

June 1, 1971

D. R. GUSTAFSON ET AL

3,582,467

TWO WIRE FORMER

Filed June 25, 1968

6 Sheets-Sheet 1

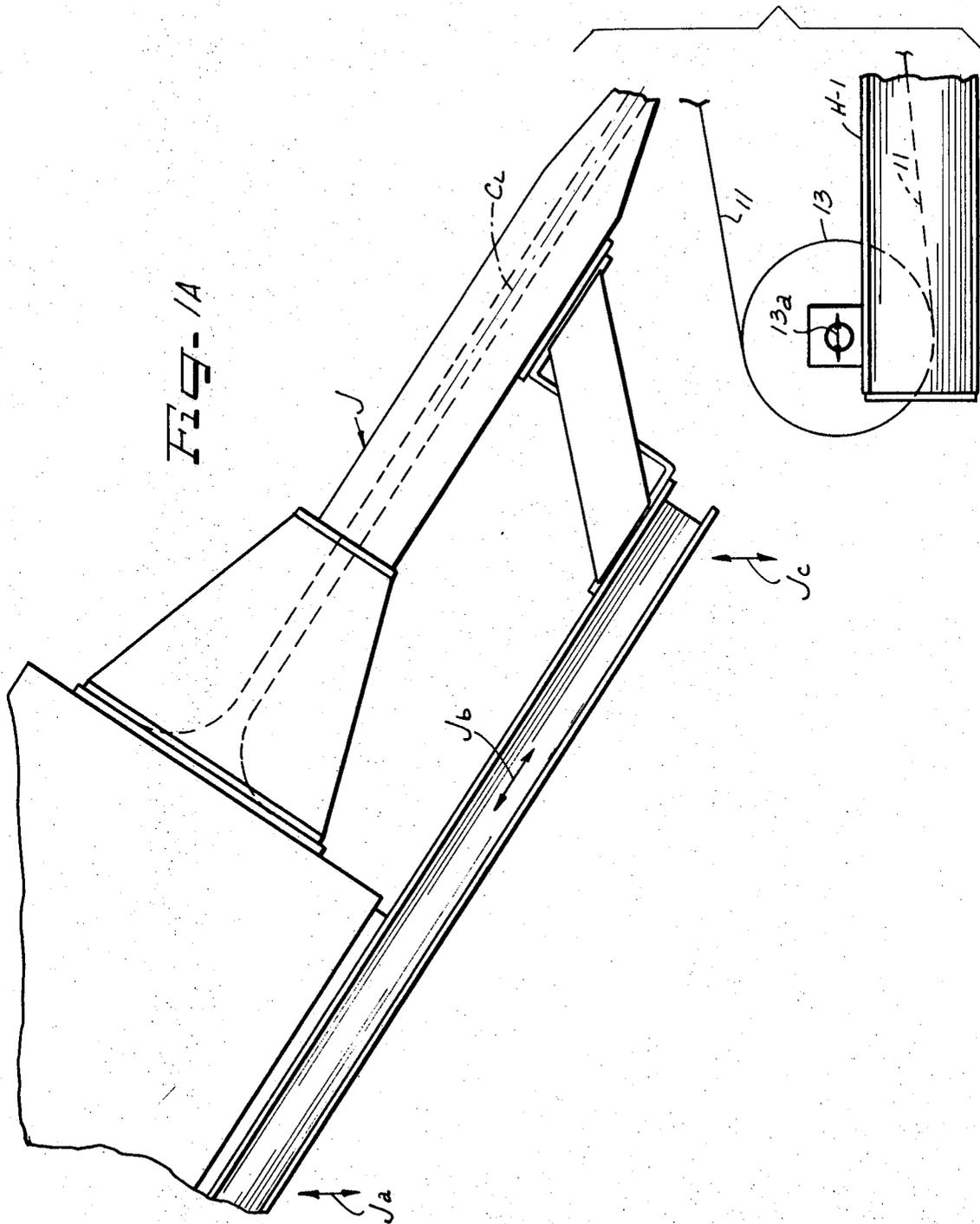


FIG-1A

INVENTORS  
David R. Gustafson  
John F. Schmaeng  
John S. Finnila  
ATTORNEYS

BY *Hill, Sherman, Morris, Green & Simpson*

June 1, 1971

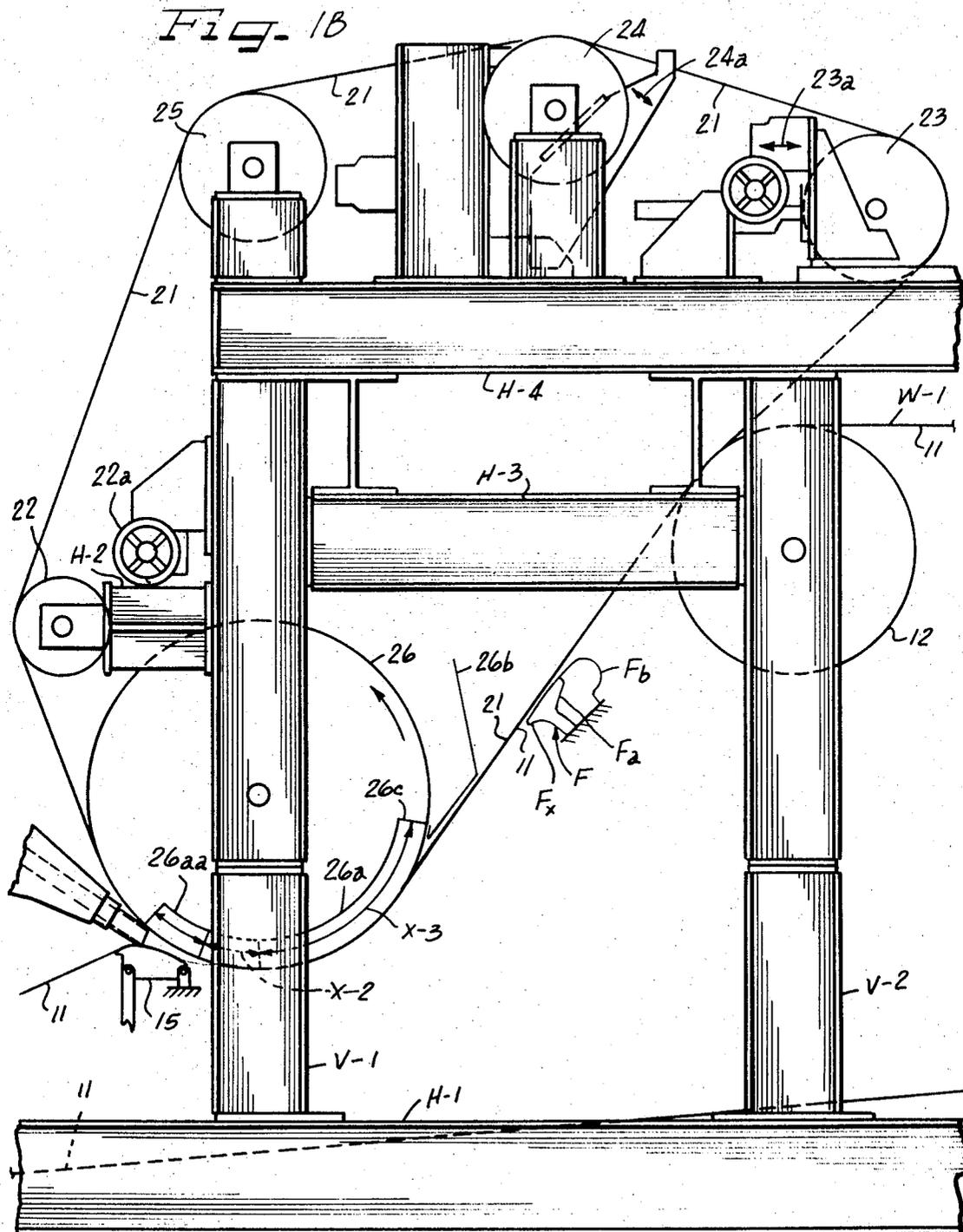
D. R. GUSTAFSON ET AL

3,582,467

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INVENTORS

David R. Gustafson

John F. Schmaeng

John S. Finnilla

BY

*Sill, Herman, Neoni, Gass & Lind*

ATTORNEYS

June 1, 1971

D. R. GUSTAFSON ET AL

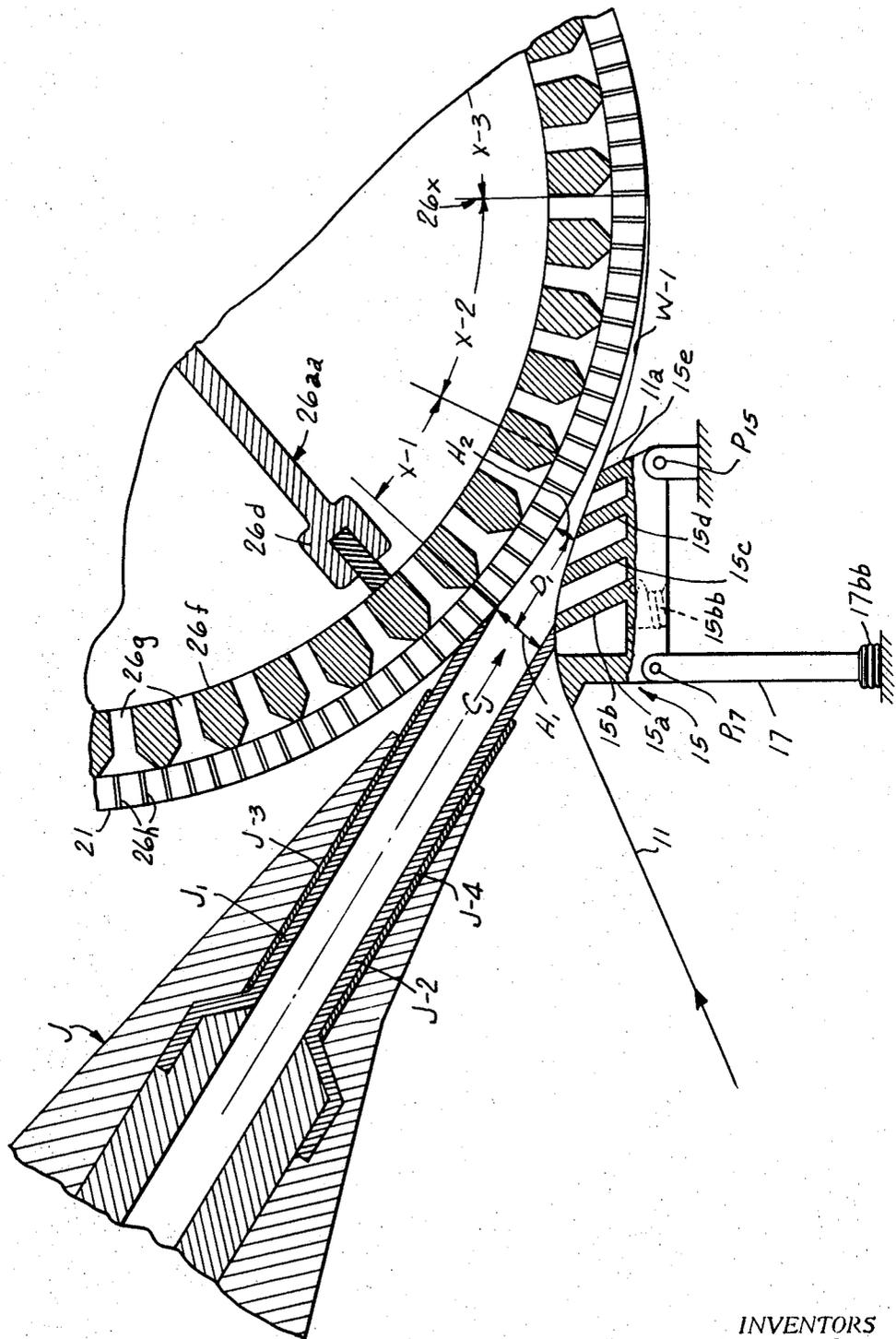
