# United States Patent [19]

**Friksson et al.**

[11] **3,878,698**

[45] **Apr. 22, 1975**


[54] **APPARATUS FOR FORMING AND WASHING A FIBROUS WEB**


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[73] Assignee: **Aktiebolaget Karlstads Mekaniska Werkstad,** Karlstad, Sweden



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[21] Appl. No.: **434,935**

**Related U.S. Application Data**

[62] Division of Ser. No. 314,164, Dec. 11, 1972, Pat. No. 3,820,452.

[30] **Foreign Application Priority Data**

Dec. 14, 1971 Sweden ..... 16035/71

[52] **U.S. Cl.** ..... **68/22 R;** 68/43; 100/45; 100/75; 100/121

[51] **Int. Cl.** ..... **B05c 3/00;** B30b 9/20

[58] **Field of Search** ..... 100/37, 45, 73, 74, 75, 100/121; 8/156; 210/402, 403, 404; 162/317, 318, 358; 68/22 R, 43, 45, 181 R, 158



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*Assistant Examiner*—Philip R. Coe
*Attorney, Agent, or Firm*—Brumbaugh, Graves, Donohue & Raymond



[57] **ABSTRACT**

A layer of fibrous material is formed from a suspension of the fibrous material in a suspension liquid by introducing the suspension into a web-forming space defined between a member impermeable to the suspension liquid and a member that is permeable to the suspension liquid but substantially impermeable to the fibrous material and that is moved along an endless path. The thickness of the web-forming space diminishes from the upstream end to the downstream end thereof, relative to the direction of movement of the permeable member. As the suspension moves through the web-forming space, liquid drains through the liquid permeable member under the influence of pressure developed by the delivery pressure, coupled with the convergence of the space, thereby producing a fibrous layer in the web-forming space. The fibrous layer is washed by supplying liquid under pressure through a permeable element positioned opposite the permeable member downstream from the web-forming space. The volumetric flow rate of liquid is controlled so that the wash liquid displaces the suspension liquid in the web to a depth that is less than the thickness of the layer. The remaining suspension liquid and a small amount of wash liquid are ultimately displaced from the web in a press nip.


