

March 28, 1961

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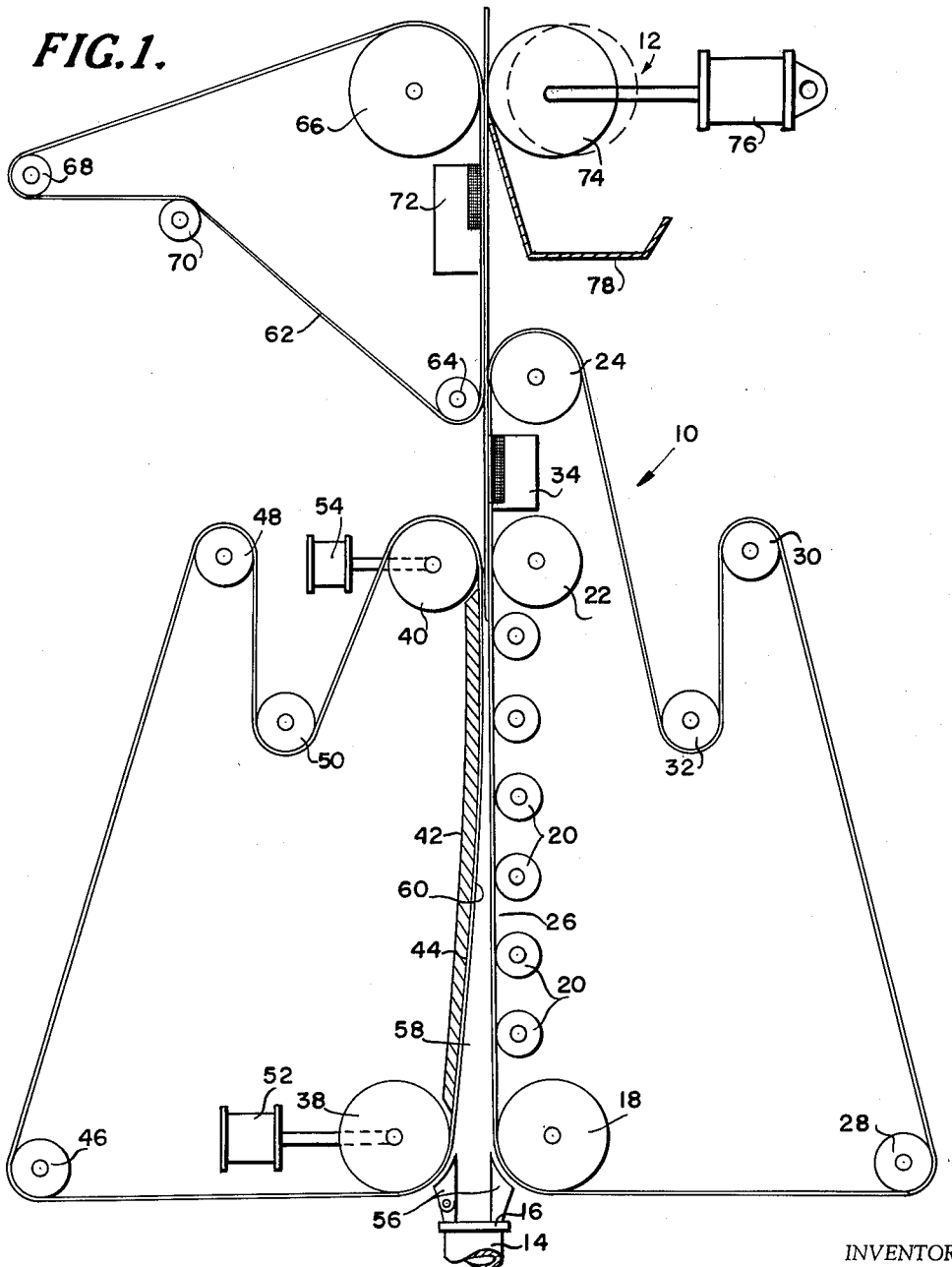
2,977,277

METHOD AND APPARATUS FOR MAKING A WEB OF FIBROUS MATERIAL

Filed July 15, 1957

3 Sheets-Sheet 1

FIG. 1.



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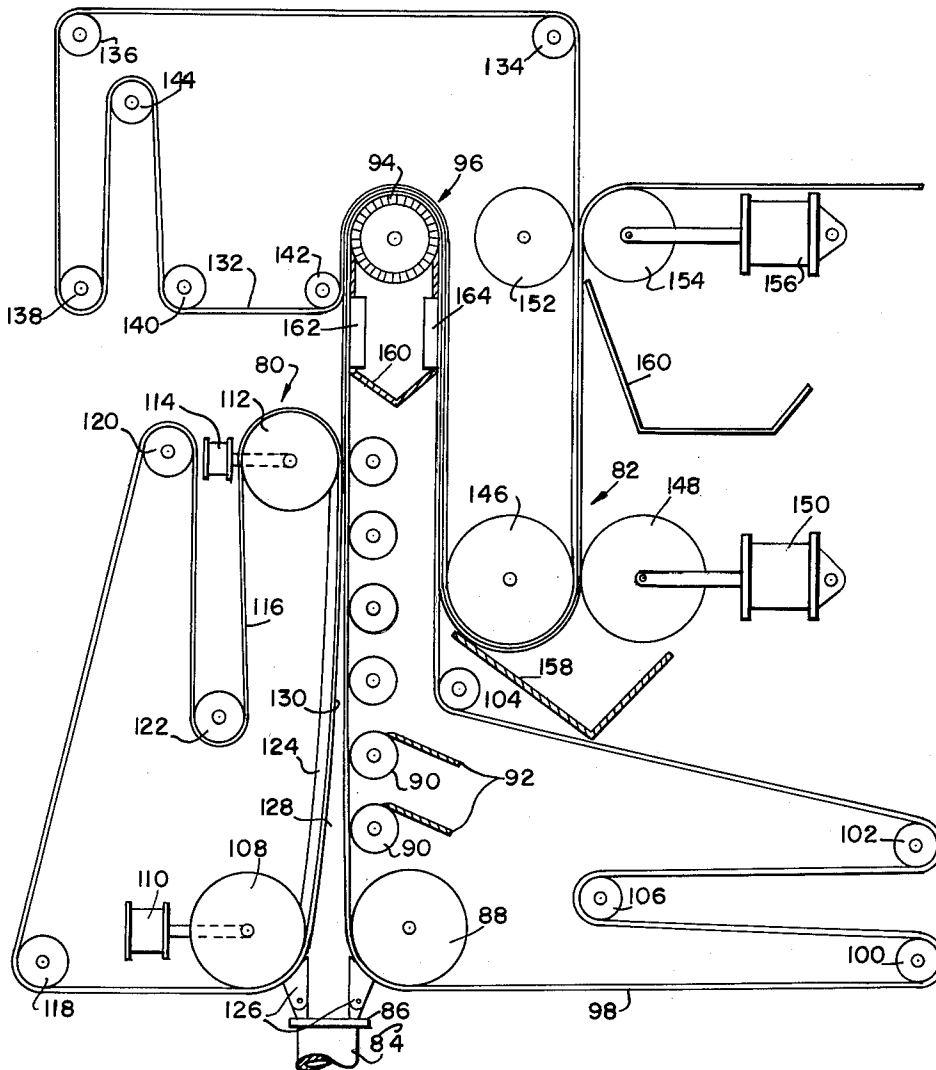
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3 Sheets-Sheet 2

FIG. 2.



