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Poulsen

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[54] **METHOD AND APPARATUS FOR CONTINUOUSLY MEASURING THE POROSITY OF A MOVING WET POROUS CONTINUOUS SHEET**

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[51] **Int. Cl.** **G01m 3/02,** G01b 13/00

[58] **Field of Search** 73/38, 37.7, 37.6, 73/73, 37.5

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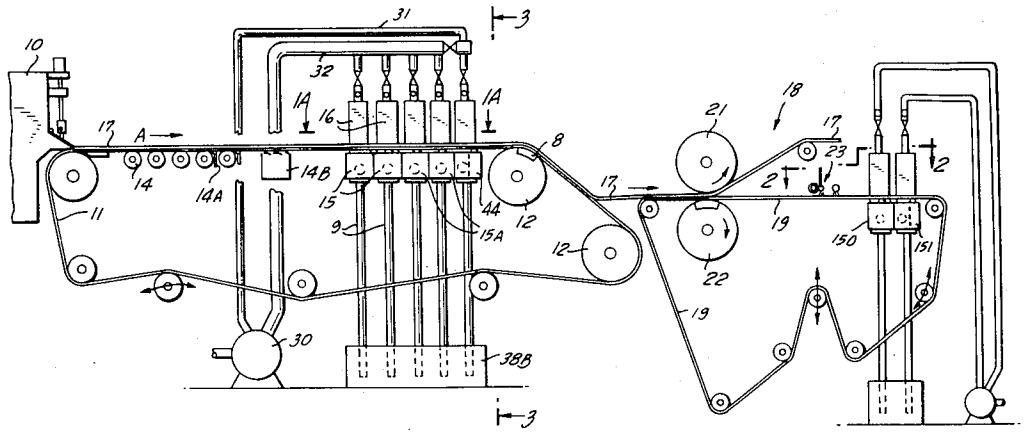
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Assistant Examiner—Daniel M. Yasich
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[57] **ABSTRACT**

Method and apparatus for continuously measuring the porosity of a moving wet porous continuous sheet by removing water from the sheet by a first uniform application of a pressure differential across the sheet through a suction slice having a uniform opening extending in a direction generally perpendicular to the direction of sheet movement. Subsequently, the moving sheet is subjected to a second uniform application of a pressure differential across the sheet in a direction generally perpendicular to the direction of the sheet movement. The flow of water and air created by the second pressure differential is passed into a measuring box through a measuring slice having a uniform opening extending across the sheet in a direction generally perpendicular to the direction of movement of the sheet. The air is expanded as it passes through a measuring slice and the velocity of the air and water is lowered and the air is separated from the water droplets. Changes in the flow of the air passed through the measuring slice is measured.