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6 Sheets-Sheet 3

Fig- 2



INVENTORS  
 David R. Gustafson  
 John F. Schmaeng  
 John S. Finnila

BY *Hill, Sperman, Menning, Chad & Stimpert* ATTORNEYS

June 1, 1971

D. R. GUSTAFSON ET AL

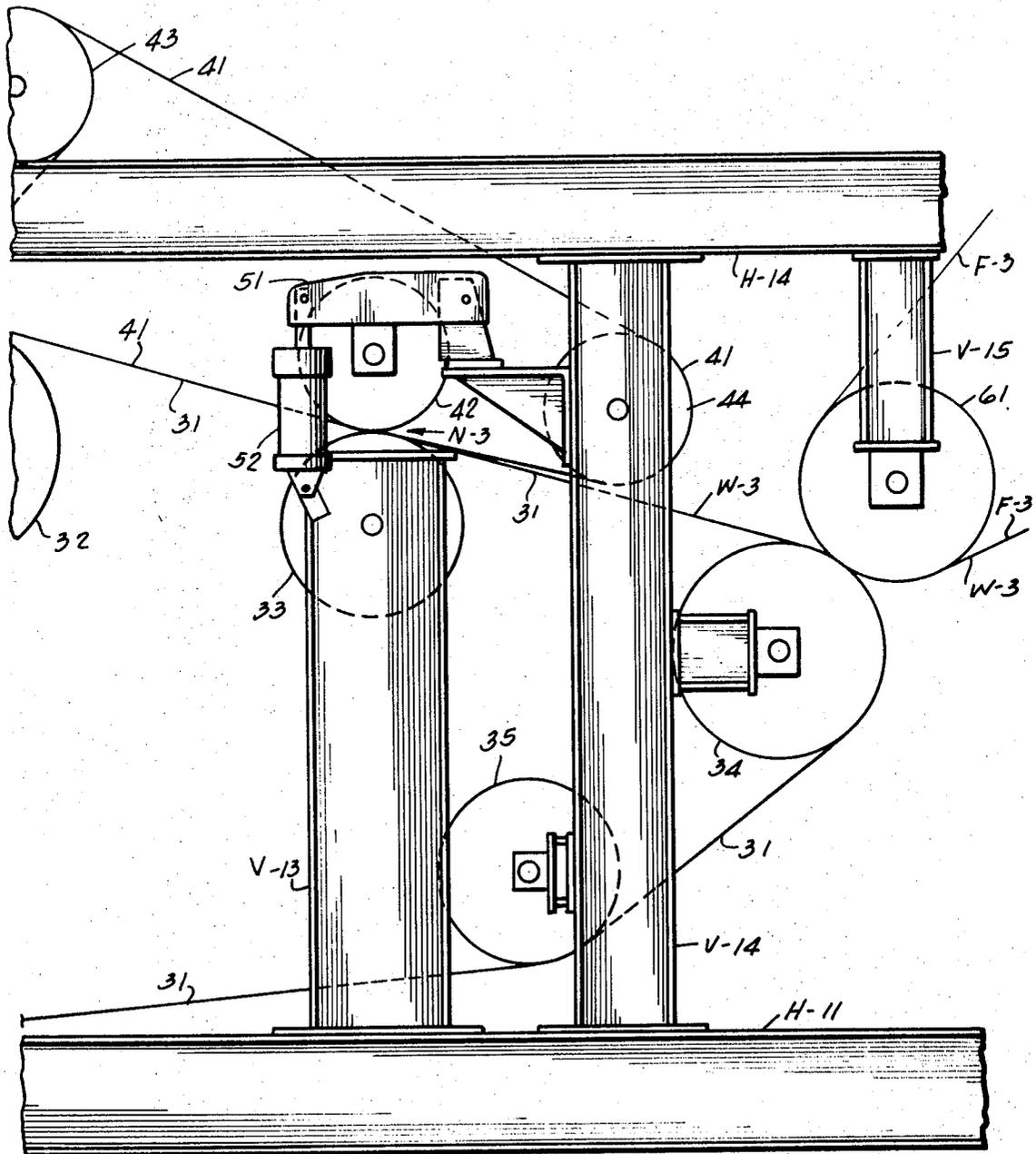
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Fig. 3



INVENTORS

David R. Gustafson  
John F. Schmaeng  
John S. Finnila

ATTORNEYS

BY *Hill, Sherman, Meroni, Good & Singer*

June 1, 1971

D. R. GUSTAFSON ET AL

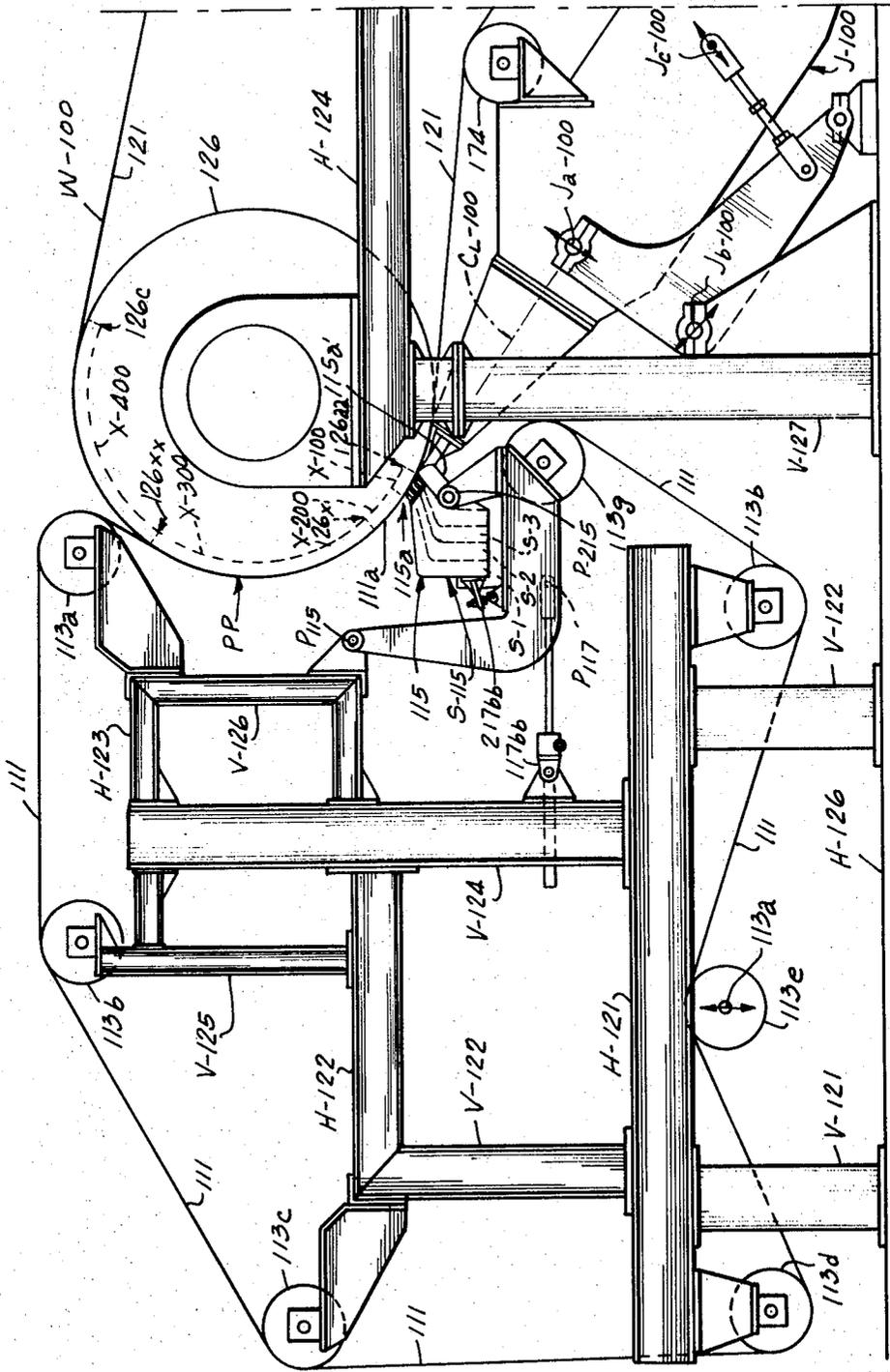
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6 Sheets-Sheet 5

