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CONTINUOUS WEB FORMING MACHINE

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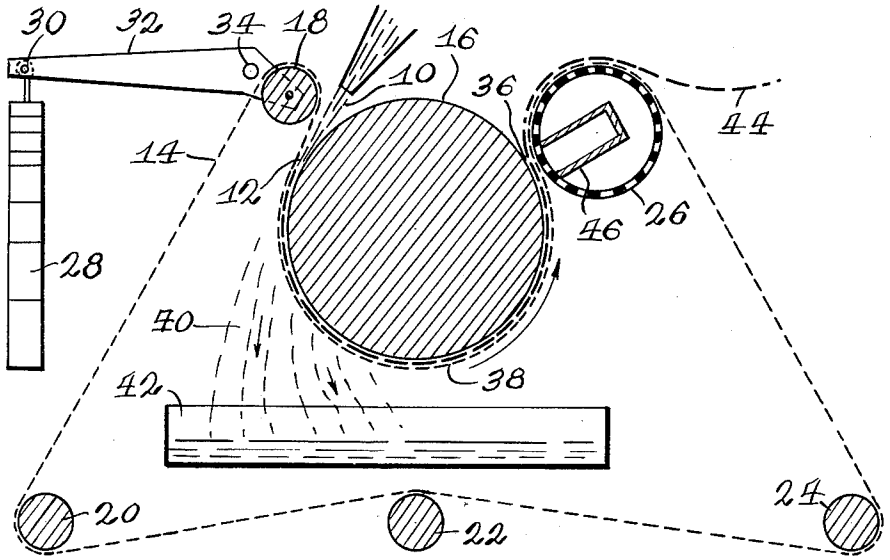


Fig. 1

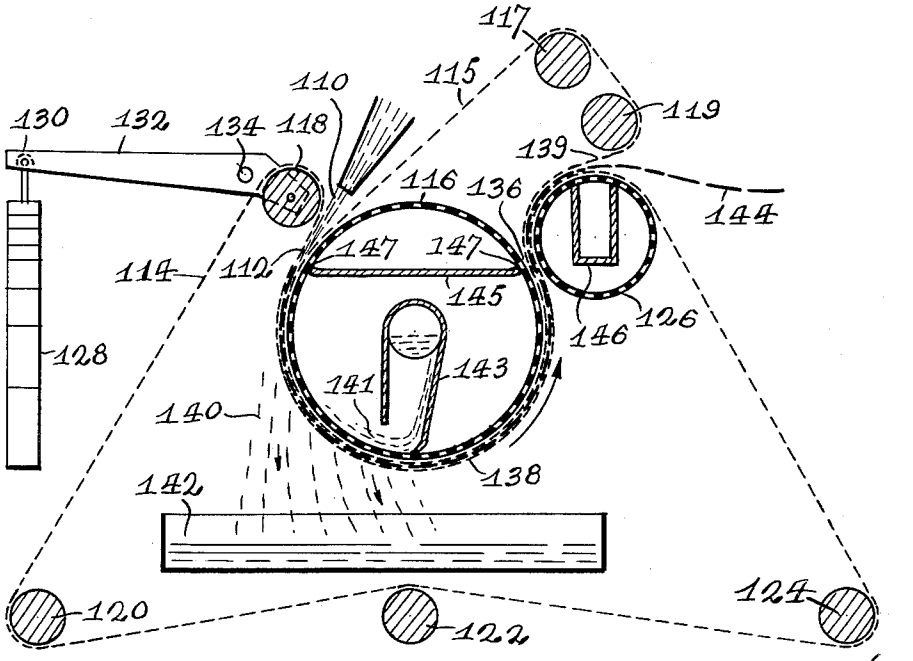


Fig. 2

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CONTINUOUS WEB FORMING MACHINE

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The present invention relates to papermarking and more particularly to a method and apparatus for producing a continuous sheet such as pulp or paper from fibers in liquid suspension delivered to the apparatus as a continuously-flowing ribbon-like jet.

Prior Art

Continuous pulp or paper sheets are made mainly by the cylinder machine or Fourdrinier machine both of which have limitations in speed imposed by the formation process.

