May 7, 1968 E. J. JUSTUS ET AL 3,382,143

# PAPER FORMING ASSEMBLY AND METHOD

Filed June 28, 1965 8 Sheets-Sheet 1

FIG. 1

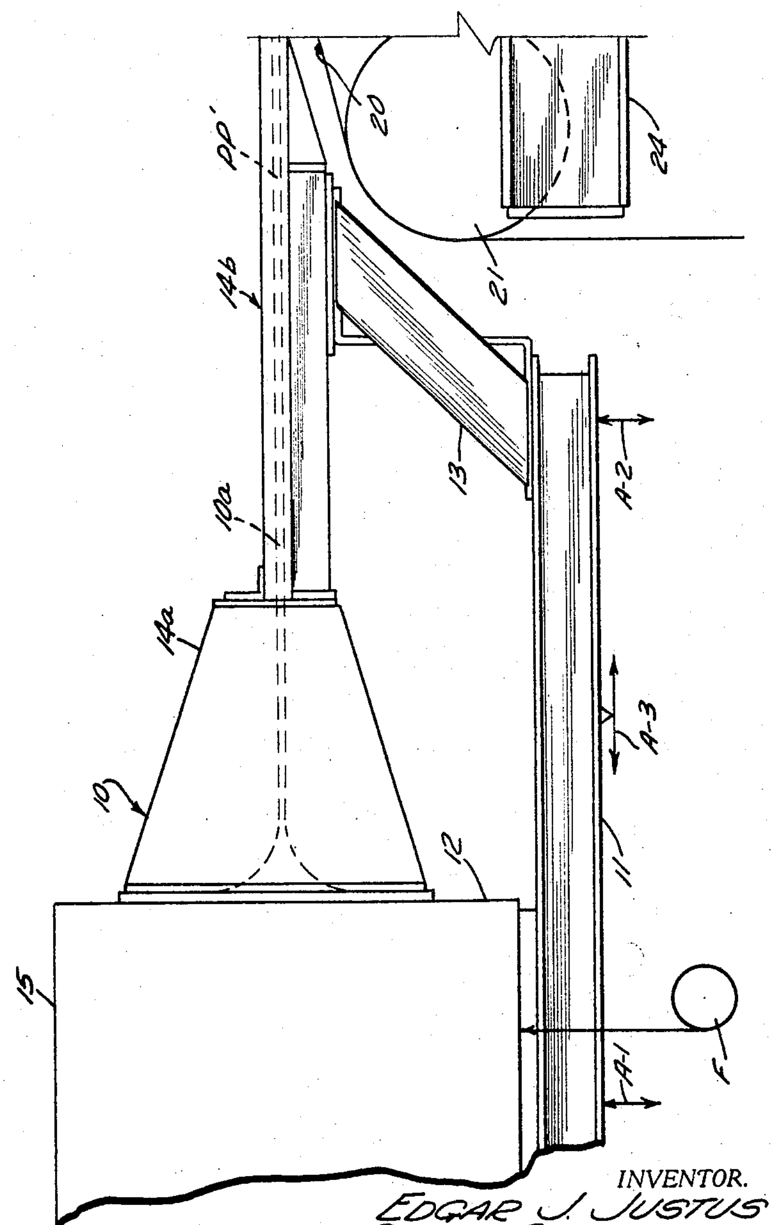


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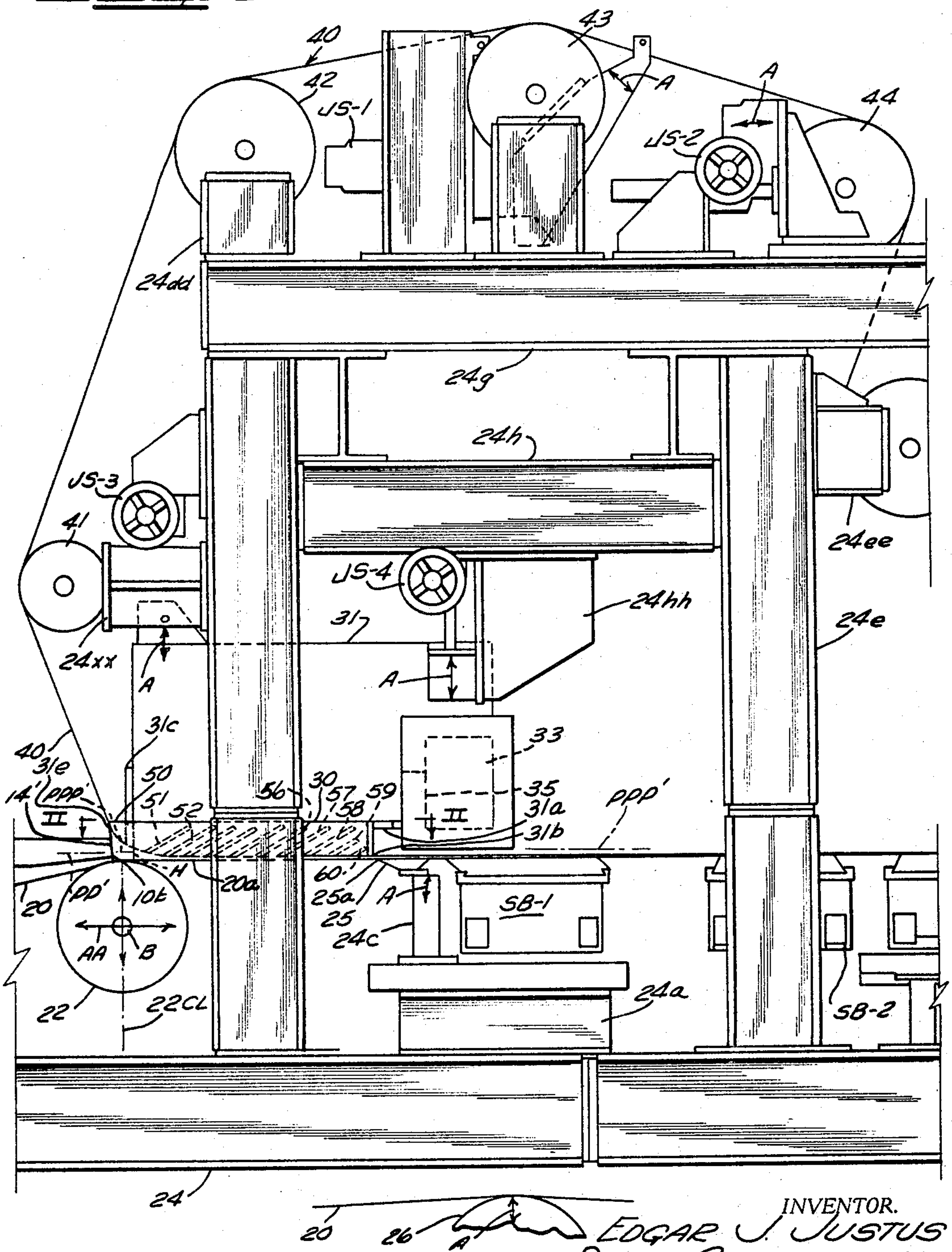
FIG. 1B



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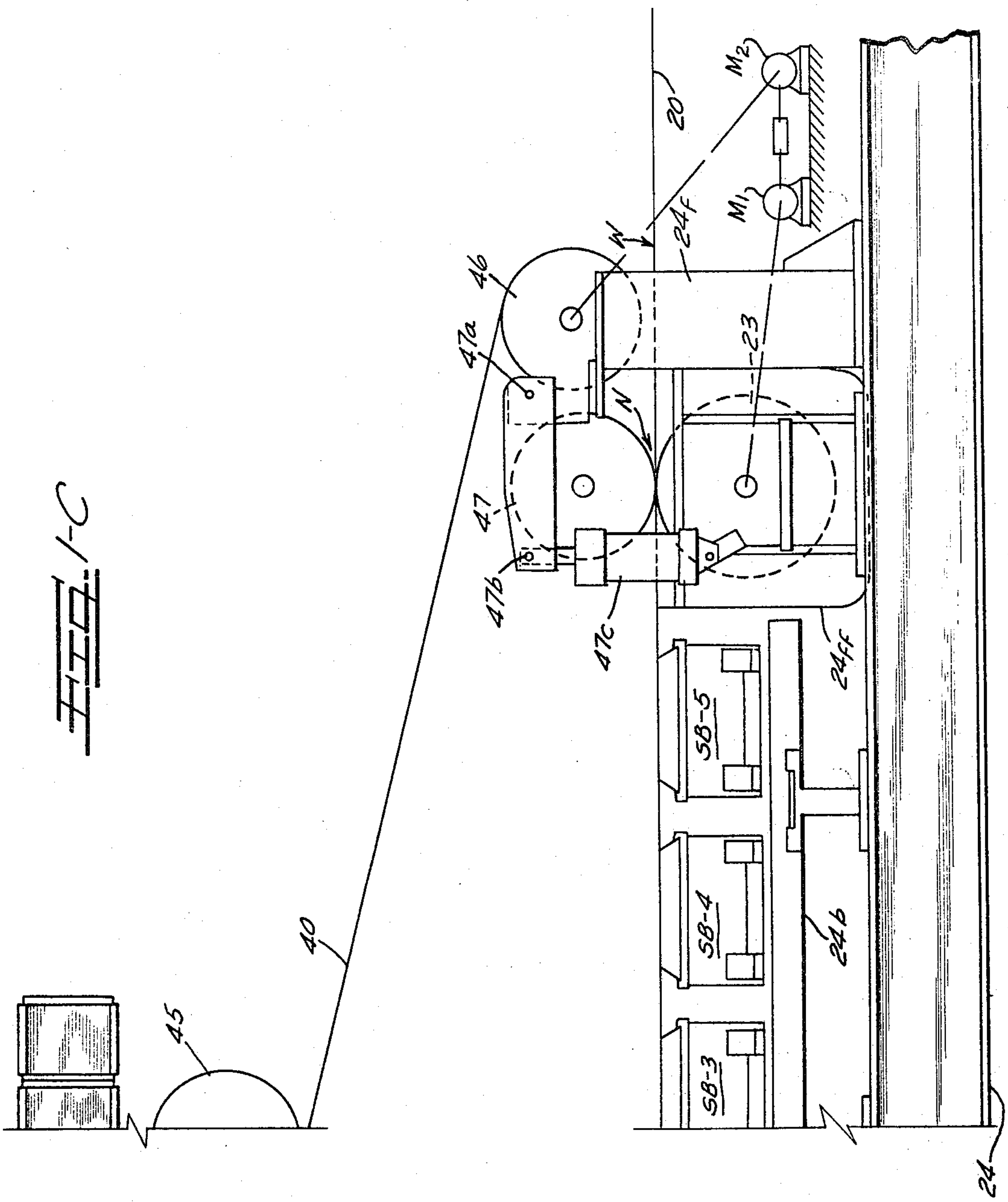


FIG. 1-C

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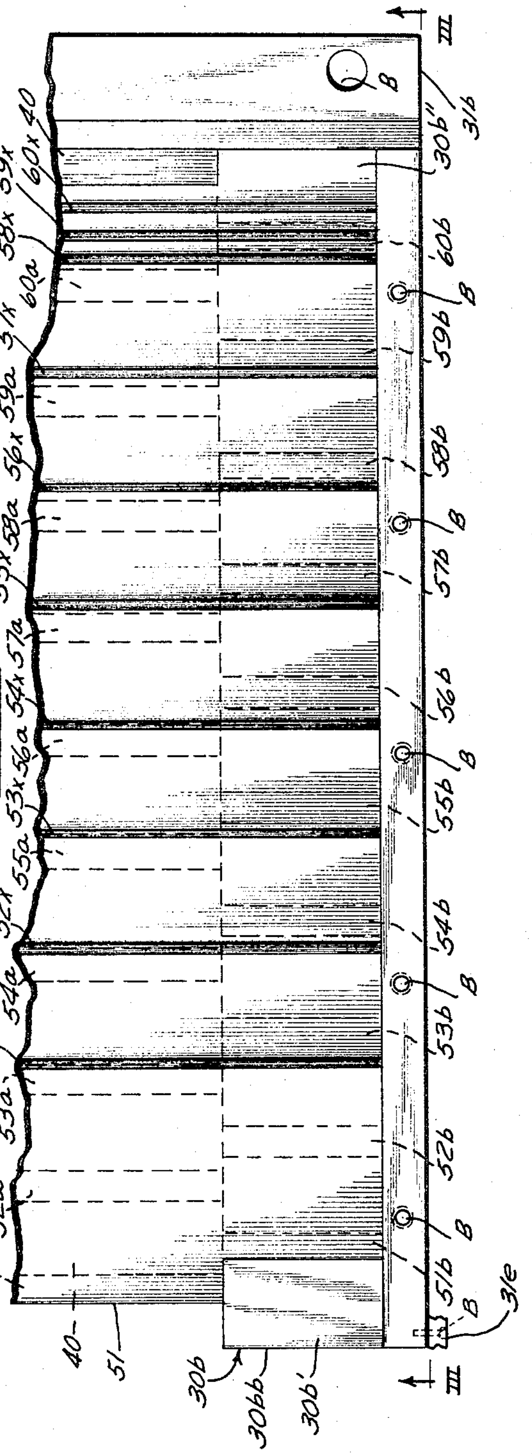


FIG. 2

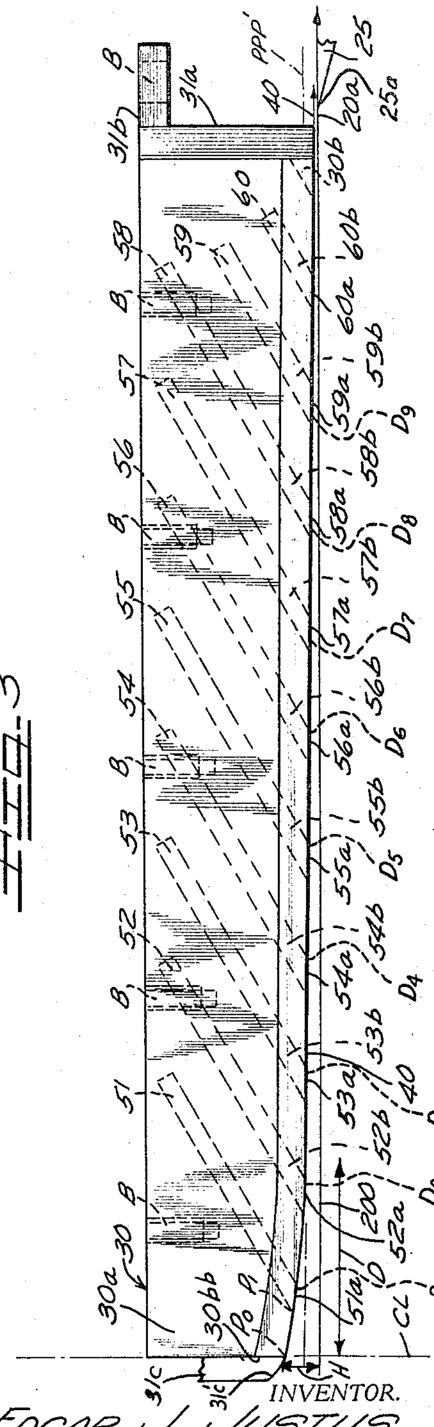


FIG. 3

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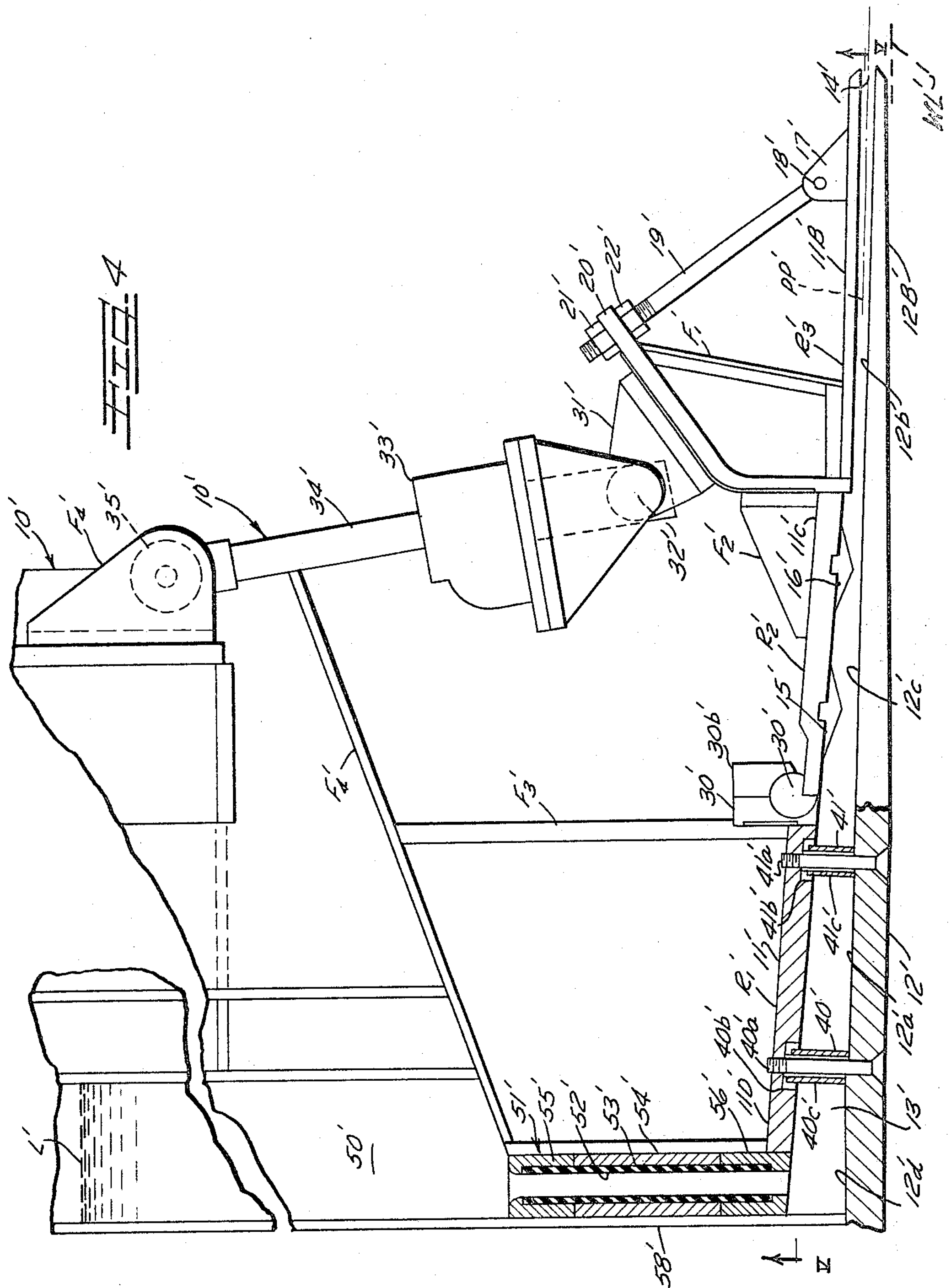