**4 Claims, 2 Drawing Figures**

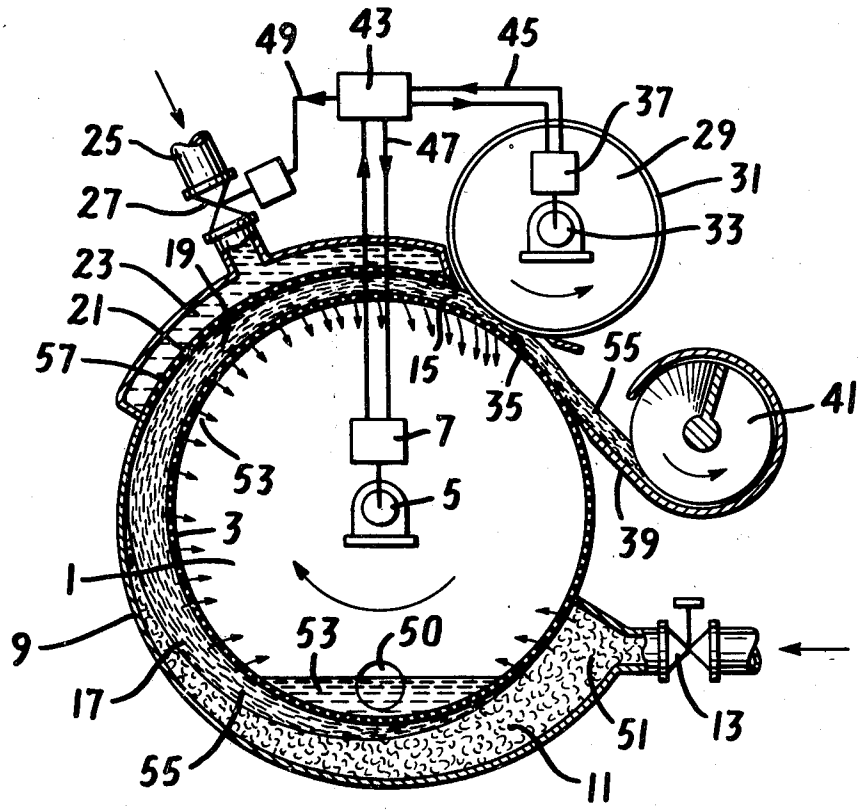


FIG. 1

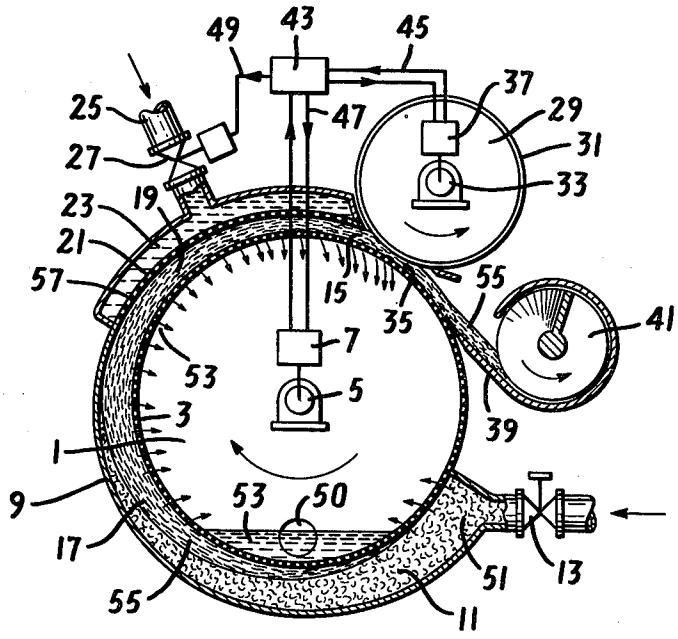
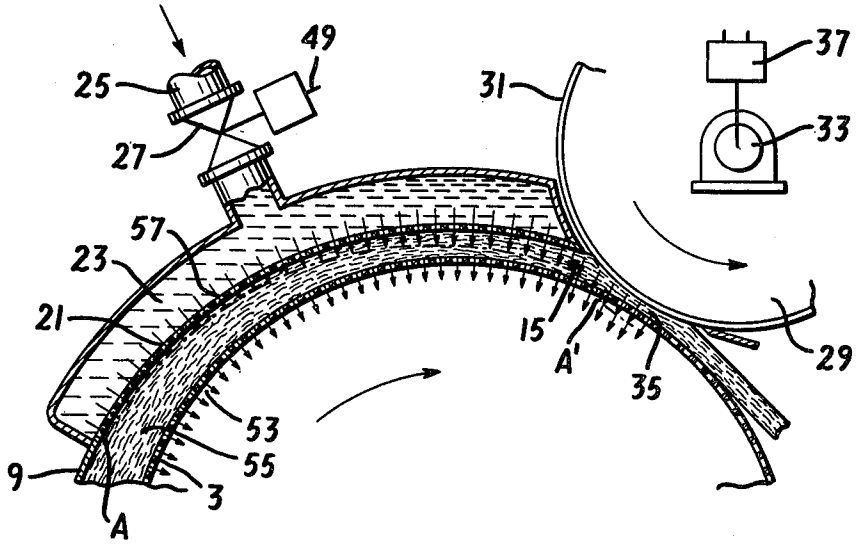

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FIG. 2


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# APPARATUS FOR FORMING AND WASHING A FIBROUS WEB

## BACKGROUND OF THE INVENTION

This is a division, of application Ser. No. 314,164 filed Dec. 11, 1972, and now U.S. Pat. No. 3,820,452.

Cellulose is extracted from cellulosic materials, such as wood, by treating the cellulosic material with certain chemicals in a digester. The chemical digestion process produces a suspension of cellulosic fibers in a suspension liquid that contains various dissolved organic and inorganic substances. After digestion, the cellulosic fibers are separated from the suspension liquid and washed to remove, as effectively as possible, the suspension liquid and the dissolved organic and inorganic substances that it contains. It is desirable to save the suspension liquid rather than discharging it as waste, since some of the chemicals in the suspension liquid can, to advantage, be recovered and reused in the cellulose extraction process. Moreover, some organic substances in the suspension are useful as fuel, and it is at least inappropriate, and it has been made unlawful in many areas, to discharge suspension liquid into water courses, since the suspension liquid contains pollutants.

