

March 5, 1963

G. I. TAYLOR ETAL

3,079,990

WET END DRAINAGE SYSTEM FOR PAPER MACHINES

Filed June 18, 1959

4 Sheets-Sheet 1

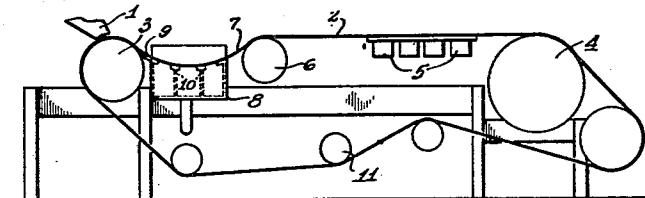


Fig. 1.

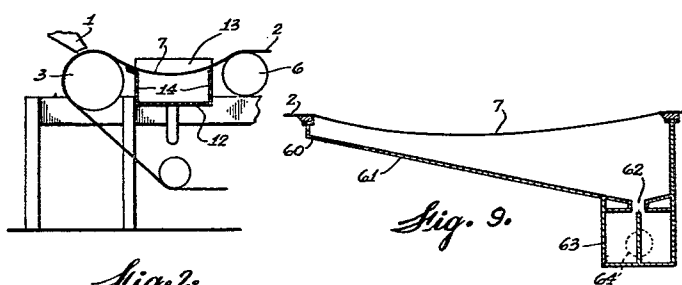


Fig. 2.

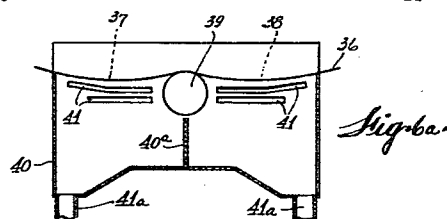


Fig. 3a.

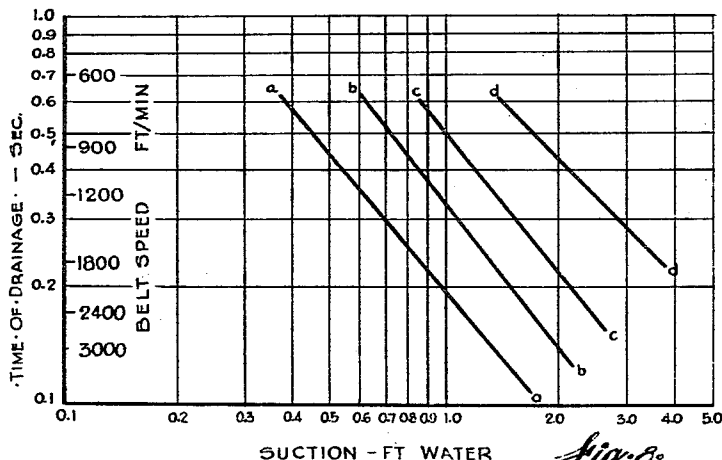


Fig. 8.