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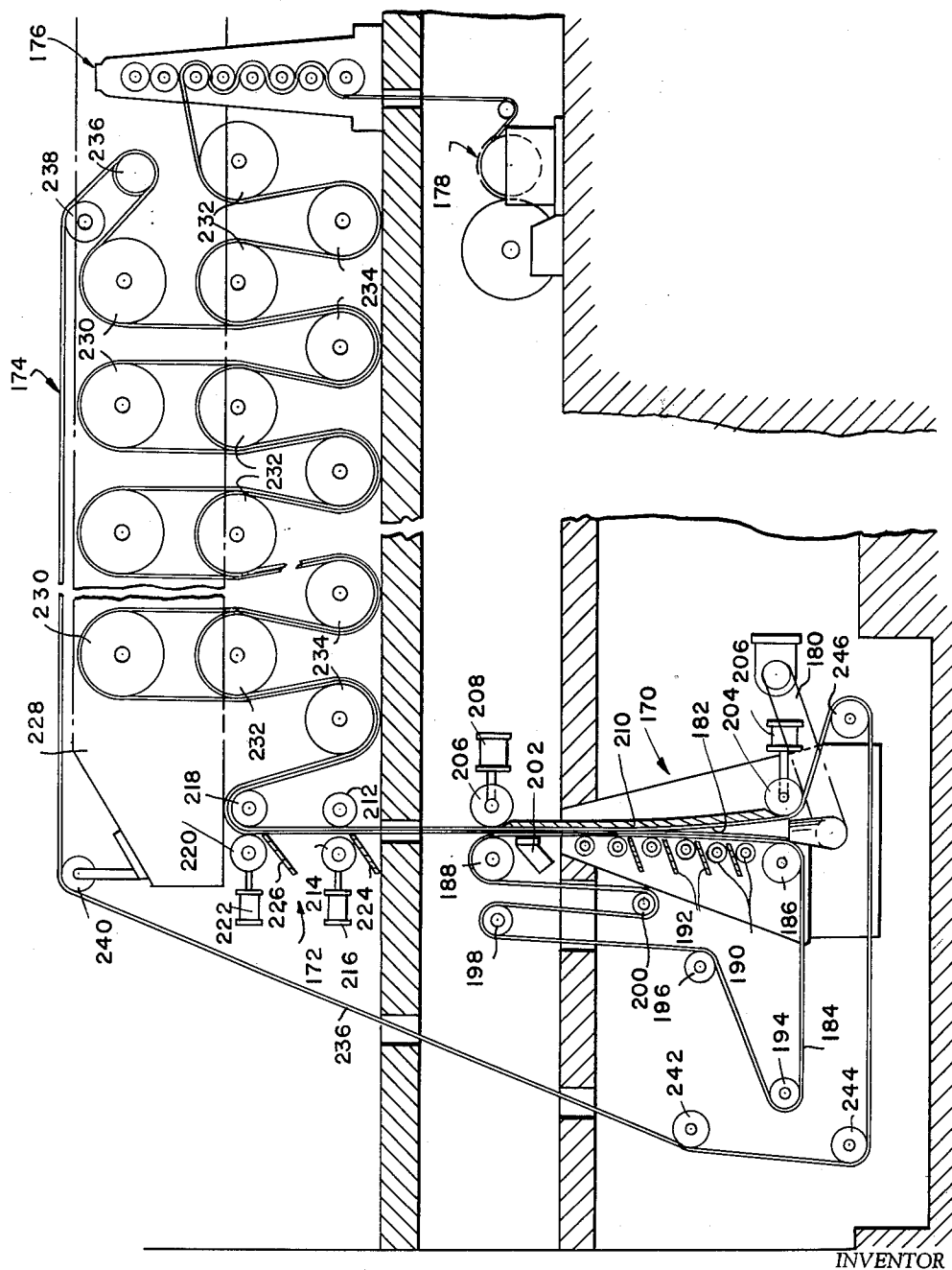
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METHOD AND APPARATUS FOR MAKING A WEB OF FIBROUS MATERIAL

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3 Sheets-Sheet 3



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FIG. 3.

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METHOD AND APPARATUS FOR MAKING A WEB OF FIBROUS MATERIAL

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17 Claims. (Cl. 162—203)

This invention relates to the formation of matted or felted sheets of fibers and more particularly to an improved apparatus and method for forming a web of fibrous material.

The present invention is hereinafter described in connection with the formation of paper. However, it will be understood that the apparatus and procedures hereinafter described may be readily utilized in the formation of fibrous boards and the like in addition to paper, as is well known in the art.

Conventionally, paper is formed on a Fourdrinier machine by flowing suitably prepared stock onto a horizontally moving wire or screen. The stock is initially fed into a head box and then passes from the head box onto the moving horizontal wire through a slice, which usually is adjustable to vary the thickness of the stock fed to the wire. The slice also distributes the stock uniformly throughout the width of the machine. As the stock is moved along with the wire, the thickness of the stock decreases as the water contained therein is drained off through the wire by gravity. The denser the mass becomes, the more resistance there is to drainage and the less the head of water within the mass to effect drainage. During the movement of the stock with the horizontal wire, sufficient liquid is drained off to change the consistency of the stock into a wet web of fibers. Further water removal is usually accomplished by means of suction boxes.

The drainage of the water on the horizontal Fourdrinier wire is effected chiefly through the head of liquid within the thickness of the stock, which varies from approximately 1/2 inch to 1 1/2 inches in conventional paper making. Additionally, the Fourdrinier wire is supported by revolving table rolls, which somewhat hasten water removal by creating capillary action and suction. However, the water so removed is largely from the underside of the stock and although a positive vacuum is created by one segment of a table roll, the same segment before it completes a revolution will have thrown back into the stock, and even through it, a substantial amount of the water already removed.

The action of the table rolls in throwing the water back up through the Fourdrinier wire and the stock formation thereon has a detrimental effect on the formation of the paper produced. That is, the water pierces through the fibers on the Fourdrinier wire and disturbs their distribution. While this piercing action has a detrimental effect on the formation, it also has the effect of opening the formation which speeds up the drainage to some extent and is, therefore, generally regarded to be desirable.