The cylinder machine is limited in speed largely because the fibers encounter a rinsing action during their deposition on the forming cylinder which revolves in a stationary vat. Arts to lessen this rinsing have included for example:

(*a*) feeding in the direction of cylinder rotation,
(*b*) tapering the throat to compensate partly for progressive drainage thereby to approximate constant feed velocity,
(*c*) increasing the adhesion of fibers to the cylinder by suction,
(*d*) mobilizing the vat wall via a belt to avoid hydraulic friction.

With all known arts the cylinder machine has attained speeds of only about 1,000 ft./min.

The Fourdrinier machine is limited in speed largely because the fibers are agitated adversely by impulses at the table rolls. Arts to lessen these impulses have included using for example:

(*a*) splash baffles between table rolls,
(*b*) forming boards,
(*c*) short spans between table rolls,
(*d*) a tight forming mesh,
(*e*) auxiliary belts around adjacent table rolls at a downward slant to lengthen each exit nip.

The Fourdrinier machine is limited in speed also because the drainage capacity is low. Arts to overcome low drainage have included using for example:

(*a*) large-diameter table rolls,
(*b*) vibratory apparatus,
(*c*) grooved table rolls,
(*d*) high feed concentration,
(*e*) high temperature,
(*f*) suction boxes as an extension of the table-roll zone.

With all known arts, the Fourdrinier has attained speeds of only about 2,500 ft./min., being only a doubling of speed in about 25 years.

Besides speed limitations, the rinsing action of the cylinder machine and impulses of the Fourdrinier leave the sheet with only about 75% the strength of a sheet made by hand. This weakness is offset partly by adding extra fibers, or longer fibers, or adhesive, any of which additions make the sheet more costly.

Besides speed and strength limitations there are other detriments. For example, the cylinder or Fourdrinier part of a paper machine occupies 50 ft. or more of linear building space, which extent of building and machinery is costly. Further, the Fourdrinier suffers erosion of the mesh at the suction boxes, and the resultant mesh replacement every few days is costly, particularly when mill

production is sacrificed. Still further the Fourdrinier drag from mesh erosion absorbs much power.

Numerous modifications and combinations of the cylinder and Fourdrinier constructions propagate these various limitations.

Present Invention

The present invention aims to avoid all these detriments by departing from some of the basic actions and constructions of the cylinder and Fourdrinier machines. With this in mind the present invention provides a method and apparatus which intensifies the drainage process necessary in pulp and paper sheet formation to gain speed; it frees the formation zone from extraneous liquid and air currents to attain the optimum strength from given fibers; and it provides a construction simpler, smaller, and having less operating cost for meshes and power than known methods and apparatus.

More specifically, the present invention discloses a method for producing a continuous pulp or paper sheet which comprises the steps of:

(*a*) delivering fibers in liquid suspension in the form of a ribbon-like free jet of regulated width, thickness, and speed to a juncture between an arcuate external surface of an unyielding rotating body and an external surface of a yielding cooperating body at least one of which surfaces is porous, thereby creating a coacting zone which extends the length of said juncture comprising a formation zone where said bodies press in contact with each other;
(*b*) applying drive means to at least one of said unyielding and yielding bodies, in the same direction as said jet, while maintaining the bodies at equal surface speeds in frictional non-sliding relationship with each other,
(*c*) tensioning said yielding body thereby to exert pressure towards said arcuate unyielding body,
(*d*) proportioning said jet speed, bodies speed, and tension to one another to cause the free jet to penetrate forcibly between the said two bodies, thereby to deflect the yielding body from the unyielding body for at least an initial portion of the coacting zone,
(*e*) maintaining constant tension during all deflections of the yielding body by guiding that body on rotating supports at least one of which is resiliently or displaceably mounted to compensate for said deflections,
(*f*) draining the jet uninterruptedly by supporting said yielding body throughout the coacting zone solely by tension as a loop free to conform to the curvature of said unyielding body and the successively variable thickness of the stock ribbon pentrating between the two said bodies, as governed by stock drainage rates thereby providing a formation or nip zone of self-regulating or pressure responsive taper,
(*g*) removing the fibers as a continuously-felted sheet at the disengagement of the two-cooperating bodies.

