude in the slurry.

One major disadvantage attendant use of such prior art devices resides in the tendency of the fibers to form clots, flocks, or agglomerations which, when deposited on the forming surface, result in undesirable localized irregularities of high density in the forming web. In some instances, such clots and the like break down the web, thereby interrupting production.

Particularly in connection with the so-called perforated rectifier rolls which are used to a great extent in paper making machinery, certain theories have been developed and one of the important purposes of such rectifier rolls is to minimize or reduce cross currents or transversely flowing stock currents in the headbox, in order to attempt to obtain a generally uniform cross machine profile of deposited stock on the forming surface.

Such rectifier rolls have been found to operate quite successfully with small diameter holes in the rectifier roll so as to obtain a very high loss with many jets issuing from the small diameter holes, but these many jets cumulatively result in a rather intensive cone of disturbance immediately following the rectifier roll. This cone of disturbance is not generally desirable at the immediate area of the slice because it results in a definite sheet pattern which is noticeable in the stock flow issuing from the headbox slice (and the sheet itself) immediately after such a rectifier roll. On the other hand, if the rectifier roll is provided with larger open area or larger holes, then it is found that the so-called cone of disturbance at the downstream side of the rectifier roll is less conspicuous, but the losses to the larger holes are much less and there is not as great an equalizing effect to minimize cross machine stock flow movement. Accordingly, the selection of rectifier rolls and the various factors of importance in their structure such as the open area and the size of the holes has been the subject of considerable study in order to determine the rectifier roll that is best to use in any given headbox.

In the instant invention, however, the necessity for using moving parts such as a rectifier roll is eliminated by an entirely different type of high loss generating device and method which eliminates cross currents and generally aligns the stock flow in the direction desired, but does not subject the stock to unnecessary flow patterns involving both acceleration and deceleration. Certain prior art workers have, for example, suggested the use of venturis as a means of inducing first an acceleration and then a deceleration in a plurality of stock streams aimed generally at the slice, but it has been found that the venturi arrangement causes a gradual increase in the stock velocity as it travels toward the throat portion of the venturi device. In contrast, the instant method and apparatus involves the use of diffuser nozzles which initiate an abrupt high loss with resultant unidirectional high velocity parallel jets at the outlet side of such diffuser nozzles. Such diffuser nozzles do not operate on the principle of the venturi in that they do not first restrict the stock flow to a region of relatively high velocity followed by a region of still greater or accelerated velocity. Instead, the diffuser nozzles simply convert the stock from the general flow pattern to stock jets of maximum velocity at the inlet of the diffuser nozzle and this maximum velocity is maintained only briefly, long enough to impart the generally parallel unidirectional character to the stock velocity which is desired, and then the diffuser nozzle expands gradually so as to cause velocity losses to take place in the stock flow without substantial losses in the generally parallel unidirection of the stock. The term unidirection is employed herein to mean a single direction, for example, a straight line direction toward the slice itself. The basic object sought here is to obtain what constitutes a plurality of generally homogeneous unflocked but entagled fibers in the stock moving unidirectionally toward the slice but moving at least partially during the sequence of stock flow treatment here employed in generally parallel high velocity streams while still moving in the same direction. To accomplish this the diffuser nozzles are so aligned in transversely extending banks that one may consider their central axes to be generally parallel and generally aimed in the so-called "unidirection" contemplated for the stock streams carrying the fibers.

It is therefore an important object of the instant invention to provide an improved method and apparatus for effecting the desired distribution of particulate material in a liquid vehicle, such as fibers in a paper making stock or slurry, by the use of stock flow control methods and means which include at least one sequence or bank of devices which effect a high entrance loss, minimum velocity head gradient or variation in the downstream flow, a low percentage open area at the entrance side to eliminate or prevent stringing of the stock fibers, and a high percent open area at the exit side so as to obtain stable flow.

Other and further objects, features and advantages of the present invention will become apparent to those skilled in the art from the following detailed disclosure thereof and the drawings attached hereto and made a part hereof.