18 Claims, 10 Drawing Figures



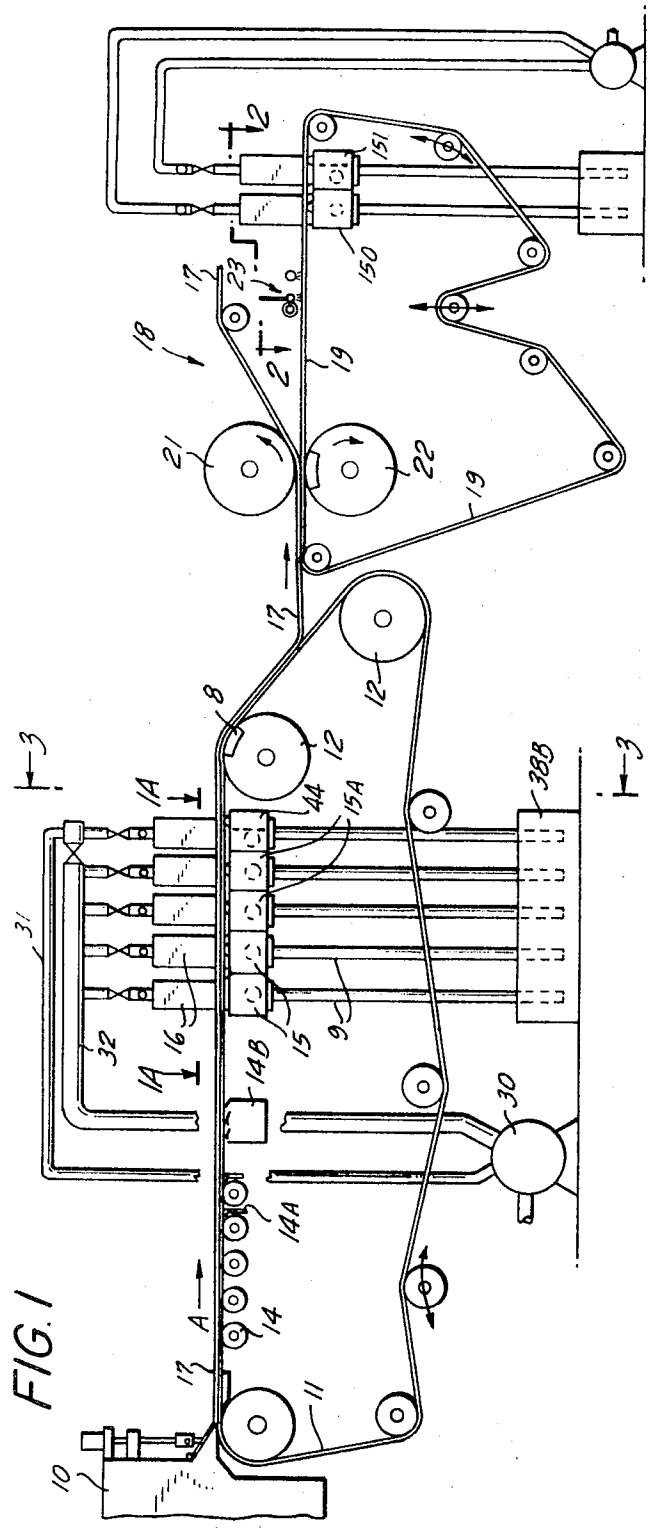


FIG. 1

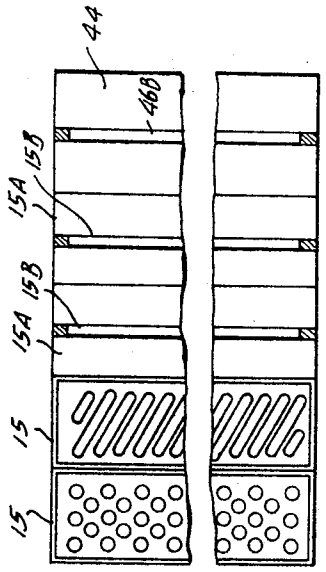


FIG. 1A

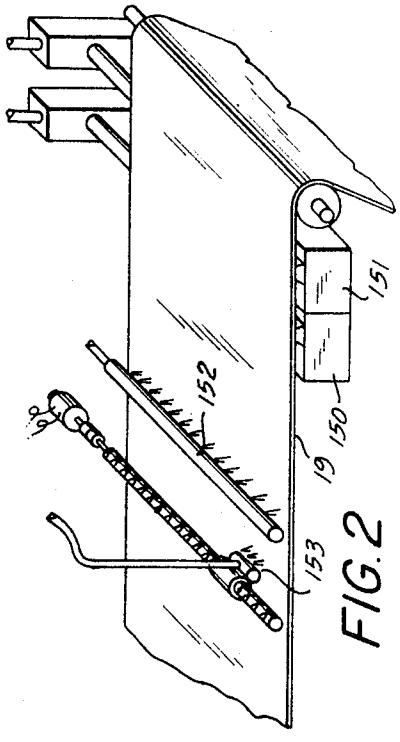


FIG. 2

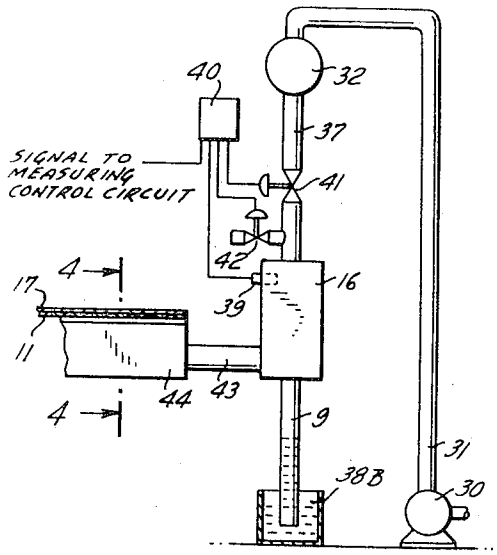


FIG.3

FIG.6

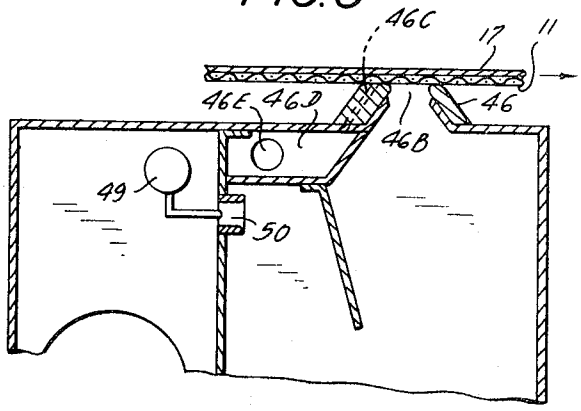
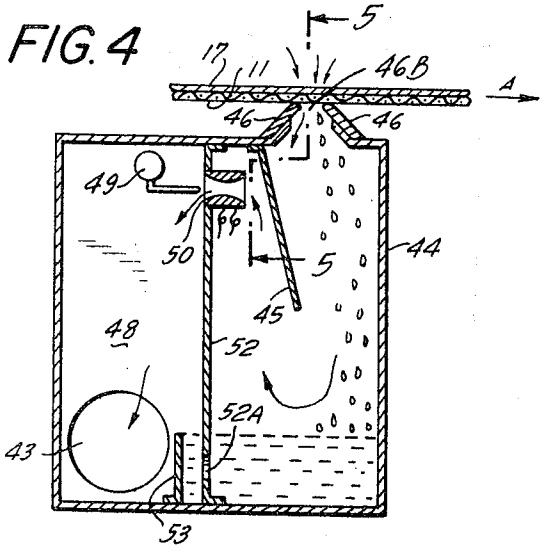


FIG.4



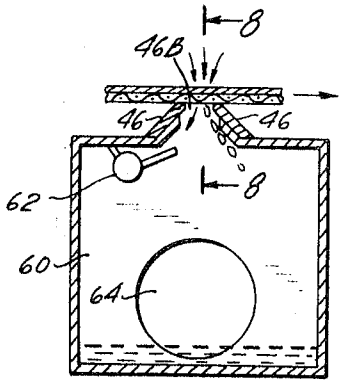


FIG.7

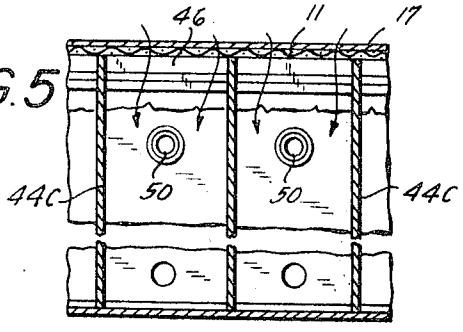


FIG.5

FIG. 8

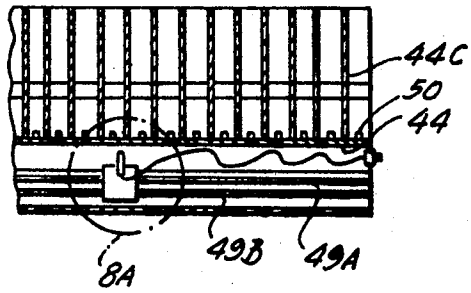
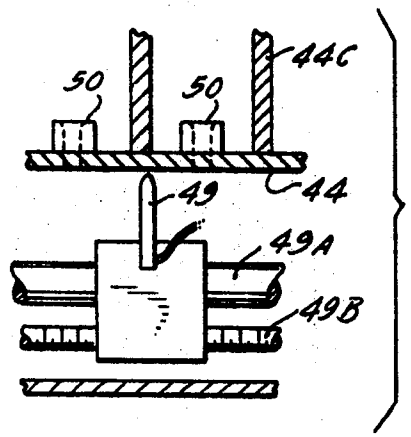


FIG. 8A



METHOD AND APPARATUS FOR CONTINUOUSLY MEASURING THE POROSITY OF A MOVING WET POROUS CONTINUOUS SHEET

BACKGROUND OF THE INVENTION

The present invention relates to measuring apparatus and methods and more particularly to the measuring of the permeability of fibrous material during a manufacturing process. The apparatus and method measures air flow through a moving porous woven or non-woven fabric, fiber mat, felt or sheet to indicate its uniformity or non-uniformity or variations from pre-recorded measurements and particularly as related to the paper industry.

Generally in the paper making process, a slurry or stock of water, fibers and often additives are deposited on an endless moving belt or belts of woven wire, fabric or felt. Water, some fiber fines and possibly additives forming a solution called white water, will drain through the wiremesh by forces created by natural gravity, by vacuum created by pumps or blowers and by centrifugal force. Often white water is removed by vacuum created by rotating rolls below the wiremesh.