Another factor which detrimentally affects the fiber formation in the conventional Fourdrinier machine is the manner in which the stock is fed onto the Fourdrinier wire. The head box usually contains a large amount of stock which must pass through a restricted slice opening. Hence, the velocity of the stock passing through the slice increases considerably, which naturally causes the fibers

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to tend to line up in the direction of flow. An attempt is made to obtain a velocity of feed equal to the speed of travel of the Fourdrinier wire, but this condition can seldom be maintained. The phenomenon of "skating" often results which causes undesirable laminations in the formation.

In addition, due to the lack of adequate drainage, a film of water usually forms on the upper surface of the stock as the same travels with the Fourdrinier wire and this film of water, due to air surface friction, tends to slow down so that a differential speed is created between the upper film of water and the fibers therebelow. This differential speed also materially aids in aligning the fibers in the direction of travel. Of course, alignment of the fibers is undesirable in that it results in a paper having more tensile strength longitudinally than transversely, or unequal tear characteristics. Present practice is to provide expensive and complicated shake equipment which provides a transverse vibration or shaking action during formation. Such equipment, therefore, has the effect of disturbing the fiber distribution and such disturbance has its detrimental effects as well.

Another phenomenon in the operation of a conventional Fourdrinier machine which detrimentally affects the formation of the paper is the creation of standing waves. Because the upper surface of the stock moving with the horizontal Fourdrinier wire is free, disturbances at the sides of the stock flow often generate waves in the free surface, which ultimately results in an overconcentration of fibers in portions of the paper formed.

"Starved edges" is another problem encountered in a conventional Fourdrinier machine. The table rolls which support the horizontal Fourdrinier wire have a natural tendency to deflect due to their own weight and the weight supported thereby in much the same manner as a beam supported at both ends. This results in a variance in the thickness of the stock during formation so that the central portion of the stock has the greatest thickness and the edges have a thickness somewhat less. Moreover, in order to reduce drag at the edges of the moving stock, complicated and expensive "deckel" straps must be provided.

Since the drainage of water becomes less and less in successive areas between the table rolls, the total length of drainage area is only a fraction of the forming length. There have been many proposals in order to effect a more efficient drainage of the water from the stock to form the fiber web. These proposals have chiefly employed the utilization of pressure, such as a static or head pressure maintained above the moving horizontal Fourdrinier wire. It has also been proposed to utilize a forming chamber which applies mechanical pressure to the fibers in opposite directions to effect water removal. With such a chamber, it is possible to feed the stock within the chamber at extremely high pressure so that the water will be expelled under such hydraulic pressure and by mechanical pressure of the fibers, rather than by gravity.

The present invention contemplates an improved procedure for effecting drainage of the water from the fibers during the formation of the fibrous web. It has been found that by feeding or projecting the stock at a predetermined velocity and pressure upwardly or in a direction to substantially increase the potential energy or head of the stock fed, the increased potential energy in the stock can be utilized to effect a highly desirable drainage of the water or liquid through the fibers. In the more specific aspects of the present invention, the forming wire upon which the fibrous web is formed extends upwardly and preferably is substantially vertical. The stock is fed or projected in the direction of extent of the wire at a velocity substantially equal to the velocity at which the wire is travelling. It is con-

templated that little, if any, mechanical or hydraulic pressure energy is utilized to effect drainage, the same being accomplished substantially entirely by the potential energy of the stock fed. The fibers in the feed are deposited on the forming wire, which is travelling at substantially the same speed as the initial feed. The stock fed is confined to the space adjacent the forming wire in such a way that there is very little, if any, pressure energy within the feed, the same being substantially velocity energy. Since the feed is against gravity, this velocity energy is progressively lost or converted into potential energy as the stock travels upwardly. Since the forming wire maintains the initial velocity of the fibers, the conversion of the velocity energy of the water in the stock into potential energy results in drainage or removal of a substantial part of the water through the fibers and travelling wire. The space adjacent the moving wire is confined in such way that the space occupied by the liquid draining through the forming wire is immediately taken up. In this way, the fibers are at all times maintained in a confined condition. However, there is substantially no pressure, as such, applied, the progressive conversion of the space being just that amount sufficient to make up for the progressive drainage of water from the stock as the fibrous web is formed. The manner in which drainage is effected and the manner in which the stock is fed to obtain such drainage results in a highly desirable formation of the web.

Accordingly, it is an object of the present invention to provide a method of forming a web of fibrous material from a suitably prepared stock in which the resultant web has a highly desirable fiber formation.

Another object of the present invention is the provision of a method of forming a fibrous web embodying an improved procedure for effecting drainage of the water from the stock.

Still another object of the present invention is the provision of a method of forming a fibrous web embodying an improved procedure for feeding the stock.

The invention further contemplates an apparatus operable to carry out the procedure noted above, which achieves many significant advantages over the conventional Fourdrinier machines heretofore utilized. For example, the present apparatus does not require the utilization of a head box or an adjustable slice. Moreover, it is possible to eliminate approximately 75% of the wire backing rolls heretofore utilized in conventional Fourdrinier machines. A substantial reduction in the length of the Fourdrinier wire required is also possible with the present invention. The entire structure is less expensive since most of the elements are in compression instead of tension with the minimum need for clad metal as protection against low pH liquids. Because of the manner in which the fibrous web is formed, there is no necessity for the utilization of shake equipment, such as required on some conventional Fourdrinier machines, to obtain superior formation. The suction box area can be reduced approximately 80% with the present apparatus over that required with a Fourdrinier machine and elimination of the breast roll removal assembly and wire buggy is also obtained. In addition, a substantial reduction of tiled pits, vacuum pumps, piping and instrumentation is also obtained with the present invention and a highly favorable saving of some 3,000 square feet of factory floor space can be effected. Insofar as the quality of paper produced is concerned, the present apparatus effects a formation of the fibrous web without the creation of standing waves, starved web edges, cross currents and unreconciled velocities of stock and wire speeds, which are present in the operation of conventional Fourdrinier machines. Tests have indicated that paper having 100% tear can be produced from low grade stock with the use of the present apparatus.

Accordingly, another object of the present invention is the provision of an apparatus for forming a web of fibrous material which obtains the advantages noted above.

Another problem which is quite prevalent in the paper making art is the formation of so-called nip ponds in the press rolls after the initial formation of the fibrous material through the Fourdrinier machine. Since the web passing from the Fourdrinier machine still contains considerable liquid, this liquid tends to build up on the upper horizontal surface of the web adjacent the nip of the press rolls and serves to prewet the web before it passes through the press rolls. Considerable development has been done to eliminate the formation of such nip ponds and it is within the contemplation of the present invention to provide a simple and effective press arrangement which eliminates this problem.