Various processes for recovering useful substances from the suspension liquid involve evaporation techniques. Accordingly, the quantities of liquids used in the digestion process should be kept as small as possible. Similarly, it is desirable that the washing process be carried out with as little washing liquid as possible, inasmuch as the washing liquid becomes mixed with and dilutes the suspension liquid.

Swedish Pat. No. 318,183 describes apparatus for separating the cellulosic fibrous material produced by a digestion process from the suspension liquid and for washing the cellulosic fibrous material. The apparatus described and illustrated in that patent includes a rotatable drum having a liquid permeable shell and two or more plate or shell-like pressing devices arranged in adjacent relation and defining with the shell a space, the thickness of which diminishes in the direction of rotation of the drum. A liquid permeable wire moves within the pressing elements, and the suspension of fibrous cellulosic material is supplied to the space between the wire loop and the drum at a location adjacent the upstream end of the first pressing element. As the suspension liquid flows through the convergent space defined between the wire and the drum, the liquid drains inwardly through the shell and outwardly through the wire and through the first pressing element, which is perforated or otherwise permeable to liquid, thereby forming a layer of the fibrous cellulosic material in sandwich relation between the shell and wire. The suspension liquid is collected both inside the drum and in a casing outside of the first pressing element and is removed for further processing. Near the end of the forming space between the drum and the wire, the layers of fibrous material formed on the surface of the drum and on the inside of the wire as suspension liquid is drained are combined into a single layer which is conveyed between the wire and the drum into the zone between the second pressing element and the drum.

A second zone, the space between the second pressing element and the drum, is a washing zone, and washing liquid is supplied under pressure through the second pressing element, which is perforated or otherwise liquid permeable, thereby to displace suspension liquid



remaining in the fibrous layer carried between the drum and wire. The fibrous web then leaves the second pressing element and is conducted between the wire and the drum through a press nip in which the fibrous web is pressed to remove washing liquid. The web is then separated from the drum and wire and removed from the apparatus.

An important advantage of the apparatus described and illustrated in Swedish Pat. No. 318,183 is that the fibrous web is maintained in a compressed condition during washing in the washing zone, such pressure resulting from the maintenance by the pressing element of a confined space of predetermined thickness through which the web moves in sandwiched relation between the wire and drum. Accordingly, after washing the fibrous web has relatively low liquid content, and both lumen liquid and volumes of liquid present in the spaces between the fibers of the cellulosic material participate in the displacement of suspension liquid by washing liquid. Accordingly, excellent washing is obtained.

## SUMMARY OF THE INVENTION

The present invention relates to an improvement of the apparatus described and illustrated in Swedish Pat. No. 318,183 and similar apparatus. More particularly, the apparatus of that patent is normally operated with washing liquid supplied under high pressure in the washing zone. Consequently, the washing liquid tends to penetrate entirely through the web along the major part of the length of the washing zone. As a result, a relatively large quantity of washing liquid is required.

In accordance with the present invention, the rate of supply of washing liquid and the pressure under which it is supplied are controlled so that the washing liquid does not at any point along the washing zone pass entirely through the layer of fibrous material but displaces the suspension liquid only to a controlled thickness or depth less than the total thickness of the web. Thus, while the apparatus of the present invention retains the advantages of the apparatus described in the Swedish Pat. No. 318,183, it provides the additional advantage of enabling washing to be accomplished with a substantially smaller amount of washing liquid. The apparatus of the present invention also embodies certain other modifications of the apparatus described in the aforementioned Swedish patent. The present invention also provides a method for separating fibrous material from a suspension liquid and for washing the fibrous material, as described more fully hereinafter.