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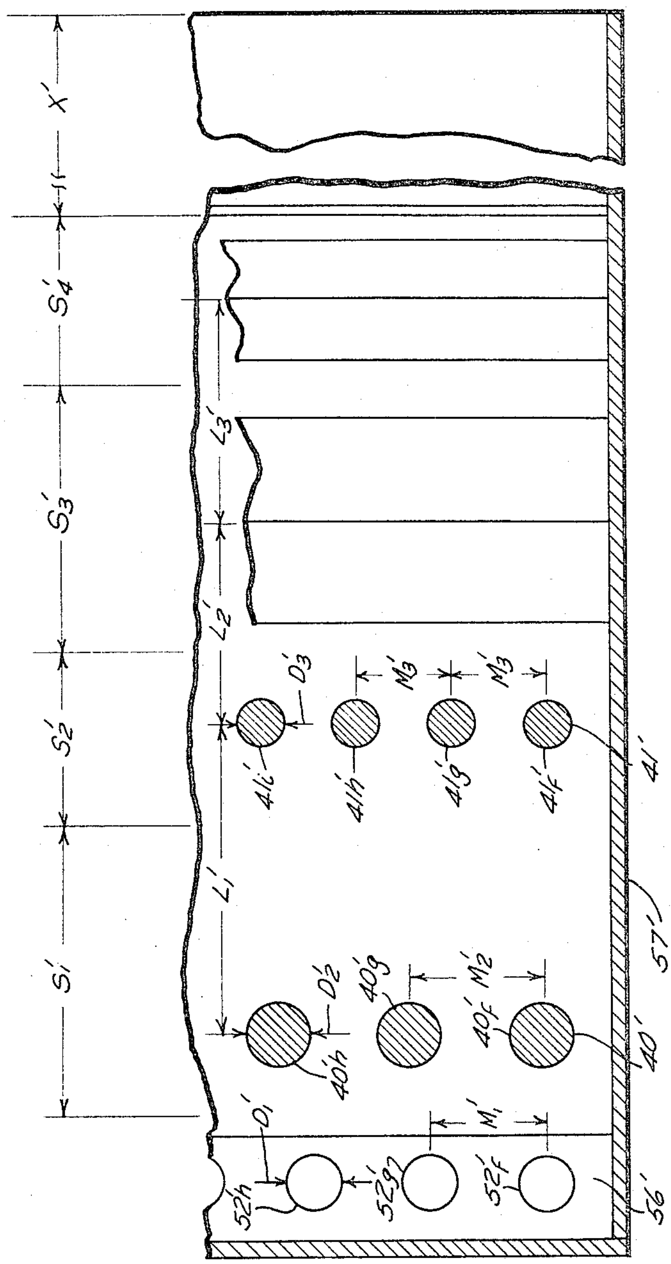


Fig. 5

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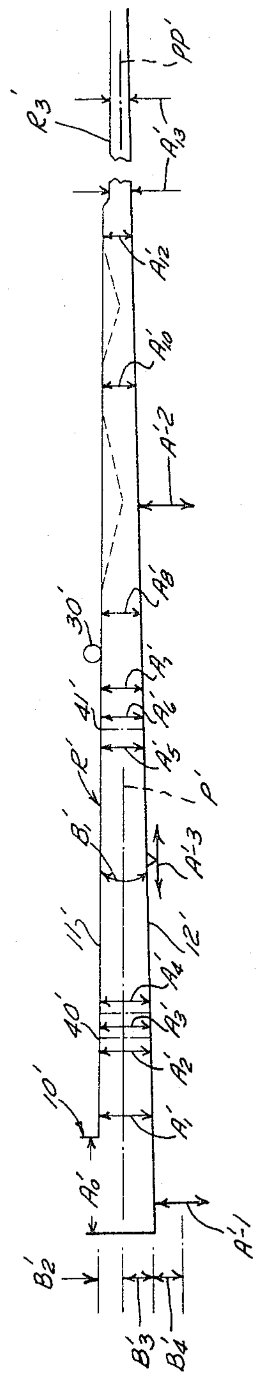

FIG. 6

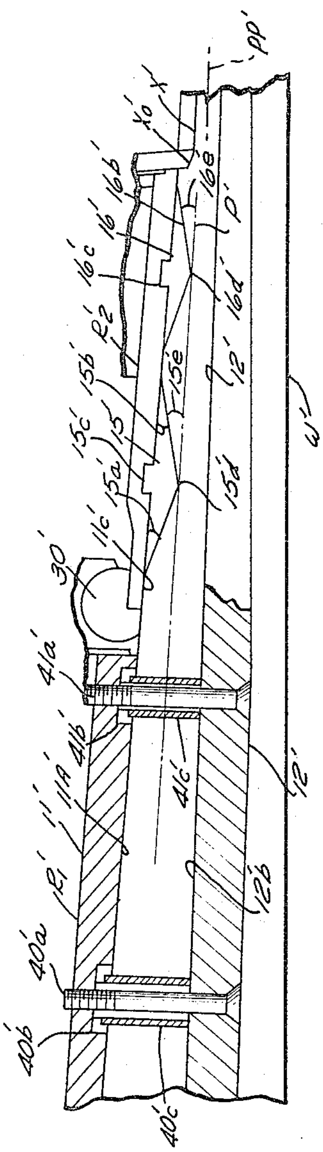

FIG. 7

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FIG. 8

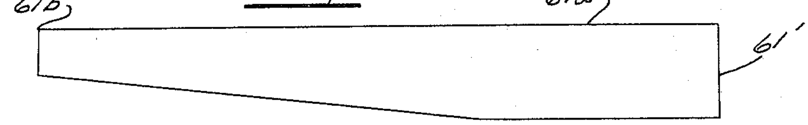



FIG. 9

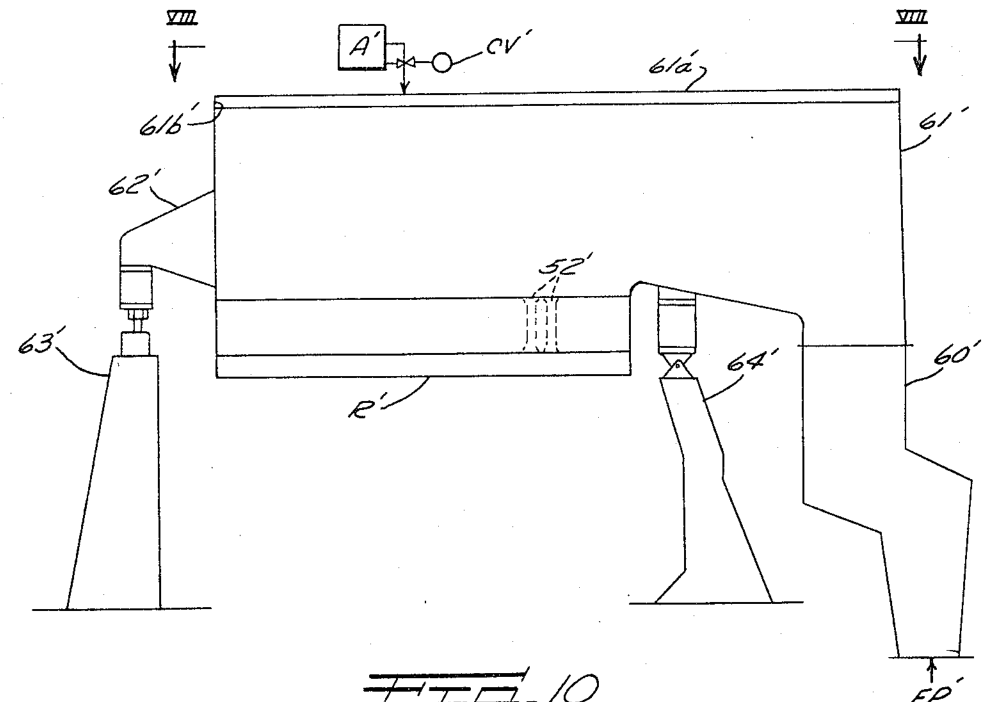
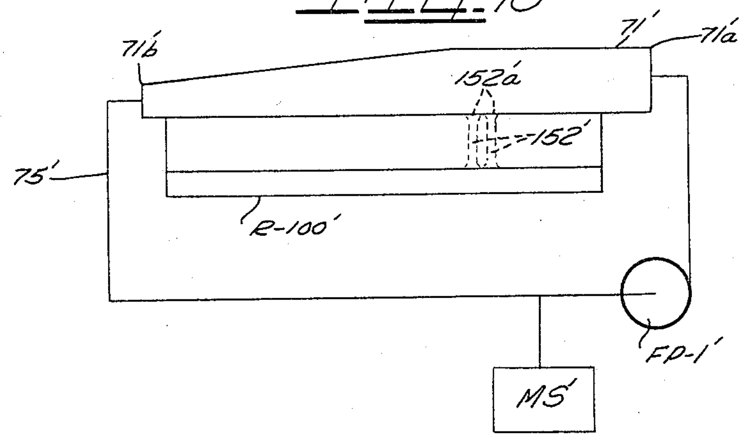



FIG. 10

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# United States Patent Office

3,382,143
Patented May 7, 1968


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3,382,143


## PAPER FORMING ASSEMBLY AND METHOD


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Continuation-in-part of application Ser. No. 412,909, Nov. 23, 1964. This application June 28, 1965, Ser. No. 467,664
9 Claims. (Cl. 162—303)



### ABSTRACT OF THE DISCLOSURE

The present invention relates to a plural wire web forming device wherein a web forming zone is defined between converging forming wires by the use of curved, stationary, permeable guide means acting against one wire to urge such wire through an elongated substantially curved path and into convergence with the opposite wire under tension. This is a continuation-in-part of our application Ser. No. 412,909, filed Nov. 23, 1964.


The present invention relates to improvements in paper making machinery or the like, and more particularly, in improvements in devices and methods for forming the initial web of fibrous material from a dilute liquid suspension in paper machines or the like.

Although the instant invention is particularly adapted for use in the forming arrangement of paper making machinery and it will be described primarily in connection therewith, it will be appreciated that the invention has other uses in related devices. Essentially, the instant invention is concerned with a new and unique forming arrangement which has been devised by us for such purposes as accommodating higher paper making machinery speeds as well as improved quality in the paper so made. It will be appreciated that the very substantial capital investment in paper making machinery makes it necessary for continuous research and development in improvements in not only paper making quality but operating speeds for such machinery. The instant invention provides a novel arrangement and method for effecting improved paper making quality at high speeds.

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:

FIGURES 1A, 1B and 1C are elevational views shown in the sequence A–B–C of a paper machine forming section embodying the instant invention and it will be appreciated that these three views may be referred to as a single embodiment of a forming unit;

FIGURE 2 is a fragmentary enlarged detail view of an upper foil suction box taken generally along the line II—II of FIGURE 1B, with parts broken away or not shown for purposes of simplification; and

FIGURE 3 is a side elevational view taken generally along the side indicated at III—III of FIGURE 2 showing in side elevation generally the specific aspects of the foil suction box employed in the practice of the instant invention;

FIGURE 4 is an elevational view, with parts broken away and parts shown in section of an inlet or headbox for use in the practice of the invention;

FIGURE 5 is an essentially diagrammatic fragmentary cross-machine section, with parts broken away and parts shown in section, taken generally along the line of the roof of the inlet of FIGURE 4, such line being indicated at V—V;

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FIGURE 6 is an essentially schematic view shown in elevation to correspond to the elevational view of the inlet indicated in FIGURE 4, but again with certain parts broken away, and the view of FIGURE 6 is intended to represent generally the variations in cross sectional area of the controlled thin portions of the stock inlet;

FIGURE 7 is a fragmentary detail enlarged view of certain essential elements in the central portion of the narrow stock inlet of FIGURE 4, taken approximately from the same view as that shown in FIGURE 4, but showing these essential elements in enlarged elevation and section;

FIGURE 8 is an essentially diagrammatic top plan view of a cross-flow header for stock for the inlet of the embodiment of the instant invention;

FIGURE 9 is an essentially diagrammatic elevational view showing the overall inlet assembly of the instant invention taken generally from the rear side of the inlet; and

FIGURE 10 is an essentially diagrammatic view comparable to that of FIGURE 9 but showing still another embodiment of the instant invention.

As shown on the drawings:

In FIGURE 1A, the reference numeral **10** indicates generally a high speed stock inlet which consists essentially in means for generating and feeding a thin generally horizontal high speed stock jet of substantially homogeneous suspended entangled co-moving stock fibers on to a bottom wire reach here indicated at **20**, of a forming wire that is trained around an initial turning and drive roll **21**, a breast roll **22**, and a couch roll shown at **23** in FIGURE 1C, each of which rolls **21**, **22** and **23** being mounted on appropriate bearings which in turn are mounted on conventional framing indicated generally at **24** in the views of FIGURES 1A, B and C, but without showing specific details of the bearing mountings for the various rolls mentioned, since such aspects of mounting forming wire **20** and supporting rolls are old and well known in the art. In addition, it will be noted that the forming wire passes from the breast roll **22** to the couch roll **23** over a plurality of suction boxes SB–**1** through SB–**5** which are of well known structure and which function to exert a subatmospheric pressure to the underside of the forming wire **20** while the stock and/or web is moving on the forming wire **20** for purposes of dewatering the same in a function that is old and well known to the skilled workers in the art. The framing support for such suction boxes SB–**1** through **5** is indicated in part at **24*a*** and **24*b*** in FIGURES 1B and 1C, for purposes of showing the general arrangement, although specific details thereof are also fully understood by the skilled workers in the art.