When as much water has been removed from the stock or sheet as found practical by gravity and vacuum, further water removal is usually done by pressing. The sheet is passed between a loaded roll nip with a felt, fabric, or similar material which can receive and absorb the water from the sheet as it passes through the press nip. One or more such dewatering steps can be utilized. Further water removal is usually done by evaporation.

It has been recognized that it is highly desirable to produce a paper of uniform and consistent thickness or basis weight exactly meeting the buyer's specifications. Paper that is too thick wastes fiber, paper that is too thin does not meet specifications and is rejected; and non-uniform paper may be unacceptable as being too thin in some areas and too thick in others. The basis weight of the sheet can be controlled, for example, by varying slurry consistency or other variables in the paper making process.

There has been a problem in the paper industry of measuring uniformity of the paper transversely across the uncompacted sheet, i.e., in the cross machine direction while the machine is running at high speed. In addition there has been the related problem of measuring the uniformity of the sheet in the longitudinal or machine direction while the machine is running at a high speed. Similar problems exist in the press section for measuring the uniformity of the felt belt across its width while the belt is running.

The apparatus and method of the present invention makes a continuous measurement of the air permeability of the material through which air is drawn by indicating actual differences in quantity of air flow under constant pressure differential. There presently exist some instruments or indicators which in a crude way may relate to air permeability measurements. However, these devices are based on an average measurement across the full width of the machine or relate to pressure drop measurements across the sheet and, as such, do not indicate any cross-machine variations. Another type of measuring device in common use is the Canadian Standard Freeness Tester which makes an off the machine measurement.

Other devices make measurements at the dry end of the machine and usually consist of a single cross-machine traveling measuring device which senses variations either by measurements of resistance, inductance, capacitance, infra-red, light beam, or similar high frequency rays. None of these devices are suitable for location at the wet end of the machine and therefore provide a time delay between the forming of the sheet and the measuring of the sheet. Consequently much paper or board can be wasted from time of detection until correctional measures can be taken. While many of these measuring devices give measurements related to basis weight, none will indicate variations in the formation of the fiber mat or sheet since none of the existing instruments measure air permeability continuously across the machine by measurement of air flow under constant pressure differential.

Paper basis weight or belt porosity, it is believed, in practical terms is directly related to the measurement of sheet or felt permeability. Accordingly air permeability measurement will indicate variations in basis weight or belt porosity. Air permeability is defined as the amount of air passing through a porous media of a given area at a given pressure differential. Thus, in paper making machines where a slurry white water, long and short fibers and probably additives are distributed uniformly across the wire, with the application of uniform vacuum drainage prior to measurement, a variation in air permeability across the wire therefore will be related to variation in basis weight of the sheet formed on the wire.

The measuring apparatus and method of the invention is not limited in its application to paper making machinery described above but can be readily used with cylinder type machine operations, batch formers, wedge formers, as well as dry formers. Also, the invention may be used on machines making high bulk sheets where no conventional pressing is done, as well as machines using natural fibers, man-made fibers, woven, non-woven, needled, or other types of permeable sheet material. The felts or fabric can be of the woven and/or non-woven or needle types. The apparatus and method of this invention are particularly applicable to measurement of moving wet sheets or felts on paper making machines. However, this invention is equally useful and adaptable to other applications where air permeability measurements can be useful.

OBJECTS OF THE INVENTION

It is an object of the present invention to provide a measuring apparatus and method for continuously measuring variations in air flow through a wet porous medium after the application of uniform vacuum drainage.

It is another object of the invention to provide such an apparatus and method that indicates porosity variations of a wet sheet in a cross-machine or transverse direction on a paper machine's forming section.

A further object of the invention is to provide such an apparatus and method that indicates machine directional porosity variations on the paper machine's forming section.

Another object of the invention is to provide such an apparatus and method that provides prior readings, to obtain a given basis weight at the start-up of the paper machine.

Another object of the invention is to provide such an apparatus and method for indicating variations in furnish composition, additives, fiber treatment, and how the fibers are compacting on the paper machine forming section.

Another object of the invention is to provide such an apparatus and method of indicating machine directional and cross-machine directional variation in air permeability of wet felts and/or fabrics in the paper machine's Press Section.

Another object of this invention is to provide such an apparatus and method that is relatively inexpensive and may be readily adapted for use with existing paper machinery.