More particularly, the apparatus, according to the invention, includes a member that is permeable to liquids and substantially impermeable to the fibrous material and is movable along an endless path. A member positioned opposite the permeable member defines with the permeable member a layer-forming space, the thickness of which diminishes from the upstream end of the space to the downstream end, relative to the direction of movement of the permeable member. The suspension of fibrous material is supplied to the upstream end of the forming space. A liquid permeable element positioned opposite a portion of the permeable member immediately downstream from the downstream end of the layer-forming space defines with the permeable member a washing zone, and wash liquid is supplied under pressure through the permeable element to the washing zone. A press roll located down-

stream from the downstream end of the washing zone forms a press nip with the permeable member.

With the apparatus, as described thus far, the suspension liquid supplied to the layer-forming space is drained through the permeable member to form a layer, the drainage being a result of forcing the fibrous suspension through the layer-forming space as a result of the diminishing of the thickness of the space and the consequent forced pressure drainage of liquid through the permeable member. The layer of material (or fibrous web) leaving the forming space passes through the wash zone where wash liquid is displaced into it and displaces suspension liquid.

In accordance with the invention, the volumetric flow rate of washing liquid supplied to the washing zone is controlled in accordance with the quantitative flow rate of fibrous material through the washing zone. Such control is indirect in the sense that it is obtained by monitoring and controlling other aspects of the operation of the equipment to ensure that the washed and pressed layer of fibrous material leaving the press nip is of substantially uniform dryness and thickness. Uniformity of dryness and thickness of the web upon leaving the press nip is obtained if the linear pressure in the press nip and the thickness of the press nip are maintained constant. Under these conditions of uniform dry content and thickness, it is readily possible to compute the quantity of washing liquid to obtain a desired degree of displacement of the washing liquid into the fibrous web.

Preferably, the volumetric flow rate of wash liquid is controlled so that the wash liquid displaces the suspension liquid from the fibrous layer to a depth at the end of the washing zone of the apparatus that is less than the total thickness of the layer at the end of the washing zone. In other words, the volumetric flow rate of wash liquid is established to provide only partial displacement of the suspension liquid so that the wash liquid does not flow entirely through the fibrous layer at any point in the washing zone. Displacement of all of the suspension liquid from the layer, together with a small displacement of washing liquid from the layer is obtained in the press nip, the thickness of the press nip being a value that is less than the depth to which wash liquid penetrates into the web and displaces suspension liquid from the layer in the washing zone.

Maintenance of the desired washing effect, as described above, can be obtained by providing in the first instance a constant nip thickness between the press roll and the permeable member that carries the fibrous layer through the nip. A constant pressure in the nip so that the dryness of the layer as it leaves the nip is constant can be maintained by either controlling the speed of movement of the permeable member or controlling the volumetric rate at which fibrous suspension is supplied to the forming zone of the apparatus or by a combination of controlling the speed of movement of the permeable member and the rate of supply of fibrous suspension. For example, if fibrous suspension is supplied at a constant rate to the apparatus, but the permeable member moves at a variable speed, the amount of fibrous material conducted through the nip per unit time is varied in accordance with the speed of movement of the permeable member. The amount of material per unit time moving through the nip directly influences the pressure in the nip.

The volumetric rate of flow of wash liquid in the washing zone is controlled in accordance with the volumetric rate of flow of the fibrous layer through the apparatus. Inasmuch as small variations will occur in the amount of fibrous material in the layer and thus the nip pressure will vary by small amounts from time to time, it is preferable that the wash liquid supply be varied in accordance with variations in the nip pressure. For example, indirect control of wash liquid supply in accordance with nip pressure is conveniently obtainable by monitoring either the speed of movement of the permeable member or the volumetric rate of flow of fibrous suspension to the layer-forming zone or both.