In addition, the framing support for the initial suction box SB–**1** shown in FIGURE 1B carries a cross-machine frame **24*c*** which mounts a foil **25** that engages the underside of the forming wire **20** for relative movement therebetween, the foil **25** being maintained stationary, but for purposes of supporting the underside of the forming wire **20** and at the same time assisting in the removal of droplets of water tending to collect on the underside of the forming wire **20** in the region of the immediate off-running side of the upper foil box, indicated at **30** and shown in greater detail in FIGURES 2 and 3. The structure of the foil **25** is well known to those skilled in the art and is provided with a rounded forward edge **25*a*** for initial engagement with the underside of the wire **20** followed by a generally flat or planar surface which gradually separates from the underside of the wire **20** through a relatively small angle of about 5° for purposes of generating a pumping effect to assist in water removal. This particular function of the foil **25** is old and well known at the present time in paper making machinery. It will be noted, however, that the foil **25** is mounted on shims or other suitable devices to afford vertical adjustment therefor indicated diagrammatically by the two-headed arrow at A in the support pedestal **24***c* of FIGURE 1B. The relative vertical adjustment of the foil **25** is also carried out by structures understood by the skilled workers in the art, and is therefore indicated diagrammatically by the two-headed arrow A, although it will be appreciated that such relative vertical adjustment of the foil **25** has certain functions in the practice of the instant invention which will be described in greater detail hereinafter. Also, it will be noted that at the bottom of FIGURE 1B there is shown fragmentarily a wire tensioning roll **26** with adjustable means indicated also by a double headed arrow designated A for purposes of adjusting the overall tension on the forming wire **20**, as it is used in the practice of the instant invention. It will thus be seen that the relative position of the wire reach **20***a* between the top of the breast roll **22** and the top of the foil **25** is controlled not only by the adjustable positioning of the foil **25** but also the adjustable tensioning on the wire **20** by the tension roll **26**, both of which adjustable devices are understood by the skilled workers in the art and need not be described in further detail herein. In fact, the breast roll **22** itself may be mounted adjustably (as indicated schematically by the double headed horizontal and vertical arrows AA at the bearing B) for additional facility in adjusting the overall position of the wire reach **20***a* which moves generally in the longitudinal direction or in the direction of stock and web movement.

Referring again to FIGURE 1A, it will be seen that the device for generating the previously described thin stream of the high speed stock jet is indicated essentially diagrammatically at **10** with an internal passage of cross-machine width being shown diagrammatically at **10***a* for purposes of indicating the location of the stock stream jet being generated. It will also be noted that the overall stock inlet **10** is mounted on suitable bottom framing indicated at **11** plus upright framing indicated at **12** and **13** for carrying the horizontal slice jet generating and defining means indicated at **14***a* and **14***b*, feeding stock from a suitable source indicated at **15** into which stock is fed at a controlled rate by a suitable stock flow device such as a fan pump indicated diagrammatically at F in FIGURE 1A at a rate sufficient to generate the desired speed and other properties in the stock jet flowing in predetermined manner out of the stock jet opening indicated at **14′** in FIGURE 1B. The stock jet generating device **10** herein indicated in essentially diagrammatic form is known to prior workers in the art and well understood thereby and need not be described in further detail, except to mention various patent disclosures hereinafter which describe suitable means for stock jet generation useful in the practice of the instant invention. It will be noted, however, that the overall stock jet generating device **10** here shown is indicated diagrammatically as generating a substantially horizontal stock jet stream at the slice outlet **14′** of FIGURE 1B at substantially the top of the breast roll **22**. It will be appreciated, however, that certain limited adjustment of the position of the breast roll **22**, via the bearings B thereof may be afforded, as indicated by the two-headed arrows AA; but it is generally preferable to provide for limited adjustment of the stock jet generating device **10** itself for purposes of the instant invention and this may be done by spaced vertical adjusting devices indicated by the double headed arrows A–**1** and A–**2** as well as a suitable horizontal adjusting device indicated by the double headed arrow at A–3, all of which adjusting devices are again means that are well known and understood by the skilled workers in the art, but because of the general size of the machinery are sufficiently complex in size and character to make the showing of the same diagrammatically advantageous in clarifying and simplifying the showing of the essence of the instant invention herein.



Referring specifically to suitable stock jet stream generating devices useful in the practice of the instant invention in the position of or as a complete substitute for the device here indicated at **10**, reference is made to certain patent and application disclosures, each of which is incorporated herein by reference, which include U.S. Patent No. 3,098,787 and Parker et al. Ser. No. 338,424, filed Jan. 17, 1964 (and the earlier applications referred to therein, all of which are owned by the assignee of the instant application). In essence, each of these various disclosures and a number of other prior art disclosures have shown various turbulence generating devices which, in the present diagrammatic showing would be located in the section indicated at **14***a* or upstream thereof and would be used essentially for initially effecting a complete distribution of discrete individual fibers in the dilute stock being generated for high speed feed through the continuous channel **10***a* here shown diagrammatically extending through the sections **14***a* and **14***b* of FIGURE 1A. It will be appreciated that the essence of the stock jet or stock stream generating channel or device **10** involves the creation of an initial turbulence of one type or another upstream in the region of the channel **10***a* for adequate fiber distribution followed by a low scale much more moderate type of turbulence which is intended to maintain the fibers in their own discrete distributed condition while the same time feeding the dilute fiber distribution at extremely high speed ultimately on to the forming wire, previously indicated at **20***a*. The thin stream is of only approximately from ¼ inch to 1½ inch in height, depending on basis weight and grade of paper, in the region of the slice **14′** as it is fed from the channel **10***b* at an extremely high velocity (in the neighborhood of 2500 to 3000 or more feet per minute) at the requisite high pressures and in the generally horizontal or longitudinal direction aligned with the direction of an imaginary reference (abscissa) line, which is indicated at the line **200** in FIGURE 3 hereof. The line **200** is an imaginary straight line drawn in a tangent plane generally from the top of the breast roll **22** at substantially the slice exit **14′** and extending to the top of the foil **25**. Since the wire **20** is not without some elasticity and flexibility, no matter how much tension is placed on the wire by the roll **26** or otherwise, it will be appreciated that the wire **20** will have a tendency to be forced downwardly slightly below this imaginary line **200** by the force of the stock on the top thereof, but one of the important objects of the instant invention involves maintenance of the forming wire **20** at a relatively high tension by the use of the tensioning roll **26** or other conventional devices so that the bottom reach **20***a* of the forming wire between the breast roll **22** and the foil **25** is here shown being maintained substantially planar, i.e., the line **20***a* appears to be substantially a straight line as indicated in FIGURE 1B and thus to align substantially with the imaginary straight line **200** of FIGURE 3 by virtue of the maintenance of the high tension therein. The device **10** provides the stock feed conduit **10***a* and associated operating elements (all understood by the skilled workers in the art) for generating and feeding a thin high speed stock jet (at approximately **14′**) of substantially homogeneous suspended entangled co-moving stock fibers in dilute aqueous system, which stock jet is fed on to the wire reach **20***a* at approximately the top of the breast roll **22** and the stock jet is substantially commensurate in transverse dimension and longitudinal speed to that of the wire reach **20***a* at the immediate vicinity (**14′**) at which the stock jet is fed on to the wire reach **20***a* and the stock jet is aligned and fed on to the wire reach **20***a* in substantially the same generally horizontal direction of the movement of the initial wire reach **20***a*. It will be appreciated that, if the general direction of the wire reach **20***a* is to be altered normally from a horizontal direction (e.g. by relative adjustment of the breast roll **22** and the foil **25**), then adjustment of the various devices A–1 through A–3 for the stock stream generating device **10** is also carried out in order to maintain the desired general alignment of the stock stream jet at **14'** in substantially the direction of the forming wire reach **20a** which for practical purposes should not vary outside of about 30° from a generally horizontal direction to be consistent with the preferred operation of the instant invention.

In summary, then, it will be seen that the high speed stock jet at **14'** flows on to the top of the forming wire **20** at substantially the top of the breast roll **22** or at least plus or minus about 10 or 15° from the vertical center line **22CL** for the breast roll **22** supporting from beneath the forming wire **20**.

As also indicated in FIGURES 1B and 1C, in the embodiment of the instant invention there is provided an upper forming wire which is indicated generally by the reference numeral **40**. The upper forming wire **40** travels beneath and is supported on the top side by the foil box **30** in the approximate region of the jet outlet **10b** (as indicated in FIGURE 1B), and it also travels around appropriate guide and tensioning rolls indicated at **41, 42, 43, 44, 45** and **46**. Although shown essentially diagrammatically, it will be seen that the horizontal framing **24** is also provided with upright frame elements **24d, 24e** and **24f**, with the last-mentioned upright **24f** supporting the guide roll **46** for rotation and separation of the forming wire **40** from the formed web W which is carried away on the lower forming wire **20**, as shown in FIGURE 1C. The upright support **24f** is also the principal support for a couch press defined by the plain bottom couch roll **23** supporting from beneath the forming wire **20** with the web W thereon and an upper couch press roll **47** within the loop of the upper wire **40** which is carried at opposite ends on fixed **47a** and movable **47b** pivots, with the movable pivots **47b** being in turn attached to a suitable power cylinder **47c** that is in turn connected to a lower extension of the framing at **24ff** for purposes of controlling the load at the couch nip N, which is the nip defined between the forming wires **20** and **40** and plain press rolls **23** and **47** for purposes of removing excess water at the location of the nip N by mechanical means, prior to subsequent treatment of the web W as it is fed into the rest of the machine on the forming wire **20**. The advantages of a couch press **23–47** are apparent to the skilled worker in the art; but the successful use of the same heretofore has been limited, if possible at all, for the reason that it is necessary to have a reasonably strong web formation prior to the application of any pressing action for dewatering thereof and webs of this strength were heretofore ordinarily not possible at such an early stage in the forming operation (or so closely spaced from the stock jet slice **10b**) as here indicated. As will be explained in greater detail hereinafter, the initial forming arrangement including particularly the top foil suction box **30** is so constructed as to afford a maximum rate of dewatering and a maximum rate of strong web formation making possible the use of the couch press **23–47** here shown.

Referring again to FIGURE 1B, it will be seen that the upright frames **24d** and **24e** are provided with appropriate cross frames **24h** and **24g**, all of conventional structure which the skilled worker in the art will understand are positioned (as in the case of all of the framing here indicated) at opposite sides of the forming wires **20** and **40** so as to mount opposite ends of the functioning devices herein described. It will thus be seen that a bearing pedestal **24ee** is indicated as being mounted on the upright **24e** for the purpose of mounting the wire guide roll **45**. A bearing pedestal **24dd** is shown as an extension of the upright **24d** for mounting the guide roll **42**; and a bearing pedestal **24xx** is shown mounted on the side of the upright **24d** for mounting the guide roll **41**. In addition, it will be noted that conventional jackscrew assemblies JS–1 and JS–2 are shown mounted on the top cross frame **24g** for suitable adjustment of the guide and tensioning rolls **43** and **44**, respectively. It will be noted that



the double headed arrows indicated in each case at A indicate approximately the direction in which adjustment is afforded for the rolls **43** and **44** so that these rolls may be used effectively to guide and tension the upper forming wire **40**, again in an essentially conventional manner which need not be described in further detail herein, since it is well understood by the skilled workers in the art.

In addition, it will be seen that the specific lower portion of the foil suction box **30** is actually mounted in a housing **31** which is pivotally mounted at its forward end on the previously described pedestal **24xx** and is adjustable in a generally vertical direction by the use of a jackscrew indicated at JS–3; whereas the rear end of the housing **31** is mounted on a depending frame **24hh** carrying a jackscrew JS–4 which is adapted for limited vertical adjustment or movement as indicated by the double headed arrow A. The jackscrews JS–3 and JS–4 thus provide conventional controlled means of adjustment for effecting overall vertical movement as well as relative tilting of the housing **31** and the lower functional portion of the foil suction box **30** which actually contacts the inside of the loop of the forming wire **40**. It will be appreciated that a side suction takeoff **33** is provided at the rear end of the housing **31** (although indicated essentially diagrammatically) with an appropriate overflow dam indicated at **35** within the housing **31**, so that water drawn up through the foil suction box **30** will fall over the dam **35** and be withdrawn from the side of the machine through the suction takeoff **33** in substantially the manner of operation employed for water and air removal through suction box takeoffs which are, of course, employed in connection with the suction boxes SB–1 through 5 hereinbefore described. The dam **35** will, of course, tend to control to some extent the water level continuously accumulating in the lower portion of the upper suction box housing **31**, whereas the top side of the housing **31** is closed and maintained at subatmospheric pressure by virtue of the suction takoff **33**.

It will be noted that the forming wire **40** travels downwardly around the guide roll **41** and then around a curvate solid surface or shoe indicated generally at **50** which aligns the same for its travel in guided fashion along the bottom of the longitudinally spaced cross-machine foils in the foil box **30** indicated at **51** through **60**. It will be seen that the individual longitudinally spaced cross-machine foils **51** through **60** are shown in an elevational view in FIGURE 3 (through the side wall **30a** of the bottom foil box **30** and fragmentarily in a top elevation in FIGURE 2); and, in contrast to the previously described foil **25**, the structures of the foils or "blades" **51, 52**, etc. are different, and these foils **51, 52**, etc. have individual structures such as those shown substantially in Van Ryzin U.S. Patent No. 2,740,332 (wherein Van Ryzin's flat wire contacting edges are uniplanar instead of the generally curved longitudinal contour which the flat wire contacting edegs **51a, 52a**, etc. define in the foil box **30** of the invention). Referring generally to the generally thin flat structure and edgewise arrangement of a single foil, attention is directed to the foil **52** which is indicated by way of example in both FIGURES 2 and 3 as the second foil in the longitudinally spaced arrangement. It will be seen from FIGURE 2 that the thin top edge of the foil **52** is shown at **52x** in full view extending from the top edge of the side wall **30a** of the foil box **30**. It will also be seen that a deckle or sealing piece **30b** is shown in FIGURE 2 as being attached to the side wall **30a** and is shown in FIGURE 3 as extending along the bottom of the side wall **30a** and having a general-curvate bottom surface which is more pronounced at the forward or left hand end **30bb** thereof. In top plan view only the portion indicated at **30b'** being visible at the forward end and the top plan portion **30b''** being visible at the rear or right hand end of the sealing piece **30b** in FIGURE 2, with the remainder thereof being shown covered at least in part by the various slanted foils 51 through 60. It will also be noted that the foils 51 through 60 extend downwardly from the top exposed thin edge portions 51*x* through 60*x* shown in FIGURE 2 down to thin edge bottom portions 51*b* through 60*b* each of which engages and is secured to the top of the side sealing strip 30*b* indicated in FIGURES 2 and 3.

It will further be seen that the central portion of each of the individual foils 51 through 60 extending downwardly beneath the sealing edge 30*b* (which is shown on one side only in FIGURE 2, but which will be understood to be present at opposite sides of the foil box 30 in a complete view) extends downwardly to engage the top side of the traveling wire 40 along a smoothly machined (i.e. mirror finished) guiding surface or edge 51*a* through 60*a* indicated for the bottom of each of the foils 51 through 60. Thus, referring again to the foil 52 in FIGURE 2, it will be seen that the top edge 52*x* is shown and this foil 52 then extends from the top edge 52 downwardly and to the left to a surface 52*b* along the edge thereof which engages the sealing strip 30*b* and to a surface which is indicated farther to the left in FIGURE 2 at 52*a* which engages the inside of the loop at the top wire 40 and controls the position thereof. The extreme bottoms of the foils 51 through 60, at the polished (i.e. preferably to a mirror finish, per Walker Ser. No. 150,917, filed Nov. 8, 1961, as preferably are all elements engaging the relatively moving wire 20), smooth guide surfaces 51*a* through 60*a*, will of course furnish relatively closely spaced (in the longitudinal direction) edge supports for the wire 40, which supporting edge surfaces 51*a* through 60*a* will be found upon examination of the substantially elongated curvate contour of the upper wire (as shown in the longitudinal contour of FIGURE 3) to define generally spaced loci of noncircular elongated curve with (convex) reference to the theoretical or imaginary straight (abscissa) line 200 herein before discussed. Beneath the suction box 31, the foil box 30 is framed by conventional removal seals, i.e., a sealing rear piece 31*a*, with an appropriate flange 31*b* to afford means for securing it to the foil box 30 (as indicated in FIGURES 2 and 3); whereas FIGURE 1B shows a front rounded cross-machine sealing piece 50 with seal shim 31*c* that is secured to the forward or left end of the foil box 30 (FIGURES 2 and 3); and a machine-side sealing piece 31*e* (counterpart of a drive side piece not shown) is seen partially in FIGURES 1B and 2 (although these are essentially omitted from other views for purposes of simplicity) to complete the peripheral seal for the foil box 30. The forward shim sealing piece 31*c*, of course, has a lower smooth bearing surface 31*c'* (abruptly terminating at its off-running edge line 30*bb*) that forms a continuation for the initial guide surface for the wire, previously indicated at 50 in FIGURE 1B, and this overall surface 50, 31*c'* is preferably generally cylindrical in contour (and abruptly terminating at 30*bb*) for smooth movement of the wire thereover and feeding of the wire 40 in smooth uninterrupted manner directly on to and over the spaced smooth bottom guide surfaces of the stationary foil edges 51*a* through 60*a* which also terminate abruptly at the off-running sides thereof (as contrasted to gradual divergence as described for the foil 25) in order to separate abruptly from the traveling wire 40 so as to preclude localized pumping effect pressure variations drastic enough to damage web formation on the wire 40.

In reference to completion of the details indicated in FIGURES 2 and 3, it will be noted that the rear flange 31*b* and the side piece 30*a*, 31*e* for the foil box 30 are provided, at the places indicated at B, with suitable apertures for receiving threaded bolts for securing the foil box 30 and peripheral seal 31*e*, etc. to the bottom of the overall suction box 31 in the conventional manner.