In structure, the present invention discloses apparatus for producing a continuous sheet of pulp or paper from a ribbon like flow of fibers at paper making concentration where a drum exterior surface acts in unison with a co-acting length of the exterior surface of a circulating belt at least one of which surfaces is pervious, for example an endless mesh, and the flow is directed between the two surfaces, characterized in that the belt is guided in a circuit solely on rotating supports at least one of which is resiliently mounted to maintain constant tension and the coacting length of the belt is urged toward the drum and supported there against solely by tension applied to the belt as a loop free to respond instantaneously to an initial deflection of the belt from the drum by reason of said flow being delivered in the form of a free jet at sufficient speed to force the belt out of contact with the drum for an initial stock entry, and a continuing stock supply,

and the free loop is adapted by its resilient or displaceable mounting to provide, in cooperation with the opposed outer surface of the drum, a gradually tapered stock drainage path having a rate-of-taper as governed by stock drainage rates thereby providing a sheet formation zone of self-regulating taper.

In one preferred construction of the invention the drum has a solid peripheral surface.

In a preferred alternative construction, the drum has a perforated peripheral surface, the perforations being large enough to permit ready drainage of stock, and a second endless mesh is used between the first endless mesh and drum to prevent stock from escaping into the perforations. The second mesh remains in contact with the perforated drum during operation and is not deflected from the drum by the jet of stock. The second mesh also has a return circuit spaced away from the drum surface and carrying rolls for tensioning and guiding the mesh are located in this space.

In this alternative construction, the ribbon-like jet thus enters between the converging and coacting surfaces of the two meshes, and emerges as a sheet at the divergence of the two meshes from the coacting zone.

This application is a continuation in part of United States application S.N. 562,314, filed January 30, 1956.

Detailed Description

Having thus generally described the nature of the invention, particular reference will be made to the accompanying drawings wherein:

FIGURE 1 is a diagrammatic view of a continuous-sheet forming apparatus using a solid-periphery drum and a single endless mesh.

FIGURE 2 is a diagrammatic view of a continuous-sheet forming apparatus using a perforated-periphery drum and a secondary endless mesh.

With reference to the drawing, it will be understood that the constructions are in diagrammatic form for the purpose of more clearly showing the operating principles involved. The detailed structure of drum, mesh, etc. is well known in the art and therefore is not shown in mechanical detail.

With particular reference to FIGURE 1, a jet **10** of regulated width, thickness, and speed is delivered to the juncture **12** between an endless mesh **14** and a solid-periphery drum **16** with sufficient kinetic energy to penetrate forcibly between the mesh **14** and drum **16**. The mesh **14** is guided on rolls **18, 20, 22, 24,** and **26** whereby preferably roll **20** or **24** is adapted for length takeup by known means, **22** is adapted for mesh alignment control, **26** is fixed, and **18** is adapted for constant tension.

Constant tension may be imparted by a number of conventional means, the one shown being a regulatable battery of weights **28** suported at a load point **30** and transmitting a thrust at roll **18** for tension in mesh **14** via lever means **32** and fulcrum **34**. This tensioning means is instantly responsive to slight changes in mesh deflection as may be caused by a change in drainage rate. A coacting zone between mesh and drum extends from the juncture **12** to a disengagement **36** of mesh and drum.

The jet **10** reaches kinetic equilibrium with mesh pressure along an initial arc **12—38** of the coacting zone **12—36** which initial zone **12—38** is a hydraulic phase variable in length depending on operating conditions as will be described. The subsequent zone **38—36** is virtually a solid phase for the sheet and thus incloses squeezed paper. This apparatus thus provides a formation zone of self-regulating length and taper as regulated by kinetic conditions.

Conventional deckle belts not shown can be used if desired to press the edges of the mesh **14** tightly against the peripheral edges of the drum **16** thereby to seal the edges of the initial arc **12—38** of the coacting zone against liquid escape.

Drainage **40** from the jet **10** discharges into a tray **42** and is led away for recirculation to jet **10** by conventional means not shown. After the initial arc **12—38** of the coacting zone, the fibers reach a solid phase, and are felted to one another by pressure while still damp and unagitated. It is generally known, particularly in the art of making hand sheets, that damp pressing improves sheet strength. The formed and pressed fibers then emerge at the disengagement **36** of mesh and drum as a self-supporting sheet **44**.

This sheet **44** as is common with sheets adheres to the smoothest of two surfaces, in this case the drum **16**, and thus is removed therefrom by suction being applied thru roll **26** as a perforated roll with a suction box **46** inside. This suction roll **26** also extracts residual moisture carried in the voids of the mesh **14** which moisture otherwise would be reabsorbed by the sheet **44** on release of the pressure in the coacting zone.