FIG-4A



INVENTORS  
 David R. Gustafson  
 John F. Schmaeng  
 John S. Finnila

BY *Hill, Sherman, Morris, Chad Simpson* ATTORNEYS

June 1, 1971

D. R. GUSTAFSON ET AL

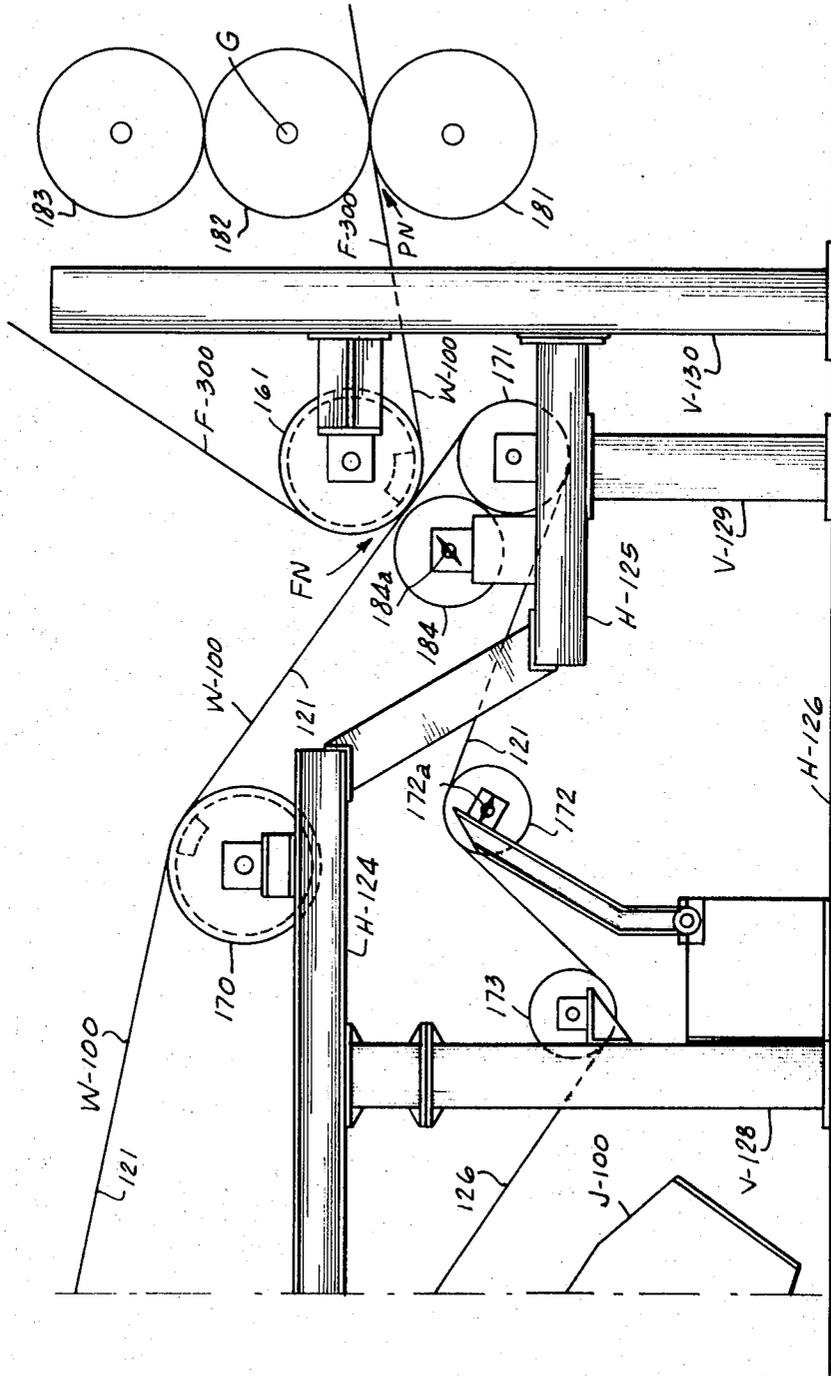
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FIG- 4B



INVENTORS

David R. Gustafson

John F. Schmaeng

John S. Finnila

ATTORNEYS

BY *Hill, Sherman, Messer, Galt & Simpson*

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**TWO WIRE FORMER**

David R. Gustafson and John F. Schmaeng, Rockton, Ill., and John S. Finnila, Kent, Wash., assignors to Beloit Corporation, Beloit, Wis.

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U.S. Cl. 162—303

14 Claims

**ABSTRACT OF THE DISCLOSURE**

The invention relates to the art of forming fibrous webs e.g., paper from dilute aqueous fiber suspensions fed into a web forming zone defined by a pair of opposed porous forming belts or "wires" driven into gradual convergence, in a forming zone, by (1) an open-faced roll wrapped by one of the belts and (2) an opposed porous stationary guide wrapped by the other of the belts and urging the same into such convergence in the forming zone with the one belt, the stationary guide presenting a non-circular active surface defined by the longitudinal contour of a plurality of belt-contacting longitudinally spaced transverse edges.

The present invention relates to improvements in paper making machinery or the like, and more particularly, to improvements in devices and methods for forming the initial web of fibrous material from a dilute 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 invention is concerned with a new and unique forming arrangement which has been devised 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**

FIGS. 1A and 1B represent side elevational views shown in longitudinal succession or sequence of a paper forming section embodying the instant invention, and it will be appreciated that these two views may be referred to as a single embodiment of the overall forming unit;

FIG. 2 represents in side elevation, with certain parts shown in section, an enlarged inlet and forming zone arrangement for use in the embodiment of FIGS. 1A and 1B;

FIG. 3 represents a side elevational view of an alternate couch section for use with the embodiment of FIGS. 1A and 1B; and

FIGS. 4A and 4B represent a side elevational view, in longitudinal succession A-B, of still another embodiment of the invention.

**AS SHOWN ON THE DRAWINGS**

In FIGS. 1A and 1B there is shown a first forming wire loop 11 that is wrapped about guide rolls including the rolls 12 and 13 shown within the loop of the wire 11

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in FIGS. 1A and 1B, although it is apparent that the loop of the wire 11 is shown to be extending beyond the right hand side of the view of FIG. 1B (obviously with other guide rolls which are not shown) and coming back along a lower return run around a forward tensioning roll 13. The roll 13 is adjustable as indicated by the double-headed arrow 13A mounting the same on bearings on a lower horizontal framing H-1, which tensioning roll 13 may be used to apply the desired tension to the forming wire loop 11 during operation in a manner that is substantially conventional for the use and function of forming wire tensioning rolls. In FIG. 1B, it will be noted that the essentially horizontal frame H-1 is provided with a pair of essentially vertical frame members V-1 and V-2 which extend upwardly to mount successively a second horizontal frame projection H-2, and a third and fourth essentially horizontal frame H-3 and H-4, again in generally conventional supporting structure. The guide roll 12 for the wire 11 is shown essentially schematically mounted for rotation on the upright frame member V-2.

A second forming wire 21 is also shown in FIG. 1B mounted on a plurality of guide and tensioning rolls which are shown mounted for rotation, respectively, at 22 on the framing projection H-2; and at 23, 24 and 25 appropriately mounted on bearings which are in turn mounted on the top horizontal frame H-4, again in essentially conventional manner which need not be described in further detail herein. It will be noted, however, that the positioning screw 22a on the framing upright V-1 assists in positioning the roll 22 and tensioning of the wire loop 21 is afforded by adjustable mounting devices shown for the rolls 23 and 24, both of which devices are represented schematically by two-headed arrows at 23a and 24a, respectively. The first mentioned forming wire 11 and the second mentioned forming wire 21 shown in FIGS. 1A and 1B are thus mounted with appropriate, although conventional, guide and tensioning means for effecting the desired tension control thereof and, although not shown specifically, drive means are provided, e.g., for the rolls 12 and 23, 24, 25, so that the actual peripheral or longitudinal machine direction speeds of the two wires 11 and 21 are controllable and are coordinated, again in conventional manner, for the purposes hereinafter described. Guide and tensioning means for forming wires generally are well known and need not be further described herein.

It will be noted, however, that the forming wire 21 is also wrapped about a large diameter open roll designated 26 (FIG. 1B), over a substantial suction area indicated essentially diagrammatically at 26a thereof, and is provided with an off-running saveall 26b extending generally upward in the view of FIG. 1B from close running relation to the surface of the open roll 26 at approximately the cross-machine line of separation of the forming wire 21 from the periphery thereof, so that droplets of water tending to be retained in the periphery of the open roll 26 may be thrown into such saveall 26b and not back against the inner periphery of the forming wire 21.