The significant feature of the overall bottom contour arrangement of the foil box 30 involves specifically a reference to an elongated curve that is based generally upon a theoretical abscissa lying along the imaginary line 200 hereinbefore described in which the increment thereof will be indicated by the reference letter D shown with a two-headed arrow in FIGURE 3; and an ordinate indicated generally by the center line CL in FIGURE 3 in which the increments thereof will be indicated by the reference letter H also indicated by a two-headed arrow in FIGURE 3. The intersection of the abscissa 200 and the ordinate CL is the theoretical 0, 0 for the curve:

$$H=CD^k$$

(which representing the box contour per se will stay within the limits herein prescribed for the constants C and *k*, during desired operation notwithstanding tilting of the foil box 30 and/or inlet 10' via the adjustments A, A, to the limited extent contemplated) wherein H is the distance (in inches) vertically up from the line 200, D is the distance (in inches) to the right indicated at $D_1$ through $D_9$ of FIGURE 3, or in the positive direction from the line CL, as shown in FIGURE 3; and C and *k* are constants. It will be understood from FIGURES 1B and 3 that the top wire 40 is there shown in a position where it is fully supported from above by the smooth surfaces 50 and 31*c* which feed the same to a point $P_0$ (FIGURE 3) on the ordinate CL; and prior to the point $P_0$ to the backing surfaces 50 and 31*c* make the wire 40 impervious or water impermeable. At the leading foil edge 51*a*, i.e., the next point $P_1$ (and, of course, at the slightly higher point $P_0$) the height H of the wire 40 above the abscissa 200 (shown in exact longitudinal alignment with the wire 20 on the breast roll 22 in the specific arrangement of FIGURE 3) is substantially the height of the stock jet stream issuing at 14' (assuming the wire run 20*a* is maintained in substantially the undeflected alignment and spacing shown in the standing arrangement of FIGURE 3), and flowing at approximately 3000 feet per minute for the present embodiment.

In the case of stock flowing between the points $P_0$ and $P_1$ which is the initial unsupported or open area for the wire 40, the wire 40 becomes functionally water-permeable and initially receives water flowing into the foil box 30. Prior to this region defined by the transverse slot between points $P_0$ and $P_1$ it will be noted that the solid supports 50 and 31*c* are positioned very closely to the top of the structure 14*b* for the stock jet inlet 14' (and the wire 40 runs therebetween in very close running relation) such that substantially the full stock jet pressure will be exerted against both the top and bottom wires 40 and 20 substantially immediately after and/or at the region $P_0$ to $P_1$, with negligible backward flow and/or loss of pressure by backward stock flow or upward flow back between the inlet structure 14*b* and the solidly supported wire 40. For purposes of the reference, point $P_0$ will be considered as lying in the ordinate CL and the distance from $P_0$ to $P_1$ will be considered to be approximately one inch (actually ¾ inch). Roughly speaking, the curve including the loci $P_0$ to $P_1$ must be considered to be a generally elongated non-circular curvature in its transition from the generally cylindrical (or circular in section defined by the cylindrical solid guiding surfaces 50, 31*c*) to the elongated curved configuration defined by the longitudinal contour of the loci of the foil bottoms 51*a*, etc. but the essence of the curve of the loci of $P_0$ to $P_1$ will not necessarily be curvilinear even though for practical purposes it is inherently curved for aligning the wire 40 with the subsequent elongated generally curved contour of the wire alignment found to be substantially essential to the practice of the invention; and the stock jet stream 14' will be considered as having substantially the same structure in width, height, speed, etc. as that passing through the center line CL (even though it may not exit from its supporting structure **14**$b$ at precisely this point, and, is shown in FIGURE 1B, is obviously upstream therefrom). Likewise, the abscissa **200** will be considered as lying in a generally horizontal plane (substantially perpendicular to the aforesaid center line CL) and defining a straight line in substantial longitudinal alignment with the wire run **20**$a$ which may be deflected somewhat away from such horizontal plane. For purposes of reference in considering the more essential features of the invention we assume for the moment that the line **200** is horizontal.

The critical area in the operation of the forming area is the converging sheet forming zone immediately after the stock leaves the inlet **14**$b$ and is deposited on the bottom wire **20**. This zone is the converging nip where the top wire **40** approaches the bottom wire **20** and where the water is drained from the stock slurry both upward and downward, leaving the fiber deposited between the two wires **20** and **40** to form the sheet or ultimate web W. The function of the top wire **40** in conjunction with the bottom wire **20**, besides providing a spetum through which water can be drained from the sheet upward as well as downwardly, is to eliminate the free surface and thus provide stability and control over the slurry as it is being drained to form the sheet. In order for this stability to exist at high speeds it is essential that the forming nip converge in such a way that the slurry will "feel" essentially a constant pressure as the sheet is being formed or until the network strength of the slurry is high enough so that an increase in the pressure gradient between the wires **20** and **40** will not have a damaging effect on the sheet W being formed.

The tests made on experimental forming units have shown that the convergence of the forming nip is critical. The nip is made by maintaining tension in the bottom wire **20** (or bottom portion **20**$a$) and having the top wire drag (also under tension) against the contoured bottom cover of the top forming box as indicated at the longitudinally spaced surfaces **51**$a$, **52**$a$, **53**$a$, etc. (i.e., the longitudinal contour of the loci of such spaced wire-contacting surfaces of edges **51**$a$, **52**$a$, etc. with the driven wire **40** driven through the general longitudinal contour of a multiplicity of short successive short reaches bridging the short spaces between such edges **51**$a$, **52**$a$, etc. so as to travel substantially along the elongated curve defined by such loci). The critical section of the cover or box **30** is machined to a curve $H=CD^k$ where C and $k$ are constants determined by the sheet weight, stock freeness and consistency. The surface of the cover from $D=0$ to $D=.75''$ is less critical and machined so that it forms a smooth transition from the nose piece to the curve $H=CD^k$. The essentially critical surfaces **51**$a$, **52**$a$, **53**$a$, etc. from $D=.75''$ to $6''$ or $8''$ (i.e. in the distance indicated from substantially $D_1$ to about $D_7$ or $D_9$) are machined according to the curve $H=CD^k$. Thus, the given formula for the curve is referenced primarily to the longitudinal contour of the active face or cover of the foil box **30** (and so are the ordinate CL and the abscissa **200** for purposes of defining such curve) although the foil box **30** itself is mounted for limited vertical and pivotal movement in the manner hereinbefore described. From $D=6''$ or $8''$ to the end of of the cover the slope of the curve can be made steeper than $H=CD^k$ to make use of higher normal forces between the wires for increased drainage. This can be done because at $D=6''$ to $8''$ where the strength of the formed mat W is high enough so that it resists disruption and damage from the increasingly higher drainage pressures. In plotting the curve of $H=CD^k$, for the relative positions of the elements in the arrangement of FIGURE 3, the D axis is the theoretically straight line previously indicated at **200**, i.e., extending from the top of the breast roll (bottom wire support roll just ahead of the open portion of the forming box) to the top of bottom wire support following the forming box and the H axis is the line perpendicular to the D axis, i.e. previously referred to as "CL" extending downward from the initial opening to the vacuum compartment in the suction box **30**.



The machined surface of the forming cover now being used on a foil box **30** may be considered to be (the longitudinal contour of loci of the blade edges **51**$a$, **52**$a$, etc.) plotted on the graph previously indicated (in FIGURE 3). This is the recommended curve for "slow" or low freeness stock such as is used for newsprint and coating rawstock. The C and $k$ values for the curve $H=CD^k$ for this surface approximate $C=.516$ and $k=-.284$. For more free draining stock (lower) $k$ value would increase in the negative direction and in running at lower consistencies the C value would be high to allow for running the greater volume. The ranges for practical purposes for upper and lower values of C and k that might be understood are $C=.5$ to $1.6$ and $k=-.2$ to $-.8$ for $H=CD^k$ for the critical forming area and for the trailing end of the cover the slope of the curve can deviate from (i.e., may be made or conformed at this stage of the curve such that the curve does not tend, e.g., to level out quite as much as the elongated curve formula suggests and the curve may thus have a downward slope steeper than) $H=CD^k$ to make use of higher normal forces between the wires for increased drainage. This can be done because at $D=6$ to $8$ the network strength of the formed mat W or web is high enough that it resists damage from the increasingly higher drainage pressures.

The essence of the concept here involved seems to be that the stock jet does not change in composition, height, width, etc. from its exit from the supporting structure **14**$b$ to substantially the point $P_0$. From the point $P_0$ to $P_1$ (which limit the longitudinal demension of the slot which extends in the full cross-machine direction) there is an initial rapid flow which occurs upwardly (and depending upon the exact position of the breast roll **22** probably also occurs downwardly simultaneously); but this is extremely difficult to control. Roughly speaking the bottom wire **20** remains tangent to the breast roll (i.e. substantially horizontal in most instances) whereas the top wire **40** moves through such loci $P_0$, $P_1$ lying in a cylindrical or curvilinear surface of comparatively great radius—for a very brief distance of less than one inch (i.e. substantially $D_1$) and preferably about ¾ inch. In these small dimensions the wires **20** and **40** function as rigid, inflexible beams, even though a certain and even a substantial amount of drainage may occur (which drainage, it will be understood from a practical point of view, does not result in any appreciable web formation and/or increase in the remaining stock consistency on the wires **20** and **40**). After D equals approximately ¾ inch, then the drainage and web formation become critical and the top wire **40** is caused to form the elongated curve:

$$H=CD^k$$

It must be understood, of course, that downward movement of the box **30** and/or excessive pressures will cause a certain downward "dip" to the lower wire **20** in this region—perhaps in the nature of a catenary but probably in an elongated curved form—although means (**26**, etc.) are provided for maintenance of high tension thereon and thus a minimum or at least controlled "dip" between the breast roll **22** and foil **25**. Drive controls (indicated schematically at $M_1$ and $M_2$ in FIGURE 1C) for the two wires **20** and **40** also carry out this function.

The object in this critical region of stock formation is to keep substantially the same internal pressure (which is within the "stock" on both the top and bottom semi-webs). Hence the stock pressure as well as foil box alignment are compensated for by the type of dipping which the bottom wire **20**$a$ may tend to undergo in this region (below the theoretical line **200**) which can and will be for this essential purpose. The relative position of the top wire **40** is fairly well fixed by the bottoms of the closely spaced foils **51, 52**, etc. which determine the longitudinal contour of loci that will define the elongated curve previously set forth. The longitudinal (linear) speeds of the two wires **20** and **40** are substantially equated by known wire drive control means (e.g. inter-connected drive motors $M_1$ and $M_2$ for any suitable driving rolls such as the couch rolls **23** and **46**, as schematically indicated in FIGURE 1C).

It has been found that the net effect of the high speed stock jet is that it actually does not impact upon this downwardly moving wire **40** until substantially the point $P_1$; and thus does not generate within itself (the maximum and/or all of) the necessary (drainage) pressure until approximately this region, whereupon the elongated curve $H=CD^k$ becomes important so that the internal stock body will feel the same pressure for the next 6 to 8 inches during which the critically sensitive web formation takes place, and at substantially the end of this travel distance (indicated in FIGURE 3 by distances from about $D_1$ to substantially $D_7$ to $D_9$) the stock body has assumed, through its entire height, a substantially uniform composition or consistency, which is not inconsistent with complete and final merging of the presently forming (or even formed) web bodies on the two wires and affords a more or less final opportunity for the ultimate integration of the fibers collected on each wire into a single web which does not have any readily recognized middle parting line. This permits the wires **20** and **40** to continue to move together, with continued dewatering of the web therebetween, up to and including the couch press **23–47**.

Thus, prior to the region of the elongated curve the object is to bring the wires together generally in conformance with the contour of the curve, and after the elongated curve the wires should be moved together, gradually, to effect water removal at increased pressure but without the necessity of extreme caution in effecting the increased pressure. This is presumably because the network strength of the web is strong enough after the region of the elongated curve to resist damage at increasingly higher pressures and because there is no real network to damage or destroy before the region of the elongated curve (because of the substantial dilution of the stock). In the critical region of the instant elongated curve, however, the fiber network is commencing to build up on the top and bottom wires **40** and **20** over the distance from about $D_1$ to substantially $D_7$ to $D_9$ and simultaneously the comparatively lower stock consistency (i.e. comparatively greater water to fiber ratio) intermediate these sensitive fiber networks on the top **40** and bottom wires **20** are responsive to pressure change between the wires and it is important to maintain temporarily a substantially constant pressure on such network or overall system on each wire until there is a substantial equalization among the consistencies of such (with the more dilute stock being drained therethrough.

In this respect, the minimization of drastic pressure variations along the wire **40** is effected by the abruptly terminating off-running sides of each of the wire guiding foil edges **51***a*, **52***a*, etc. plus the overall slanted configuration of the foils **51, 52**, etc. cooperating with the overflow dam and the suction or subatmospheric pressure maintenance arrangement within the structure of the box **31** will all contribute to the maintenance of such substantially constant pressure on the web network on the wire **40**; and in addition the selectivity and control of relative rates of dewatering between the two wires **40** and **20** afforded by virtue of the limited tilting and/or horizontal or vertical movement of the overall box **31** in conjunction with a corresponding pressure responsive deflection in wire **20** plus adjustment of the alignment of the stock jet from the inlet **14***b*, all serve to assist in the aforesaid pressure control during the critical formation stages just described.

It will be appreciated that the stock consistency for newsprint (e.g. as much as 0.5% up to even 1.0%) is much greater than that of the so-called tissue (e.g. which is in the lower range of about 0.1% to about 0.5%, by weight). Because of the extremely high speed which the "tissue" vehicle or "water" goes through the forming wire, it will be appreciated that the comparative rate at which a web is built upon the forming wire in a tissue machine is so slow, that the present device may be used with great advantage on the tissue machine (but over a correspondingly greater distance D). In other words, on the tissue machine the consistency is so low that the rate of "build up" of a web or "septum" on the wire is even less than (and certainly not more than) that which occurs in a machine having both top and bottom *active* wires—subject to vacuum, etc. Hence the elongated curved contour of the bottom wire on a tissue machine (of the type disclosed in the application of E. J. Justus, filed Jan. 18, 1965 may have many, if not all, of the advantages of the elongated curved top configuration of a top wire on the instant preferably high consistency, e.g. newsprint machine), which because of its lower consistency, not only tends preferably to conform to the desired elongated curve along the top wire but also drives the bottom wire into a conforming noncircular-type curve.

It will be appreciated that the initial reach of bottom wire **20***a* from the breast roll **22** to the foil **25** is otherwise unsupported (i.e. free of restraining means in contact therewith at locations opposite the permeable stationary supporting surface of the box **30** in the forming zone, as defined essentially by the foil or guide bottoms **51***a*, **52***a*, **53***a*, etc.) but under high tension such that the configuration of any curve therein is nominal (as compared to the elongated curved contour of the bottom of the foil box **30**) although even theoretically such that neither a true catenary nor a true beam deflection is obtained in the bottom wire. Instead, even though the initial forces applied to the bottom wire of said tissue machine, as well as the instant bottom wire **20***a*, are considerably higher than those later applied (e.g. as the wire reach **20***a* apoaches the foil **25**) and this results in each case in an "elongated-type" curve which is definitely non-circular in configuration, but any such curve in the highly tensional bottom wire **20***a* is so nominal that it is essentially theoretical, and not perceptible (visibly) as a practical matter. Of course, the same is true in the instant case in which the upper device is a suction-backed wire **40**, rather than a felt, but the curve which the bottom wire tends to form is different, in theory and practice. In considering linear velocity conditions herein, it must be appreciated that, (1) in FIGURES 1, 2 and 3, the linear velocity generally equated to the linear speed of the wires **20** and **40** is actually based on fibers by weight (which go to make up the web); whereas (2) in the subsequent figures hereof we are concerned primarily with linear stock velocities based on the whole volume of the very dilute stock. Since the weight of fibers coming through the jet **14′** at a given moment is only that required to make a very thin web, the comparison therewith in terms of linear speed with the hereinafter so-called "stock speed" is difficult by virtue of the fact that the jet **14′** cross-section is substantially greater than that of the ultimate web, while also containing substantially greater volumes of water that will be contained in the ultimate web.

In order to show additionally the preferred assembly hereof, the previously mentioned Parker et al. disclosure is shown in the subsequent views hereof in the assembly of the invention in combination with the previously described forming section of FIGURES 1, 2 and 3.