Drive means not shown are applied preferably to suction roll **26** or alternatively to drum **16**. Motion is transmitted by frictional contact to the mesh and other rolls which therefore travel in unison with the drive roll. All parts of the apparatus are supported in accordance with usual paper-machine art by framing not shown.

With particular reference to FIGURE 2, a jet **110** of regulated width, thickness, and speed is delivered to the juncture **112** between an endless mesh **114** and a second endless mesh **115** with sufficient kinetic energy to penetrate forcibly between the meshes **114** and **115**. The mesh **114** is guided on rotating rolls **118, 120, 122, 124,** and **126** whereby preferably roll **120** or roll **124** is adapted for length takeup, **122** is adapted for mesh alignment control, **126** is fixed, and **118** is adapted for constant tension.

Constant tension may be imparted to mesh **114** by a number of conventional means, the one shown being a regulatable battery of weights **128** supported at a load point **130** and transmitting a thrust at roll **118** for tension in the mesh **114** via lever means **132** and fulcrum **134**.

The second endless mesh **115** is guided on a rotating roll **117**, which is adapted for mesh alignment control, and a roll **119** which is adapted for length takeup by suitable means. Both meshes **114** and **115** conform to the curvature of drum **116** which has a perforated periphery. This drum **116** rotates, external to the circuit of mesh **114**, and inside the circuit of secondary mesh **115**.

A coacting zone between the meshes and drum extends from the juncture **112** to a disengagement **136** of meshes and drum. The meshes preferably disengage simultaneously from the drum but need not in which case they have a later disengagement **139** from each other.

The jet **110** reaches kinetic equilibrium along an initial arc **112—138** of the coacting zone **112—136**, which initial zone is a hydraulic phase variable in length depending on operating conditions as will be described.

Conventional deckle belts not shown can be used if desired to press the edges of the mesh **114** tightly against the peripheral edges of the drum **116** thereby to seal the edges of the initial arc **112—138** of the coacting zone **112—136** against liquid escape.

Drainage **140** from the jet **110** discharges into a tray **142** and is led away for recirculation to jet **110** by conventional means not shown. Drainage **141** from the jet **110** discharges thru the perforated periphery of roll **116** as a result of vacuum being applied within the roll **116** by a conventional fixed-siphon means **143** which discharges thru conventional rotary-joint means not shown. The ends of drum **116** are solid except for the siphon outlet at the drum axis. Vacuum applied thru siphon means **143** is confined to the coacting zone **112—138—136** by means of a fixed partition **145** with seal strips **147** contacting the moving interior of perforated roll **116**.

After the initial arc **112—138** of the coacting zone **112—136** the fibers reach a solid phase and are felted to one another by pressure while still damp and unagitated. The formed and pressed fibers in the latter arc **138—136**

of the coacting zone have reached a state of drainage where the suction causes air to force its way thru the capillaries between the fibers, and into the drum 116, thereby speeding the removal of moisture both by advancing the liquid-vapor boundary within the sheet and by evaporation. The fibers at 136 then continue to travel between the meshes 114 and 115, away from the vacuum of drum 116, and emerge at the disengagement 139 of the meshes from each other as a self-supporting sheet 144.

The sheet 144 is assured a positive adherence to one mesh by suction being applied to roll 126 via internal box 146. Numerous alternative means of handling the sheet 144 after disengagement 136 will be evident to persons skilled in the art.

Drive means not shown are applied preferably to both drum 116 and suction roll 126 these two rolls being interlocked for equal surface velocities by means such as gears not shown. When operating conditions produce a sheet sufficiently dry at disengagement 136 for the sheet 144 to separate independently from both meshes, without suction aid, then roll 126 can be plain like the other mesh-carrying rolls and need not be driven except by frictional contact with the mesh 116. Also, roll 126 may be plain because the suction of drum 116 extracts moisture carried in the voids of the meshes 114 and 115, thereby eliminating the danger of moisture being re-absorbed by the sheet 144.

All parts of the apparatus are supported in accordance with usual paper-machine art by framing not shown.

A main feature of the perforated drum alternative as described and shown in FIGURE 2 is to increase the drainage capacity, and thus the machine speed beyond that of the solid-drum construction, particularly for slow-draining stock and thick sheets. The capacity increases partly because the average distance for a particle to travel to escape the ribbon-like depth with a perforated drum amounts to only half what the escape distance is with a solid drum. Also, the capacity increases partly because the discharge area is doubled. Assuming that the drainage rate is proportional to thickness, and area of the ribbon surface, the perforated drum then quadruples the drainage rate over that with a solid-surfaced drum.