It will also be noted that the first mentioned forming wire 11 approaches the open faced roll 26 (wrapped by the second mentioned wire 21) over a wire guide device 15 (which will be described in greater detail hereinafter) which acts against the inner periphery of the loop of the wire 11 to control the position of the wire 11 as it travels thereover and also to control its position relative to its spacing from the second mentioned wire 21 wrapped about the open roll 26 at a critical web-forming zone between the wires 11 and 21 at the upstream end 26aa of the suction area for the open roll 26. Immediately after the position controlling box or device 15 for the wire 11, in its longitudinal or machine direction travel, it will be seen that the wire 11 continues in its direction of travel

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under tension as what might be called a free loop for a short distance of travel before it appears, in FIG. 1B, to be wrapped about and on the second wire 21 that is being carried on the outer periphery of the open roll 26 opposite the overall suction area 26a thereof. Actually, it is apparent from FIG. 1B that there is an initial convergence between the wires 11 and 21 that is controlled by the substantially unyielding periphery of the open roll 26 and the substantially unyielding elements of the guide box 15 (in an initial forming zone region designated X-1) after which the forming wire 21 continues to travel on the outer periphery of the open roll 26 while the opposed forming wire 11 travels in the substantial absence of restraining contact through a terminal forming zone portion indicated at X-2 in FIG. 1B. The overall web-forming zone is represented as the total peripheral dimension of X-1 plus X-2 in FIG. 1B, after which the initial or insipient web is formed in essentially a sandwich-type structure between the wires 11 and 21 and continues to travel around a substantial additional portion of the periphery of the open roll 26, opposite an additional portion of the suction area 26a thereof.

To recapitulate, then, the forming wire 21 is caused to travel in a substantially unyielding course of travel against and around the periphery of the open roll 26 through the forming area, which in composite may be referred to as X, and afterwards until approximately the off-running suction sealing strip 26c and the saveall 26b adjacent thereto; whereas the opposed forming wire 11 travels under tension and with controlled spacing from the opposite forming wire 21 over the box 15 for an initial peripheral forming zone region X-1, then as a yielding but tensioned free loop through a second forming zone portion X-2, and finally in the aforesaid sandwich structure for the remainder of the suction area X-3 of the open roll 26.

Essentially the wire guide and control box 15 shown in FIG. 1B functions to effect a desired and quite precise positioning of the wire 11 and spacing of the same from the wire 21 during an early and very critical portion of the forming zone X-1, and it will be appreciated that this concept of control of the positioning of the outer wire 11 in the early stages of the forming zone X-1 is of particular significance in the operation of the instant forming zone, not only from the point of view of affording considerable flexibility in adjusting water drainage ratios through the wire 11 as against through the wire 21 and into the interior of the roll 26, but also control as to the incremental pressure differences that might otherwise tend to be created against the stock in the forming zone X-1 and also X-2 at this extremely significant region of web formation.

It will be appreciated that, particularly in the case of the formation of paper webs from stocks of various concentrations, the rate of deposition of the stock fibers onto the opposed wires 11 and 21 at the very initial forming zone region X-1 creates a fiber bed on each of these two wires that will function only generally like a filter bed. In filtration, the filter aid often used has definite drainage characteristics, particle sizes, and even particle orientation so that its rate of drainage relative to its thickness is often believed to be a function that can be calculated, or at least many skilled workers in the art pretend to be able to calculate the same. Filter aids and materials being filtered have been studied for the purpose of making such calculations and some degree of uniformity is ordinarily sought in this respect.

Studies have been made in connection with the deposition of fibers from paper making stock onto a wire in an effort to correlate the academic principles and concepts thereof with those of filtration calculations, but for a number of different reasons these calculations proved to be primarily approximations rather than something in the nature of exact predictions. Paper stock fibers are not identical in size and shape and this serves to be particu-

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larly complicating in this situation, since certain filter aids may often be selected in such a way that their size and shape characteristics can be controlled. With paper web formation, it is perhaps particularly significant to note that the object is not that of protecting some sort of exact control on the bases of the types of uniformity which might be used in filtration calculations, because the felting of a paper web of a multiplicity of particle sizes (plus a multiplicity of additives such as clay and the like which really bear no physical resemblance to fibers of various sizes in the paper machine stock) serve to substantially defy intelligent and predictable calculation. It is also understood that the cellulosic fibers of the usual paper machine stock actually have a certain amount of "semi-chemical" solvation characteristics in retention of water molecules and the like, so that the notion of predictable calculations relative thereto may be attractive and the subject of a number of academic efforts on the part of the skilled workers in the art; but it can hardly be denied that the actual problems of "practice" in connection with web formation are instead very deceptive. Additionally, the paper machine stock is known to have properties that are not consistent with the classic "Newtonian" fluid flow properties by virtue of the suspended matter therein, so that translation of high speed machine direction stock jets to stock bodies under pressure exerted more or less in the normal direction to the machine direction represents still another phase of the complications here involved.

The instant invention is based upon certain discoveries which are not represented as solving the academic problems which have frustrated workers in the art over the years. Instead, the instant invention affords certain significant aspects of versatility in the forming zone operation which make it possible for the operator to adjust the paper machine forming zone to various stock characteristics, within quite broad but reasonable limits, while at the same time affording uniquely practicable and functional operation.

With respect to the functional and practical aspects of the instant invention, attention is directed to the fact that the forming wire 21 is carried substantially entirely by co-moving functional parts, including particularly the open roll 26 which travels at a peripheral speed that is matched with the desired peripheral speed of the longitudinally moving forming wire 21. In addition, the forming wire 11 also travels substantially over co-moving guide and tensioning devices which, as in the case of the wire 21, serve to minimize wear on the wire and serve generally to add substantially to the practical aspects of the operation of the instant paper making machine, and particularly the function of the forming zone therein.

It will be seen, however, that there are certain elements in the positioning and guiding control box 15 which are stationary and over which the forming wire 11 travels; but these elements offer unique advantages in the instant device in that they provide a substantial minimum number of wire contacting surfaces and/or a minimum area of wire contacting surface with respect to which there is in fact relative movement between the rapidly traveling wire 11 and the stationary elements of the box 15. Also, it will be appreciated that the wire contacting elements in the box 15, which will be defined in greater detail hereinafter, are preferably provided with substantially frictionless wire contacting surfaces in the form of such surfaces as extremely hard, refractory and smooth (micro-finish) elements which will in fact minimize wear on the wire 11. The nature and character of such refractory ceramic types of surfaces has already been described in detail and does not require additional description herein.

Referring to FIG. 2, it will be seen that FIG. 2 shows an enlargement of the essential features of the forming area here involved. Thus, referring to FIG. 2, it will be noted that the upstream sealing strip 26d is shown positioned at approximately (or slightly upstream of) the slice exit (which is here designated by the dimension  $H_1$ ).

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The forming zone portion X-1 which is defined by the wire 21 wrapping the outer periphery of the open roll 26 and the wire 11 wrapping the functional wire guide surfaces of the box 15 is shown as having diminishing thickness from the slice jet dimension  $H_1$  to an intermediate dimension  $H_2$  over a distance designated  $D_1$ . Actually the overall initial forming zone region X-1 in which both wires 11 and 21 are being guided into convergence is longer than the intermediate dimension  $D_1$  which is used for reference in FIG. 2, since the guided convergent zone X-1 terminates approximately at the beginning of the forming zone X-2 which is defined by the wire portion 11a at the off-running side of the box 15 which is itself free from restraining support contact for the peripheral dimension indicated in FIG. 2. Without elaborating upon the particular longitudinal alignment of the stock jet centerline CL indicated in FIG. 2, being fed from the stock jet inlet designated generally J, it will be sufficient to note that the approximate thickness of the stock jet that is fed out of the inlet device J is designated  $H_1$  and after the stock has traveled the relatively short distance  $D_1$  the overall thickness of the stock in the initial forming zone X-1 has diminished to the dimension indicated at  $H_2$ , by virtue of the desired rapid drainage into the suction area 26aa of the open roll 26 and downwardly between the blades or foils 15a through 15e, alphabetically, of the guide box 15. The open roll 26 may have a number of conventional constructions, which are not per se novel in the instant arrangement. As here shown, the open roll 26 is provided with an outer shell 26f with perforations indicated partly at 26g, to provide structural strength thereto. The outer portion of the shell 16f may be provided with honeycomb cells or simply a plurality of cross-machine radial extensions here indicated at 26h, and about which a surface screen or wire of spiral configuration (not shown) is ordinarily employed to uniformly support the traveling forming wire here designated only by the line 21. In short, the open roll 26 does not provide substantial land areas backing against the forming wire 21 which would tend to effect the formation of pressure differentials on the inside of the loop of the wire 21 opposite the forming zone regions X-1, X-2, or even the subsequent dewatering region X-3, but the screen or spiral wire covered fins 26h are mounted essentially for structural support for the forming wire 21, in an open roll arrangement of generally conventional structure. The sealing strip 26d and its downstream counterpart 26c (FIG. 1B) are connected to a conventional pressure control gland that is coaxially mounted within the open roll shell 26 and is equipped by conventional means which need not be described herein for maintenance of a desired, generally subatmospheric pressure between these glands 26d and 26c over the various zones X-1, X-2 and X-3 already described. With the woven forming wire 21 (which may be formed of plastic or synthetic resin (e.g. nylon) fabric) mounted on the outer periphery of the open roll 26 is thus maintained throughout the forming zone regions just described with a substantially uniform pressure (i.e. subatmospheric pressure) so that there is continuously maintained at such forming wire 21 (on both the inner periphery and outer periphery as a practical matter) a predetermined pressure that is essentially constant for the more critical regions of the forming zone and which is controlled as a practical matter quite readily simply by controlling the pressure within the suction gland between the sealing strips 26c and 26d. Thus, the rate of drainage from the stock issuing from the jet J and flowing through the forming wire 21 into the interior of the open roll 26 is functionally controlled. Moreover, the pressure control arrangement just described is functionally adequate to maintain a substantially uniform pressure continuously along the inner periphery of the forming wire 21 during the initial forming zone peripheral region X-1, and the subsequent forming zone region X-2, and/or the subsequent dewatering zone X-3, primarily on the basis of known operating controls

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in paper machines. The functional capability of the open roll 26 to perform in this manner is understood by those skilled in the art. It will be appreciated, however, that by relative tilting of the stock jet device J so that the centerline CJ of the stock jet may be tilted relative to an approximate tangent to the open roll 26 is also used to assist in the actual control of the amount of drainage through the wire 21 and into the interior of the open roll 26. Again, this is a concept which the skilled worker in the art can readily appreciate.