In FIGURE 4 there is shown the essential concept of the preferred inlet in the combination of the invention from a side elevational view with parts shown in section, showing primarily certain fundamental features of the instant inlet designated generally by the reference numeral **10′**. These include generally closely spaced, laterally or cross-machine extending top **11′** and bottom **12′**

walls which converge from a relatively thin (i.e. small in height) inlet 13′, from which the walls 11′ and 12′ extend longitudinally from right to left in the direction of stock flow in the device 10′ a substantial distance convergingly, in fact, so as to converge approximately at an angle of convergence of about 3°, but which may range from a minimum practical angle of convergence of about 1° to a maximum practical angle of convergence of about 10°, which angle of convergence is indicated in the schematic showing of FIGURE 6 as the angle $B_1'$, or as the total of the two halves indicated at $B_2'$ and $B_3'$ in FIGURE 6. In general, the top and bottom walls 11′ and 12′ extend the full width of the paper machine which may range from minimum commercial machine sizes in the neighborhood of 100 to 150 inches to as much as the maximum known commercial machine sizes which are now in the neighbrohood of about 340 or 350 inches. In contrast, the longitudinal dimension of these walls 11′ and 12′ in the direction of stock flow from the inlet 13′ to the very small outlet indicated at 14′ in FIGURE 4, which outlet is referred to in paper making as the slice, will ordinarily be only about 40 to 50 inches, or something in the neighborhood of ⅓ to 1/10 of the cross-machine dimension for the walls 11 and 12.

As the terms are used herein, transverse refers to the cross-machine direction whereas longitudinal refers to the so-called machine direction. The stock flows through the inlet portion defined between the generally converging walls 11′ and 12′ in a generally longitudinal direction toward the slice 14′, from which it flows (usually through a slight drop) onto a lower traveling forming surface 20 which is the usually very fine woven screen that is referred to in the paper machine trade as the forming wire. The stock may thus be fed from the slice 14′ onto the top of one forming wire 20 and between two converging forming wires 20, 40, in the type of forming device to be used. For the moment, we are concerned primarily with the inlet itself and the conversion of the stock flow from the initial generally transverse or cross-machine introductory stock flow to an essentially longitudinal thin stream of stock flowing through the slice 14′ The stock (volume) velocity at the slice 14′, being essentially the velocity of fibers as well as water at the slice, is essentially the velocity of the forming wires 20, 40 and thus, as previously indicated in a paper machine operating at 2,400 feet per minute the linear velocity of stock at the slice 14′ will be approximately 40 feet per second. The slice 14′ has a definite but very thin dimension as well as its very substantial transverse dimension. This thin dimension is generally perpendicular to the horizontal or to the lower forming wire 20 itself, with respect to the alignment of the dimension, which is indicated schematically in FIGURE 6 as the dimension $A_{13}'$.

The dimension $A_{13}'$ is in effect the cross-sectional area (or at least representative of the cross-sectional area) of the slice 14′ from which the stock flows between the forming wires at a linear velocity of, for example, 40 feet per second. It will be appreciated that if we are to assume negligible frictional losses, then we may assume that the stock linear velocity at any point in this inlet between the walls 11′ and 12′ will be approximately inversely proportional to the ratio between the cross-setcional area at the location in question and the cross-sectional area of the slice itself. Thus, referring to FIGURE 6, we see that the cross-sectional area of the slice is represented by the dimension $A_{13}'$ whereas the cross-sectional area of the inlet previously described in connection with FIGURE 4 as 13′ is designated in FIGURE 6 by the reference letter $A_1'$. Assuming the back pressures on the stock flowing the full longitudinal dimension of this portion of the inlet, which is generally considered to be the inlet channel R′, is substantially constant at all times, it can be assumed that the velocity of the stock in the longitudinal direction of flow in the region of the inlet $A_1'$ will be 40 times $A_{13}'$ divided by $A_1'$. In other words, if the slice velocity is 40



feet per second at a cross-sectional area of $A_{13}'$, then the stock velocity coming into the channel R′ in the region $A_1'$ would be only 20 feet per second if the dimension $A_1'$ is twice the dimension $A_{13}'$, which happens to be approximately the case, although in the preferred embodiment of the instant invention the dimension $A_1'$ is actually closer to about three times the dimension $A_{13}'$.

In any event, it is apparent from the showing in FIGURE 4 and the schematic showing in FIGURE 6 that the top wall or roof 11′ and the bottom wall or floor 12′ converge gradually and thus they impart to the stock a continuously increasing velocity over the longitudinal dimension of the inlet channel R′. It will also be noted that the surface 12a′ of the floor or bottom wall 12′ is a relatively smooth straight surface that slopes downwardly slightly toward the forming wire 20 and the angle of slope is indicated at $B_4'$ schematically in FIGURE 6 with reference to the wire line WL′, and it will be noted that this angle of slope $B_4'$ (i.e., shown to be expressed in terms of total drop in the floor 12a′, etc. of FIGURE 4 per substantially 5 to 10 feet from $A_0'$ of FIGURE 6 to 14′ of FIGURE 4 is preferably in the neighborhood of about ½ to 5 or even 10 inches) depending upon the type of inlet desired. In general, the purpose of the inlet is to feed the stock through the slice 14′ in generally substantially parallel alignment with respect to the bottom forming wire 20 so the floor 12a′ should have only a very slight downward slope in the neighborhood of about 1 to 3° from the horizontal, and preferably about 2° as here shown in order to permit stock flow out of the inlet during shutdown and avoid the collection of pools of stock on the surface of the floor 12a′ during such shutdown of the device. Added to this convenience is the fact that the bump-like turbulence generators indicated in FIGURE 4 generally at 15′ and 16′ in the intermediate section $R_2'$ of the channel are mounted only on the roof of the channel. The forward section of the channel $R_3'$ is defined between two relatively narrow wall sections of the roof 11B′ and the floor 12B′ which provide a channel spacing indicated schematically in FIGURES 6 as $A_{13}'$ that is substantially equal for the full dimension of this exit 14′, or terminal section $R_3'$, of the channel, although a nominal taper (compared to that upstream) or reduction in the spacing $A_{13}'$ between such smooth walls is not precluded and may even be helpful in the final guidance of the stock jet at 14′. As is indicated in FIGURE 4, the roof portion 11B′ is secured rather rigidly by suitable means such as welds or bolts (not shown) to the roof section 11C′ of the second section $R_2'$ of the channel, by framing generally indicated at $F_1'$ and $F_2'$, such framing $F_1'$ and $F_2'$ extending the full width of the machine and being connected by bolts or welds (not shown) in such a manner as to afford a generally rigid connection between the intermediate roof section 11C′ and the exit roof section 11B′, leaving the exit roof section 11B′ to extend in a generally cantilever type mounting longitudinally to the slice 14′. It will be noted, however, that the slice extremity of the roof portion 11B′ is provided with a plurality of ears, only one of which is shown at 17′, each having pivotal connections 18′ to rods 19′ that are adjustably connected to a flange portion 20′ on the framing $F_1'$ via twin lock nuts 21′ and 22′ which afford limited adjustment of the rod 19′ longitudinally or axially so as to afford limited local adjustment of the relative spacing between the slice extremity of the roof wall portion 11B′ and the channel floor portion opposite thereto designated 12B′. This is for very minor adjustment of flow via very minor adjustment of the cross-sectional area in the local region, since the overall cross-sectional area in the final exit section $R_3'$ of the inlet shown in FIGURE 4 is generally uniform and is designated schematically in FIGURE 6 as being generally of the dimension $A_{13}'$ throughout its entire transverse as well as longitudinal dimension.

The essential convergence of the walls 11′ and 12′ thus takes place at the first channel section $R_1'$ and the second channel section $R_2'$, which are already indicated as converging approximately along an angle of convergence $B_1'$ of about 3 to 5°, and preferably about 3°. In addition to the limited adjustment for the final roof portion 11B′ via the rods 19′, it will be appreciated that the final roof portion 11B securely anchored to the intermediate roof portion 11C′ is carried by a cross-machine pivot, indicated generally at 30′ in FIGURE 4. The pivot 30′ is carried in mating blocks 30*a*′ and 30*b*′ carried on the forward end of a generally rigid cross-machine frame element $F_3'$ which also carries the forward end of the roof portion 11D′ of the first channel section $R_1'$. The connected cross-machine framing sections $F_1'$ and $F_2'$ also have an ear 31′ carrying a pivot 32′ at opposite sides of the machine (only one of which being shown in FIGURE 4) which pivots 32′ are connected through motors shown schematically at 33′ to tie rods 34′ which are in turn mounted on the fixed framing $F_4'$ by pivots 35′. The motor 33′ is of conventional structure and is used to coact with the tie rods 34′ to lift the forward roof wall portions 11C′ and 11B′ simultaneously in and out of operating position and to leave open a corresponding flat smooth merging sequence of wall surfaces 12*c*′ and 12*b*′ which form the continuation of the floor 12*a*′ for the bottom of the channel R′ from the inlet 13′ down to the slice 14′ at the gradual slope of approximately 2° hereinbefore mentioned. It will thus be seen that the swinging of the roof portions 11C′ and 11B′ out of operating position will leave exposed an open smooth flat floor area 12*c*′–12*b*′ which will not collect pools of stock and which can be readily worked on to the extent required and will be readily exposed as a clean smooth surface for this purpose. In this way the turbulence generators 15′ and 16′ which will be described in detail hereinafter are moved out of operating position also and, by carrying these turbulence generators 15′ and 16′ on the roof portion 11C′ which is swingable in and out of operating position, it is possible to make available a flat floor section 12*c*′–12*b*′ available for immediate maintenance in the most convenient manner.

In contrast, in connection with the first channel portion or section $R_1'$, it will be seen that turbulence generators are indicated generally at 40′ and 41′ in the form of transversely extending rod banks, which will be described in greater detail hereinafter, but which will be understood to be defined by a multiplicity of relatively small abutments extending between the walls 11′ and 12′ to afford support thereto and also to afford controlled reduction in the cross-sectional area in the immediate location thereof and further, it being generally rods, terminating abruptly at the down stream end thereof for desired vortex turbulence generation in the stock flowing past such rods. The upstream sides of the rods are smooth and rounded so as not to collect fibers or strings thereon. This is the general structure of the rods in the banks 40′ and 41′, which will be discussed in greater detail hereinafter, but which for the moment will be described directly in connection with the overall support of the physical structure in that these rods 40′ and 41′ actually maintain the top and bottom walls $11_2$ and 12′ in the desired converging closely spaced relation hereinbefore described. Above this initial section $R_1'$, it will be seen in FIGURE 4 that there is provided substantial reinforcement and additional framing including the upright framing $F_3'$ and additional framing $F_4'$ thereabove which mounts the pivots 35′ hereinbefore described and which also mounts the initial stock inlet indicated generally at 50′ at the left end of FIGURE 4 and showing in the fragmentary view a definite level L′ also at the left hand side of FIGURE 4.

The particular details of the framing $F_4'$ do not require additional description, since the general nature of cross-machine framing and mounting of pivots such as the pivots 35′ will be fully understood by those skilled in the art. The cross-machine or transversely flowing stock 50′ at the level L′ is indicated as the stock which enters the inlet 10′ initially from one side of the machine and then flows downwardly through a perforated body indicated generally at 51′ which actually constitutes a multiplicity of transversely spaced tubes only one of which 52′ is shown in FIGURE 4. These tubes are shown as being provided with a suitable noncorrosive cylindrical liner 53′ which is preferably synthetic rubber or some other noncorrosive material that is mounted in cylindrical stainless steel spacers or backers 54′ which are mounted in alignment with perforations in a top cross-beam 55′ and a bottom cross-beam 56′ to complete the extension of the tubular conduits 52′, each of which have a substantial length-to-diameter ratio of at least 7:1 and preferably in the neighborhood of 10 to 15:1 or more, depending upon the space available for teh mounting of these tubes 52′. Again, it will be appreciated that the essential concept of fiber distribution within the individual tubes 52′ by virtue of high velocity stock flow vertically downwardly therethrough is accomplished preferably by the use of the length-to-diameter ratios specified. It will be appreciated that essentially there must be a stock jet generation in this area in the form of a myriad or multiplicity of individual stock jets each of which will lie in a plane that is longitudinally aligned with respect to the overall inlet. Thus the plane of the section shown in FIGURE 4 is longitudinally aligned and so will the planes be aligned which are parallel thereto and which pass through the respective axes of the successive transversely spaced tubes in the transverse series thereof. In general, the alignment of stock in the jet streams within the tubes 52′ is the first step in converting the stock from the transverse flow in the inlet 50′ to flow in a longitudinal direction, even though the stock flows directly out of the tubes 52′ and against the channel floor at 12*d*′ to impinge thereon and develop lateral stock flow components as well as additional longitudinal stock flow components in the direction of the channel inlet 13′. The impingement of stock against the floor 12*d*′ which functions as a baffle results in a general change in direction of stock flow of at least about 90° (in this case substantially 90°) which effects by virtue of such impingement and turning of the stock streams the required reconversion of lateral flow components in the stock so that the stock is spread laterally in such a manner that it will tend to enter the channel inlet 13′ at approximately the same or at least a substantially uniform transverse pressure profile and overall stock linear velocity. It will be appreciated that the effects of impingement against the wall 12*d*′ and the immediate spreading of the stock in this chamber area will cause a rapid deceleration of stock flow from the point of view of linear velocity and will result in what might be considered heterogeneous rather than uniform stock flow components, but at the same time it will result in a spreading of the stock in such a manner, under the particular conditions here involved, that the overall stock pressure entering the very thin inlet end 13′ of the channel R′ will be generally uniform and at this stage we will have approximated a conversion from an essentially transverse or cross-machine stock flow to an essentially and generally uniform longitudinal stock flow in a thin stream at the inlet 13′.

Before going into further detail in connection with the nature of the turbulence generators hereinbefore noted in the succession 40′, 41′, 15′ and 16′, reference is made to the overall cross-machine stock flow inlet devices in FIGURES 8, 9 and 10.

Referring first to FIGURE 9, it will be seen that the stock flows from a fan pump FP′, indicated only as an arrow for schematic purposes, upwardly through a vertical channel 60′ and into a cross-machine channel 61′. It will be noted that the general profile shown in FIGURE 8 is really a top plan of FIGURE 9 of the channel 61′ showing an enlarged inlet end 61*a*′ and a relatively narrow opposite end 61*b*′. The channel 61′ thus extends in a cross-machine direction but it diminishes in cross-sectional area in the cross-machine direction.

As indicated in FIGURE 9, the overall cross-machine channel **61'** need not be built for stock recirculation therethrough and can simply be mounted on a structural arm **62'** extending outwardly from the narrow end **61*b*'** and mounted on a conventional supporting pillar **63'**, while the inlet end **61*a*'** is also mounted on a corresponding supporting pillar **64'** in corresponding manner so that the cross-machine channel **61'** will be maintained generally horizontal. It will also be noted that a source of gas such as air A' under pressure is shown diagrammatically being fed through a control valve CV' into the top of the cross-machine channel **61'** so as to maintain a predetermined superatmospheric pressure on top of the level (L' of FIGURE 4) of the stock in the cross-machine channel **61'**. The combination of the taper or diminution in cross-sectional area in the channel **51'** and the superatmospheric air pressure maintained on the top thereof will have the effect of presenting stock to the top of each of the small perforations or mouths for the tubes (only two of which are indicated at **52'**, **52'** and dotted lines in FIGURE 9) so that a generally uniform cross-machine pressure is exerted against the stock at the mouth or tops of each of the tubes **52'** and the stock jet or stream generated therein will thus be substantially uniform in velocity, volume, turbulence and other characteristics. These tubes **52'**, **52'** will then feed the stock into the channel R' which is shown only from the rear in FIGURE 9 and then schematically in order to avoid confusing the view.

In an alternative embodiment also shown schematically, in FIGURE 10 is will be seen that a fan pump FP–1' feeds stock into the inlet side **71*a*'** of a generally cylindrical tapered header **71'** extending in cross-machine direction toward a relatively narrow exit end **71*b*'**, from which a certain amount of stock is recirculated through the conduit indicated at **75'** back into the inlet of the fan pump FP–1' and makeup stock MS is also fed into the inlet of the fan pump FP–1' to maintain the desired amount of total stock entering the tapered cross-machine header **71'**. The tapered cross-machine header **71'** will thus provide by means of pressure control from the fan pump FP–1' and the effect of the gradually diminishing cross-sectional area of the body of the header **71'** itself a generally transversely uniform inlet pressure into the mouths **152*a*'**, **152*a*'** of the multiplicity of transversely spaced tubes, only two of which are indicated schematically at **152'**, **152'** in FIGURE 10, so that the stock will flow in jets downwardly into the channel inlet indicated in FIGURE 10 as R–**100'** corresponding to the channel R' of FIGURE 9.