DRAINAGE TIME VS. PRESSURE FOR OPERATIONAL UNIT

LINE	DRYNESS % FIBRE	WATER/FIBRE
a-a	5.6	27
b-b	4.0	24
c-c	5.3	18
d-d	6.9	13.5

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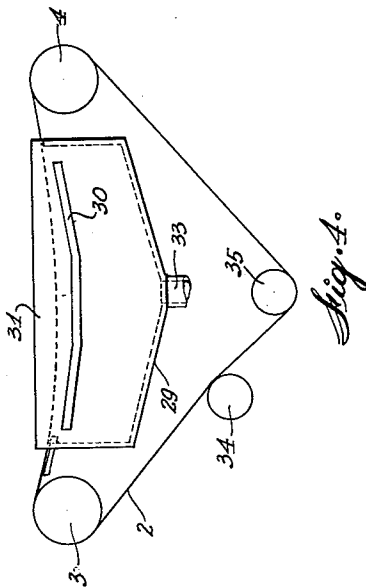
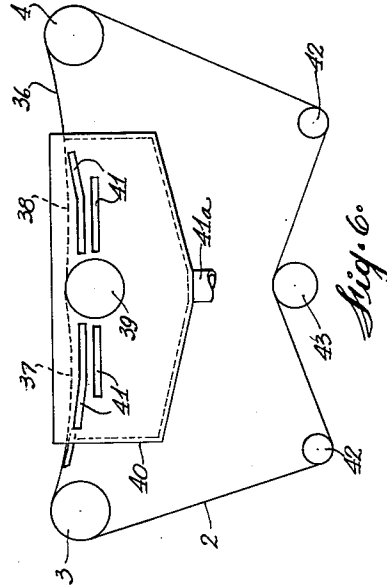
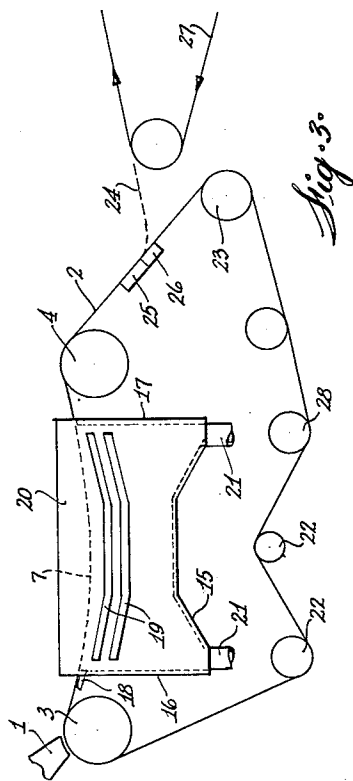
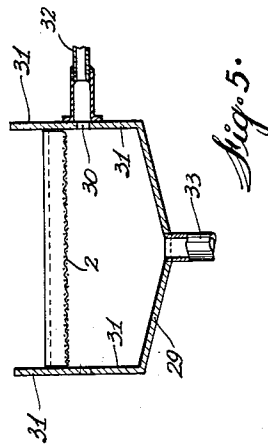
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WET END DRAINAGE SYSTEM FOR PAPER MACHINES