With respect to the instant invention, however, the additional variable, which is now controllable, involves the control of drainage in the opposite direction through the box 15.

Starting with an initial assumption that each of the blade elements 15a through 15e, alphabetically, is actually positioned in the manner desired for a given operation of a paper machine in the forming zone, it must be appreciated that the element 15a is primarily a member for guiding the wire 11 into an appropriate approach to the initial and critical forming zone area X-1; but the immediately subsequent blades 15b through 15e, alphabetically, are positioned in FIG. 2 with their top surfaces extending transversely of the machine direction. These top surfaces for the elements 15b through 15e, alphabetically, are actually quite narrow in the longitudinal dimension and they are spaced longitudinally a relatively substantial distance (at least in relation to the longitudinal dimension of their top surfaces). In fact, the preferred open area for the box 15 is ordinarily at least 50% and in the practical embodiments of the invention presently recognized something in the nature of 60 to 80% averaging perhaps about 75% open area. The blades 15b through 15e, alphabetically, are formed so as to effect substantially a cross-machine or transverse line contact with the traveling wire 11. The less surface contacting the wire 11, essentially the less wear on the wire 11. Of course, since the stock jet itself will be issuing at the location indicated at  $H_1$  under considerable pressure (by virtue of high speed jet velocities in the nature of 2000, 3000 or perhaps 3500 or more feet per minute) this very high speed stock jet tends to develop substantial pressures in the stock that is being driven into a zone of convergence wherein the apparent volume is being diminished very rapidly at the operating speeds here involved. Of course, drainage of the stock through the wires 11 and 21 accommodates this rapid diminution of the apparent forming zone volume, but the drainage must necessarily occur by forcing the water in the stock through the dispersed stock solids of fiber, clay, etc. which build up rapidly on each of the wires 11 and 21 and afford resistance. Accordingly, the stock jet speed in translated into pressure that is generally normal to the tangent of the wire wrapped open roll 26 and, of course, the tangent of the guided wire 11. The guided wire 11 moves under relatively high tension so that it will not be depressed by such pressure in the open areas between the blades 15a through 15e, alphabetically, but it is apparent that by the use of high tension effective to avoid this relatively undesirable result the wire 11 does not really travel through a true curve over the blades 15a through 15e. Instead, it travels through a plurality of chords from the approximate line of contact at the top of each of these blades 15b through 15e, alphabetically, to the next approximate line of contact. The more tension that is applied to the wire 11, the more closely the wire 11 will assume the configuration of a plurality of chords passing from one blade to the next in the box 15. It is also apparent, however, that the longitudinal or machine direction profile or contour of the loci of such multiplicity of relatively closely longitudinally spaced porous belt or wire 11 contacting generally transverse edges 15b through 15e, alphabetically, will be a curve. It is conceivable that under a certain set of unique circumstances the operating conditions within the forming zone X-1 might call for substantially a co-planar contour of such wire contacting edges, particularly if the diameter

of the open roll 26 were extremely great in size. But this could only be approximately co-planar, because the mathematics of the drainage curves (to the extent that the same can be intelligently represented), do not call for a straight line function. Thus the mathematics here involved call for a relationship between the spacing between the wires 11 and 21, which is shown at the slice outlet to be  $H_1$  as a function of the longitudinal or downstream distance of the stock, which distance is here represented in a specific instance as  $D_1$ , to reach a spacing between the wires that is designated  $H_2$  in the instant FIG. 2, for purposes of example.

With respect to the mathematics here involved, those skilled in the art will recognize that a general evaluation may be possible on the basis of the teachings already set forth herein, although it is hardly possible to expect a formula which will offer the solution for all types of stock simply by elementary arithmetic. Thus the formula for the relationship between the spacing between the wires 11 and 21 as a function of the downstream dimension from the slice outlet may best be represented by the following formula:  $H=CD^k$  wherein H is the distance in inches between the wires (i.e. the wires 11 and 21 FIG. 2), D is the distance in inches longitudinally or downstream from substantially the point of introduction of the stock jet between the wires (i.e. here shown to be substantially at  $H_1$ ), C is a constant which for the preferred thin channel jet is substantially 0.5 (although it may range over the practical jet thickness dimension from perhaps slightly less than 0.5, i.e. for usual circumstances involving 0.25 or 0.3 jet stream thicknesses to thicker jet streams of 1 to 1.5 or more which might be used). The exponent k is a negative fraction of preferably about  $-\frac{1}{4}$  preferably but also could range from slightly lower, i.e.,  $-0.2$  to relatively higher with the thicker jet streams, i.e.  $-0.8$ . As an exemplary calculation, it will be recognized that H would change negligibly in approximately the first one inch downstream:

$H=0.5$  jet thickness (inch)

$C=0.5$  preferred

$D=1$  inch

$k=-0.25$

$H=CD^k$

$0.5=(0.5)(1)^{-0.25}$

but the critical aspects of this formula are involved in determining the spacing H over the range of D=from 1 to 8 to 12 inches.

It will be appreciated that the formula just used more or less assumes the longitudinal contour of a curve for the wire 11 passing over the blades 15b through 15e, alphabetically, even though this is obviously not the case when one considers the nature of the plural chord-like configuration of the wire 11 passing over the blades in the box 15. Also, further study of this formula will reveal that it does not actually require that the wires 21 and 11 will converge through opposed convex configurations, except in situations in which the diameter of the open roll 26 is extremely great. Essentially, the curve defined by the longitudinal contour of the loci of points of contact between the blades 15b, etc. and the wire 11 is one which will correlate the recognized variables such as drainage rate (and particle characteristics which cause variations therein), machine speed, stock concentration, overall jet direction, volume and speed, etc. The correlation represented by the instant formula is an unusually adequate guide, however, for a determination of the rate of convergence should be effected between the wires 11 and 21. This rate of convergence in the initial and critical forming zone X-1 is not left to chance, nor is it left to such things as tension control and the like which ordinarily do not turn out to be satisfactory means for maintenance of the correct critical positioning of the wire 11 in this arrangement. As mentioned, the forming wire 11 may not be in opposed convex relation to the forming wire 21 unless the diameter

of the roll 26 is very substantial, but this does not mean that an essentially straight line function of the tension on the wire 11 will satisfy this formula. Essentially, the transverse blades of the 15 series are quite narrow longitudinally, with substantial longitudinal spacing therebetween to afford minimum inhibition of flow through the wire 11. It is also apparent from an examination of the elevational profile of the individual blade elements 15b through 15e, alphabetically, that these blades not only present approximately a transverse line of contact with the traveling wire 11 but they also present a very abrupt off-running edge or separation from the wire 11 so that there will not be "pumping" effect at the off-running side of such blades, as there would be in the case of the so-called conventional paper machine "foil" element F which is designed with a very limited angle of approximately 3 to 5° off-running taper. Such a pumping effect would necessarily cause pressure differentials to be created at the immediate underside of the traveling wire 11 as it passes over the box 15. In particular, it is an important concept of the instant invention to strive for the maintenance of substantially uniform pressures on the back side of not only the converging wire 11 but also the converging wire 21. In this way the initially forming paper web, which is very sensitive to any type of disturbance in the early stages of its formation, will not be disturbed by any abrupt pressure changes exerted thereagainst from the inner periphery of the forming wires. The blades 15b through 15e are functional essentially as guides for positioning the wire 11 in precisely the manner desired. In fact, such positioning of the forming wire 11 traveling thereover is done essentially to correlate such factors as the rate of drainage and the drainage resistance provided by the earliest stages of web formation on the outer peripheries of the two wires 11 and 21, such that the translation of the relatively high machine direction or longitudinal direction velocity into pressures within the stock body in the forming zone X-1 will not be afforded an opportunity to undergo fluctuation or variation, if at all possible. Instead, the desired here is to carry out this phase of initial web formation by subjecting an increasing web buildup (even though of very thin and delicate nature) on each of the forming wires in this critical forming area by continuously and without interruption or variation subjecting these delicate early-formed web elements to a predetermined pressure.

Considering next the very important matter of bringing about convergence between the two wires so that disproportionately greater drainings will not occur in only one direction, it will be noted from FIG. 2 that the box 15 is mounted on a fixed pivot  $P_{15}$  actuatable by the arm 17 which is in turn connected to the upstream end of the box 15 at a second pivot  $P_{17}$ . This is essentially a simplified showing of a control aspect which can be varied to suit the purpose of the operator. A slight tilting of the box 15 will, of course, cause a definite change in the previously expressed constants C and k in the formula relative to the spacing, for obvious reasons. Except for the fact that paper making machinery must be maintained as simple as possible for practical use in the mill, other known devices for varying the relative positions of the contacting edges of the blades 15b through 15e, alphabetically, can be accommodated. For that matter, even the rod 17 may be mounted so that it is yieldable to a predetermined pressure that might be generated within the stock jet, or each of the individual blades 15b through 15e, alphabetically, may also be so mounted, so that the actual line pressure exerted against the same by the wire 11 traveling thereover would be continuously constant. Thus, without attempting to limit the invention to any particular type of control, it will be noted that a diaphragm 17bb might be used to hold the box 15 in a position responsive to pressure within the forming zone X-1 via the arm 17, or the individual transverse blade 15b could be pivotally mounted and actuated in response to a pneumatic diaphragm 15bb for maintaining the in-

dividual operating edge of the blade 15b against the underside of the wire 11 at a particular pressure generated within the stock jet. Such showings are intended to be only schematic for the purpose of representing the concept that conventional means for mounting each of the blades 15b through 15e, alphabetically, are certainly available such that an additional aspect of versatility is afforded in the box 15 so that the individual operating edges of the blades in the box may in fact act against the underside of the wire 11 such as to preclude excessive pressure differences within the stock in the forming zone from one transverse blade edge to the next, and so forth. It is appreciated that operativeness of devices of this type in a paper mill depend upon numerous other practical factors, but the essential concept of the invention provides for positioning of the various blades 15b through 15e so that a given paper making stock at specific speeds and other operating conditions may actually be able to exert at least practically uniform if not exactly uniform pressures against the forming wire in this critical area and variations of the nature which may cause disturbances in web formation can be avoided by the use of the concepts here involved.