BRIEF SUMMARY OF THE INVENTION

It has now been found that the foregoing objects and other advantages can be attained in a method for continuously measuring the porosity of a moving wet porous continuous sheet. Advantageously water is removed from the sheet by a first uniform application of a pressure differential across the sheet through a suction slice having a uniform opening extending in a direction generally perpendicular to the direction of sheet movement. Subsequently, the moving sheet is subjected to a second uniform application of a pressure differential across the sheet in a direction generally perpendicular to the direction of the sheet movement. The flow of water and air created by the second pressure differential is passed into a measuring box through a measuring slice having a uniform opening extending across the sheet in a direction generally perpendicular to the direction of the movement of the sheet. The air is expanded as it passes through a measuring slice and the velocity of the air and water is lowered to below 1,500 feet per minute and the air is separated from the water droplets. Changes in the flow of the air pass through the measuring slice are measured as an indication of the uniformity of the sheet porosity.

In order to separate the air and water rapidly, desirably the suction slice and measuring slice have a diverging opening. The measurement of the changes in the flow of air through the measuring slice may take place at a point adjacent to measuring slice on the upstream side thereof when the second pressure differential applied is below 2 inches of mercury.

Desirably the flow of air in the measuring box is passed through an orifice in the side of the measuring box at a velocity below 15,000 feet per minute and the changes in the flow of the air through the orifice measured. In addition, the flow of air and water passed through the measuring slice may be first directed downwardly and then the flow of air reversed to a generally upward direction before the separated air passes out through the orifice for measurement.

When the method is used for measuring the porosity of a moving wet porous continuous uncompacted fiber sheet being formed on the forming section of a paper making machine advantageously a dry line is created on the sheet at the special suction slice. A plurality of suction boxes each having a diverging slice with a uniform opening extending generally perpendicular to the direction of sheet movement may be used prior to the measuring box.

On the Forming Section of a conventional Fourdrinier type paper making machine, the flow of stock formed on a wire flows over cross-machine directional suction boxes. These suction boxes are installed beneath the wire or fabric mesh to receive flow of the water being removed from the sheet-fabric or sheet-wire sandwich by the application of a vacuum. The purpose of these suction boxes are to remove excessive amounts of water from the sheet-wire sandwich. Advantageously this invention provides a special type suction box slice, which can replace or follow the conventional type suction boxes, the purpose of which is to provide a uniform vacuum application across the sheet before the permeability measurement takes place. The usual suction boxes with drilled holes or herringbone slots do not provide the required uniform pressure differential across the sheet. The special suction box is in the form of a perpendicular slice having a uniform opening in the cross machine direction. This special suction slice creates the dry line or the area at which the water layer on the surface of the sheet disappears. Before the dry line the permeability of the sheet is affected by the surface layer of water. The number of special perpendicular suction slices as well as their size will vary as a function of machine speed, type of paper grade made, etc. On suction breast roll machines only one of these special perpendicular suction slices is required prior to the measuring slice.

In the press section of a paper making machine where the permeability of felts and/or fabrics is measured, usually only one or two special suction perpendicular slices will be required prior to the measuring slice and these should be located as close as possible following the press rolls. The vacuum connected to perpendicular suction slices and measuring slice should be controlled and preferably connected to independent vacuum sources.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages of the present invention will be apparent from the following detailed description and the accompanying drawings wherein:

FIG. 1 is a schematic side view of a Fourdrinier paper making machine and Press Section utilizing the method and apparatus of the present invention;

FIG. 1A is a partial top view of the suction box section of the Fourdrinier machine of FIG. 1;

FIG. 2 is a perspective view of the shower portion of the Press Section of the machine of FIG. 1;

FIG. 3 is a partial cross-sectional view taken along lines 3—3 of FIG. 1;

FIG. 4 is an enlarged cross-sectional side view taken along lines 4—4 of FIG. 3;

FIG. 5 is a partial cross-sectional side view taken along lines 5—5 of FIG. 4;

FIG. 6 is a partial view similar to FIG. 4 of an alternative construction of the slice lip of the measuring box;

FIG. 7 is a cross-sectional view of an alternative construction of a measuring box to that of FIGS. 4 and 5;

FIG. 8 is a side cross-sectional view showing the placement of movable sensors in the measuring box of FIGS. 4 and 5;

FIG. 8A is an enlarged view of the circled portion marked 8A of FIG. 8.

DETAILED DESCRIPTION OF A PAPER MAKING MACHINE USING THE MEASURING APPARATUS AND METHOD OF THIS INVENTION

Although the term paper is used herein, it also refers to any type of permeable sheet material such as natural

or manmade fibers, for instance, cellulose, cotton, wool, as well as synthetic materials, etc., and the sheet material may be non-woven or woven.