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4 Sheets-Sheet 2



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WET END DRAINAGE SYSTEM FOR PAPER MACHINES

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4 Sheets-Sheet 3

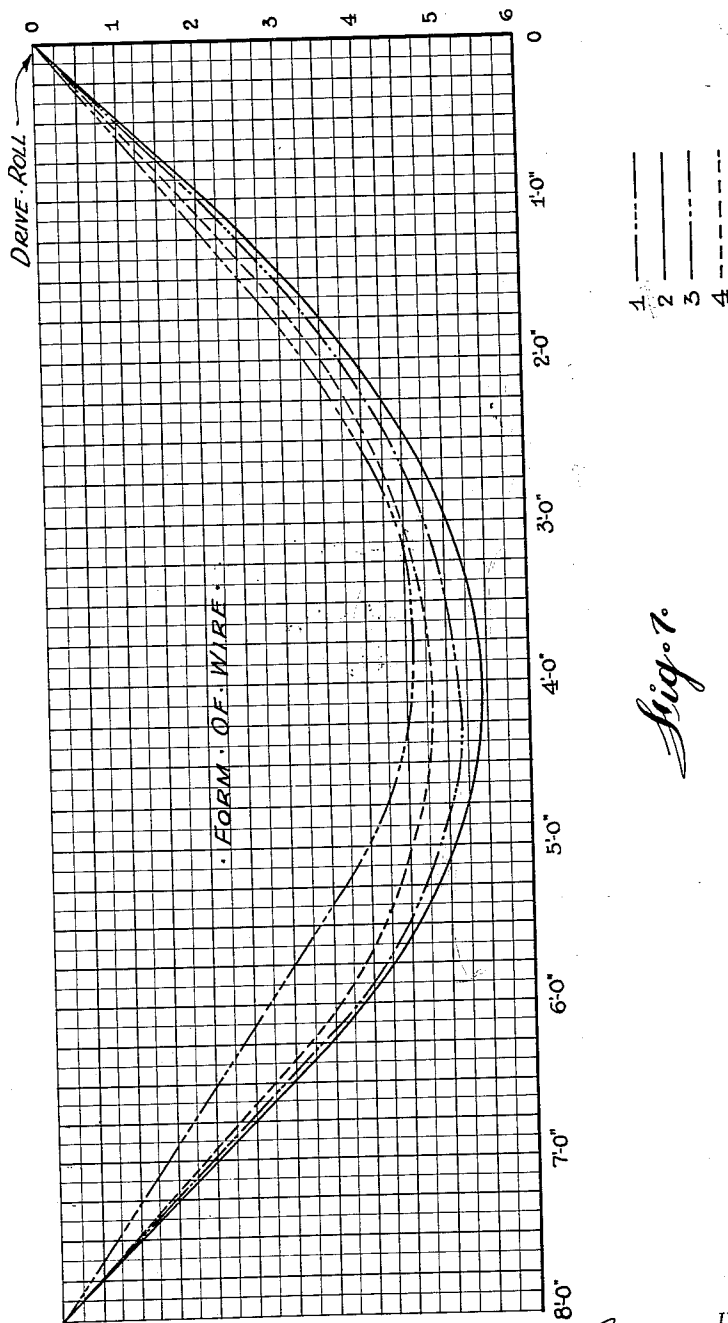


Fig. 1

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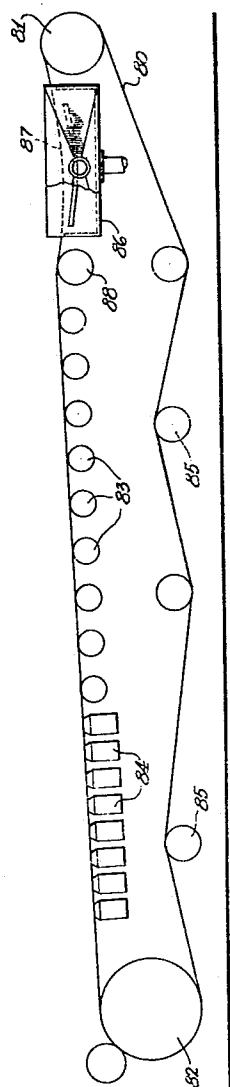
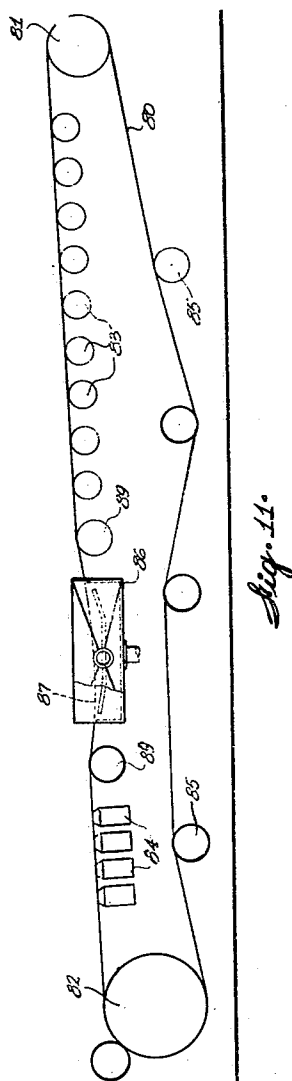
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WET END DRAINAGE SYSTEM FOR PAPER MACHINES

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4 Sheets-Sheet 4



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WET END DRAINAGE SYSTEM FOR PAPER MACHINES

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10 Claims. (Cl. 162-350)

This invention relates to drainage systems for wet ends of paper machines.

This application is a continuation-in-part of applicants' prior copending abandoned application Serial No. 746,195, filed July 2, 1958.

The manner of obtaining drainage of fibre suspensions at the wet ends of paper machines has not changed materially for a great many years. This conventional manner is therefore in widespread and universal use despite the disadvantages thereof.

In the standard paper machine the paper stock or fibre suspension is fed from the head box through a slice onto the wire supported on breast and couch rolls. Between the breast and couch rolls drainage is effected by leading the wire over:

- (1) A plurality of table rolls which usually reduce the water-fibre ratio to from approximately 40 to 1, to 5 to 1, and
- (2) a series of stationary vacuum boxes.

Good papermaking may be defined as the running of the paper machine at high efficiency with the production of paper of desired quality.

For the maximum strength of dry paper consistent with the grade of fibre used, the most uniform dispersion of fibres possible is required, both in the horizontal and in the vertical planes. This is also the criterion for obtaining the maximum wet web strength at any point on the paper machine for a given water:fibre ratio.

This desired distribution of fibres can be obtained initially by the production of a stable and regular slice jet of even pressure entirely across the paper machine. With such a slice jet, large adjustments of the flexible slice lip, which causes longitudinal ridges in the slice jet and subsequent crossing waves on the wire, can be avoided.