Still another object of the present invention is the provision of an improved press for a wet fibrous web which eliminates the creation of nip ponds which heretofore existed in the prior art presses.

A still further object of the present invention is the provision of improved means for conveying the web from the forming machine to the press.

A still further object of the present invention is the provision of a conveying means of the type described having improved suction means embodied therein for removing water from the web prior to entry into the press.

The dryer section used with a conventional Fourdrinier machine embodies extensive dry felts which serve to transport the formed web through the dryer section and also to absorb moisture therefrom. These endless dry felts are heat treated during their return travel and expensive equipment is necessary to achieve this function. The present invention also contemplates improvements in the dryer section wherein the web formed is recycled, at least through the press and dryer section, and thus used as a transport of the newly formed web therethrough. This aspect of the present invention is particularly advantageous when used in conjunction with the forming chamber, such as described above. That is, the web formed in this instance is recycled through the forming chamber, before going through the press and dryer section, and is utilized to confine the stock in the forming chamber as a traveling backing web. In this way, the recycled web serves two functions and achieves not only a saving in the dry felts heretofore necessary, but in the provision of backing webs as well.

Accordingly, still another object of the present invention is to provide a method of the type described embodying an improved procedure for confining the stock within the forming chamber and for transporting the formed web through the press and dryer section.

Still another object of the present invention is the provision of an improved dryer construction for a wet fibrous web embodying improved means for transporting the web therethrough.

These and other objects of the present invention will become more apparent during the course of the following detailed description and appended claims.

The invention may best be understood with reference to the accompanying drawings wherein an illustrative embodiment is shown.

In the drawings:

Figure 1 is a somewhat schematic side elevational view of a paper forming apparatus and press embodying the principles of the present invention;

Figure 2 is a view similar to Figure 1 illustrating a modified form of the paper forming apparatus and press; and

Figure 3 is a schematic side elevational view of a paper making machine embodying the principles of the invention including a modified paper forming apparatus, a modified press and dryer section.

Referring now more particularly to Figure 1 of the drawings, there is shown a forming machine, generally indicated at 10, and a press, generally indicated at 12, for receiving the web issuing from the forming machine. It will be understood that the web passing through the press is subsequently fed through dryer rolls, calender rolls and other conventional apparatus to finish the web formed into paper. The stock utilized to form the paper is fed or projected to the machine 10 through an inlet pipe 14 having a suitable source of pressure, such as a pump or the like (not shown), applied thereto. The inlet pipe terminates in a discharge end 16 which extends throughout the width of the machine.

A breast roll 18 is mounted adjacent the discharge end of the inlet pipe and a plurality of vertically spaced backing rolls 20 are suitably mounted above the breast roll 18. Above the backing rolls 20 are a pair of vertically spaced large drive rolls 22 and 24, the latter constituting a drive roll for an endless forming wire or web 26 of any suitable construction trained about the breast roll 18 and drive roll 24 and supported therebetween by the backing rolls 20 and large roll 22. The return of the forming wire is suitably supported by rolls 28 and 30 and a tensioning roll 32, which may be adjusted to vary the tension on the forming wire 26. The extent of the forming wire 26 between the rolls 18 and 22 constitutes an upright portion where the fibers of the stock are deposited to form the web. That is, a majority of the stock liquid has been removed from the fibers carried upwardly past the roll 22 and further liquid is removed by a suction box 34 of conventional construction disposed between the roll 22 and the drive roll 24.

Adjacent the breast roll 18 is a cooperating breast roll 38 and a second drive roll 40 is disposed in vertically spaced relation to the breast roll 38 in cooperation with the roll 22 supporting the forming wire. A backing plate 42, preferably of a curved configuration, is mounted between the rolls 38 and 40 and an endless backing web 44 of suitable material, such as fabric or plastic, is trained about the rolls 38 and 40 and supported by the backing plate 42. The return flight of the backing web is supported by rolls 46 and 48 and a tensioning roll 50 is provided for varying the tension on the backing web.

Preferably, the breast roll 38 is adjustably mounted, by any suitable means, schematically illustrated as a hydraulic cylinder and piston unit 52, for varying the distance or spacing between the cooperating breast rolls. In a like manner, the upper drive roll 40 is provided with suitable means, schematically illustrated as a hydraulic piston and cylinder unit 54, for varying the space between the cooperating upper rolls 22 and 40. Extending between the pipe discharge end 16 and the cooperating breast rolls are cooperating inlet guide plates 56, either one or both of which are pivoted or otherwise adjustable to accommodate the adjustment between the breast rolls and still provide for a fluid-tight projection of the stock between the upright portions of the forming and backing webs. The edges of the latter have stationary side plates 58 mounted in closely spaced relation thereto and the space bounded by the forming and backing webs and the side plates constitutes a forming chamber 60.

The stock projected through the inlet guide plates 56 is formed into a continuous fibrous web within the forming chamber and issues therefrom on the wire 26 in a wet condition. Additional water removal is effected as the fibrous web and wire 26 passes the suction box 34. The press 12 is disposed above the forming machine 10 so as to receive the web after it passes the suction box 34 and includes an endless wet felt 62 trained about a lower roll 64, mounted adjacent the drive roll 24 in cooperating relation therewith, a vertically spaced press roll 66, a return supporting roll 68 and tensioning roll 70. The vertical portion of the wet felt between the lower roll 64 and press roll 66 serves to transport the wet fibrous web from the forming machine through the press 75

and a suction box 72 of conventional construction is preferably provided adjacent this vertical portion of the wet felt to effect further water removal.

A cooperating press roll 74 is mounted in horizontally spaced relation to the press roll 66 and is movable horizontally by any suitable means, such as a hydraulic piston and cylinder unit 76. Extending downwardly from the nip of the cooperating press rolls 66 and 74 and below the press roll 74 is a catch basin 78 for receiving the water removed from the wet web as it passes between the press rolls. It will be understood that suitable conduits or other means are provided for conveying the liquid or white water collected in the catch basin to a central station so that it may be reclaimed, if desired. In a like manner, suitable provision is made for reclaiming the water collected in the suction boxes 34 and 72, as well as that draining through the forming wire 26.

Referring now more particularly to Figure 2 of the drawings, there is shown a modified forming apparatus, generally indicated at 80, and a modified press, generally indicated at 82, arranged to receive the fibrous web issued from the forming machine. The forming machine 80 includes a suitable feed pipe 84 from which a source of stock is fed or projected under a suitable pressure, such as a pump or the like (not shown). The feed pipe 84 terminates at a discharge end 86, which extends throughout the width of the machine. Disposed adjacent the discharge end of the feed pipe 84 is a breast roll 88 suitably mounted for rotation about a horizontal axis. Mounted above the breast roll 88 in vertically spaced relation is a series of backing rolls 90, some or all of which may have doctor blades 92 positioned adjacent their peripheries for stripping liquid therefrom. Disposed above the backing rolls 90 is a suction roll 94 which forms a part of a suction unit, generally indicated at 96, hereinafter to be more fully described.