Referring now generally to the overall stock velocities in the inlet **10'** shown schematically in FIGURE 6, it will be appreciated that reference must be had first to what may be considered to be the controlling velocity and that will be the velocity of the stock in the slice channel $A_{13}'$, which is approximately the linear velocity of the forming wire itself. Previously we have assumed a paper machine speed of 2,400 feet per minute which will mean a stock velocity at the slice $A_{13}'$ of 40 feet per minute. This will not necessarily determine the exact size or thickness of the slice $A_{13}'$ here indicated schematically, because for certain weights of paper a greater total volume of stock will be employed than in other cases. The linear velocity will be the same or substantially the same for each paper machine speed, but the slice opening $A_{13}'$ will differ with different weights of stock.

If we are to assume in terms of sixteenths of an inch that the thickness of the slice $A_{13}'$ in this particular instance is substantially 12/16 of an inch then the cross-sectional area indicated by the number **12'** represents a number of units which correspond in cross-sectional area to a linear velocity of 40 feet per second. Using **12'** as a reference, it will be seen that the open area $A_0'$ in the region of the stock jets or tubes (hereinbefore described at **52'**) is comparatively limited and a high velocity high pressure stock jet is desired in this area. Accordingly, the linear velocity in the tubes **52'**, expressed in terms of the overall open area $A_0'$ will preferably range from about the slice speed to twice the slice speed, or expressed in the numerical terminology, the area ratios $A_0':A_{13}'$ will range from 1:1 to 2:1 and are preferably about 12:7. This results in a very high stock velocity for impingement against the floor extension **12*d*** and for turning the stock jets through substantially at least about 90°. As previously mentioned, the best overall control of the stock jets is obtained by using a length-to-diameter ratio within the tubes **52'** of at least about 7:1 and preferably 10 to 15:1 and actually up to about 25 or 30:1, depending to a great extent upon the limitations of available space. In any event, better results are obtained using ratios of at least about 7:1 such that uniformity of stock flow in the individual jets is obtained and the various other desirable characteristics in stock flow are obtained and maintained with greater facility. The impingement of these jets is preferably carried out against the floor **12*d*'** of the overall channel section R' for the reason that this simplifies the structure and the stock then immediately impinges upon the first set of turbulence generators **40'**.



As indicated in FIGURE 4, the individual turbulence generators **40'** and **41'** in the two banks are actually formed by through bolts **40*a*'** and **41*a*'** extending through the floor **12'** and in threaded engagement in the roof **11'** seating in appropriate roof recesses annular locking devices **40*b*'** and **41*b*'** in the roof **11'** (which are shown in full view for purposes of simplifying the drawing) which provide the necessary annular recess to receive the top of the rod cover **40*c*'** and **41*c*'** which in each case is preferably a noncorrosive material such as a solid elastomer (i.e. synthetic rubber or a stainless steel material in the form of a tube which slopes over the tie rods **40*a*'** and **41*a*'** and is mounted in the annular seating devices **40*b*'** and **41*b*'** so as to remain rigid and in clamped position during operation. The details of the individual rods **40'** and **41'** are directed essentially to the problems of convenient mounting and in the schematic view of FIGURE 5, these details are not shown. FIGURE 5 is concerned primarily with the concepts of turbulence generation. It will be seen from FIGURE 5 that, looking upwardly toward the roof as the view V—V of FIGURE 4 indicates, one will note the discharges of the transversely spaced tubes indicated at **52*f*'**, **52*g*'** and **52*h*'** in the bottom perforate plate hereinbefore described by the reference numeral **56'**. Side channel walls are, of course, provided, although only the single wall **57'** is shown and the end wall **58'** is of course provided and is actually reinforced in the structure of the instant device to hold the pressure. The tubes **52'** are indicated as having diameters $D_1'$ which are spaced on centers $M_1'$ such that the overall open area is $A_0'$, which is described hereinbefore as being preferably an open area $A_0'$ equalling in total to from 50% to about 100% of the slice cross-sectional area $A_{13}'$. In essence, the tubes **52'** should have relativelly small diameters in the neighborhood of about 1 inch and should be approximately 12 inches in length so as to effect the desired stock jet generation and this will result in their centers being approximately 2 inches apart in the spacing $M_1'$ herein indicated for the diameters $D_1'$ in FIGURE 5. The spacing arrangement can be changed and the open area can be changed therein such that the diameters $D_1'$ may range from ½ to 1½ inches and the spacing between the centers thereof may range from slightly more than $D_1'$ to as much as two or three times $D_1'$. The smaller the overall open area $A_0'$ in this region, the greater the jet velocity impinging against the floor **12*d*'**. The stock impinges against the floor **12*d*'** as indicated in FIGURE 4, and then makes the right angle turn. In making the right angle turn after impingement upon the floor **12*d*'**, it will be appreciated that the stock flows into a chamber area having a substantially greater cross-sectional area $A_1'$ which numerically speaking affords a cross-sectional area ratio $A_0':A_1'$ ranging from about 7:20 to 60, and is preferably about 7:40, which affords a deceleration of stock velocity that averages such that the stock velocity is reduced from the jet velocity to about 1/5 to 1/6 of the jet velocity in the initial impingement, deceleration and turning chamber indicated schematically at $R_3'$ in FIGURE 6. The stock then proceeds into the inlet indicated diagrammatically at $A_1'$ in such a manner as to have imposed on the stock a primary velocity increase in the direction of the slice $A_{13}'$ by virtue of the converging walls.

The walls **11'** and **12'** preferably converge along a general angle of convergence of about 3 to 5°, but under certain conditions this range may be expanded to from 1° to 10°. It must be appreciated that a pair of closely spaced walls **11'** and **12'** in the total absence of any turbulence generating devices **40'**, **41'**, **15'**, **16'**, etc. may extend for a very substantial longitudinal dimension (much greater than the approximately 4 or 5 feet here shown) so as to impart to the stock a generally uniform cross-machine velocity profile as well as imparting the desired turbulence within the stock itself. By cross-machine velocity profile, we refer to the longitudinal speed of stock at various cross-machine locations in a given region such as along a plane taken through the line $A_1'$ in FIGURE 6. It is desirable to develop a generally uniform longitudinal velocity component in the stock across the full width of the machine. It must be appreciated that initially the stock flowing in the cross machine header **61'** has no longitudinal velocity component at all. Even in the jet streams in the tubes **52'**, the forward longitudinal component is O, although the stock streams have been converted from a cross-machine direction to at least parallel planes in longitudinal alignment. This is followed by impingement and then a series of turbulence generating devices **40'**, **41'**, **15'**, **16'**, etc. or expressed in other words, a plurality of sequences wherein the stock will go through comparatively rapid maximum and minimum cross-sectional areas (from the transverse cross-sectional area point of view) so as to superimpose upon the overall generally increasing primary velocity a rather drastic secondary velocity change in the stock. This secondary velocity change in each of these so-called sequences $S_1'$, $S_2'$, $S_3'$, $S_4'$ indicated in FIGURE 5 will in each case effect a certain amount of correction of the overall cross-machine velocity profile.

In the sequences herein described, it is preferable that at least the first two sequences $S_1'$ and $S_2'$ be defined by abutments which terminate abruptly at the downstream side so as to effect vortex turbulene generation and so as to effect relatively drastic turbulence generation, compared to that generated later on. Preferably this is done using a multiplicity of rod banks, in which banks each rod **40*f*'**, **40*g*'**, **40*h*'**, etc. will be generally cylindrical in form and in the case of the first sequence $S_1'$, will have approximately a diameter $D_2'$ of about 1½ inches. The center spacing therebetween is preferably about twice the diameter hence $M_2'$ is preferably 2 times $D_2'$ in order to provide an open area of approximately 50% and thus obtain the desired turbulence. As a matter of fact the open area may range from perhaps about 25% to 75%, but 50% has been found to be preferable and the particular center-to-center spacing $M_2'$ is also found to be significant in that the individual rods or abutments in the first bank **40'** will leave trailing wakes and this is desirable. The rods in the initial bank **40'** are of substantial size and are smoothly curved at their upstream ends so that they will not collect fibers, strings, or other matter and they will remain clean. This is very important from the point of view of continuous operation of the device. In addition, they will generate turbulene (sometimes referred to as vortex-type turbulence) at the downstream side thereof because they terminate abruptly at the downstream sides of each of such rods (by virtue of their circular cross-section) and this turbulence will start to decay at the off-running side of the first rod bank **40'**, but it will not have completely decayed within a dimension $L_1'$ which is preferably within the range of about two to five times $M_2'$. The preferred relationship between the center-to-center spacing of the rods or abutments in one bank and the downstream spacing of the rods or abutments **41'** in the second bank (i.e. the distance $L_1'$) is described in considerable detail in the previously mentioned application Ser. No. 228,621 and need not be described in further detail herein. Essentially, the function involves that of having turbulence in a condition of partial but incomplete decay as the stock impinges upon the relatively smaller smooth round upstream surfaces of the rod bank **41'**, as indicated in connection with the individual rods **41*f*'**, **41*g*'**, **41*h*'**, **41*i*'**, etc. The individual rods **41'** are about 1 inch in diameter which is approximately a preferred size so that the relationship between the diameters $D_2':D_3'$ will be about 1:0.9 to 0.5 and preferably about 3:2. The upstream rods **40'** are of comparatively large size so that it will be possible to make sure that there will be no collection of fibers or the like thereon. In addition, the upstream faces of these rods **40'** will be continuously cleaned by the net effect of the impinging jets against the floor and the miscellaneous currents in the stock generated thereby. This is the type of turbulence generation of rather substantial scale which is effected at this stage in the inlet at the stage indicated diagrammatically at $A_1'$ in FIGURE 6. As the stock approaches the oncoming side of the first bank of rods **40'**, it will be appreciated that the cross-sectional area of the channel R' has diminished slightly to $A_2'$, but this diminution is not particularly significant. In the middle of the rod bank **40'** extending transversely of the machine, however, it must be appreciated that there is a drastic reduction in overall cross-sectional area $A_3'$ and as here shown this is approximately a 50% reduction. The net result will be a velocity increase in the neighborhood of about 100% as the stock moves from the location $A_3'$ at the oncoming side of the rod bank to the middle of the rod bank **40'** at the location $A_3'$; and then as the stock completes the sequence $S_1'$ of the initial sequence herein described, the stock exits from the initial rod bank **40'** and reaches a substantially greater cross-sectional area $A_4'$ indicated in FIGURE 6. It will be appreciated that the overall cross channel cross-sectional areas indicated by the units $A_1':A_2':A_4'$ will in effect constitute decreases in the neighborhood of ratios of approximately 40:35 to 39:33 to 38, etc. so that there is a primary velocity increase, but there is a drastic reduction in cross-sectional area in the middle of the sequence $S_1'$ at $A_3'$, such that the open area or cross-sectional area ratio $A_2':A_3'$ will range from 4:1 to 4:3 and is preferably about 2:1, with velocity changes in substantially the inverse ratio. In other words, with a velocity increase at the decreased cross-sectional area $A_3'$.

In referring to the sequences $S_1'$, $S_2'$, etc. herein, it will be appreciated that each sequence is in effect a cycle through which the stock is put sequentially from a minimum to a maximum and then to a minimum or conversely from a maximum then to a minimum and back to a maximum cross-sectional area. As here described schematically, each sequence goes through the cycle from maximum to minimum to maximum cross-sectional area, and it will be appreciated that the second "maximum" cross-sectional area is slightly smaller than the first, in other words $A_4'$ is a maximum that is slightly smaller than $A_2'$ because of the general convergence of the walls and the general reduction in cross-sectional area of the channel which is undergone during the overall longitudinal movement of the stock through the channel.

It will also be appreciated that each sequence $S_1'$, $S_2'$, $S_3'$, $S_4'$, will have a general longitudinal dimension which is indicated schematically in FIGURE 5 in that it will involve the flow of stock approaching whatever the turbulence generating device might be plus the flow of stock past the turbulence generating device and then the flow of stock into what amounts to the subsequent maximum cross-sectional area, which for the sequence $S_1'$ involves the sequence shown schematically in FIGURE 6 as $A_2'$, $A_3'$, $A_4'$. The exact longitudinal dimension is not absolutely critical, but it may be considered to be a dimension from approximately midway between one set of turbulence generators to midway between the next set of turbulence generators, as in the case of the later sequences $S_2'$, $S_3'$, $S_4'$.

The two rod banks **40'** and **41'** thus preferably have the same open areas and this is preferably approximately a 50% open area so that there is an effective doubling of the velocity at least in the secondary or superimposed stock velocity at each of the sequences $S_1'$ and $S_2'$ and the overall turbulence generation is such that the second rod bank **41'** receives turbulence from the upstream rod bank **40'** so as to keep the upstream faces of the rods **41'** clean and permit the use of relatively smaller diameter $D_3'$ rods in this bank.

Rather than having a multiplicity of smaller and smaller rods, which must necessarily in each case result in some trailing vortex turbulence generation because of the abrupt downstream termination of a rod by the very nature of its construction, the instant inlet provides still another type of turbulence generation in the latter sequences $S_3'$ and $S_4'$ (i.e. at least the last two sequences) before the exit X.

As has previously been described, the exit chamber X is preferably defined by a pair of smooth closely spaced walls that are generally equidistant and effect whatever turbulence generation they are capable of effecting purely by virtue of the fact that the stock stream flowing thereby is moving at a very rapid rate and the walls are necessarily standing still. This exit region X' preferably has a longitudinal dimension that is at least as great as that of the last sequence $S_4'$ and preferably at least as great as twice or more the longitudinal dimension of the last sequence $S_4'$. In fact, in the arrangement here shown, the exit section X' has a longitudinal dimension that is substantially three times that of the last sequence $S_4'$. This results in turbulence decay. It is desired to obtain a certain amount of turbulence decay in the final exit chamber. Actually the amount of turbulence decay will depend upon the velocity of stock in the channel R'. If the velocity is very slow, the turbulence generating devices will have to be more closely spaced and the exit chamber X' will not be very long, because the benefit of turbulence generation and deflocking will not want to be lost completely. On the other hand, if the stock speed is relatively high even the closely spaced walls of the exit chamber X' will impart a certain amount of turbulence and they will permit a great deal of equalizing or generation of uniformity in the fiber distribution if they are at least equal to two or three times the longitudinal dimension $S_4'$ of the last sequence.

Referring to the sequences $S_3'$ and $S_4'$ it will be appreciated that these turbulence generating devices are shear-generators. In other words, they do not rely solely on the vortex turbulence generation concept that necessarily results from the abrupt downstream ends of rods. Instead, they impart a general shearing effect to the stock stream.

Considering first the average velocity in the stock, it will be appreciated that as the stock moves from the position $A_1'$ to the position $A_7'$ in FIGURE 6 it has already gone through two sequences $S_1'$ and $S_2'$ in which a doubling of the stock velocity has been superimposed upon the primary generally increasing stock velocity by virtue of the two reductions in cross-sectional area at the locations $A_3'$ and $A_6'$. The primary reduction in cross-sectional area from $A_1'$ to $A_7'$ and thus the corresponding primary increase in stock velocity from $A_1'$ to $A_7'$ is in an approximate ratio of 30:35 to 50. Preferably the ratio of $A_1'$ to $A_7'$ is about 4:3 and the velocity increase is thus the inverse of this cross-sectional area ratio by the end of the second sequence $S_2'$. In the third and fourth sequences $S_3'$ and $S_4'$, the cross-sectional areas go through the ranges $A_8'$ and $A_9'$, $A_{10}'$ in maximum minimum maximum such that $A_9'$ is in a cross-sectional area ratio to $A_8'$ within the range of about $A_8'$:$A_9'$ ranging from 4:1 to 4:3, but preferably about 2:1. This again results in an approximate superimposition of double the velocity in the region $A_9'$ with almost a halving of the velocity in the region $A_{10}'$, but followed by another doubling of the velocity in the second of these sequences $S_4'$ at the region $A_{11}'$ and followed again by almost a 50% reduction in velocity at the off-running side at $A_{12}'$. It will be appreciated that the general cross-sectional area in each of the successive sequences $S_1'$, $S_2'$, $S_3'$, $S_4'$ involves a reduction, hence the general velocity increases all the way along. On top of this we have the super-imposition of drastic velocity changes by virtue of either the abutment turbulence generators **40'** and **41'** or the shear turbulence generators **15'** and **16'**. The shear turbulence generators **15'** and **16'** generate a lower scale of turbulence but still give excellent fiber distribution and the desired fiber distribution for ultimate feeding to the exit channel X'.