Even with this initial desired distribution of suspension, a relatively tremendous disturbance of the same is introduced in its subsequent passage over the table rolls. (See "Investigation of High Speed Paper Machine Drainage Phenomena," G. Burkhard and P. E. Wrist, Pulp and Paper Magazine of Canada, vol. 57, March 1956, pages 100-118; "Flocculation, Formation and Headbox Design," part IV, J. Mardon and N. Shoumatoff, Pulp and Paper Magazine of Canada, vol. 57, February 1956, pages 305-319; and "The Behaviour of Fibre Suspensions on the Paper Machine Wire," J. Mardon, Proceedings of the Symposium on the Flow of Suspensions, National Research Council of Canada, November 1956.)

It is known that this disturbance is dependent to some extent on roll size, wire tension, and speed, and is largely due to the flexion of the wire around the table roll resulting in a combination of centrifugal force and downward acceleration. The higher the speed the greater the disturbance, which, for a given machine, is absent below a certain speed. Qualitative connection has been established between the ease of running the machine and the degree of disturbance of the stock on the wire over the table rolls (see "The Use of High Speed Cinematography in Certain Aspects of Papermaking," K. C. Logan, J. Mardon, A. Easson, R. Petersons and G. Samson, Proceedings of the Technical Section of The British Paper & Board Makers' Association, 1956, vol. 37, part 3, pages

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341-352). However, even at comparatively low speeds, the forces mentioned create a multiplicity of spouts in the liquid suspension with the result that the drops from the tops of the spouts produce cavities and "explosions" when they land.

Thus, to retain the good qualities resulting from the "perfect" slice jet, it is clearly and highly desirable to remove or greatly reduce the disturbance caused by the table rolls.

- 10 It is an object of this invention to provide a simple and effective apparatus for producing drainage at the wet end of a paper machine whereby uniform dispersion of fibres in the liquid suspension is substantially maintained by avoidance of disturbances therein during the drainage period.

It will be apparent that if one were to substitute for the usual table rolls a conventional suction box with a flat top surface defined by the usual well spaced cross bars, the wire will loop between the bars to a degree which will result in unstable and objectionable operation.

The invention contemplates the provision of drainage apparatus including a suction box arranged to receive a substantial portion of the length of the wire, said suction box defining a substantially arcuate path of travel for such portion of the wire, said path of travel having a predetermined radius of curvature whereby it is possible to balance the degree of suction applied to the wire through the box and the tension of the wire without increasing the tension to damaging values and thereby achieve stable operation of the drainage apparatus without substantial disturbance of the liquid suspension under treatment.

The invention will be described with reference to the accompanying drawings, in which

- 35 FIGURES 1 to 4 inclusive, are side elevations, in diagrammatic form, of various embodiments of the invention,

FIGURE 5 is a cross-sectional view of the suction box shown in FIGURE 4,

- 40 FIGURE 6 is a side elevation of still another modification of the invention,

FIGURE 6a illustrates a variation of the modification shown in FIGURE 6,

- 45 FIGURE 7 is a graphical illustration of the form of arcs taken by the wire under varying conditions,

FIGURE 8 is a graph illustrating drainage results achieved by the invention,

- 50 FIGURE 9 is a partial side elevation of still another form of the invention,

FIGURES 10 and 11 are side elevations illustrating diagrammatically, application of apparatus in accordance with the invention to existing types of paper making machines.

- 55 Referring to FIGURE 1, the paper machine shown comprises a slice 1 adapted to deliver paper stock or water-fibre suspension onto a forming wire 2 carried by a breast roll 3, and a couch roll 4. Conventional suction boxes 5 adjacent the couch roll are shown.

A wire-supporting roll 6 is located adjacent the breast roll to provide a wire portion 7 extending from the breast roll to the roll 6. In accordance with the invention, this portion 7 of the forming wire is subjected to suction to remove the major portion of the water in the suspension carried thereby and thus eliminate the need for use of table rolls.

- 65 A suction box 8 is mounted beneath the wire portion 7, such box being located below the normal horizontal plane in which the top surfaces of breast roll 3 and supporting roll 6 lie. With appropriate adjustment of the wire tension, the wire portion 7, under the influence of suction in the suction box 8, will curve downwardly to follow a generally arcuate path. The initial wire supporting board 9 lead-

ing to the suction box from the breast roll, and the wire-engaging cross bars 10 of the suction box, define such arcuate path. Tension of the wire may be adjusted by means of a tension roll 11 engaging the lower travelling portion of the wire.