Of course, the view of FIG. 1A introduces still another important variable in the overall concept and that is the ability to vary the actual centerline of the stock jet as it is fed into the critical regions of the forming zone or zones X-1 and X-2, so that there will be a reasonable distribution of drainage in the two principal directions. Preferably, the rate of drainage, expressed in a ratio, should not be such that less than substantially 30% or more than substantially 70% occurs through either one of the wires 11 and 21, and optimum results are believed to be obtained by using a substantially 50:50 drainage ratio. The overall stock inlet which is shown as J in FIG. 1A is conventional in its overall structure, in that it will deliver a dilute aqueous suspension of entangled co-moving fibers in a ribbon-thin stream exiting from the slice (at H<sub>1</sub> of FIG. 2, for example) at a very high speed and in a substantially longitudinally unidirectional condition. Such unidirectional condition in this instance is approximately tangential to the open roll 26 but the selection of very slight variations from a true tangential direction makes possible very helpful proportioning of the drainage relative to the two wires 11 and 21 in a manner previously described. Thus, a very slight tilting of the jet centerline so that it tends to impinge more toward the wire 21 on the open roll 26 will tend to increase the rate of drainage in this direction (which drainage in the arrangement of FIG. 2 is against the pull of gravity, although it is in the direction urged by the suction box). The inlet itself is a structure that is already well known and understood in the trade, and is further described in detail in such applications as Justus and Gustafson Ser. No. 467,664, filed June 28, 1965 now Pat. No. 3,382,143, which is incorporated herein by reference. Essentially, the overall inlet arrangement is mounted for the desired adjustment on conventional means which are here indicated by the double-headed arrows designated J<sub>a</sub>, J<sub>b</sub>, and J<sub>c</sub>. Such inlet device is essentially functional for the purpose herein described.

In FIG. 2, however, it will be noted that the inlet is provided with an additional feature in the form of a pair of transverse top and bottom relatively stiff but resilient (i.e. relatively hard rubber) elements clamped in the slice exit end of the inlet device J and designated J-1 and J-2 with metallic sheet support elements designated J-3 and J-4 for additional stiffening. Such rubber elements or solid elastomer elements J-1 and J-2 are positioned at the slice outlet so as to extend forward into very close running and sealing relationship with the wires 11 and 21, respectively, at the location of the slice jet stream outlet H<sub>1</sub> to effect a nominal pressure seal with the wires 11 and 21. Such elements J-1 and J-2 would otherwise feed a "free" jet stream into the convergence be-

tween the wires 11 and 21, but in this arrangement shown in FIG. 2 these elements effect a seal with the wires 11 and 21 and thus afford an additional pressurized or "hydraulic" forming zone at X-1 and X-2 between the wires 11 and 21, such that superatmospheric pressure may be generated therein to accelerate drainage without backflow of stock in directions opposite to either of the wires 11 or 21. Practical sealing effect is obtained from a close-running spacing of ¼ inch from the wires 11 and 21 to the elements J-1 and J-2. The essentials of the spacing between the wires 11 and 21 permit accelerated drainage by virtue of the additional hydraulic pressure in the forming zone, which hydraulic pressure is also used much more effectively in this particular instance by virtue of a generally downwardly directed jet centerline CJ, as shown in FIG. 2. Deckle edges (not shown) can, of course, be used to add to the uniform cross-machine pressure maintenance in the forming zone.

It should also be noted that the most critical region of the forming zone here designated X-1 is actually controlled by the combination of the surface of the open roll 26 and the guiding blades of the box 15, but the terminal portion of the forming zone, designated X-2, in FIG. 2 is not necessarily provided with restraining means in contact with the wire 11 on the underside thereof. In this latter forming zone region X-2, it will be appreciated that the most delicate aspects of the web formation have taken place and the finalization of what may be termed "web formation" as compared to web drainage which will occur more or less continuously during the remainder of the suction area at X-3 will not require as delicate a positioning of the outboard forming wire portion 11a. In fact, the outboard portion of the forming wire 11a will wrap the open roll 26 but in a closely spaced condition for a substantial peripheral region before it is brought (by virtue of the tension under which it operates) into the so-called sandwich structure holding the web W-1 against the in-board forming wire 21 wrapping the open roll 26. The concept here involved is that the invention provides critical positioning of the wire 11 in only the most critical regions of the forming zone X-1, as contrasted to continued support further downstream. The advantage involved is that the configuration through which the wire 11 must go in order to conform to the predetermined curvature required for best formation in the zone X-1 is such that a rotary surface or a co-moving surface is neither practical nor ordinarily available to hold the wire 11 in the position that is here shown as being defined by the longitudinal contour of the locii of generally transverse belt-contacting edges of the elements 15b through 15e, alphabetically. Because of the ideal configuration for the wire 11 that is desired in the practice of the instant invention in the critical region of the forming zone X-1, it has been found that a limited number of stationary blades of minimum total contacting area should be used and such transverse lines of contact afforded by the blades of the box 15 are thus held to a minimum for the purpose of minimizing any tendency toward wearing of the wire 11 in this arrangement. Substantially after the last of these blades 15e, it is found that the internal pressures within the partially dewatered stock appear to be sufficient to effect not only the desired configuration in the "free loop" of the wire 11a, but the relatively substantial initial web formation which has occurred prior to the last indicated blade 15e is such that opportunities of damaging the web being formed thereafter are also minimized and the wire 11 may under reasonable tension forces conform adequately to carry out the remainder of the web formation in this region X-2 so that neither excessive wear of the wire (by inordinate tensions thereon) nor excessive additional guidance of the wire reach 11a (also tending to cause some wear) are required. Under these circumstances, it is possible to strike a balance between the positive guidance of the configuration of the wire 11 for optimum condi-

tions for initial and critical web formation in the zone X-1 and more reasonable positioning of the tensioned wire loop 11a free from contact with restraining surface elements in order to complete the desired web formation without risks of damage make possible the overall arrangement here shown. This overall arrangement affords excellent web forming conditions of high quality, while at the same time practical machine operation from the point of view of very simple equipment and minimum wear and/or replacement of parts for one reason or another. Additionally, the unique flexibility of operation that is here afforded by the use of a relatively large open roll 26 to afford a substantial portion of the curved configuration of one of the forming wires (i.e. 21) which is at least a part of one of the essential aspects of best web formation makes possible the use of the greatly simplified nominal tilting adjustment of the stock jet inlet J coupled with the very nominal adjustment of the blade box 15 so as to afford the remainder of the elements which have been found to be fundamental to conditions for optimum web formation at high speeds in accordance with present-day quality and production requirements.

It will also be noted that an intermediate suction box sealing strip may be positioned at the location designated 26x in FIG. 2 (at approximately the end of the forming zone X-2 and the beginning of the dewatering zone X-3) so that an additional control may be afforded in selective variation of the pressure to be maintained against the inner periphery of the wire 21 in the regions X-1 and X-2, as compared to the selection of a different back pressure against the inner periphery of the wire 21 in the region X-3.

As earlier indicated, with reference to FIG. 1B, a typical known foil structure F may be operated in substantially close running relation to the inner periphery of the wire 11 at the approach of the roll 12. Such foil device has a taper at its off-running portions  $F_a$ , such as to exert some additional pumping effect for dewatering against a conventional save-all  $F_b$ ; and the structure of one or more such foils F removed from the immediate vicinity of the forming zones X-1 and X-2, is often found to be quite useful in tending to wipe off droplets which may be accumulating on the underside of the wire 11 as the overall sandwich structure of the two wires 11 and 21 with the web W-1 therebetween travels toward the roll 12 indicated in FIG. 1B. It is important to note, however, that the foil F need not actually contact the underside of the wire 11, such that it might cause increase operating wear on the wire 11, but such foil structure F may still function to wipe off water droplets at its oncoming side  $F_x$ , even though the pumping effect of the off-running side  $F_a$  might be nominal, if minimum wearing of the wire 11 by contact with the foil F is desired. In any event, the function of a foil-type structure F such as that here shown, whether or not it actually engages the wire 11, such foil F is positioned preferably substantially longitudinally downstream from the periphery of the roll 26 and at a location in which parallelism between the runs of wire 11 and 21 has already been reached and dewatering of the web W-1 sandwiched therebetween is in process. Thus, the free loop portion 11a of the wire 11 at the immediate off-running side of the blade box 15 will still remain substantially free from any restraining wire contacting means prior to actual convergence of such free loop 11a into essential parallelism with the wire 21, at approximately the location 26x indicated in FIG. 2.

Referring briefly to FIG. 3, it will be seen that the embodiment shown in FIG. 3 relates to an alternate travel arrangement for the wires traveling in parallelism. In FIG. 1B the wires 11 and 21 are separated at approximately the region of off-running contact over the roll 12. The roll 12 is preferably a plain roll in FIG. 1B so that it may effect substantial retention of the web W-1 on the off-running wire 11 (while permitting ambient atmos-

pheric pressure against the backside of the separating wire 21 for this purpose).

In FIG. 3, however, the position for the roll 12 is indicated at 32 and the off-running wires 31 and 41 correspond, respectively, to the wires 11 and 21 previously described. In such arrangement, it will be seen that the wire 31 travels over rolls 32, 33, 34 and 35 (all of which represent traveling wire guides acting against the inner periphery of the loop of the wire 31). The top wire 41 is shown moving initially in substantial parallelism with the bottom wire 31 (and with the web designated W-3 in FIG. 3) first through a couch press defined by a top roll 42 which is pivotally mounted on an arm 51 with a pressure applying coacting means 52 (in the form of a pneumatic cylinder) mounted for applying pressure between the rolls 33 and 42 at a couch nip N-3, for some additional dewatering of the web W-3, and followed by separation of the top wire 41 as it travels around an additional guide roll 44 and then back up to a roll 43, which is in substantially the position of the roll 23 of FIG. 1B.