The separate elements of jet, drum, belt, supports, and drive as mentioned above are known generally in prior art, but in the present invention are so combined as to form a new apparatus of a distinct character and function which provides a novel result due to the joint and co-operating action of all the elements. As described, the pressure zone created between the opposed surfaces of mesh and drum incloses initially a formation zone of self-regulating length and taper toward the drum, grading into a paper-squeeze zone for the remainder of the contact area.

Referring to the preferred embodiment of the invention using a solid-peripheral drum, a main feature of the apparatus as shown and described resides in the belt tension being the active element for both continuous pressure and uninterrupted drainage.

Referring to the preferred alternative embodiment of the invention using a perforated-peripheral drum, the operation and results are as described below except that vacuum is added as a fifth variable to machine speed, jet speed, mesh tension, and drum diameter. The main result is an intensifying of the drainage beyond that possible by mesh tension alone.

The new results are:

(*a*) paper formation speeds of up to several times the present maximum speeds of about 2,500 ft./min.,
(*b*) strength near that of a hand-made sheet, newly possible by the avoidance of rinsing currents and drainage impulses,
(*c*) compaction of the paper machine by the forming zone being arcuate and continuously draining thereby saving machine and space costs,
(*d*) simple apparatus through avoiding a grillage or table to support the mesh thereby saving capital, maintenance, and operating costs,
(*e*) long life for the mesh by its being guided solely on mobile supports without scraping over static supports,
(*f*) low power to drive the mesh thru its being guided soley on mobile supports.

In operation the forming zone reaches kinetic equilibrium thru the interaction of mesh tension, machine speed, and jet speed; and the novelty of operation resides in

(*a*) the nature of stock entry
(*b*) the configuration of the forming zone, and
(*c*) the continuity of formation, each described in detail below.

(*a*) *Nature of Stock Entry*

Depending on the nature of stock entry, the mesh follows a slightly variable path at the formation zone, which accounts for one roll being portably mounted to accommodate that change and maintain constant tension instantaneously. Startup of this method and apparatus is with the mesh in tight resiliently tensioned contact with the drum. The free jet forces and wedges the mesh away from contact with the drum. Although flow speed, machine speed, and drainage pressure of the cylinder and Fourdrinier machines may be adjusted, no known art teaches the coordination of those factors with mesh tension and drum diameter to produce the new results herein disclosed.

Unless these factors are properly coordinated all stock may not enter between mesh and drum. Some basic considerations are that the drum diameter once chosen is invariable; the mesh tension has a maximum value which affects the selection of drum diameter; and both machine and jet speed are widely controllable during operation. Thus, to choose the proper working ranges for these four factors, one must start with the knowns and proceed stepwise by calculation to the unknowns, but not necessarily in the order given below.

Firstly, the machine speed is chosen arbitrarily to suit mill capacity.

Secondly, mesh tension is chosen for machine design purposes at the maximum working tension in order to create the greatest drainage pressure, although the tension may be regulated to lesser values for some grades of paper. The maximum working tension is several times that possible on Fourdriniers, and thus is nearer the ultimate mesh strength, because that part of mesh thickness previously needed for Fourdrinier erosion is now available for the production of tension and pressure. The mesh still gains a new long life, despite the higher working tension.

Thirdly, drum diameter is chosen to provide the optimum combination of pressure and time. Thus, a knowledge of the laws governing pulp drainage is needed to predict the optimum diameter. Pressure between drum and mesh is inversely proportional to drum diameter. The duration of this pressure is proportional to the diameter. Therefore a constant tension and constant speed yield a constant product of pressure×time regardless of drum diameter.

Both pressure and time are represented in the various published formulae on general filtration. But the accurate prediction of drainage rates for small particles is not known to be possible yet, because although filtration is known to follow closely the laws of flow thru straight capillaries, the capillaries of slurries such as pulp are variable in size and shape. At the present stage of filtration art, knowledge of filtration rates requires actual measurement on the particular particles being handled, and under the conditions intended. In this direction, a few authors have published the results of pulp drainage at low pressures, and have tried to fit these results to empirical formulae for Fourdrinier and cylinder

machines. But the present invention uses greater pressures than for those published conditions, and the fiber sheet is strongly compressed by mesh tension, so that prediction of drainage rates for the present invention is hypothetical.