In paper making often different types of additives are introduced into the slurry of fibers and water to obtain specific characteristics and this composition of fibers, water and possibly additives, is called stock. As illustrated in FIG. **1**, a paper machine includes a head box **10** from which the stock is deposited through a slice on to a moving Fourdrinier belt or wire **11**. The stock passes through the slice in the form of a controlled jet or sprought and the Fourdrinier wire **11** is driven in the direction of the arrow A by motor driven rolls **12** so that the stock is gradually drained on the wire **11** to form the sheet **17**.

The wire is permeable and may be in the form of an endless or seamed woven fabric or wire **11** which supports the stock and allows the water to drain therethrough. When the stock is deposited from the headbox **10** onto the wire **11**, it will have a consistency generally from 0.01 percent to 1.5 percent of fiber to water, depending primarily upon the type of paper to be manufactured. The type of paper is frequently specified by "basis weight", which for instance can be the weight in pounds of 3,000 square feet of paper sheet. Basis weight is frequently specified from 5 to 400 pounds.

A natural vacuum is created by the rotating table roll **14**, foils **14A**, foil boxes **14B**, which also support the wire. This vacuum as well as normal gravity force will remove some of the white water from the stock. White water is a common term which refers to water containing fines, and when used, additives. Additional white water is removed from the sheet by conventional suction boxes **15** which are operated under a vacuum created by conventional vacuum pumps. The water is drawn into the suction boxes by vacuum and gravity. The suction boxes have either a conventional cover with holes or herringbone slots through which the air and water flows into the suction boxes **15** and transversely out to the usual separating chambers **16** located and adjacent the back side of the machine as viewed in FIG. **1**. As illustrated in FIG. **1A** the first suction box **15** has conventional shaped apertures for removing water from the sheet. The second suction box **15** has conventional herringbone type slots for removing water from the wire and sheet. Neither the holes or the herringbone slots will remove water uniformly across the sheet. In the separating chambers **16** the heavy water droplets are separated from the air with the water flowing down through a drop-leg **9** to a collection trough **38B**. To maintain the vacuum the outlet of the drop-leg **9** is held below the water surface in the trough. The moist air is removed from the top of the separating chamber by the vacuum pump or blower.

Advantageously after the two conventional suction boxes **15**, special suction boxes **15A** and measuring box **44** of this invention are located before the couch roll **8**. The desirable construction and operation of the boxes **15A** and **44** is described in detail hereinafter. The couch roll **8** has a shell perforated with drilled holes and a stationary internal suction box in which a high vacuum level is applied. The formed sheet **17** is then transferred to the press section **18**, and passes on to an endless belt **19** of felt or fabric felt, for example, of wool or synthetic fibers, or a mixture of both, or other water absorbent material. The wet paper sheet **17** is disposed on a felt belt **19** and is moved to a press nip formed by a top press roll **21** and a bottom suction roll **22** which has apertures in the shell through which a stationary vacuum box pulls a vacuum to aid in water removal in the nip. One or more press sections **18** can be applied to the paper machine.

The press and further dried sheet **17** is then removed from the felt belt **19** and the belt is washed by a water cleaning shower **23**. The water and dirt is partially removed by one or more suction boxes **150**, the advantageous design of which is described in detail hereinafter. When the sheet **17** is removed from the press section **18** it is important that it has a uniform moisture profile across the sheet width to prevent subsequent overdrying and possible damage to portions of the sheet. Generally to obtain such a uniform moisture profile a crown compensated roll **22** or rolls **21** and **22** are used. Also, because the water is transferred from the sheet to the felt belt **19** of absorbent material at the press nips, it is of the greatest importance that the ability of the felt to receive and hold the moisture at the press nip be as uniform as possible. The measuring device and method of this invention is also highly desirable in this area since it not only will detect inadequate crown for a given nip load, but also can detect variations of the porosity of the felt across the full width of the machine.

The sheet **17** enters the press section **18** at approximately a consistency of 5 percent to 25 percent fiber and leaves at a consistency of approximately 35 percent to 45 percent fiber. After the press section the sheet **17** may be transported through one or more dryer sections in which the remaining water is evaporated by using steam heated rotating cast iron rolls.