As mentioned hereinbefore, the overall channel R' could have the general characteristics of the exit channel X' if it had a great enough longitudinal dimension. The difficulty is that paper machines do not provide for this much space. Accordingly, it is necessary to add to the device for converting the cross-machine stock flow into longitudinally directed stock flow a certain number of turbulance generators which will greatly diminish the overall exit stage dimension X'. These various turbulence generators **40'**, **41'**, **15'** and **16'** will not completely eliminate the exit stage X' but they will reduce the dimension thereof materially and make the size of the machine workable for practical purposes. In developing turbulence generating systems which will do this, it has been found that at least the first two sequences $S_1'$ and $S_2'$ are preferably of the vortex generating type, as in the case of the rods **40'** and **41'**; whereas it has also been found that preferably the last two sequences here designated $S_3'$ and $S_4'$ are preferably of the shear or approximately shear generating devices in the sense that a lower scale of turbulence will be fed into the exit chamber X' and a better fiber distribution is ultimately obtained at the slice **14'**. Also, the drastic impingement in the initial chamber $R_c'$ plus the vortex generation at the rods **40'** and **41'** will cause complete breakup of fiber clots and the like so that the random distribution of fibers in the stock that is desired will have been obtained, but the problem of maintaining this random distribution of fibers in the stock is not simple and also the problem of obtaining the desired cross-machine profile for longitudinal stock velocity is not simple and it has been found that these shear-turbulence generating devices **15'** and **16'** are particularly useful at least as the last pair of turbulence generators just before the exist chamber X'. The importance of the exit chamber has already been discussed. The nature of shear turbulence generators **15'** and **16'** has been discussed in considerable detail in, for example, the previously mentioned application Ser. No. 69,338 which need not be described in complete detail, since this and the other applications hereinbefore referred to are actually incorporated herein by reference. In essence, the purpose of a shear generator is to cause abrupt convergence followed by abrupt divergence (which would be from the area $A_8'$ to the area $A_9'$ during the abrupt convergence and from the area $A_9'$ to the area $A_{10}'$ for the abrupt divergence in such a manner as to superimpose an abrupt velocity change upon the stock (although this velocity change is actually at a rate that is from $\frac{1}{10}$ to perhaps $\frac{6}{10}$ or $\frac{7}{10}$ the rate of velocity change that is imposed by the upstream rod banks **40'** and **41'**). In addition, the purpose of shear generators is to minimize vortex type of turbulence generation by separation of the stock from the walls during the downstream or divergent flow of each sequence $S_3'$ and $S_4'$. Referring to the details of FIGURE 7, it will be seen that the angle of convergence **15*a*'** between the surface of the roof **11*c*** and the turbulence generator **15'** is approximately an angle of 15° in the device here shown. This is a relatively abrupt angle of convergence and a more gradual angle could be used ranging perhaps down to as low as about 3° to 5° and up to as much as about 20° for the more drastic conditions. On the other hand, the angle of divergence at the off-running side is of somewhat greater importance from the point of view of avoiding separation of the stock from the wall. In the turbulence generator **15'** the angle of divergence **15*b*'** is also here indicated as being about 15°, although it may range from this approximate maximum down to as low as about 3° to 5° depending upon the speed of stock.

Departing briefly from the mechanics of shear turbulence generation here involved, it will be appreciated that as indicated in FIGURE 7, the roof **11*c*'** is provided with a pair of cross-machine slots into which the anchoring portions **15*c*** and **16*c*** of the turbulence generators **15'** and **16'** may be slipped and retained for ordinary operation. These devices are thus moved in and out of position by sliding the same in the transverse or cross-machine direction which is a convenient arrangement. The turbulence generators **15'** and **16'**, however, extend the full width of the channel section $R_2'$ and althouh they are shown in FIGURE 7 in full view it will be appreciated that the longitudinal section at any location across the machine will be the same. As indicated in FIGURE 6, the actual cross-sectional dimension in the minimum area $A_{11}'$ is slightly smaller than in the minimum area $A_9'$ and in each case these dimensions are in a ratio to the dimension $A_{13}'$ of approximately 1:4 to 3:4, so the velocities at the locations $A_9'$ and $A_{11}'$ are actually greater than the slice longitudinal stock velocity and this is desired for purposes of imparting a final shearing force to the stock approaching the slice **14'**. As previously indicated, the floor **12*c*'** in the second section $R_2'$ is at approximately an angle of about 2° to the horizontal or to the wire line indicated by the line marked W' in FIGURE 7. The roof **11*c*** which is a continuation of the roof **11*a*'** of the first section $R_1'$ in the operating arrangement is approximately at an angle of about 5 or 5¼° to the wire line W', so that the angle of convergence in the preferred embodiment here shown is slightly over 3°. This means that the centerline plane for the channel R' is a line indicated generally at P'—P', which is really a centerline plane P'—P' that is used essentially for reference purposes. It will be seen that the convergence and divergence in the stock stream created by the shear generators **15'** and **16'** is not symmetrical with respect thereto and this seems to impart an improvement in the overall fiber distribution. In addition, it affords the mounting of the turbulence generators **15'** and **16'** only on the roof so that they may be swung in and out of operating position during maintenance and at other cenvenient times while still carrying out their essential and complete function when in operating position. The peak for the first of these sequences $S_3'$ is the peak indicated at the apex of the triangular configuration at **15*d*'** for the shear turbulence generator **15'**. This is not a sharp peak but a generally rounded peak and it is positioned a distance $L_2'$ (FIGURE 5) that is approximately within the range of 2 to 5 times the dimension $M_3'$ which is the center-to-center spacing in the upstream vortex turbulence generating rod bank **41'**, so that the convergence will be maximized at the region of incomplete turbulence decay from the upstream turbulence generating device, which in this case is the rod bank **41'**. The same is true of the peak **16*d*'** for the downstream shear generator in that it also results in maximum stock convergence at a region of only partial decay from the upstream turbulence generator **15'**.

With respect to the problem of shear generation, it must be appreciated that purely shear-turbulence generation does not permit any separation of the stock from the wall during the divergent flow. Thus in the region



designated **15*e*'** and in the subsequent region of divergence designated **16*e*'**, the rapid flow of stock past the shear turbulence generators **15'** and **16'**, respectively, preferably does not result in separation from the channel walls or the channel roof **11*c*** in this instance. It is known that in the case of relatively high speeds pure water will separate from a divergent wall if the angle of divergence from the centerline or center plane of the channel is greater than about 7°. In other words, in the case of pure water, if the angle indicated at **15*e*'** and **16*e*'** were greater than 7°, there would be separation of the pure water from the off-running side of the generators **15'** and **16'**. The angle of divergence **15*e*'** and **16*e*'** is represented in relation to the center plane P'—P' and the divergent trailing face **15*b*'** and **16*b*'** for the generators **15'** and **16'** respectively, and it will be appreciated that in the construction here shown these angles of divergence **15*e*'** and **16*e*'** are at the maximum or perhaps somewhat above the maximum tolerated angle of divergence to completely avoid separation. It is known that stock with even relatively small percentages of fiber there in does not behave like pure water and it does not behave like a true fluid or liquid. Instead, it has peculiarities in behavior and it will not separate from the wall at an angle of divergence immediately above 7°, in fact, angles of divergence as high as 12', 13' or even 14° are permitted. In the present instance simple arithmetic will reveal that the angle of divergence **15*e*'** and **16*e*'** is approximately 13½° in each case. This is about the maximum tolerated for practical purposes. It may result in a slight amount of separation but it does not result in a significant amount of separation or a harmful amount of separation, particularly in view of the fact that the exit channel X' is at least twice and preferably three times the longitudinal dimension $S_4'$ of the last sequence of shear turbulence generation. In other words, these turbulence generators **15'** and **16'** are designed to obtain the maximum desired turbulence under the circumstances without causing any undesirable results at the ultimate slice **14'** and this is done by using a rather drastic angle of divergence, preferably, in conjunction with a reasonably long exit channel X' which has the description already given. It will be appreciated that the angle of divergence may be reduced from the indicated 13 or 14° down to as low as 3, 5 or 6° in certain instances and in the case of certain types of stock this is not a difficult problem since the generators **15'** and **16'** may be readily constructed so as to reduce this angle of divergence. The type of shear turbulence generator **15'** and **16'** here shown readily accommodates this type of change since the variable involves nothing more than adding to or subtracting from the material employed in the off-running side of the turbulence generator relative to the center plane P'—P' of the channel. Thus the channel itself may have its angle of convergence increased or decreased somewhat under certain circumstances, and this will involve a rather major change in the overall structure. On the other hand, by very nominal and relatively easily made changes the shear generators **15'** and **16'** may be altered to obtain whatever angle of divergence **15*e*'** and **16*e*'** may be desired or may be found to be desirable. Also, it will be noted that at the approach to the channel X' there is a slight reduction from $A_{12}'$ to $A_{13}'$ in cross-sectional area and the stock does pass a rounded edge, indicated at $X_0'$ in FIGURE 7 so as to obtain a slight additional turbulence generation by virtue of the rather abrupt change in cross-sectional area and thus abrupt velocity change at this very point. Moreover, a taper (involving an overall decrease in $A_{13}'$ of no more than the decrease at $X_0'$) between the generally parallel smooth walls in the elongated section $R_3'$ may effect therein a gradual helpful velocity acceleration in the final stock jet. This serves to cooperate with the downstream sequence $S_4'$ to afford the best fiber distribution and the best results in high speed machines.

As previously mentioned the slice jet **14'** is so positioned as to be substantially aimed at the previously recited dimension H of FIGURE 3, and the height (¾ inch, e.g., in the range of ¼ to 1½ inch) of the dimension H and the opening at the jet **14'** is substantially the same. The slight downward tilt of 1° to 3° for the floor **12'** of the inlet is generally parallel to the line **200** (FIGURE 3), which is considered for practical purposes to be substantially planar and likewise in this embodiment, tilting downwardly parallel with the floor **12'** by virtue of alignment of the breast roll **22**, foil **25**, and first suction box SB–**1**. The plane P' shown in FIGURES 6 and 7, may not thus be a parting plane PP' (FIGURE 6) for the final section $R_3'$ or the jet **14'** itself; but this plane PP' substantially intersects the midpoint of the height H (plus or minus 30%, preferably 10%) for best operation, and the various adjustment devices A afford this, such that the wire **20***a* and the plane PP' are substantially parallel. The close-running relation of (a) the front edge of the top wall 11B' and the wire covered sealing piece **50–31***e* and (b) the bottom wall **12**B' front edge and the wire covered breast roll **22** are both arranged for minimum operating clearance and hence minimum creation of stock levels exposed to ambient atmosphere at each clearance point, although structural necessities preclude elimination of such stock levels and speeds of the wires **20**, **40** preclude harmful side effects by the fact of the existence thereof (since the wires **20**, **40** tend to pull the stock away therefrom at substantially the stock jet speed).

It is also understood that the elongated curve shown in FIGURES 2 and 3 hereof has a typical noncircular characteristic of curving downwardly more sharply at the upstream end (near the intersection of line **200** and dimension H of FIGURE 3) than at the downstream end, which expressed in other typical curvilinear terms means that although the curve radius is increasing more gradually from the immediate vicinity of said dimension H than it is later downstream, its center point is also considered to be continuously moving downstream (along an imaginary axis generally parallel to the line **200** but positioned above said dimension H of FIGURE 3). Once the curve $H=CD^k$ (wherein H and D are understood to be variables and C and $k$ constants, all within certain ranges) starts to "flatten out" and becomes closer and closer to a line parallel to the line **200**, which in turn is representative of the substantially planar position and configuration of the bottom wire **20***a* under the high tension used herein, then we consider that the imaginary radius of the elongated curve diminishes in its continuous increase down to zero increase and the imaginary center for such curve accelerates in its downstream movement —whereupon we ultimately arrive at the definition of a straight line parallel to the line **200** as well as the previously mentioned imaginary downstream aligned "axis" for the aforesaid elongated curve. It is for this reason that reference has been made to the importance of an elongated curve within the relatively limited but active forming area (a) from the intersection of H of FIGURE 3 and line **200** to substantially 6 to 8 (inches) D along the line **200**, or (b), expressed in terms of an ordinate CL and abscissa **200**, between the values in inches for D from substantially ¾ to 1 ranging to substantially 6 to 8. This critical area is also expressed on the basis of more or less conventional newspring stock dilution and characteristics; but all of the figures and ranges could readily be translated to other "numerical" terms in instances of extreme departure from the aforesaid conventional dilution and characteristics, all consistent with the general considerations and principles hereinbefore set forth concerning speeds of drainage and web formation on the top and bottom wires **40** and **20**, maintenance of substantially constant pressures in the stock intermediate such webs, ultimate merging of the webs, etc., all which considerations and principles will be readily understood by skilled workers upon reading the instant specification.

Still another aspect relates to the aiming of the stock jet **14'** itself, which is shown in FIGURE 1A as being a narrow ribbon of stock formed between two closely spaced (upper and lower) generally smooth and generally parallel (at least for the downstream end **14***b* of the stock jet generator **10** of FIGURE 1A) surfaces. As this application points out, the last portion X' of FIGURE 5 shown with parallel spacing $A_{13}'$ in FIGURE 6 not only can and should have thin substantially parallel (or very slightly convergent) surfaces to define the final stock jet **14'** (as herein described), but may be a part of an extremely long inlet, e.g., **10***a* of FIGURE 1A of very substantial length, even much greater than that shown in FIGURE 1A. The fact is that, if the stock travel is substantially extensive between such closely spaced surfaces both the fiber distribution (to the end that the previously mentioned semi-rigid uniform distribution) will be obtained and the substantially uniform stock jet downstream alignment (expressed in terms of the alignment of the mid-plane PP' in FIGURE 6) will also be obtained. FIGURES 3 et seq. show a device of much shorter length using initially certain combinations of turbulence generators, ahead of such closely spaced substantially parallel surfaces which ultimately define the configuration and exact direction (PP') of the jet **14'** fed onto the wire, in an overall combination of elements which has numerous advantages including the use of less space and material.

Nevertheless, the forming area here defined by the overhead elongated curve of top wire **40** (free on the inside for upward drainage from point H of FIGURE 3 on, downstream) converging with the opposed reach **20***a* of the bottom wire **20** (lying substantially in the plane of the line **200**) is fed by a stock jet **14'**, as here shown, which is in direct alignment therewith and hence substantially parallel to the wire **20***a* (and line **200** of FIGURE 3), with its mid-plane PP' substantially intersecting the mid-point of the dimension H (plus or minus about 20% of such dimension) and being released as a jet **14'** just upstream of such dimension H of FIGURE 3 that it will reach the region of such dimension H of FIGURE 3 in substantially the condition just described. This would appear to mean that, with the mid-plane PP' and line **200** (or planar lower wire **20***a*) being substantially parallel, there might be a greater tendency for the impact of the jet against the generally curved wire **40** to cause disproportionately greater or faster web formation and/or drainage on the upper wire, thereby leading to what observers might expect to be an undesirable result. It so happens that this is not the fact however, and without attempting to limit the invention to any particular theory, it is now believed that after initial impact and web formation on the top wire **40** (just after the line H of FIGURE 3) there is a commencement of force readjustment (which makes possible the superior results here obtained) quite probably by combinations of gravity forces, ease of initial reception of drainage water by the lower wire **20***a* and incipient reception of such water and web formation during the initial distance from the top of the breast roll **22** (i.e. such distance being described as about ¾ to 1 inch from CL of FIGURE 1B to the line H of FIGURE 3 during which the lower wire **20***a* is being separated slightly from the large diameter breast roll **22** but such wire **20***a* is moving very rapidly).

It will thus be seen that, although the upper and lower forming wires **40** and **20** have substantially the same (and preferably substantially identical) weave and drainage characteristics, being in an ideal arrangement substantially interchangeable typical of forming wires which would be selected for high speed web formation of the particular stock type selected; the adjustable means H for both the stock jet midplane PP' and the converging wire runs in the immediate region of simultaneous initial stock drainage and web formation effect entirely different wire run configurations. Thus, the lower wire run **20***a* is maintained under high tension (by the roll **26** or the like) so as to be in substantially closely spaced, parallel, planar relationship just beneath the mid-plane PP′ and a straight line downstream projection thereof PPP′ (which is a classical representation of the "direction" in which the high speed jet is "aimed" directly into the converging wire paths, in the initial critical forming region of $D \cong 0$ to substantially 6 to 8 inches, for typical newsprint). In contrast, the uper wire run **40** enters initially into such area of convergence (just described as the initial critical forming region) not only (a) when its elongated curve is "sharpest," i.e. has the shortest radius of curvature, but also (b) at a region in the immediate vicinity of dimension H in FIGURE 3, whereat the noncircularly curved upper wire loop is closely spaced above such mid-plane PP′ a distance substantially equal to the close spacing of the lower wire run **20***a* beneath the mid-plane PP′. This again is another way of expressing the fact that the stock jet is "fed between" the converging wires at the large end of the converging area and in size commensurate with the cross-sectional dimension thereof.