Nevertheless, by extending the available published data to the conditions of the present invention, thereby estimating progressive drainage quantities along the formation zone, the practicable limits of solid-peripheral drum appear to be from 2 to 10 ft. diameter for a range of paper grades and operating conditions.

Fourthly, having determined the machine speed, maximum mesh tension, and drum diameter for a given stock, one can calculate the proper jet speed which is chosen mainly to suit machine speed and mesh tension. Several conditions of entry can result.

For example, when the jet speed is slow, impingement of the jet as usual is tangential to the drum and thus is wholly against the mesh. This slow jet speed can result in such a small stock volume that all drainage can occur sometimes without the formation zone needing to advance beyond the initial tangency of mesh and drum. As a result, all the drained fibers are led as a sheet continuously between mesh and drum by the coacting and travelling surfaces.

When the jet remains at slow speed but is deepened, such as for a thicker sheet, the stock volume increases and the rate of feed eventually exceeds the rate of primary drainage before the tangency of mesh and drum. As a result, a corresponding sheet of fibers is led between the mesh and drum as previously, but excess feed beyond that able to be drained before the tangency of mesh and drum overflows the edges of the machine. This overflow can be accommodated by speeding the paper machine to present more mesh surface and thus more drainage capacity. But is mentioned, the machine speed usually is fixed to suit mill capacity, and some other variable such as jet speed or mesh tension normally would be chosen to regulate stock entry.

When jet speed is increased to accommodate an overflow, the jet flows as before tangential to the drum, and impinges wholly against the mesh but with sufficient kinetic energy to deflect the mesh, thus causing the mesh to stand away hydraulically from the drum for an initial portion of the coacting zone, and the jet penetrates forcibly between mesh and drum. As a result, more mesh surface is exposed to hydraulic conditions, even though the machine speed remains constant. Any speedup of the jet results in more stock feed, and thus for constant machine speed and paper thickness, any jet speedup needs to be accompanied by a decrease in jet depth.

Alternatively, an overflow could be accommodated by reducing the mesh tension. Again, the jet would penetrate beyond the initial line of tangency of mesh and drum, the mesh standing away hydraulically from part of the drum periphery. Also as belofre, more mesh surface becomes exposed to hydraulic conditions, even though machine speed remains constant. Thereby the drainage capacity is increased.

Reducing mesh tension thus appears to have the same effect as speeding the jet while decreasing jet depth, because both actions admit the same volume of stock at the same machine speed. But there are differences.

One difference is that the high-speed jet causes a high-pressure formation zone, and the low-tension mesh a low-pressure zone. As pressure increases the drainage rate, the high-pressure zone is short, and the low-pressure zone is long. Thus the eventual drainage is the same for both pressures only if the coacting zone is long enough to contain the long low-pressure zone. If the available coacting zone is too short then the low-pressure zone will be unable to complete the drainage and will produce a damper sheet than the short high-pressure zone.

Another difference is that the high-speed and low-speed jets have different ratios of jet speed:machine speed. The ratio is termed "lead" when the jet exceeds machine speed and "lag" when it falls behind. It is generally known that "lag" causes the fibers to be dragged into the machine direction by the mesh, thereby imparting the major tensile strength to the paper in the machine direction. Conversely, "lead" increases the tensile strength in the cross-machine direction. Thus admitting overflow by speeding the jet changes the directional strength of the paper.

The stock can thus be admitted completely between mesh and drum, even when the jet travels much slower than the machine, by reason of adjustment in mesh tension. In the forming zone, hydraulic pressure to oppose the pressure of the mesh is derived from the jet impulse, and the conversion of jet kinetic energy to static pressure. The choice between jet speed and mesh tension for controlling stock entry would thus be determined by the relative importance between the length of forming zone and the directional paper strength. The free-spurting jet needs a dynamic head substantially equal to the combined dynamic and static head along the forming zone.

However, preliminary tests on a model of the invention indicate that this dynamic head in the forming zone need not be as high as that corresponding to machine speed, but for acceptable formation with certain paper grades can be as low as 10% of the machine speed. The low head is made possible by the integration of the four factors of jet speed, machine speed, mesh tension, and drum diameter as described, and the novel adaptation of forces in the forming zone. In contrast, Fourdrinier machines seldom use a jet below 90% of machine speed. The new result is that the present invention can operate on certain paper grades with a lower head than a Fourdrinier with resultant savings in head box and pumping costs.