Although the present invention is described in connection with the drying of stock in a Fourdrinier type paper making machine, it is also applicable to other machines in which stock or fiber is dried on a moving mesh support such as with textile machines. For example, the sheet may be formed on a cylinder machine, removed, joined to other similarly formed sheet or sheets and further dried on a moving wire or on a moving absorbent belt or unsupported in a section where the water is evaporated.

DETAILS OF THE MEASURING DEVICE AND METHOD OF THIS INVENTION

It is desirable in paper making to produce a uniform sheet, both in cross-machine direction as well as in machine direction, and of the desired basis weight. If the sheet is non-uniform, usually costly waste of fibers occurs where the basis weight of the sheet is too high or where the basis weight is too low and must be rejected for failure to meet the buyer's specifications. Also, a sheet which is non-uniform in basis weight may produce a sheet which is dried differently and can result in variations in pick-up of sizing and coatings, sheet breaks, etc. Therefore, it is important to produce a uniform sheet of exact pre-determined characteristics. Assuming uniformity in furnish composition and treatment and uniform mixture of fibers across the machine, an air permeability measurement variation across the machine will indicate a non-uniform basis weight profile across the sheet in the cross machine or transverse direction. Non-uniformity in basis weight can be caused by inaccurate head box slice adjustment, unbalance of rolls and misaligned Fourdrinier and head box equipment.

When the machine is adjusted to make changes in the basis weight to meet different specifications variance in air permeability measurement occur in the machine or longitudinal direction. Changes in basis weight in the machine direction can also occur due to improper machine settings. When specified basis weight is required, reference can be made to air permeability measurements of previous runs for that desired basis weight and the air permeability measurements increased or decreased by changing the consistency of the stock or varying the opening of the head box slice. If, during production, all the readings across the machine increase or decrease uniformly, it will indicate that a change has occurred in the fiber treatment, fiber composition, additives, or variations of stock temperature, a looser or tightened fiber mat, so that the operator is informed of possible malfunction and can adjust the machine accordingly.

In reference to FIGS. **1** and **1A** the measuring device of this invention includes the measuring box **44** with one or more special suction boxes **15A** disposed prior to the measuring box **44.** In order for the air permeability of the sheet to be measured as it passes over the measuring box **44,** it is necessary that a "dry line" be created prior to the measuring box **44** by the special suction boxes **15A** in order to have uniform water removal and rewetting prior to the point of air permeability measurement. The suction boxes **15** with conventional covers with the usual apertures or herringbone slots pattern do not provide for uniform water removal across the sheet. In order to provide for uniform water removal across the sheet **17** the special boxes **15A** have openings or slices **15B** in the form of a slot extending perpendicularly to the direction of paper flow. The width of the slice **15B** may vary for instance from 1/16 inch to 1 inch depending on the type of use. The purpose of the perpendicular slice **15B** is to form the dry line before the measuring box **44** and to provide for uniform water removal in order to get accurate permeability readings. Permeability measurements can be made with the formation of the dry line at the measuring box **44,** however, for accurate measurements it is desirable to have the formation of the dry line occur before the measuring box **44.**

In the measuring box **44,** as illustrated in FIGS. **3** and **4,** a flow of moist air, having "white water" drops is pulled by vacuum through the sheet **17** and the moving wire **11.** The vacuum is produced in the usual manner by a vacuum pump **30** which communicates through a pipe **31** to a vacuum header **32.** The vacuum header is connected by pipe **37** to an individual separator **16.** A conventional vacuum sensor **39** within the separator **16** provides signals, dependent upon the vacuum, to the conventional control **40** in order to keep a uniform vacuum level in the separator **16,** for instance, to keep a uniform pressure differential of 5 inches of mercury across the sheet **17** and wire **11.** A dropleg **9** from the separator **16** discharges beneath the water level in the trough **38B.** The vacuum control **40** is connected to, and controls, the vacuum throttle valve **41** and the vacuum bleed valve **42** in order to insure that a uniform pressure differential is maintained. The separator **38** in turn is connected by a pipe **43** to the measuring box **44.**

After the air has been pulled through the mat sandwich **11** and **17** into the suction slice lips **46** of the measuring box, the heavy water droplets advantageously are separated from the air flow by lowering the velocity of the air, so as to expand it, preferably below 1,200 feet per minute in the measuring box **44.** The deflection plate or baffle means **45** inhibits heavy water droplets from coming in contact with a sensing head **49,** as well as increasing the length of the air flow path in order to enhance water separation. The water accumulates in bottom of the measuring box **44** and flows through opening **52A** in an internal wall **52** of the measuring box **44.** The water then flows over a weir **53** in the adjacent compartment **48** and out through the pipe **43** to the separator **16** and down through the drop leg **9** to the trough **38B.** The weir **53** is of sufficient height to prevent air from being drawn through the opening **52A.** It is important to maintain a uniform vacuum level in compartments **44** and **48** to obtain accurate measurements of changes in permeability of the sheet **17** by the sensing head **49.**