It will also be seen that the horizontal support structures H-11 and H-14 correspond to extensions of the previously designated horizontal supports H-1 and H-4 of FIG. 1B, and the vertical supports V-13 and V-14 shown in FIG. 3, plus the depending support V-15, are essentially conventional support structure which does not require additional description.

The web W-3 is picked off the bottom wire 31 as it travels around a plain couch roll 34 (which can be an open couch if desired) by a traveling felt F-3 wrapped around a pickup roll designated at 61, which may be a plain pickup roll or a suction pickup roll, depending upon the particular type of operation contemplated for removal of the web W-3 from the bottom wire 31. Essentially, the arrangement of FIG. 3 shows a longer travel path for the wires 11 and 21, or their counterparts 31 and 41, in substantial parallelism beyond the roll position 32 and through a couch nip N-3, after which separation of the wires 31 and 41 is effected in conventional manner.

Referring now to FIG. 4A and 4B, it will be seen that elements corresponding to some extent to the elements already described in substantial detail in the previous figures hereof are designated by reference numerals or letters in the 100 series. Thus, it will be seen in FIG. 4A that one of the forming wires 121 wraps a large open faced roll 126 having a suction area extending from approximately 126aa (i.e. opposite a slice outlet) to 126c, whereupon the traveling wire 121 continues (as shown in FIG. 4B) with the web W-100 thereon over a suction couch roll 170 and along a downwardly inclined wire reach 121 to a plain turning roll 171 and then back over rolls 172 and 173, all as indicated in FIG. 4B. The traveling web W-100 is thus shown as being removed by a felt F-300 wrapping a suction pickup roll 161 and urged against the web W-100 along the downward incline of the wire run 121. The felt F-300 carries the web W-100 along its underside and into a press section, here shown as comprising a plain roll 181 and a grooved roll 182 defining a first press nip PN, pressure forces being applied via a third roll 183. The roll designated 182 in the press section is also designated with G to indicate that it is a grooved roll having the structure described and claimed for press rolls in E. J. Justus U.S. Pat. Nos. 3,198,693; 3,198,694; 3,198,695; 3,198,696; and 3,198,697.

Also, it will be seen that a type of couch press arrangement with the suction pickup roll 161 and an opposite adjustably positioned roll 184 may be employed, the positioning of the roll 184 being shown as adjustable by virtue of the two-headed arrow at 184a, such that a nominal pressure at the pickup felt nip FN may be employed, if desired for such purposes as improved pickup and dewatering in this immediate location.

The guide roll 172 shown in FIG. 4B is also indicated as being pivotally adjustable by virtue of the two-headed

arrow 172a, for purposes of maintaining a controlled desired tension on the wire 121.

Referring to FIG. 4A, it will be seen that there is also shown a looped forming wire 111 traveling over a plurality of co-moving guide rolls 113a through 113g, alphabetically, with the roll 113e functioning as a tension control roll adjustably mounted as indicated diagrammatically by the double-headed arrow 113A. Of course, any of the rolls in the 113 series may also be used to cooperate in part as tensioning as well as drive rolls for the wire 111 which also travels over a blade box 115, which is functionally comparable in many respects to the blade box 15 of FIG. 2. The blade box 115 cooperates with the roll 126 in FIG. 4A to maintain the previously described wire travel spacing (as defined by the previously described formula  $H=CD^k$ ). In the arrangement of FIG. 4A, however, it will be seen that the foil box 115 is provided with a moving pivot P-117 adjustably actuated by conventional jackscrew means 117bb, and swingable about a fixed pivot P-115 mounted on the overall framework composed of a plurality of generally horizontal supports H-121 through H-126 and a plurality of generally vertically aligned supports V-121 through V-130, which horizontal and vertical supports need not be described in greater detail since they are of conventional framework structure.

Referring again to the swingably mounted blade box 115, it will be seen that refinements in adjustment are also afforded by an additional pivot P-215 and an additional pivotally mounted adjusting device 217bb, such that a desired positioning of the active lines of contact for the blades (designated generally at 115a herein for convenience) may be effected in accordance with the convergence formula previously described and also affording a free wire loop 111a at the immediate off-running side of the lines of contact 115a for the blades 115, essentially in a reversed position to that shown in FIG. 2 direction-wise but in a comparable functional arrangement, which need not be described in greater detail herein. The corresponding forming areas are designated X-100, X-200 and X-300, which correspond generally to the previously described suction areas within the roll 26 as X-1, X-2 and X-3, in FIGS. 1B and 2.

It will be appreciated, however, that the roll 126 is shown herein as being substantially greater in diameter than its counterpart 26 of FIGS. 1B and 2, and it may thus carry out still an additional function in the region X-400, as it holds the web W-100 on the wire 121 and effects separation of the web W-100 from the opposed traveling wire 111. For such purposes, it will be appreciated that additional suction sealing strips 126x and 126xx may be mounted in the positions indicated inside the open roll shell 126 for purposes of effecting different pressure controls at different peripheral regions in the travel of the roll 126.

Essentially, there is shown in the roll 126 an initial sealing strip 126aa and a sealing strip position 126x at the end of the region X-200, which would comprise the forming zone region at the inner periphery of the wire 121. The opposed wire 111 in such region (i.e. X-100 and X-200) travels over the lines of contact 115a of the blade box 115, and then briefly through a tensioned free loop travel 111a for the wire 111 during which the tensioned, yielding but free from restraining contact wire region 111a approaches substantial parallelism with the wire 121, converging against the web W-11 sandwiched therebetween.

It will be noted also that the means corresponding to the stock jet delivering device J already described is designated generally by J-100 in FIGS. 4A and 4B and is shown as being mounted for primary adjustment at J<sub>c</sub> (via a turnbuckle-type of adjustment) but also providing or limited adjustment J<sub>a</sub>-100 and at J<sub>b</sub>-100, which adjustable elements will correspond essentially to the previously described J<sub>a</sub>, J<sub>b</sub> and J<sub>c</sub>, for what amounts to

adjustment of the centerline CL-100 of the jet stream that is shown in FIG. 4A as being fed upwardly (at a general incline) and substantially tangential to the roll 126. The details of sealing the slice inlet, which are described in detail in connection with the embodiment of FIG. 2, are employed in such upwardly aligned slice inlet arrangement for the embodiment J-100, but additional description thereof is not necessary, since essentially the purpose is to provide close running sealing elements of solid elastomer structure (corresponding to J-1 and J-2) for effecting a pressure sealing of the jet stream as it is fed into a hydraulic forming zone between the converging wires in the regions X-100 and X-200.

An additional adjustable feature is controlling the relative ratios of drainage between the two wires 121 and 111 is afforded by the compact suction arrangement S-115 here shown schematically as being divided into partitions S-1, S-2, S-3, etc., each opposite the longitudinal spacing between a successive pair of lines of contact 115a for the blades in the box 115, so that a selected application of water removal subatmospheric pressure is possible in each of such longitudinal spacings between the lines of contact 115a. In such arrangement, it is, of course, possible to effect actual pressure differentials from one to another of the successive longitudinal spacings between the lines of contact 115a, should such be desired. It is understood, however, that preferably this is not the desired operation for the box 115 and the function of the subatmospheric pressurized compartments S-1, S-2, etc. is thus to facilitate water removal in a controlled manner by maintenance of a controlled pressure within each of such compartments of the box S-115 such that the pressure on the incipient web that is forming on the outer periphery of the wire 111 immediately opposite the lines of contact 115a may be controlled and preferably maintained substantially constant in this specific region X-100. The suction sealing strip 126a within the roll 126 will also function in comparable manner to effect water drainage and pressure control within the open roll 126 to the extent required to maintain a comparable substantially constant pressure against the incipient web forming on the outer periphery of the wire 121 in the forming region here designated X-100.

In connection with the embodiment of FIG. 4A, it will be appreciated that the various control elements for positioning the traveling wires 121 and 111 as well as effecting water removal from the inner peripheries thereof may act in a different number of controlled operations, such that it is possible to maintain what constitutes a practically uniform and substantially non-varying pressure against the fragile initially forming incipient webs within the forming zone X-100 and on the opposed outer peripheries of the wire 111 and 121 in such region X-100. The control arrangements thus shown effect the desired predetermined pressures by acting against the inner peripheries of the two wires 111 and 121 in the region X-100, coupled with adjustable direction of the longitudinally unidirectional jet, i.e. along the centerline CL-100, so as to effect the desired conditions within the forming zone between the opposed outer periphery of the wire 111 and 121. The desired conditions of spacing between the wires 111 and 121 in accordance with the formula previously disclosed herein is thus one aspect of the control feature, but in the arrangement shown in FIG. 4A, the suction elements 126aa-126x and S-115 will additionally cooperate with each other to effect the relatively equal drainage in opposite directions that is desired. The additional adjustable alignment of the jet stream centerline CL-100 serves to cooperate with such drainage devices for the purpose of effecting a desired relative drainage rate between the two wires, also as previously described in connection with the general concept of aligning the jet stream centerline CL-100 more or less tangentially with respect to the roll 26, as indicated in FIG. 2.

Because of the size of the open roll 126 and a prede-

terminated selection of the nature and character of the stock being used in the web W-100 being formed, the embodiment of FIG. 4A demonstrates a highly simplified paper forming arrangement wherein advantage is taken of a stock stream centerline direction CL-100 that is upward rather than horizontal or downward, such that the travel of the wires in parallelism in the general region PP on FIG. 4A (with the web W-100 sandwiched therebetween) is required for a relatively short travel path.