For any one combination of machine speed, mesh tension, drum diameter, and jet speed there are thus 4 possible entry results:

(1) some acceptance and some overflow,
(2) complete acceptance with insufficient drainage capacity,
(3) complete acceptance exactly to the drainage capacity, or
(4) complete acceptance with spare drainage capacity.

(b) Configuration of Formation Zone

Drainage is known to begin rapidly and to slow down as accumulating fibers offer increasing resistance to filtration. It is known also that different kinds of fiber have distinctive drainage rate, and that influences such as pressure, temperature, and vibration have distinctive effects on drainage. Plotting drainage quantities against time reveals the effect of these combined influences as a "drainage curve."

As the distance along a Fourdrinier is a factor of time, a drainage curve also can be made by plotting drainage for successive table rolls. Also, as the Fourdrinier has a free liquid surface, the profile of that formation zone follows the natural gradient of the drainage curve. Thus the Fourdrinier drainage rate is governed by influences such as fiber quality, pressure at each table-roll nip, temperature, and vibration, rather than by some arbitrarily positioned walls adjusted to a fixed taper.

Unlike the open Fourdrinier, a cylinder machine with a throat of fixed taper cannot conform to the instantaneous changes that occur continuously in the natural gradient of any formation profile, even though there may be some rigid adjustment means. Thus, the cross-section of a rigidly-tapered throat is not proportional to the captive stock volume, and the velocity must therefore be irregular along such a throat. The resultant liquid shearing is harmful to formation in those machines.

Thus, the cylinder machine is plagued with rinsing

even when the throat is tapered, and the Fourdrinier is plagued with adverse impulses at table rolls even though it avoids that rinsing by having a free surface. As a solution to these problems, the present invention has a tensioned loop free to conform to the natural drainage gradient thereby avoiding the cylinder machine shearing, and the loop is free from supports obstructive to drainage thereby avoiding Fourdrinier impulses.

In the present invention, some liquid shearing does occur when some kinetic energy of the jet is converted to static pressure in the forming zone. But as described, the mesh tension can be so reduced that the jet actually can lag the machine speed, and thus both "lead" and "lag" may be positively adjusted. Concerning liquid shear, the formation zone is so short that scant opportunity occurs to drag the fibers. That is, the moving walls of the coacting zone seize the jet so quickly that most drainage occurs before there can be much liquid shearing, and formation is unharmed.

Besides impulses, the present invention avoids other detriments of the Fourdrinier. One is that the Fourdrinier suffers from a rebounding of the jet at the machine edges and a resultant uneven paper thickness across the machine. The present invention has no deckle boards reaching the length of the formation zone from which stock can rebound. Also, if some wave should occur, the formation zone is so short that such a disturbance could not penetrate far across the machine width. Further, the mesh of the present invention forms a cover over the formation zone thereby offering more resistance to surface disturbance than merely the liquid surface-tension on a Fourdrinier.

Another detriment of the Fourdrinier is the disturbance to the formation surface from air currents overcome in the present invention by the forming zone being enclosed between moving walls.

The carrying rolls 18 or 118, which are portably mounted as described to compensate for entry conditions, also compensate for the slight mesh changes resulting from the drainage gradient varying continuously. Thus, the present invention discloses a novel means of conforming the mesh in the forming zone continuously to the natural drainage gradient.

(c) *Continuity of Formation*

In cylinder machines of the inward-flow type there is a rigid-support means under the forming mesh, which divides the drainage into a plurality of streams so near the mesh, that the sheet reflects the foundation structure enough to show what are termed "shadow marks." These marks are more or less severe as the drainage rate is increased or decreased. The foundation structure also has many corners inaccessible for easy cleaning which therefore are conducive to blockages particularly from gummy substances such as pitch. Defects in the sheet result.

In cylinder machines of the outward-flow type, such as disclosed in U.S. Patent 2,473,269 to Adams, the supporting structures comprising bars or rolls also interrupt the drainage and adversely affect formation by impulses.

In Fourdrinier machines the support structures also cause intermittent drainage and adverse impulses as described.