On the drawings:

FIGURE 1 is an elevational view of a headbox or preslice chamber of the invention, showing parts diagrammatically and parts in sectional elevation;

FIGURE 2 is a detail sectional elevation showing a single diffuser nozzle in one arrangement embodying the instant invention;

FIGURE 2A is a modification of the elevational view of FIGURE 2 with respect to the mounting of the diffuser nozzle inlet in a transverse wall;

FIGURE 3 is an essentially diagrammatic view taken generally from the line III—III shown in FIGURE 1, showing a part of the barrier means or plate employed in the headbox of FIGURE 1;

FIGURE 4 is an essentially diagrammatic view taken substantially along the line IV—IV showing fragmentarily a portion of the partially expanded diffusion nozzles in transverse and vertical section; and

FIGURE 5 is still another essentially diagrammatic view showing a transverse and vertical section, which might be taken along the line of V—V of FIGURE 1 but which shows the expanded portions of the diffusion nozzles near the downstream mouths thereof in generally rectangular cross-section, as compared to the generally circular cross-section, shown in FIGURE 4.

As shown on the drawings:

In FIGURE 1, it will be seen that there is shown a forming wire F traveling around a breast roll **10** to define a conventional forming surface onto which paper making stock is fed through a slice indicated generally at S. The slice S is mounted at the forward end of a headbox indicated generally at **11**, such headbox being what constitutes a pre-slice chamber in that it aligns the stock for flow toward the slice S.

In a conventional stock inlet the stock is generally fed to the headbox or pre-slice chamber **11**, such as the one here employed, from a fan pump or other suitable source of stock in a relatively small high speed conduit which is indicated in FIGURE 1 by the reference numeral **12** as a tapered cross machine header having an inlet **12*a*** at the side of the headbox **11** from which it is viewed in FIGURE 1 and an outlet **12*b*** of diminishing cross-sectional area at the back side of the chamber **12** for flow of stock in a generally cross machine direction through the tapered inlet header **12**. Any of a number of known stock inlet devices may be provided to present a cross machine flow of stock into the chamber **12** under a substantially uniform pressure in the general area of the barrier or perforated mounting plate indicated at **13**. The perforated plate **13** extends transversely across the top of the stock inlet **12** and it is provided with a plurality of apertures **13*a*, 13*b*, 13*c***, etc. which are generally parallel and which are spaced transversely to define a multiplicity of generally parallel apertures extending across the entire plate **13**. The plate **13** carries a multiplicity of diffuser nozzles **14*a*, 14*b*, 14*c***, each of which is received in one of the multiplicity of apertures **13*a*, 13*b*, 13*c*** in the plate **13**.

To refer generally to the unit shown in FIGURE 1, it will be seen that there is provided a first sequence indicated at S_1 during which the stock flows into the diffuser nozzle inlets **14*a*, 14*b*, 14*c***, at the approximate face of the plate **13** via the apertures therein and in which sequence S_1 the stock streams are thus converted from the cross machine flow in the cross machine header **12** into a generally parallel unidirectional high velocity flow. The direction of this flow in the nozzles **14*a*, 14*b*, 14*c*** is generally upwardly and since these nozzles **14*a*, 14*b*, 14*c*** expand gradually after an initial inlet region it will be appreciated that the velocity will decrease gradually (preferably without cavitation) as the stock flows upwardly but the general direction of stock flow velocity in the vertical direction will not be altered within the nozzles **14**. The stock flows upwardly into a large air cushioned equalizing zone at the off-running side of the first sequence S_1 and the stock in the area A_1 is subjected to controlled air pressure via a conventional controlled air pressure device indicated diagrammatically at **15** to maintain a super or sub-atmospheric pressure on the top level of the stock in the air dome A for controlled high speed flow of stock through the overall headbox **11**.

It will next be seen that there are provided second and third sequences S_2 and S_3 aligned in the pre-slice chamber **11**. It will also be seen that the sequences S_1, S_2 and S_3 each have generally the same structure with like elements in the sequence S_2 indicated by the same reference numerals in the twenty series and like elements in the sequence S_3 indicated by the same reference numerals in the thirty series. It will also be seen that at the off-running side of each such sequence S_2 and S_3 there is again a so-called equalizing zone A_2 and A_3 respectively.