An endless forming wire or web 98 is trained about the breast roll 88 and the suction roll 94, which preferably also is driven so as to constitute a drive roll for the forming wire 98. The return of the forming wire is supported by a series of supporting rolls 100, 102 and 104 and a tensioning roll 106. As shown in Figure 2, the forming wire 98 includes an upwardly extending portion between the breast roll 88 and the suction roll 94, which is backed by the backing rolls 90, and a downwardly extending portion between the drive roll 96 and supporting roll 104.

Disposed in cooperating relation with the breast roll 88 is a second breast roll 108, which is mounted for rotation about a parallel horizontal axis, as well as horizontal adjustment by any suitable means, such as a hydraulic piston and cylinder unit 110. A drive roll 112 is disposed above the breast roll 108 in cooperating relation with the upper backing roll 90 and is likewise mounted for horizontal adjustment by any suitable means, such as a hydraulic piston and cylinder unit 114. An endless backing web 116 is trained about the breast roll 108 and drive roll 112 and the return is supported by suitable supporting rolls 118 and 120 and a tensioning roll 122. The backing web includes an upwardly extending portion between the breast roll 108 and drive roll 112, which is supported by a backing plate 124 having a slightly convexly curved backing surface.

Extending between the discharge end of the feed pipe 84 and the cooperating breast rolls 88 and 108 is a pair of cooperating inlet guide plates 126, either or both of which is pivoted or otherwise rendered adjustable to accommodate the adjustment between the breast rolls and still provide for the substantial fluid-tight introduction of the stock from the feed pipe between the forming and backing webs. The edges of the latter have stationary side plates 128 mounted in closely spaced relation thereto and the space bounded by the forming and backing webs and the side plates constitutes a forming chamber 130 similar to the chamber previously described.

The fibrous web issuing from the upper end of the form-

ing chamber 130 is transported by the forming web 98 upwardly around the suction roll 94. In order to facilitate the movement of the newly formed web around the suction roll 94, there is provided an endless wet felt 132 which is trained about a series of suitably mounted supporting rolls 134, 136, 138, 140 and 142 and a tensioning roll 144. The supporting roll 142 is disposed just below and adjacent to the suction roll 94 and the wet felt 132 is trained about this roll and the suction roll 94 and extends downwardly along the downwardly extending portion of the forming web and around a lower press roll 146 of the press 82. A cooperating press roll 148 is mounted in parallel horizontal relation with respect to the press roll 146 and has any suitable means, such as a hydraulic piston and cylinder unit 150, connected therewith for effecting horizontal movement thereof with respect to the roll 146. The wet felt trained around the press roll 146 extends upwardly through a second pair of press rolls 152 and 154. The press roll 154 is mounted for horizontal movement with respect to the press roll 152 by any suitable means, such as hydraulic piston and cylinder unit 156.

The cooperating pairs of press rolls 146 and 148 and 152 and 154 comprise the press 82 and means, such as catch basins 158 and 160, are provided below each pair of cooperating press rolls to collect the liquid expressed from the fibrous web as it passes therethrough.

The suction unit 96, which includes the suction roll 94, is arranged to apply suction to the fibrous web passing thereover throughout approximately 180° of the roll. Rather than having an axial outlet through which the suction is maintained, the suction for the roll 94 is through the foraminous periphery thereof by means of a housing 160 disposed below the suction roll 94 in engagement with the forming web portion extending upwardly and downwardly therefrom. If desired, a suction box 162 may be provided on the upwardly extending side and an additional suction box 164 may be provided on the downwardly extending side. It will be understood that a single source of suction may be introduced into the housing 160 to effect suction through the boxes 162 and 164, as well as the suction roll 94.

Referring now more particularly to Figure 3, there is shown still another modified form of the present invention. The modification illustrated in Figure 3 includes a forming apparatus, generally indicated at 170, and a press, generally indicated at 172, for receiving the fibrous web issuing from the forming apparatus and for expressing a portion of the liquid therefrom. The fibrous web issuing from the press 172 then passes into a dryer section, generally indicated at 174, where still more of the moisture contained within the fibrous web is removed by the application of heat. From the dryer section, the fibrous web moves through a series of calendar rolls 176 and then into a slicer and rewinder mechanism, generally indicated at 178, as is well known in the art.

The forming apparatus 170 is generally similar to the forming apparatus 10 described in connection with the embodiment disclosed in Figure 1 and the forming apparatus 80 described in connection with the embodiment disclosed in Figure 2. In brief, the apparatus 170 includes a feed pipe 180 from which stock is fed or projected under a suitable pressure from a suitable source. The feed pipe 180 is arranged to feed or project within a forming chamber 182 similar to the chambers 60 and 130 previously described. The fibrous web is formed within the chamber 182 on a forming web or wire 184, which extends upwardly therethrough between a breast roll 186 and a drive roll 188. A series of backing rolls 190 serve to support the forming web between the breast roll and drive roll and, preferably, deflector plates 192 are disposed between some or all of the backing rolls in order to direct the liquid away from the adjacent surface of the forming web. The return of the forming web is supported by suitable supporting rolls 194, 196 and 198 and a tensioning roll 200. Disposed between the upper

backing roll 190 and the drive roll 188 is a suction box 202 of conventional construction.

The side of the forming chamber 182 opposite from the forming web 184 is defined by a backing web, herein-after to be more fully described. A breast roll 204 is rotatably mounted on a horizontal axis in cooperating relation with the breast roll 186 and is horizontally adjustable by any suitable means, such as a hydraulic piston and cylinder unit 206. A vertically spaced drive roll 208 is rotatably mounted in cooperating relation with the drive roll 188 and is likewise horizontally adjustable by any suitable means, such as a hydraulic piston and cylinder unit 208. A backing plate 210 extends between the breast roll 204 and drive roll 206 and is suitably curved in a manner similar to that described above in connection with the backing plates 42 and 124. The press 172 includes a pair of lower cooperating press rolls 212 and 214, the latter of which is horizontally movable by any suitable means, such as a hydraulic piston and cylinder unit 216. Disposed above the lower cooperating press rolls is a second pair of cooperating press rolls 218 and 220, the latter of which is horizontally movable by any suitable means, such as a hydraulic piston and cylinder unit 222. As before, suitable catch basins 224 and 226 are provided for each pair of cooperating press rolls to collect the liquid expressed from the fibrous web as it passes therebetween.