The apparatus illustrated in FIGURE 2 is substantially the same as that shown in FIGURE 1 except that a suction box 12 is provided which is "surfaceless," i.e., the wire is substantially free of engagement with a surface thereof. Thus, the box has side walls 13 between which the wire portion 7 will loop and end walls 14 of less height than the side walls over which the wire will travel. The wire may engage the top edges of the end walls 14 or be disposed in slight clearance therewith. It is, of course, important that the top edges of end walls 14 be substantially lower than the upper common tangential plane of rolls 3 and 6 to permit unrestricted formation of the arcuate path of travel of the wire. The walls 13 of the suction box are as close as possible to the edges of the wire. It will be apparent that there will be a slight air leak between the wire and the side and end walls 13 and 14 of the suction box, but such air leak is not of significance in the operation of the device.

Referring to FIGURE 3, an arrangement is shown wherein the looped or arcuate portion 7 of the wire 2 occupies substantially the entire upper travelling portion of the wire between the breast roll 3 and couch roll 4. A suction box 15 has its end walls 16 and 17 in close proximity to respective rolls 3 and 4. A wire supporting board 18 leading from the breast roll may be provided. Suction slots 19 are provided in one or both side walls 20 of the head box and suction is thereby imparted to the box from a suitable connection (not shown). Drainage outlets 21 are provided in the bottom of the box. The lower travelling portion of the wire is supported on guide rolls 22. The wire is also directed over a drive roll 23 positioned somewhat forwardly of the couch roll. The paper web 24 is taken off the downwardly inclined portion of the wire between the couch roll and the drive roll 23. A conventional suction box 25 may be provided under the wire just prior to the take-off which may be effected by a blower 26. As shown, the web 24 is then led over the first press felt 27.

Tension of the wire is adjusted by means of a vertically adjustable tension roll 28.

FIGURES 4 and 5 show a modification which is quite similar to that illustrated in FIGURE 3. The suction box 29 has a suction slot 30 in a side wall 31 connected to a source of vacuum by a conduit 32. The suction box has a drainage outlet 33 in its bottom wall. A wire guide roll 34 and a tension adjustment roll 35 are provided.

FIGURE 6 illustrates a modification wherein the entire upper travelling portion of the wire has a main downwardly looped portion 36; to which is imparted two arcuate sections 37 and 38 as by means of a roll 39 in a suction box 40. Suction slots 41 are provided in the suction box below each arcuate section 37 and 38. The suction box has a drainage outlet 41a. The return portion of the wire is provided with guide rolls 42 and a tension adjustment roll 43.

FIGURE 6a illustrates a variation in the modification shown in FIGURE 6 wherein the box 40 is provided with a partition 40a extending to the lower portion of roll 39 and dividing the box into two sections. In this instance, it is possible to vary independently the degree of vacuum in each part.

It will be understood that the dimensional and other operational characteristics of the device will vary in accordance with the required operating circumstances.

By way of example, with a suction box providing a drainage area 3 feet long on a three foot radius of curvature (430 square inches per foot width) and in order to provide drainage equivalent to 15 table rolls, then a suction of 0.89 p.s.i must be applied. In such a case, a wire

tension of approximately 30 lbs. per lineal inch would be needed to maintain equilibrium.

If, however, the maximum average length of nip be taken as being three-quarters inch with corresponding lower maximum and average pressures, then a five foot unit would be needed and the radius of curvature could be greater. This would imply greater wire tension.

It will be appreciated that the suction may be balanced by wire tension. In a suction box having wire supporting surfaces, differences can be taken by friction of the wire on such wire supporting surfaces.

The relationship of the tension of the wire to the frictional pressure drop across the wire and the radius of curvature of the wire may be defined by the equation

$$T = PR \quad (1)$$

where T is the tension of the wire in pounds per foot, P is the frictional pressure drop in pounds per square foot and R is the radius of curvature in feet. It will be apparent that the frictional pressure drop across the wire consists both of the suction applied and that of the centrifugal force dependent upon the radius of curvature. However, it has been determined that the suction caused by the curvature is negligible and thus may be substantially disregarded.

It will also be apparent that the tension will be affected by the velocity of the belt and the layer of stock on top. Because the belt and the stock have mass, a definite force will be required to maintain their motion in a circular path. The magnitude of this pressure is readily shown to be

$$p_i = \frac{\rho_1 U^2}{R} \quad (2)$$

in which

U = the velocity of the belt.