The general function and nature of the diffuser nozzles will be considered primarily in connection with the individual diffuser and nozzle **24*c*** indicated in FIGURE 2, although it will be appreciated that the diagrammatic showing in FIGURE 3 brings out the fact that the transverse plate **23** is actually provided with a plurality of spaced apertures **23*c*, 23*c*′** and **23*c*″** which extend horizontally in the cross machine direction as well as a plurality of generally parallel spaced apertures **23*c*, 23*b*** and **23** and which are shown to be spaced vertically with respect to the overall stock stream flow going through the apertures indicated in the plate **23**. Referring again to FIGURE 2 it will be seen that the plate **23** has an upstream face **23*f*** which is presented to the body of stock under pressure in the area A_1. This upstream face **23*f*** is substantially aligned with the inlet mouth of **24*c*–1** of the diffuser nozzle **24*c***. The inlet mouth **24*c*–1** has a substantially uniform cross-sectional area for an initial downstream distance D1 (or about 6 r_1) extending from the face **23*f*** of the plate to a region indicated at **24*c*–2** at the downstream side of the plate **23**.

Then the diffuser nozzle gradually expands (along an angle α=less than 15° and preferably less than 7°) in the subsequent section indicated at **24*c*–3**. As is indicated in FIGURE 4 the gradual expansion of the nozzle portion **24*c*–3** occurs to the same extent with the various other nozzle elements which are indicated only generally by the reference numeral **24** in each instance in the essentially diagrammatic showing of the sectional view of FIGURE 4. It should further be noted that the nozzle **24*c*** indicated in FIGURE 2 is shown as being generally cylindrical in the first section from the inlet **24*c*–1** to the merging point **24*c*–2** and then as being generally conical in the expanding portion **24*c*–3**. Such nozzle **24*c*** may thus be considered to have an axis indicated generally along the center line shown in FIGURE 2 which is aimed in the direction of stock flow intended. Each center line CL for each of the nozzles **24** is generally parallel in any given bank **14, 24** or **34** of nozzles and it will thus be appreciated that the essential effect of the arrangement here involved is that the front face of the plate **23** has a minimum open area represented by the nozzle inlet **24*c*–1**. The average open area of **24*c*–1** to **23*f*** is about 0.3 to about 0.1 so as to effect high friction losses in transferring the flow from A_1 to the nozzle area defined by the plate face **23*f*** and the nozzle portion **24*c*–2**.

As indicated in Perry "Chemical Engineers Handbook" (3rd Ed., 1950) p. 388 (FIGURES 28 and 28A) the various diffuser nozzle devices of interest herein are known per se, although not kown for use in a pre-slice chamber. For example in the present FIGURE 2 there is a sudden contraction or entrance loss at the sharp edged mouth **24*c*–1**, wherein the frictional loss is measurable in the loss of kinetic energy, in accordance with the following Formula I:

$$\text{(I)} \qquad F=\frac{KV_2}{2gc} \text{ Ft.-lb. of mass of fluid}$$

wherein V_2 is the linear velocity (ft./sec.) in the smallest pipe portion **24*c*–1** to **24*c*–2** of FIGURES 2 and 3 and K is a factor depending on the nature of the entrance portion S_2 of the nozzle. This loss occurs in the initial portion of the small diameter tube **24*c*–1** to **24*c*–2**. As here shown the tube is followed by the diffuser shown having an angle of divergence α as previously indicated which permits controlled deceleration and which avoids formation of large scale eddies.

As previously indicated a venturi arrangement (as distinguished from the present diffuser arrangement) causes a gradual increase in stock velocity as it travels toward the throat portion of the venturi device. This gradual increase in velocity results in a lower K-factor of about .05 as distinguished from a K-factor of about .5 for the sharp edged entrance portion of diffuser of the present invention. This is consistent with our desire to obtain a high entrance loss at the inlet portion of the diffuser while yet maintaining control of the velocity of the flow in the discharge portion of the diffuser. By thus maintaining control of the flow we effectively minimize large flow instabilities on the downstream side. The fundamental features of the diffuser type nozzles of the present invention permit a large land area at the upstream side of the diffuser bank while at the same time affording maximum open area at the downstream side of the diffuser bank.