The dryer section 174 includes a hood 228 having a series of upper rolls 230 suitably mounted therebelow, a series of intermediate rolls 232 disposed in alignment below the rolls 230 and a series of cooperating lower rolls 234 disposed below and horizontally between each pair of aligned upper and intermediate rolls.

The backing web which passes through the forming chamber 182 is also utilized as a transport web for the fibrous web formed in the forming chamber as the latter is passed through the press 172 and the dryer section 174. To this end, a starting web of paper or the like, indicated at 236, is disposed adjacent the upper rear end of the dryer section and extends over supporting rolls 238, 240, 242, 244 and 246, which direct the starting web over the dryer section, around the press 172, beneath the forming apparatus 170 and upwardly around the lower breast roll and through the forming chamber.

To commence operation of the apparatus illustrated in Figure 3, the starting web is fed around the supporting rolls and upwardly through the forming chamber and the forming apparatus is set in operation at a relatively low speed. As the fibrous web is formed, it is transported by the starting web and fed through the cooperating press rolls and then through the dryer rolls, the newly formed web being trained about the lower dryer rolls 234 and the upper dryer rolls 230, while the starting web is trained about the lower rolls 234 and the intermediate rolls 232, as shown in Figure 3. When the newly formed web reaches the last upper roll 230, it is united with the trailing end of the starting web, as by glue or other suitable cement or the like, and during subsequent operation, the newly formed web is then recycled through the forming apparatus, press 172 and dryer section until the same goes through the calendar rolls 176 and then through the rewinder and slicer mechanism. Thus, in the apparatus disclosed in Figure 3, the fibrous web formed in the forming chamber 130 is recirculated through the apparatus after it has been pressed and dried to serve as the backing web for the newly formed web within the forming chamber and as a transporting web for the newly formed fibrous web through the press 172 and the dryer section 174.

Operation

The manner in which the apparatus disclosed in Figure 3 is started so that the fibrous web formed is continuously recirculated to be used as a backing web in the formation of the fibrous web within the forming cham-

ber and a transport web for the fibrous web thus formed through the remainder of the apparatus, has already been described. In general, the operation of the forming apparatus 10, the forming apparatus 80 and the forming apparatus 170 disclosed in Figures 1, 2 and 3 respectively is similar so that a description of one should suffice to give a clear understanding of the operation of all. In the subsequent description, the operation of the forming apparatus, as well as the presses 12, 82 and 172 disclosed in Figures 1, 2 and 3 respectively, will be set forth in terms of the common operation of all and where differences exist, these will be set forth.

While the theory of operation of the present forming apparatus is not fully understood, it is believed that the same can best be explained in terms of the various types of energies or heads present in the flowing stock at different points throughout the travel thereof. In the normal operation of the apparatus, it is contemplated that the cross-sectional area of the forming chamber progressively decreases in accordance with the amount of liquid removed from the stock. Assume first that the stock is fed or projected upwardly into an unconfined space. With this assumption, the pressure energy or head of the stock would at all times be equal to atmospheric pressure, while the velocity head would progressively decrease from the point of feed to a point where the same is zero, while the potential head increases from the feed to a maximum where the velocity head equals zero. Under these conditions, the stock would fall by gravity as the velocity of incremental portions thereof reaches zero and the potential energy causes the same to fall. Next, assume that the forming web is provided adjacent the free flowing stock mass and is moved at the same velocity as the initial velocity of feed. The forming web has the effect of maintaining the initial velocity of the fibers but the liquid will follow the same reduction of velocity energy and increase in potential energy as above without the provision of the forming web, although the rate of conversion is lessened somewhat due to the velocity energy added by the moving forming wire. Thus, as the velocity energy of the water or liquid decreases and its potential head increases, drainage will occur which effects a decrease in the cross-sectional area or quantity of the stock carried upwardly with the forming web. Finally, the backing web is provided which is shaped to define a confining chamber which decreases in cross-sectional area in accordance with the decrease in cross-sectional area of the stock, as noted above. Thus, it is not contemplated that the backing web apply any substantial mechanical pressure to the fibers in the stock to express the liquid therefrom. Water removal is effected by gravity utilizing the potential energy created as a result of the direction in which the stock is fed or projected. Any substantial mechanical pressure exerted during the removal of the water by gravity within the forming chamber is a result of maladjustment of the backing web or feed.

The manner in which the stock is fed or projected within the forming chamber of the forming apparatus results in a highly advantageous fiber distribution within the fibrous web formed. It is to be noted that the feed pipe is arranged so that the stock projected into the forming chamber does not undergo a sudden or fast acceleration as it issues from the discharge end thereof between the inlet guide pipes. That is, it is contemplated that the feed is gradually moved through the pipe so that when it enters the forming chamber, there is no abrupt change in velocity or an acceleration which would tend to align the fibers in the direction of flow. Preferably, the velocity of feed is the same as the speed of travel of the forming and backing webs, although it will be understood that it may be either slower or faster, so long as it is substantially the same.

As pointed out above in the theory of operation of the forming apparatus, the potential energy imparted to the stock immediately effects a drainage of the liquid through

the forming web. That is, the fibers are immediately deposited on the forming web and as will hereinafter be more fully explained, the subsequent actions within the forming chamber are such that there is no disturbance of the formation of the fibers thus initially deposited. As the forming web moves upwardly with the fibers deposited thereon, more and more fibers build up on the forming web and the drainage is such that no alignment of the fibers takes place. Due to the utilization of the potential energy of the liquid within the stock as a drainage medium, drainage takes place in a relatively short period of time and in a relatively short distance of travel.

Since the opposite surface of the stock within the forming chamber is confined, no standing waves can develop which would detrimentally affect the formation. Moreover, since the natural deflection of the rolls is in a direction perpendicular to the extent of the forming web, there is no increased thickness in the formation at the central portion as a result thereof. By disposing the side plates in spaced relation to the edges of the forming web and backing web, the formation of starved edges is completely eliminated. This latter feature also serves to permit liquid to enter between the backing web and the backing plate so as to serve as a lubricant between the sliding surfaces thereof. Because drainage occurs in a relatively short period of time in a relatively short distance, a large quantity of water passes through the forming web and drains or cascades downwardly on the opposite side thereof. This falling or cascading of water has a tendency to envelope the supporting rolls and in itself has a pulling effect on the water through the forming web. The enveloping film of cascading water around the forming rolls tends to prevent water being flung out and back in through the forming wire.