Thus, the method and apparatus according to the invention, involve using a minimum amount of wash liquid only partially to displace the suspension liquid from the layer in the washing zone. Complete displacement of the washing liquid occurs in the press nip, the press nip having a thickness no greater than the depth to which wash liquid is displaced into the layer in the washing zone, thereby ensuring that the remaining suspension liquid is displaced from the layer at the press nip. The invention ensures the maintenance of an appropriate volumetric rate of flow of wash liquid into the fibrous layer and the production of a washed and pressed layer of fibrous material of substantially uniform thickness, homogenous structure and a high dry content. The displacement of suspension liquid from the layer in the washing zone is obtained with a minimum of pressure difference across the layer so that disruption of the fibrous structure is held to a minimum. The layer reaches the washing zone at the end of the forming zone at a relatively high dry content, thereby minimizing the quantity of washing liquid required to attain a desired washing effect. A uniform washing effect is assured, because the ratio of the volume of washing liquid supplied to the layer and the dry content of the web as it leaves the press nip are maintained constant.

Further features of the invention and the advantages provided by the invention may be better understood by reference to the following description of an exemplary embodiment, taken in conjunction with the figures of the accompanying drawings.

## DESCRIPTION OF THE DRAWINGS

FIG. 1 is a generally schematic side-elevational view of an embodiment of the apparatus of the invention and depicting a method according to the invention; and

FIG. 2 is a side view of the washing zone and press nip of the apparatus of FIG. 1 illustrating the progress of wash liquid displacement of suspension liquid as the layer progresses through the wash zone and the press nip, the view being on a larger scale than FIG. 1.

## DESCRIPTION OF EXEMPLARY EMBODIMENT

In the embodiment of the invention illustrated in the drawings, the permeable member that is moved along an endless path is in the form of a rotatable drum 1 having a shell 3 that is permeable to the suspension and wash liquids but substantially impermeable to the fibrous material. The drum 1 is mounted for rotation in journals 5 and is driven by an appropriate drive system that includes a variable speed drive 7. A shell or casing 9 that extends around a large portion of the drum surface includes a portion that is impermeable and defines a closed layer-forming space, the thickness of which, as

measured in the radial direction relative to the shell, diminishes from the upstream end to its downstream end, relative to the direction of rotation of the shell (which direction is clockwise in the figures of the drawings, as indicated by the arrows).

The fibrous suspension to be formed into a layer and washed in the apparatus is delivered at the upstream end of the forming space **11**, the supply apparatus being of a construction such that a substantially uniform flow of suspension is supplied along the whole length of the upstream end of the forming zone **11**. One or more controllable valves or gates **13** is provided to enable the volumetric flow rate of the fibrous suspension to the forming zone to be controlled.

A perforated or otherwise liquid permeable portion of the shell **9** extends from the downstream end of the impermeable portion and defines with the zone of the drum surface over which it extends a washing zone **19**. Preferably, the thickness of the washing zone (measured radially of the drum) diminishes in the downstream direction and terminates at the downstream end in a slot or opening **15** of substantially uniform thickness. A casing **23** associated with the permeable portion of the shell forms a chamber for the supply of wash liquid to the washing zone **19**, and wash liquid is conducted from a supply **25** through one or more variable flow control valves **27** of the type that enables the volumetric flow rate of wash liquid to the washing zone **19** to be controlled. The wash liquid passes from the chamber through perforations **21** into the web.

A rotatable press roll **29** located immediately downstream from the downstream end of the washing zone **19** defines with the drum surface a press nip **35**, the surface or shell **31** of the press roll being liquid-impermeable. The press roll **19** is mounted in journals **33**, preferably in the same machine framework as the journals for the drum **1**, so that the thickness of the press nip may be maintained substantially constant during operation. A pressure monitor **37** for continuously monitoring the pressure in the press nip **35**, such as a strain gauge type of pressure measuring instrument, is associated with the press roll journals **33** and produces a signal indicative of the linear pressure in the press nip **35**. Apparatus for removing the web of fibrous material after it leaves the press nip is provided, such apparatus including a doctor blade **39** and a combined feeding and shredding screw **41**.

The operation of the apparatus of the invention is controlled by a control system comprising a controller **43** that is connected by control signal conductors **45**, 47 and **49** to, respectively, the press roll pressure monitor **37**, the speed control device **7** and the controllable valve or valves **27** associated with the washing liquid supply system. The specific type and construction of the components of the control system and the system as a whole may be selected, as a matter of ordinary engineering skill, by one skilled in the art from a variety of known electrical, hydraulic, pneumatic or mechanical components and systems that are well known per se.