FIGURE 2A hereof demonstrates a re-entrant mouthpiece **25** or the so-called "Borda mouthpiece" (Perry, FIGURE 54*a*, p. 407) which when running free with pure water may have a coefficient higher than the previously quoted 0.5.

FIGURE 5 demonstrates a view comparable to FIGURE 4 except that the terminal portions of the expanding diffuser portion **34***c* are not rounded as usual but are polygonal, i.e., squared but also triangular or hexagonal to minimize re-entry problems at the off-running side of the diffusers, here designated **34**.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of the present invention.

I claim as my invention:

1. Apparatus for supplying a paper stock to a papermaking machine, comprising a slice and a pre-slice flow chamber connected to said slice for directing a flow of paper stock to said slice, means in such chamber defining at least one stock flow sequence, such sequence consisting essentially of a transversely extending apertured plate retaining in the apertures thereof a multiplicity of generally parallel closely spaced diffuser nozzles, each said diffuser nozzle having an upstream portion of substantially uniform cross-section and feeding directly into a downstream portion of gradually expanding cross-section with a discharge downstream that is greater than the cross-section of the upstream portion, the upstream face of said plate being substantially aligned with the upstream inlet opening of each such nozzle to effect at the upstream inlet of each nozzle an abrupt pressure loss with generation of maximum generally parallel velocity components in the stock at upstream inlet and maintenance of maximum stock velocity in each nozzle at the immediate inlet thereof.

2. Apparatus for supplying a paper stock to a papermaking machine, comprising a slice and a pre-slice flow chamber connected to said slice for directing a flow of paper stock to said slice, means in such chamber defining at least one stock flow sequence, such sequence consisting essentially of a transversely extending apertured plate retaining in the apertures thereof a multiplicity of generally parallel closely spaced diffuser nozzles, each said diffuser nozzle having an upstream portion of substantially uniform cross-section and feeding directly into a downstream portion of gradually expanding cross-section with a discharge downstream that is greater than the cross-section of the upstream portion, the upstream face of said plate being closely spaced downstream from the inlet opening of each such nozzle projecting upstream slightly from the face of said plate to effect at the upstream inlet of each nozzle an abrupt pressure loss with generation of maximum generally parallel velocity components in the stock at upstream inlet and maintenance of maximum stock velocity in each nozzle at the inlet thereof.

3. Apparatus for supplying a paper stock to a papermaking machine, comprising a slice and a pre-slice flow chamber connected to said slice for directing a flow of paper stock to said slice, means in such chamber defining a plurality of downstream-wise spaced sequences, each such sequence consisting essentially of a transversely extending apertured plate retaining in the apertures thereof a multiplicity of generally parallel spaced diffuser nozzles, each said diffuser nozzle having an upstream portion of substantially uniform cross-section and feeding directly into a downstream portion of gradually expanding cross-section with a discharge downstream that is greater than the cross-section of the upstream portion, the upstream face of said plate being substantially aligned with the upstream inlet opening of each such nozzle to effect at the upstream inlet of each nozzle an abrupt pressure loss with generation of maximum generally parallel velocity components in the stock at upstream inlet and maintenance of maximum stock velocity in each nozzle at the inlet thereof.

4. Apparatus for supplying a paper stock to a papermaking machine, comprising a slice and a pre-slice flow chamber connected to said slice for directing a flow of paper stock to said slice, means in such chamber defining a plurality of downstream-wise spaced sequences, each such sequence consisting essentially of a transversely extending apertured plate retaining in the apertures thereof a multiplicity of generally parallel spaced diffuser nozzles, each said diffuser nozzle having an upstream portion of substantially uniform cross-section and feeding directly into a downstream portion of gradually expanding cross-section with a discharge downstream that is greater than the cross-section of the upstream portion, the upstream face of said plate being closely spaced downstream from the inlet opening of each such nozzle projecting upstream slightly from the face of said plate to effect at the upstream inlet of each nozzle an abrupt pressure loss with generation of maximum generally parallel velocity components in the stock at upstream inlet and maintenance of maximum stock velocity in each nozzle at the inlet thereof.

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