As shown in Figure 1, it is contemplated that the film of water passing through the forming web and falling downwardly is sufficient to prevent the throwing of water back into the forming web and, therefore, deflector plates are not believed to be essential. However, where such water becomes difficult to handle, it may be doctored off the rolls, as illustrated in Figure 2, or directed away from the forming web by deflector plates, such as illustrated in Figure 3. In any event, the drainage of the water from the stock within the forming chamber is not in any sense dependent on the capillary action or the suction of the backing rolls, nor is it considered desirable to permit the water to be thrown back into the forming web so that it would pierce through the fibers deposited thereon to thereby enhance the drainage effect. With the present arrangement, the throwing of the water back into the web is prevented in the manner disclosed above and thus the formation of the fibers initially deposited on the forming web remains undisturbed.

For the reasons indicated above, the fiber formation achieved by the present invention is highly desirable. Formation is accomplished without disturbing the fibers after initial depositing on the forming web. Starved edges, standing waves, fiber alignment, lamination, and other imperfections caused by unreconciled differences in feed velocity and forming wire travel are completely eliminated. Tests have indicated that paper having 100% tear and equal tensile strength, both traverserly and longitudinally, can be produced with low grade stock.

The provision of a vertical forming chamber in which the stock is fed or projected upwardly therethrough constitutes a highly significant feature of the present invention. While a vertical position of this chamber is greatly preferred, it will be understood that the same may be inclined with respect to the vertical and still obtain satisfactory results, although it has been found that an angle of approximately 45° represents a limit to which the chamber may be inclined and still obtain efficient operation. The stock is fed or projected into the chamber by a pump which is provided with suitable controls (not shown) at a rate sufficient to establish an initial velocity

between the breast rolls, which is substantially equal to the velocity at which the forming wire is moving. It will be understood that the position of the backing web may be suitably adjusted either at the breast roll or drive roll thereof, or both, with a corresponding adjustment of the backing plate. Thus, the size and taper of the forming chamber can be varied to accommodate various feed rates. The forming web is preferably of conventional wire construction and constitutes a foraminous member upon which the fibers are deposited. It is contemplated that the foraminous member and backing rolls could be replaced by a stationary foraminous member or perforated plate, although the use of a travelling forming web is greatly preferred. With the use of such forming webs, formation speeds above 3,000 feet per minute can be employed.

Preferably, the backing web is made of a substantially impervious material, such as impregnated fabric, plastic, canvas, or the like, where the recirculation of the fibrous web formed is not utilized. In paper making, it is desirable to form the web on at least one surface without wire marks, such as would be present on the forming wire side, and, accordingly, a smooth surfaced impervious material is preferable as a backing web. The recycled fibrous web formed serves well in this capacity. The significant feature of the backing web is that it confines the stock and directs the drainage through the forming web. Thus, it is possible to utilize a foraminous backing web with an impervious backing plate and, in low speed operation, the moving backing web can be eliminated entirely and the backing plate utilized alone. Of course, where an impervious backing web is utilized, the backing plate may be replaced by backing rolls.

If drainage is allowed to take place through the backing web, as when a foraminous backing web and backing rolls are utilized, a web is formed thereon which must subsequently be united with the web formed on the forming wire. In paper making, this leads to an undesirable lamination of the fibers of the paper ultimately formed and, therefore, the arrangement illustrated is preferred. However, it is contemplated that the use of two forming wires within the forming chamber may be employed when making fibrous board, since the formation of laminations therein is not considered undesirable.

With respect to the use of the present forming apparatus in making fibrous board, many advantages are contemplated due to the vertical position of the forming chamber. For example, the present apparatus lends itself readily to the positioning of a series of such apparatus in side by side relation so that the formed webs moving upwardly therefrom may be moved together and united in a single press to form a laminated fibrous board. More specifically, three such webs could be formed with the outer webs of relatively thin high grade paper and the intermediate web made in a relatively thick formation of low grade stock.

Aside from the superior formation achieved as a result of the improved feed and drainage of the stock, the present apparatus presents many advantages over the conventional Fourdrinier machines heretofore utilized. The present forming apparatus does not require the provision of a head box or an adjustable slice. Because the backing rolls do not act under any significant pressure, a fewer number may be provided with greater spacing therebetween than is ordinarily required in a conventional horizontal Fourdrinier machine. The problem of misalignment of the backing rolls previously encountered in the table rolls of a horizontal Fourdrinier machine, usually due to the operator walking thereon, is also eliminated for obvious reasons. Moreover, due to the superior drainage, less suction box area is necessary. Due to the superior formation, shake equipment is not necessary and a substantial saving in the length of forming wire provided can be achieved over that necessary in the conventional horizontal Fourdrinier machine. Because of

the horizontal disposition of the forming apparatus, the majority of the structure would be in compression instead of tension, and the girders, rails and stainless steel covered areas, cross bracings, tracks, wheels and roll out winches of conventional machines would be eliminated in lieu of columns not exposed to lower pH liquids. A substantial saving in tiled pit construction, in vacuum pumps, piping and instrumentation can also be achieved in view of the vertical disposition of the apparatus. Finally, a saving of more than 3,000 square feet of floor space is possible. Note particularly Figure 3, which illustrates a contemplated arrangement of a paper making factory embodying the apparatus. The forming apparatus may be disposed at the ground level and arranged to feed the fibers formed thereby upwardly into the press and dryer section disposed at a level thereabove.

The press arrangement disclosed in the drawings is significant when used in conjunction with the vertically disposed forming apparatus in that the press rolls are arranged to receive a vertically moving fibrous web. The significant feature of the press disclosed is that it completely eliminates the creation of nip ponds which were a troublesome problem in the conventional Fourdrinier machine presses. Nip ponds are formed in the operation of a conventional Fourdrinier machine press on the upper surface of the fibrous web as it passes horizontally through the cooperating press rolls and act to prewet the fibrous web before it passes through the press rolls. Many proposals have been advanced to take care of the water of the nip ponds inherently created. With the present arrangement, there is no horizontal surface on the fibrous web suitable to support a nip pond and, therefore, they are never created or are non-existent. Moreover, vertical formation of the fibrous web does not result in a film of liquid on the top thereof as is the case with a horizontal Fourdrinier machine. The liquid expressed by the present press displays a greater affinity for the peripheries of the press rolls and, therefore, follows the same and falls downwardly into the catch basins provided therebelow. Thus, there is no prewetting of the fibrous web before it passes through the press rolls and hence a much more efficient removal of the liquid is accomplished.

The dryer section arrangement disclosed in Figure 3, as well as the recycling of the fibrous web formed, effects a significant saving in the dry felts heretofore regarded to be essential in the proper operation of a dryer section. In principle, the fibrous web formed and recycled is utilized in place of the expensive drying felts heretofore required. This arrangement eliminates the necessity of regenerating chambers for the dry felts, as well as the initial expense and expense of replacement of the dry felts. The present dryer arrangement is particularly advantageous in connection with the present forming apparatus in that the recirculated fibrous web serves two functions. First, it serves to replace the backing web in the forming apparatus and, second, it serves to transport the formed fibrous web through the press and the dryer section. The arrangement of dryer rolls is such that the newly formed web is disposed in the upper portion of the hood and has a longer path of travel through the dryer section. The recycled web, which is merely wetted as it passes through the forming chamber, takes a shorter path of travel through the dryer section, which renders the same more efficient.