The above-described apparatus operates in the following manner. A suspension of fibrous material is supplied at a constant amount per unit of time, i.e., constant flow rate, under pressure to the upstream end of the web-forming zone **17** constituted by the space **11**, the valve or valves **13** being appropriately set to provide the desired flow rate. The drum **1** is rotated at a substantially constant speed of a desired, appropriate value. The pressure of the fibrous suspension delivered to the forming space is above the pressure within the drum, and consequently suspension liquid **53** passes through the liquid permeable shell **3** of the drum and is removed from within the drum through an outlet **50**. A fibrous web **55** is progressively formed as drainage of liquid through the permeable shell occurs throughout the web-forming space **17**. In particular, as illustrated schematically in FIG. **1** of the drawings, the thickness of the fibrous web gradually increases as the web moves with the rotating drum through the web-forming space until the thickness of the web is equal to the thickness of the space between the shell **3** and the casing **9** and thus fills the space. After the web builds to the thickness equal to the thickness of the forming space, it is thereafter subjected to mechanical compression as it continues to move with the rotating drum through the downstream end portion of the web-forming space and through the washing zone **19**. Liquid continues to drain from the web due to the mechanical pressure, but the pressure is maintained by the convergence of the casing **9** toward the shell **3** of the drum.

As the fibrous web **55** moves through the washing zone **19** of the apparatus, washing liquid **57** is delivered at a generally constant but controlled quantity per unit of time, i.e., volumetric flow rate, under pressure into the chamber **23** and passes through the perforations **21** in the perforated portion of the casing and flows into the fibrous web. The flow of washing liquid under pressure into the web displaces suspension liquid **53** remaining in the fibrous web to a degree that is a function of the flow rate of liquid into the web. As illustrated in FIG. **2**, such displacement occurs continuously and progressively as the web **55** moves through the washing zone, the degree or level of penetration of washing liquid into the web and consequent displacement of suspension liquid from the web depicted by the line AA'. In other words, above the line AA' in FIG. **2**, washing liquid has displaced suspension liquid from the web, while below the line AA' in FIG. **2**, suspension liquid remains in the web, washing liquid having not penetrated into the web below the line AA'.

The web passes from the washing zone into the press nip **35** where it is pressed to a thickness substantially less than its thickness as it left the washing zone through the opening or slot **15** at the downstream end of the washing zone. Preferably, the pressure in the press nip is such as to produce a web that leaves the press nip with a dryness of in the range of from **30** to **70%**. Inasmuch as the shell **31** of the press roll **29** is liquid impermeable, all drainage occurring in the press nip is through the shell **3** of the drum **1**. Consequently, the first fraction of the liquid content of the web to drain through the shell **3** is the suspension liquid **53** that remains in the fibrous web **55** as it leaves the washing zone. Subsequently a part of the washing liquid **57** is also pressed from the web and through the permeable shell **3**. It is evident from the foregoing, and also from a consideration of FIG. **2** of the drawings that the only place in the apparatus where wash liquid actually is drained or pressed from the fibrous web is in the press nip. Preferably the amount of washing liquid removed from the web at the press nip is kept to a minimum, thereby to minimize the amount of washing liquid required in the processing and thus to limit the amount of liquid ultimately to be treated for recovery of valu-

able chemicals and to condition it for discharge from the system.

The maintenance of a flow rate of wash liquid into the washing zone to produce a desired profile in the extent of displacement of wash liquid to the level approximating the line AA' in FIG. 2 of the drawings requires coordinating several variables employing the control system of the apparatus, such variables including the linear pressure in the press nip **35**, the speed of rotation of the drum **1** and the flow rate of washing liquid **57** into the casing. Preferably, the thickness of the press nip **35** and the rate of supply of fibrous suspension **51** are maintained essentially constant. Appropriate control devices known per se and not shown in the figures of the drawings are employed to maintain a constant press nip thickness and a constant flow rate of fibrous suspension to the apparatus.