It will be appreciated that in defining the height and vicinity H there must be some practical estimations which do not involve practically significant dimensional differences. Thus the practical necessities of stock inlet **14***b* structure generally make it necessary to feed the stock jet **14′** onto the top of the breast roll **22** (as shown in FIGURE 1B) slightly ahead of the breast roll center line **22CL**. We have already explained, however, that the effect of the close-running relationship between the solid breast roll **22** backing the fast moving lower wire **20** and the solid cross-machine sealing assembly **50–31***c* is to cause negligible back flow, so the stock jet **14′** effectively continues (in the direction aimed and in substantially its initial cross-sectional dimension) from just upstream to slightly downstream of the breast roll center line **22CL** (also as shown in FIGURE 1B before the jet stream actually reaches the ordinate CL of FIGURE 3; which ordinate CL is spaced, in generally parallel alignment, downstream from the breast roll center line **22CL** a distance shown in FIGURE 1B to be at least about the distance H of FIGURE 3). In fact, the downstream spacing of the ordinate CL of FIGURE 3 may be 1 to 3 or 4H in high speed machines, without significant disturbance of the "aiming" of the stock jet at the center of the dimension H (on the ordinate CL of FIGURE 3) because in the region the high speed stock jet is passing between the upper wire solidly backed by the seal assembly **50–31***c* and the lower wire **20** is for the most part backed by a solid breast roll **22** and is otherwise aligned generally parallel to the stock jet **14′** so that these elements effectively cause a continuance of the initially aimed direction of the stock jet (without any significant disturbance to this "aiming of the jet" by undesirable or substantial premature drainage through the lower wire **20***a* as it leaves the breast roll **22**). Moreover, it is apparent from FIGURE 3 that the distance H which $P_0$ is on the ordinate CL above line **200** substantially no more than perhaps 5 to 15% greater than the distance $P_1$ is above the line **200**, which is calculated to be from (0.75) (0.05)= (approx.) 4 mils (to about 10 mils for 15%). Thus, $P_1$ is also considered to be substantially H inches above the line **200**; and it actually deviates therefrom dimensionally in minute and practiaclly insignificant manner when one considers the dimensional comparison between stock jet thickness (which is generally thought of as being in the range of ½ to 1 inch) with the comparatively much greater initial and critical forming area downstream dimension of substantially 6 to 8 inches (e.g. 2000 times 4 mils).

Although the upper wire run must also be under considerable driven tension to maintain its parabolic curve configuration over the smooth foils **51**, etc., and under such tension it should maintain overall drainage characteristics substantially the same as those of the lower wire run **20***a* under tension (since these wires **20** and **40** are obviously selected for the particular stock, i.e., newsprint and will thus normally, under zero or the same longitudinal tension, have substantially identical structures, weave, and drainage characteristics for the same stock), the upper wire **40** is moved entirely differently from the lower wire run **20***a* relative to the general direction in which the stock jet is aimed, i.e., any straight-line projection PPP′ of the aforesaid jet mid-plane PP′. In fact, the upper wire run is caused to move in its elongated curve (of decreasing radii and/or downstream moving centers of curvature) downstream such that it actually intersects the mid-plane projection PPP′ (or in more common language the stock jet **14′** is actually aimed at this elongated curve in the wire **40**). Again, one must appreciate that the projected aim suggested by the line PPP′ is essentially imaginary in the sense that, although the elongated curve does intersect and actually pass beneath this projected line PPP′, the impact of the jet against the noncircularly curved wire and its consequent web formation with resultant build-up of downward forces in the stock to accelerate similar phenomena on the generally planar lower wire **20***a* will necessarily effect a curvature downwardly in the more fluid central portion of the stock during the very brief (time-wise) transition from dilute stock (at H of FIGURE 3) to complete (although very moist) web between the wires **20** and **40**, at substantially $D=6$ to 8 inches (and surely at more remote regions, e.g. opposite the terminal foils **59** and **60**).



Contrary to prior art teachings about the undesirability of disturbing webs (direction-wise or otherwise) during formation, the instant invention seems to render such teachings obsolete, violating them to produce a uniquely superior web at remarkably high-speed web formation.

As previously indicated in column 19 line 8 hereof, the closely spaced walls **11′** and **12′**, or preferably the more closely spaced extensions **11***a* and **12***a* thereof, could extend longitudinally (in an arrangement such as **14***b* suggests) for substantially more than the present longitudinal dimension of the walls **11′** and **12***a′* and yet produce the stock jet **14′** in the condition desired; in the total absence the various turbulence generators **40′**, **41′**, **15′**, **16′**, etc. which make the present longitudinal dimension for the walls **11** and **12** of 4 to 5 feet possible. Simple arithmetic will establish that, on the basis of this present longitudinal dimension, the last sequence $S_4'$ has a longitudinal dimension of substantially ½ to 1 foot and the dimension X′ is thus preferably from a minimum of at least $S_4'$ or ½ foot (but preferably about $3S_4'$ or 1½ feet) to a practical maximum of substantially 10 feet, depending upon whether or not and/or what type of turbulence generators are used upstream therefrom.

Although specific aspects of the instant invention are described in our aforesaid prior application, it will be appreciated that modifications may be made herein without departing from the spirit and scope of the instant invention.

We claim as our invention:

1. Apparatus for forming paper comprising first and second belt-training means mounted in spaced-apart relation to each other, there being a first belt path therebetween, third and fourth belt-training means mounted in spaced-apart relation to each other, there being a second belt path therebetween, said first and second belt paths being at least in part closely spaced apart from and generally parallel to each other, a first permeable belt trained about said first and second belt-training means and having a portion lying in said first path, a second permeable belt trained about said third and fourth belt-training means and having a portion lying in said second path, said portions defining a forming zone, means connected to said first and second belts for driving said first belt over said first and second belt-training means and from said first belt-training means to said second belt-training means in said first path and second belt over said third and fourth belt-training means and from said third belt-training

means to said fourth belt-training means in said second path, said portions moving at least in part generally in the same direction, and permeable, stationary, substantially curved longitudinally elongated belt-converging means contacting one of said belts in said forming zone to establish convergence of said portions, said substantially curved means being defined by the longitudinal contour of loci of a plurality of closely spaced belt-contacting generally transverse edges, wherein said longitudinal contour of loci defines an elongated curve having the formula: $H=CD^k$, wherein H represents the space in inches from the curved converging means surface in contact with said one of said belts to a reference plane of substantial longitudinal alignment with the opposed belt at the forming zone, D represents the distance in inches downstream from the large end of the forming zone, C is a constant within the range of 0.5 to 1.6, and $k$ is a constant within the range of $-0.2$ to $-0.8$, and means maintaining the other of said belt under tension but free of restraining means in contact therewith at locations opposite said one belt-converging means.

**2.** In a device for forming an aqueous suspension of fibers into a sheet, in combination, a first forming wire loop having a reach extending from a rotary breast roll to a rotary couch roll, tension control means controlling the tension in the looped forming wire, speed control means controlling the longitudinal speed of travel of the wire reach, stock feed means generating and feeding a thin high speed stock jet of substantially homogeneous suspended entangled co-moving stock fibers onto said wire reach substantially at the breast roll, said stock jet being substantially commensurate in transverse dimension and longitudinal speed to that of said wire reach at the immediate vicinity at which the stock jet is fed onto said wire reach, a top porous looped traveling second wire substantially commensurate in transverse dimension and longitudinal speed to that of said first wire reach at the immediate vicinity at which the stock jet is fed onto said wire reach, guide means inside of the second wire loop and substantially commensurate with the aforesaid transverse dimension and guiding the second wire over a multiplicity of longitudinally spaced stationary wire-contacting surfaces which define in the longitudinal direction loci of a generally elongated curve and against the stock jet on the first wire reach in the substantial vicinity at which the stock jet is fed onto said first wire reach, and mounting means positioning the two wires to align the space therebetween with the stock jet, said tension control, speed, control, stock feed and guide means cooperating with said mounting means to define a gradually tapered forming zone into which said stock jet is fed and in which such sheet is formed between said two wires with substantially continuous maintenance in the stock jet and subsequently formed sheet of the aforesaid longitudinal speed in a non-vertical direction and at pressure resulting from a substantially constant tension in each said opposed wire reaches, while continuously removing water from the forming zone through both wires, the contour of the generally elongated curve having substantially the formula. $H=CD^k$, wherein H represents the space in inches from the curved guide means in contact with said one wire to a reference plane of substantial longitudinal alignment with the opposed wire in the forming zone, D represents the distance in inches downstream from said large end of the forming zone, C is a constant within the range of 0.5 to 1.6 and $k$ is a constant within the range of $-0.2$ to $-0.8$.

**3.** The apparatus of claim **1** wherein said transverse edges terminate abruptly at their off-running sides relative to their stationary edge portions contacting said one belt traveling longitudinally thereover, thereby assisting to maintain a substantially constant pressure in the forming zone along such traveling belt portions.

**4.** In a device for forming an aqueous suspension of fibers into a sheet, in combination, upper and lower forming wire loops, upper and lower guide means within the corresponding upper and lower wire loops for moving opposed reaches of the loops through a generally converging but closely spaced path defining a forming zone at substantially the same speed, stock feed means for generating and feeding a thin high speed stock jet of substantially homogeneous suspended entangled co-moving stock fibers into the large end of such converging forming zone, said stock jet being substantially commensurate in transverse dimension and longitudinal speed to that of said wire reaches of both the upper and lower looped converging wires at the immediate vicinity at which the stock jet is fed into the forming zone, and mounting means for adjustably positioning the stock jet and said upper and lower wire-converging guide means, said upper guide means within the upper converging wire loop including a generally curved guide surface being defined to guide the upper loop through a generally elongated curve in said converging path in the forming zone and having a hollow body maintained at subatmospheric pressure to assist in dewatering the stock and also having a plurality of closely longitudinally spaced wire guiding and contacting means extending transversely along the inside of such substantially elongated curved to guide the wire through such substantially elongated curve defined by the longitudinal contour of loci of the wire contacts with such wire guiding and contacting means, said lower wire being free from restraining means in contact therewith at locations opposite such forming zone, said substantially elongated curve having substantially the formul: $H=CD^k$, wherein H represents the space in inches from the curved guide means in contact with said one wire to a reference plane of substantial longitudinal alignment with the opposed wire as the forming zone, D represents the distance in inches downstream from said large end of the forming zone, C is a constant within the range of 0.5 to 1.6 and $k$ is a constant within the range of $-0.2$ to $-0.8$.

**5.** In a device for forming an aqueous suspension of fibers into a sheet, in combination, upper and lower forming wire loops, upper and lower wire guide means within the corresponding upper and lower wire loops for moving opposed reaches of the loops through a generally converging but closelyi spaced path defining a forming zone at substantially the same speed, stock feed means for generating and feeding a thin high speed stock jet of substantially homogeneous suspended entangled co-moving stock fibers into the large end of such converging forming zone, said stock jet being substantially commensurate in transverse dimension and longitudinal speed to that of said wire reaches of both the upper and lower looped converging wires at the immediate vicinity at which the stock pet is fed into the forming zone, and mounting means for adjustably positioning the stock jet and upper and lower wire guide means, one such wire guide means within one such converging wire loop being defined by a plurality of longitudinally closely spaced transversely extending stationary blades presenting transverse wire-contacting edges which in longitudinal contour define the loci of a generally elongated curve to drive such one wire through a generally elongated curve in said converging path and maintaining a generally elongated curve in the forming zone to dewater stock therethrough, the other such wire guide means within such other wire loop driving the same under tension but free from restraining means in contact therewith at locations opposite the forming zone, and a couch press defined by press rolls within the respective wire loops and defining a couch press nip longitudinal spaced beyond the forming zone defined between the converging wire loops, said longitudinal contour of the generally elongated curve having substantially the formula: $H=CD^k$, wherein H represents the space in inches from the aforesaid wire-contacting edges of said one wire guide means in contact with said one wire to a reference plane of substantial longitudinal alignment with the opposed wire at the forming zone, D represents the distance in inches downstream along such plane from the large end of the forming zone, C is a constant within the range of 0.5 to 1.6 and $k$ is a constant within the range of —0.2 to —0.8.

**6.** The device of claim **5** wherein such transverse blade edges terminate abruptly along their longitudinally downstream sides so as to substantially preclude localized disturbance of the generally uniform pressure differential across such wire in the forming zone.

**7.** Apparatus for forming paper comprising first and second belt-training means mounted in spaced-apart relation to each other, there being a first belt path therebetween, third and fourth belt-training means mounted in spaced-apart relation to each other, there being a second belt path therebetween, said first and second belt paths being at least in part closely spaced apart from and generally parallel to each other, a first permeable belt trained about said first and second belt-training means and having a portion lying in said first path, a second permeable belt trained about said third and fourth belt-training means and having a portion lying in said second path, said portions defining a forming zone, means connected to said first and second belts for driving said first belt over said first and second belt-training means and from said first belt-training means to said second belt-training means in said first path and said second belt over said third and fourth belt-training means and from said third belt-training means to said fourth belt-training means in said second path, said portions moving at least in part generally in the same direction, and permeable, stationary, substantially curved longitudinally elongated belt-converging means contacting one of said belts in said forming zone to establish convergence of said portions, said substantially curved means being defined by the longitudinal contour of loci of a plurality of closely spaced belt-contacting generally transverse edges, wherein said longitudinal contour of said loci defines an elongated curve having the formula: $H=CD^k$, wherein H represents the space in inches from the belt-converging means surface in contact with said one belt to a reference plane of substantial longitudinal alignment with the belt path for the opposed belt at the forming zone, D represents the distance in inches downstream from the large end of the forming zone, C is a constant within the range of 0.5 to 1.6 and $k$ is a constant within the range of —0.2 to —0.8, pivot means mounting said substantially curved means for adjustment of said one belt contacting the same relative to the other belt, and means maintaining said opposed belt under tension but free of restraining means in contact therewith at locations opposite said one belt converging means.

**8.** Apparatus for forming paper comprising first and second belt-training means mounted in spaced-apart relation to each other, there being a first belt path therebetween, third and fourth belt-training means mounted in spaced-apart relation to each other, there being a second belt path therebetween, said first and second belt paths being at least in part closely spaced apart from and generally parallel to each other, a first permeable belt trained about said first and second belt-training means and having a portion lying in said first path, a second permeable belt trained about said third and fourth belt-training means and having a portion lying in said second path, said portions defining a forming zone, means connected to said first and second belts for driving said first belt over said first and second belt-training means and from said first belt-training means to said second belt-training means in said first path and said second belt over said third and fourth belt-training means and from said third belt-training means to said fourth belt-training means in said second path, said portions moving at least in part generally in the same direction, and permeable, stationary, substantially curved longitudinally elongated belt-converging means contacting one of said belts in said forming zone to establish convergence of said portions, said substantially curved means being defined by the longitudinal contour of loci of a plurality of closely spaced belt-contacting generally transverse edges, wherein said longitudinal contour of said loci defines a curve having the formula: $H=CD^k$, wherein H represents the space in inches from the curved belt-converging means surface in contact with said one belt to a reference plane in substantial longitudinal alignment with the opposed belt at the forming zone, D represents the distance in inches downstream from the large end of the forming zone, C is a constant within the range of 0.5 to 1.6 and $k$ is a constant within the range of —0.2 to —0.8, and means maintaining said opposed belt under tension but free of restraining means in contact therewith at locations opposite said one belt converging means, said belt converging means establishing a generally elongated curvature in the path of motion of said belt portion contacting the same to express water through said portions of said belts and through said belt-converging means for formation of a paper web between such belts and for effecting a deflection responsvie to pressure in the forming zone in the path of motion of the other said belt portions free of restraining means in contact therewith at such forming zone.

**9.** In a device for forming an aqueous suspension of fibers into a sheet, in combination, upper and lower wire loops, upper and lower guide means within the corresponding upper and lower wire loops for moving opposed generally horizontal reaches of the wire loops through a generally converging but closely spaced path defining a forming zone at substantially the same speed, stock feed means generating and feeding a thin high speed stock jet of substantially homogeneous suspended entangled comoving stock fibers into the large end of such converging forming zone, said stock jet being substantially commensurate in transverse dimension and longitudinal speed to that of said wire reaches of both the upper and lower looped converging wires at the immediate vicinity at which the stock jet is fed into the forming zone, and mounting means for adjustably positioning the stock jet and said upper and lower wire converging means relative to each other, one of said wire guide mans within such converging wire loop presenting a substantially curved surface defined by a plurality of longitudinally spaced transversely aligned stationary wire-contacting edge members defining in longitudinal contour the loci of a generally elongated curve and driving such one wire loop through such generally elongated curve in the forming zone, and the other of such wire guide means within such other wire loop contacting such other wire loop before and after such forming zone leaving such other wire loop free of restraining means in contact therewith at such forming zone, the aforesaid generally elongated curve having substantially the formula: $H=CD^k$, wherein H represents the space in inches from the aforesaid wire-contacting edge members of such one wire guide in contact with said one wire to a reference plane in substantial longitudinal alignment with the path of the opposed other wire at the forming zone, D represents the distance in inches downstream from said large end of the forming zone, C is a constant within the range of 0.5 to 1.6 and $k$ is a constant within the range of —0.2 to —0.8.

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