ρ_1 = density per unit length of the belt and stock.

The effect of the stock differs from that of the belt because there will be drainage through the belt and the density ρ_1 will have to be replaced by ρt in which t is the thickness of the stock layer. The total expression for the tension will thus be

$$T = pR + \rho_1 U^2 + \rho t U^2 \quad (3)$$

It can be seen that if the device is run with constant tension the radius of curvature will be specified by Equation 3 and the length of the belt will be automatically adjusted by moving the weight. If, on the other hand, the length of belt is fixed, the radius of curvature and shape of the belt will be determined by the length available. It can be seen that if a very flat curve is specified, the radius of curvature will be large and hence very high tensions will be induced by average pressures. With these ideas, control schemes for starting the device can be readily devised.

It has been determined that the wire will maintain a stable curve in operation. The following table gives results of tests with varying speeds of wire travel:

Wire speed, f.p.m.	Tension applied, lb./in.	Radius of Curvature, ft.	Diff. Pressure, in. water	Tension Computed, $T = pR$, lb./in.
0 to 3,750	10.6	16.0	1.7	11.9
0 to 5,500	10.6	16.1	1.45	10.3
0 to 5,500	17.3	17.9	2.0	15.6
0 to 5,500	21.0	23.5	2.1	21.5

FIGURE 7 illustrates the steady form of wire curve for each of the tests. It will be observed that the equation $T = pR$ is thus substantially correct and constitutes an adequately accurate method of determining the required conditions.

It will be apparent that successful drainage in a construction in accordance with the invention is dependent upon obtaining drainage to the desired dryness with the

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permissible suction in the time allowed by the dimensions of the equipment. FIGURE 8 illustrates the drainage results of tests employing a device of the present invention and using newsprint stock at normal headbox consistency to produce wet newsprint with a basic weight of 30 lbs. per 3000 square feet. These tests indicate that the device is entirely adequate for draining a sheet to dry-line condition.

Whereas the preferred form of the invention resides in the provision of a suction box such as, for instance, shown in FIGURE 3, which is large enough that separation of air and water occurs in the box, the water being pumped out or removed by barometric leg and the air being removed by vacuum pump, it is possible to produce a form of the invention wherein the box is kept almost full and air and water removed by one pump to a separator. Such a form of the invention is shown in FIGURE 9, wherein a shallow box 60 is employed having an inclined bottom wall 61. Bottom wall 61 has a slit 62 leading to a flow spreader box 63, to which suction is applied, preferably from both ends thereof, by pipes 64.

FIGURES 10 and 11 illustrate application of the invention to existing types of paper machines. In each figure, there is indicated, in conventional form, the wire 80, breast roll 81, couch 82, table rolls 83, suction boxes 84 adjacent the couch, and guide rolls 85. In FIGURE 10, a suction box 86 for imparting an arcuate loop 87 to the wire is interposed directly following the breast roll. Thus, the loop extends substantially from the breast roll to a supporting roll 88 adjacent the other end of the box. FIGURE 11 shows the box 86 interposed between the last table roll 83 and the first suction box 84, the loop 87 being supported on rolls 89. It will be understood that the number of table rolls 83 and suction boxes 84 will be adjusted as required by each particular installation.

In each of the modifications of the invention as illustrated, the ends of the curved or arcuate portion of the wire have been shown as disposed in a substantially horizontal plane. It will be understood that, in order to meet certain operational circumstances, it may be necessary to change the orientation of the arcuate portion as a whole with respect to the slice and/or other parts of the paper machine. Thus, the curve forming suction box and supporting roll or rolls may be positioned to tilt the wire curve as a whole whereby its ends lie in a plane which is angular to the horizontal.

It will be understood that the longitudinal extent of the arcuate path of travel of the wire is a substantial portion of the length of the wire. By "substantial portion" as employed in this specification and claims is meant a length of at least several feet.

We claim:

1. In a paper machine having an endless forming wire, rolls supporting said wire, said wire having upper and lower paths of travelling movement, and a slice for delivering liquid suspension onto said wire during said upper path of movement, apparatus for effecting drainage of said suspension comprising, in combination with a pair of said rolls defining therebetween a section of said upper path extending from one to the other of said pair of rolls, a suction box located beneath said section of travel of said wire and having a single uninterrupted suction area extending throughout the major longitudinal extent of said section of travel, said wire having an arcuate portion in its upper path of movement depending between said pair of rolls into said suction area, said arcuate portion of said wire being of uninterrupted contour and having an under surface free from bearing contact throughout said suction area and an unconstrained upper surface freely exposed to atmospheric pressure, means for applying suction to said box to cause formation of said arcuate portion of said wire, and means for applying tension to said wire to adjust the radius of curvature of said arcuate portion.