The pressure monitor **37** associated with the press roll continuously produces signals indicative of the actual value of the linear pressure in the press nip **35**, and those signals are conducted to the controller **43** through conductors **45**. The controller includes a device for generating a signal indicative of a known, desired pressure value, which is hereafter referred to as a "set point value." The controller further includes a device or devices for continuously monitoring, and for detecting any difference between, the actual value of linear pressure derived from the pressure monitor and the set point value. Upon detecting a difference between the actual linear pressure and the set point value, the control unit produces a signal indicative of such difference, and such signal is processed and conducted as a correction signal to the speed control device **7** of the drum **1**. The correction signal conducted to the speed control device **7** is such that when the linear pressure drops below the set point value in the controller, the speed of the drum will be reduced, thereby slowing the movement of the drum, allowing a thicker web to form for a given supply of fibrous suspension, and ultimately increasing nip pressure. Conversely, if the correction signal is indicative of an actual linear pressure in the press nip above the set point value, the speed of the drum **1** is increased, with an effect that is the reverse of the one just referred to for a decrease in drum speed.

The controller **43** also produces a control signal that is a function of the actual value of the speed of the drum, as monitored by a monitor portion of the speed control element **7**, and transmits that signal to the servo-controlled valve or valves **27**. The servo-valve adjusts the flow rate of washing liquid to the washing zone of the apparatus in accordance with the flow rate of fibrous material carried by the drum through the washing zone.

The above-described embodiment of the invention is intended to be merely exemplary, and many variations and modifications of it will be readily apparent to those skilled in the art without departing from the spirit and scope of the invention. All such variations and modifications are intended to be included within the scope of the invention as defined in the appended claims.

We claim:

**1.** In apparatus for forming a layer of fibrous material from a suspension of the fibrous material in a suspension liquid and for washing the layer with a wash liquid, the apparatus including a member permeable to the liquids and substantially impermeable to the fibrous material, means for moving the permeable member along an endless path, a member positioned opposite the permeable member and defining with the permeable member a layer-forming space the thickness of which diminishes from the upstream end of such space to the downstream end, relative to the direction of movement of the permeable member, means for supplying the suspension of fibrous material to the upstream end of the forming space, a liquid permeable element positioned opposite a portion of the permeable member immediately downstream from the downstream end of the layer-forming space and defining with the permeable member a washing zone, means for supplying washing liquid under pressure through the permeable element to the washing zone, and a press roll positioned opposite the permeable member and defining therewith a press nip adjacent the downstream end of the washing zone, the improvement comprising means for monitoring the pressure in the layer of fibrous material at the press nip and producing a nip-pressure signal indicative thereof, means for varying the volumetric rate of flow of fibrous material through the nip and for producing a rate signal indicative thereof, and means for controlling the volumetric flow rate of washing liquid to the washing zone in response to said rate signal.

**2.** The improvement according to claim **1** wherein the means for controlling the supply of wash liquid is responsive to said rate signal to supply wash liquid at a volumetric flow rate such that the wash liquid displaces suspension liquid from the fibrous layer to a depth A adjacent the downstream end of the washing zone less than the total thickness of the layer adjacent the downstream end of the washing zone, and wherein the thickness B of the nip is less than said depth A.

**3.** The improvement according to claim **1** wherein the means for varying the volumetric flow rate of fibrous material through the nip includes means for varying the speed of movement of the permeable member, and wherein the means for supplying the suspension of fibrous material supplies the suspension at a substantially constant rate.

**4.** The improvement according to claim **1** wherein the means for controlling the volumetric rate of flow of fibrous material through the nip includes means for varying the rate of supply of fibrous suspension to the layer-forming space, and wherein the means for moving the permeable member moves the member at a substantially constant speed.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,878,698 Dated April 22, 1975

Inventor(s) Erik Sture Eriksson; Gosta Ingemar Ingemarsson

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

Item [75] Inventors: "Erik Sture Friksson;" should be
-- Erik Sture Eriksson;--

Signed and Sealed this

*sixteenth* Day of *September 1975*

[SEAL]

*Attest:*

**RUTH C. MASON**
*Attesting Officer*

**C. MARSHALL DANN**
*Commissioner of Patents and Trademarks*