It will be understood that the particular arrangements shown in Figures 1, 2 and 3 for taking care of the water passing through the forming web may be interchanged as desired. Moreover, the various press arrangements may likewise be interchanged as desired. While the press arrangements and dryer section have particular utility with the forming apparatus shown, it will be apparent that the principles thereof may be readily embodied in conventional apparatus. Recycling of the fibrous web

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in conventional machines would be through the press and dryer section only, however.

It thus will be seen that the objects of this invention have been fully and effectively accomplished. It will be realized, however, that the foregoing specific embodiment has been shown and described only for the purpose of illustrating the principles of this invention and is subject to extensive change without departure from such principles. Therefore, this invention includes all modifications encompassed within the spirit and scope of the following claims.

I claim:

1. A method of making a continuous web of fibrous material which comprises continuously projecting a stock containing liquid and fibers upwardly at an angle to the horizontal of at least of the order of 45° at a rate such that its initial energy is substantially entirely velocity energy, directing the fibers so that their upward movement is continued while allowing a substantial part of the upwardly moving liquid to be progressively halted by the action of gravity and moved downwardly away from the upwardly directed fibers and the stock projection, and continuously removing in a continued upward direction the upwardly directed fibers as a web of fibrous material.

2. A method of forming a continuous web of fibrous material which comprises continuously projecting stock containing liquid and fibers at a predetermined initial velocity and pressure in a direction at an angle to the horizontal at least of the order of 45° to substantially increase the potential energy of the stock fed, substantially maintaining the velocity of the fibers in the general direction of projection while allowing progressive conversion of the velocity energy of a substantial part of the liquid into potential energy, simultaneously confining the fibers during their movement while allowing the potential energy of the liquid to effect a drainage of the liquid through the moving fibers, and continuously removing in the general direction of projection the confined fibers as a web of fibrous material.

3. A method as defined in claim 2 wherein the web formed is subsequently passed upwardly between a pair of cooperating press rolls.

4. A method as defined in claim 3 wherein the web passing through said rolls is subsequently heated and dried by passing the same through a dryer and wherein the dried web is recycled to serve as a moving confining surface during subsequent web formation and a transport during subsequent passage of the newly formed web through said press rolls and said dryer.

5. A method as defined in claim 2 wherein the web formed is utilized as a moving confining surface during subsequent web formation.

6. A method of making a continuous web of fibrous material which comprises continuously feeding stock containing liquid and fibers adjacent a moving foraminous member, effecting removal of a substantial part of the liquid through the foraminous member while depositing the fibers thereon in layer formation, moving the fibers in layer formation along with an adjacent transporting web through cooperating press rolls to express further liquid from the fibers, moving the expressed fibers in layer formation along with the transport web through a dryer section to remove further liquid by heat, separating the dried fibers in layer formation from the transport web, and then utilizing the dried fibers in layer formation as a transport web for movement along with subsequently formed fibers through said press rolls and said dryer section.

7. Apparatus for forming a continuous web of fibrous material comprising means defining an elongated upstanding forming chamber which converges upwardly including spaced rollers and an endless foraminous member trained thereabout having a portion defining one side of said chamber which extends upwardly at an angle to the horizontal at least of the order of 45°, means for pro-

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jecting stock containing liquid and fibers upwardly to the lower end of said chamber at a rate sufficient to fill said chamber so as to effect a drainage of the water through said foraminous member and to deposit the fibers thereon in layer formation, said foraminous member being movable in a direction such that the forming chamber defining portion moves upwardly at generally the same velocity as the velocity of said projection to thereby move the fibers deposited thereon out of said forming chamber.

8. Apparatus as defined in claim 7 wherein said chamber defining means further includes an upwardly travelling backing web defining the side of the forming chamber opposite from said one side.

9. Apparatus as defined in claim 8 wherein said upwardly travelling backing web comprises a web of fibrous material formed in said forming chamber.

10. Apparatus as defined in claim 8 wherein said backing web is backed by a stationary impervious plate presenting a convexly curved surface in engagement with the backing web.

11. Apparatus as defined in claim 7 including a pair of cooperating press rolls rotatable about horizontally spaced axes receiving the web of fibrous material formed in said forming chamber vertically upwardly therethrough so as to express further liquid therefrom.

12. Apparatus for forming a continuous web of fibrous material comprising means defining a substantially vertically extending elongated forming chamber which converges upwardly including a foraminous member having a portion defining one side of said chamber which extends upwardly at an angle to the horizontal at least of the order of 45°, and means at the lower end of said chamber for projecting stock containing liquid and fibers upwardly into said chamber at a rate sufficient to cause the fibers of said stock to deposit on said foraminous member and continue their movement upwardly out of said chamber while the movement of a substantial part of the liquid of said stock is halted by the action of gravity and moved downwardly thereby through said foraminous member.

13. Apparatus as defined in claim 12 wherein said foraminous member comprises an endless wire mesh, the portion of said wire mesh defining said one chamber side being movable upwardly at approximately the same speed as the initial velocity of stock projection into said chamber.

14. Apparatus as defined in claim 12 wherein the means defining the side of said chamber opposite from said foraminous member is impervious to the passage of liquid.

15. In an apparatus for making a continuous web of fibrous material, a forming machine for forming a wet web of fibrous material from stock containing liquid and fibers, cooperating press rolls receiving the wet web of fibrous material therethrough for expressing further liquid therefrom, a dryer section including a plurality of dryer rolls receiving the pressed wet web for effecting still further liquid removal by the application of heat, and means for recycling the web of fibrous material issuing from the dryer rolls so as to provide a transport web for the newly formed web of fibrous material passing through said press rolls and said dryer rolls.

16. Apparatus as defined in claim 15 wherein the dryer rolls are arranged in a series of horizontally spaced upper rolls, a series of horizontally spaced intermediate rolls disposed in vertical alignment with the series of upper rolls, and a series of horizontally spaced lower rolls disposed intermediate the aligned upper and intermediate series, the pressed wet web passing over the series of lower rolls and the series of upper rolls and the recycled web passing over the series of lower rolls and the series of intermediate rolls.

17. Apparatus as defined in claim 15 wherein said forming machine includes an upright forming chamber within which the wet web is formed and issues upwardly

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therefrom, said web recycling means including means for recycling the pressed and dried web through said forming chamber to serve as a backing web therein prior to its passage through said press rolls and said dryer rolls.

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