It will be appreciated, however, that the length of the travel path in parallelism PP can be increased easily in the embodiment of FIG. 4A by moving the position of the roll 113a peripherally over the top of the roll 126, if such is desired. Also, the jet stream delivering device J-100 may be adjustably positioned with nominal changes being made in the device of FIG. 4A so as to feed generally horizontally as well as generally tangentially along the bottom side of the roll 126, or even along a downwardly inclined side of the roll 126, although adjustments to this extent are not suggested as being possible with the specific adjusting devices herein designed J<sub>a</sub>-100, J<sub>b</sub>-100 and J<sub>c</sub>-100. Instead, the overall arrangement of elements shown in the two different positions of the FIG. 1 and the FIG. 4 series will demonstrate to the workers in the art certain essential features of versatility in the overall arrangement herein contemplated for excellent control of web formation in a high speed web forming device.

For example, in the arrangement of FIG. 4A, it will be appreciated that wire guides shown in longitudinal succession include the upstream counterpart 115a' to the element 15A in FIG. 2, as well as the lines of contact 115a shown in spaced longitudinal transverse alignment, which may be considered as a stationary water-permeable wire direction controlling guide. A second wire direction controlling it, of course, provided by the outer periphery of the open roll 126, and a third wire direction changing guide in the embodiment of FIG. 4A is designated by the guide roll 113a. Each of the guides just mentioned extends transversely of the machine and the loops of the wires 111 and 121 which pass over the first and second guides, respectively, and through initially closed spacing for receiving therebetween the jet stream aligned at CL-100. Substantially immediately upon receiving the jet stream a gradual convergence between the wires 111 and 121 is effected by the opposed first guide means 115 and second guide means 126 in such a web forming zone or zones X-100 and X-200, until the wires 111 and 121 reach substantial or general parallelism PP with the resultant fibrous web W-100 therebetween, and which parallelism the wires 111 and 121 travel longitudinally downstream over a portion of one of the initial guide means, i.e. the roll 126, and toward a third guide element, which has been designated in this instance as the roll 113a. The wire 111 does travel over the third guide means 113a herein shown, although the embodiment of FIG. 4A differs from that of FIG. 1B in that the web follows the opposite wire 121 in FIG. 4A, whereas it follows the wire 11 in FIG. 1B. In either case, however, the two initial guide elements, 115 and 126 (or 15 and 26, respectively) comprise a rotary member with an open water receiving periphery about which one of the wire runs is wrapped throughout the forming zone, and a substantially non-circularly curved stationary water-permeable surface for effecting gradual convergence between the wire runs in the web forming zone, which is the embodiment of 15 or 115, in either case, constituting a substantially non-circularly curved surface for the wire 11 or 111. Such substantially curved surface in each instance is defined by the longitudinal contour of the loci of the lines of contact, designated generally 115a in FIG. 4A but described as being along the tops of the elements of 15b, 15c, etc. in FIG. 2, in each case such longitudinally spaced wire contacting generally transverse edges or lines of contact defining the hereinbefore described substantially non-

circularly curved surface actually in terms of a plurality of successive chords in longitudinal contour. The forming wires 11 and 111 are maintained under sufficient tension in the two arrangements here shown so that such essentially chord-like structures between the lines of contact for the blade boxes 15 and 115 will be substantially maintained in spite of pressure generation within the forming zone which might otherwise tend to cause the forming wire 11 or 111 to pass through reversed curves intermediate the lines of contact. It will be appreciated that such curve reversals would actually result in excessively greater wire contact with the stationary surfaces of the blades in the boxes 15 and 115 and thus result in greater wire wear and a tendency to lose control of pressures at one or both sides of the wires 11 or 111 in the forming zone. Hence, the higher tension operation employed for the wire 111 is preferred and such wire is preferably formed of a conventional metal woven forming wire, whereas the opposite forming wire 121 or 21 may be a plastic wire or a conventional metal fiber-woven wire, since the porous forming belt or wire 21 or 121 can be supported very conveniently on the co-moving and substantially unyielding outer periphery of the open rolls 26 and 126. In either event, the cooperating configurations of the open rolls 26 and 126 and the boxes 15 and 115 is such that the gradual convergence in the forming zone, when plotted as spacing between the wire runs against the distance downstream in the forming zone defines an elongated curve with its radii increasing with increases in the downstream distance, such curve thus preferably will conform to the definition of an elongated parabolic curve, and preferably specifically that of the formula hereinbefore discussed. The various water removal as well as positional structural elements hereinbefore described are controlled mutually to effect relative drainage ratios preferably within the ranges of about 3:7 to 7:3, which represent the relative drainage volumes through the opposed wires in the forming zones X-1 and X-100, and preferably also X-2 and X-200.

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

We claim as our invention:

1. In a device for forming a fibrous web from a dilute aqueous suspension of entangled co-moving fibers exiting from a slice as a high-speed substantially longitudinally unidirectional ribbon-thin jet-stream, in combination,

spaced successive first, second and third transverse guides arranged to define a smoothly curved upwardly directed path of travel in respect to said unidirectional jet-stream; and first and second opposed substantially transversely co-extensive porous forming belt runs traveling longitudinally substantially at the jet-stream speed

(a) over said first and second guides, respectively, and through initially close spacing for receiving therebetween the jet stream, and

(b) immediately thereafter through a curved gradual convergence in a web-forming zone and into general parallelism with a resultant fibrous formed web therebetween in which parallelism said runs are maintained as they travel longitudinally downstream over a portion of one of said first and second guides upwardly toward

(c) said third guide, over which at least one of said runs travels,

said second guide being a rotary member with an open water-receiving periphery about which said second run is wrapped throughout the forming zone, said first guide presenting to said first run a substantially non-circularly curved stationary water-permeable surface for causing said gradual convergence between said runs in the web-forming zone, said substantially non-circularly curved surface of the first guide being defined by the longitudinal contour of loci of a multiplicity of closely longitudinally spaced belt-contacting generally transverse edges.

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2. The device of claim 1 wherein said transverse edges terminate abruptly at their off-running sides relative to their stationary edge portions contacting said first belt run traveling longitudinally thereover for substantially minimizing forming zone stock pressure variation along said one belt.

3. The device of claim 2 wherein said first run travels under tension over said first and third guides, and an additional guide maintains tension thereon.

4. The device of claim 1 wherein said first and second guides maintain gradual convergence and diminishing spacing between the first and second runs downstream from such initially close spacing at the upstream end of the forming zone, whereat such initial spacing is substantially equal to the thickness of the jet-stream being received in the forming zone.

5. The device of claim 4 wherein said first and second guides effectively maintain substantially uniform pressure in the jet-stream within the forming zone.

6. The device of claim 4 wherein such spacing plotted against the distance downstream from the upstream end of the forming zone define substantially the curve:  $H=CD^k$  wherein H is the spacing in inches, D is such downstream distance in inches, C is a constant from substantially 0.5 to 1.6 and k ranges from substantially -0.2 to -0.8.

7. The device of claim 1 wherein said gradual convergence in the forming zone, when plotted as spacing between the runs against distance downstream in the forming zone defines an elongated curve with its radii increasing with increases in the downstream distance.

8. The device of claim 1 wherein said gradual convergence in the forming zone, when plotted as spacing between the runs against distance downstream in the forming zone defines an elongated parabolic curve.

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9. The device of claim 1 wherein means are provided to align the slice relative to entrance of the forming zone to maintain the ratio of water removed by the first run to that removed by the second run in such forming zone with the range of about 3:7 to 7:3.

10. The device of claim 1 wherein said second guide is provided with an internal suction gland communicating with the open periphery thereof opposite the forming zone for effecting a control of water removal from the forming zone via the second run.

11. The device of claim 1 wherein said first guide water-permeable surface has at least substantially 50% open area.

12. The device of claim 1 wherein means are provided for aligning the slice to feed the jet stream upwardly and into said forming zone along the uprunning side of said rotary open roll guiding the second run.

13. The device of claim 12 wherein said first run is defined by a forming wire consisting essentially of water-lubricated flexible stretchable synthetic fibers.

14. The device of claim 12 wherein said first run travels wrapped about the uprunning side of said open roll, in the aforesaid parallelism with said second run and means are provided adjacent the top of said roll whereby said first run is separated from the open roll leaving the web traveling over the top of the open roll on said second run.

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REUBEN FRIEDMAN, Primary Examiner

35 T. A. GRANGER, Assistant Examiner

UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,582,467

Dated June 1, 1971

Inventor(s) David R. Gustafson, John F. Schmaeng, John S. Finnila.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2, line 71 "well" should read -- will --;

Col. 4, line 64 "(micro-finish)" should read -- (mirror-finish) --;

Col. 5, line 32 "16f" should read -- 26f --;

Col. 8, line 40 "desired" should read -- desire --;

Col. 8, line 48 "drainings" should read -- drainage --;

Col. 9, lines 6-7, "avialable" should read -- available --;

Col. 9, line 9 "box" should read -- box 15 --;

Col. 10, line 15 "generallyy" should read -- generally --;

Col. 10, line 16 "not shown)" should read -- (not shown)--;

Col. 11, line 49 "increase" should read -- increased--;

Col. 13, line 72 "or" should read -- for --;

Col. 14, line 14 "is" should read -- in --;

Col 14, line 16 "the" should read -- a --;

Col. 15, line 36 "it" should read -- is--;

Col. 16, line 67 "reeciving" should read -- receiving --; (Continued)

UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

PAGE - 2

Patent No. 3,582,467 Dated June 1, 1971

Inventor(s) David R. Gustafson, John F. Schmaeng, John S. Finnla.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

(Continued)

line 72 "cured" should read --curved--.

Col. 18, line 8 "forminz" should read --forming--.

Signed and sealed this 11th day of January 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.  
Attesting Officer

ROBERT GOTTSCHALK  
Acting Commissioner of Patents