In the present invention the forming mesh is supported without drainage division or obstruction in order to avoid both shadow marks and impulses. Also, easy access is provided for cleaning the mesh at any time. The new results of this continuity-of-formation are a quiescent drainage, for greater sheet strength than currently attainable from a given stock, and a compaction of the forming zone for a simplification of apparatus and operation over known art. Other new results are this continuity combined with a speedup of drainage, through the formation zone being pressurized by novel means, and a long mesh-life and small drive-power through the mesh being live-supported. These simultaneous results are not known in prior art.

I claim:

1. A method for producing a continuous sheet such as paper which comprises the steps of: delivering fibers in liquid suspension of papermaking concentration and as a ribbon-like free jet to a juncture between an arcuate external surface of an unyielding rotating body and an adjacent external surface of a yieldably supported body converging in an arcuate path therewith and forming a pressure responsive nip, at least one of which surfaces is porous, thereby creating a co-acting zone the length of said juncture; driving said bodies in the same direction as said jet at said juncture and at the same linear speed; proportioning the speed of said free jet, the speed of said juncture of bodies, and the pressure between said bodies to cause the jet to force a deflection of said pressure responsive nip from said unyielding body, thereby forcing said bodies out of contact with each other by an inflow of stock; maintaining a residual tension in said yielding body, thereby creating a constant pressure against said unyielding body during said deflection, by guiding said yieldably supported body on rotating supports with at least one of which being displaceably mounted for instantaneous constant-tension control; draining each element of said stock uninterruptedly throughout said pressure responsive nip by supporting said yieldably supported body solely by tension throughout said zone as a loop free for any deflection of said yieldably supported body from said unyielding body throughout said co-acting zone and thereby free for variable nip formations of said yieldably supported body toward said unyielding body as determined by stock-drainage rates; and removing the fibers as a continuous sheet at disengagement of said unyielding and yielding bodies.

2. A method for producing a continuous sheet such as paper which comprises the steps of: delivering fibers in liquid suspension of papermaking concentration in the form of a ribbon-like free jet to a pressure-responsive nip between an arcuate external surface of an unyielding rotating body and an opposed surface of a cooperating yieldably supported body at least one of which surfaces is porous, said yieldably supported body surface being constantly tensioned towards contact with said unyielding body surface thereby creating between said opposed surfaces a coacting drainage and formation zone; applying driving means in the same direction as said jet delivery to at least one of said unyielding and yielding bodies maintaining said bodies at equal surface speeds; controlling the delivery speed of said jet, the said equal surface speeds, and tension applied to said yieldably supported body toward said other body to cause the said jet to penetrate forcibly between the said unyielding and yielding body surfaces, thereby to deflect the said yieldably supported body surface from contact with the opposed unyielding body surface by kinetic energy of said free jet for at least an initial portion of said co-acting zone; maintaining constant said tension acting on said yielding body surface by guiding said yieldably supported body on rotating supports at least one of which is displaceably mounted to compensate instantly for deflections created by entry of said jet; a portion of said yieldably supported body thus being supported throughout said co-acting zone as a tensioned loop free to conform said nip to progressive changes in jet delivered stock thickness as determined by progressive changes in drainage rate thereby making said formation zone between said opposed yieldably supported and unyielding surfaces one of self-regulating taper; and removing the said fibers as a continuously-felted sheet at a disengagement point of the said unyielding and yieldably supported bodies.

3. Apparatus for producing a continuous sheet of material from a pulp stock comprising a rotatable body having a substantially rigid, arcuate forming surface; a pair of spaced supports disposed on parallel axes of rotation

parallel to the axis of rotation of said rotatable body; said arcuate forming surface being disposed between said supports; a flexible body including a free-loop forming portion extending between and supported in wrapped relation about a portion of said arcuate forming surface solely by said supports; one of said supports being spaced from said arcuate forming surface and being displaceably mounted for instantaneous constant tension control and causing said free-loop portion to converge in intersecting relation to form a juncture with an intermediate portion of said arcuate forming surface; said juncture forming a pressure-responsive, deformable, co-acting sheet-forming zone extending from the point of convergence to said one support; driving means connected to at least one of said bodies for moving the same at substatially the same

rate of travel; and nozzle means formed to deliver a ribbon-like jet of pulp stock directed between said one support and said arcuate forming surface in the same direction which said bodies travel; at least one of said bodies being porous, said co-acting sheet-forming zone being freely drainable therealong and having a variable cross section determined by drainage rates.

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