2. Drainage apparatus as defined in claim 1, said suc-

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tion box having an open top, side walls extending above said upper path of travel, and end walls each having an upper edge disposed below said upper path of travel, said tension applying means comprising a tension roll engaging said wire in its lower path of travel.

3. Drainage apparatus as defined in claim 2, said pair of rolls comprising a breast roll and a couch roll.

4. Drainage apparatus as defined in claim 1, said suction box having side walls extending above said upper path of travel, said arcuate portion of said wire substantially throughout its extent extending transversely from one of said side walls to the other of said side walls, said arcuate portion being freely suspended between said side walls.

5. Drainage apparatus as defined in claim 1, said radius of curvature of said arcuate portion being solely responsive to tension and pressure approximately in accordance with the equation $T=PR$ where T is the tension, P is the frictional pressure drop across the wire in said box, and R is said radius of curvature, whereby a stable configuration of said arcuate portion is obtained at substantially all speeds of travel of said wire.

6. Drainage apparatus as defined in claim 1, said suction box having an open top, upstanding side walls extending above said upper path of travel, and end walls each having an upper edge disposed below said upper path of travel, said arcuate portion of said wire being substantially freely suspended between said side walls of said suction box.

7. In a paper machine having an endless forming wire, rolls supporting said wire, said wire having upper and lower paths of travelling movement, and a slice for delivering liquid suspension onto said wire during said upper path of movement, apparatus for effecting drainage of said suspension comprising, in combination with a pair of said rolls defining therebetween a section of said upper path extending from one to the other of said pair of rolls, a suction box located beneath said section of travel of said wire and having a single uninterrupted suction area extending throughout the major longitudinal extent of said section of travel, said suction box having a wire-engaging roll therein, said wire having a pair of arcuate portions in its upper path of travel each disposed between said last-mentioned roll and one of said pair of rolls and depending into said suction area, means for applying suction to said box to cause formation of said arcuate portions of said wire, and a tension roll engaging said wire in its lower path of travel to adjust the radius of curvature of each said arcuate portion.

8. In a paper machine having an endless forming wire, rolls supporting said wire, said wire having upper and lower paths of travelling movement, and a slice for delivering liquid suspension onto said wire during said upper path of movement, apparatus for effecting drainage of said suspension comprising in combination with a pair of said rolls defining therebetween a section of said upper path extending from one to the other of said pair of rolls, a suction box located beneath said section of travel of said wire and having a single uninterrupted suction area extending throughout the major longitudinal extent of said section of travel, said wire having an arcuate portion in its upper path of movement depending between said pair of rolls into said suction area, said arcuate portion of said wire being of uninterrupted contour and having an under surface free from bearing contact throughout said suction area and an unconstrained upper surface freely exposed to atmospheric pressure, and means for applying suction to said box to cause formation of said arcuate portion of said wire.

9. Drainage apparatus as defined in claim 8, said suction box having upstanding side walls extending above said upper path of travel, said arcuate portion of said wire within said box being substantially unsupported for substantially free movement between said upstanding walls of said box.

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10. In a paper machine having an endless forming wire, rolls supporting said wire, said wire having upper and lower paths of travelling movement, and slice for delivering liquid suspension onto said wire during said upper path of movement, apparatus for effecting drainage of said suspension comprising, in combination with a pair of said rolls defining therebetween a section of said upper path extending from one to the other of said pair of rolls, a suction box located beneath said section of travel of said wire and having a single uninterrupted suction area extending throughout the major longitudinal extent of said section of travel, said wire having an arcuate portion in its upper path of movement depending between said pair of rolls into said suction area, the space above said arcuate portion of said wire below a straight line joining the ends of said arcuate portion being uninterrupted whereby the upper surface of said arcuate portions is unconstrained and freely exposed to atmospheric pressure, said arcuate portion of said wire having an under surface free from bearing contact throughout said suction area, means for applying suction to said box to cause formation of said arcuate portion, and means for

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applying tension to said wire to adjust the radius of curvature of said arcuate portion.

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