As illustrated in FIG. **4,** after separation from the water droplets the air flow is reversed in direction upwardly through the orifice **50** in the wall **52** and into the compartment **48** from which it jointly flows out with the water through the pipe **43** into the separator **16** where it is removed by the vacuum pump **30.**

The air passes through the wire **11** and sheet **17** at a relatively high velocity and enters the measuring box **44** through the suction slice lips **46** where the velocity is rapidly reduced so that water droplets carried in the air will readily separate before the air passes through the orifice **50** in order to insure accurate measurement of air flow. This construction advantageously provides for the maintenance of the air flow past the sensing head **49** at a desirable velocity below 15,000 feet per minute in order to obtain accurate measurements of the air flow.

As illustrated in FIG. **5** the measuring box **44** is desirably divided into a plurality of individual compartments by longitudinal dividing walls **44C** wherein each compartment has an air outlet orifice **50** and an individual sensing head **49.** This compartmentation enhances the accuracy of the air flow measurement. In order to reduce the number of sensing heads **49,** as illustrated in FIGS. **8** and **8A,** the sensing head **49** may be slideably mounted in a conventional manner on a transverse bar **49A** and moved adjacent the orifice **50** of the desired compartment for air flow measurement by means of a transverse threaded rod **49B** which engages a cooperating threaded surface provided on the housing for the sensing head **49.** Rotation of the rod **49B** will transport the sensing head **49** to the desired location for air flow measurement.

THE DESIGN OF THE SPECIAL PERPENDICULAR SUCTION SLICE FOR THE SPECIAL SUCTION BOX 15A AND THE MEASURING BOX 44

The suction opening or slice **15B** of the special suction boxes **15A** and the opening or slice **46B** of the measuring box **44** are of identical construction. Accordingly only the details of the slice lips **46** for the measuring box are illustrated in FIG. **4.** The slices **15B** and **46B** are formed perpendicularly and beneath the wire or fabric mesh carrying the flow of the material which is shall dewater. The slices **15B** and **46B** have a uniform gas perpendicular to the machine flow and can vary for instance from 1/16 inch to approximately 1 inch in width. The width of the suction slice gap will be a function of its application as related to furnish type, basis weight, machine speed, location, or combinations

thereof. The inside edge of the suction slice lips **46** have a slight rounding which may vary from approximately 1/64 to ¼ inch radius to protect the wire or fabric from high unit pressure caused by vacuum surges. Also, to diminish high unit pressure and wear on the wire or fabric, it is desirable to curve the part of the slice lip which is in contact with the wire. The curvature should not be more than few thousands of an inch and will of course vary with slot width and vacuum level.

Immediately following the slice **46B**, as illustrated in FIG. **4** the lips **46** diverge rapidly to allow for the natural expansion of the atmospheric air and rapid separation from the water which is pulled into the box. The trailing slice lip **46** of the suction slice **46B** desirably is constructed to diverge at an angle less than 90° to a perpendiclar in order to direct the water downwardly which feature is particularly desirable in the suction boxes **15A** and measuring slice **44** to diminish rewetting of the sheet. Conventional types of suction box covers cause less uniform water removal and more rewetting than the suction slices **15B** and **46B** which have a uniform gap and profile across the full width of the machine and diverge rapidly. The vacuum level across the full length of the suction slices **15B** and **46B** should remain constant in order to assure as uniform water removal as possible across the full width of the machine.

A modified construction illustrated in FIG. **6** has an additional suction slice **46C** prior to the measuring slice **46B**. The purpose of the additional slice **46C** is to remove the air film which may be carried under the wire **11** and which may give a noticeable inaccuracy in measurement on tight or heavy sheets, or at high machine speeds. The air flow from this pre-slice **46C** is pulled through a separate vacuum compartment **46D** and out through a conduit **46E** connected to a vacuum pump.

An alternative measuring box construction is illustrated in FIG. **7** which has a measuring slice **46B** as the same design as illustrated in FIG. **4**, however, the sensing head is in the form of a series of such sensing heads **62** disposed below and adjacent to the forward side of the measuring slice **46B**. The air passes over the sensing heads **62**, which may be the same type as sensing head **49**, and the water and air flows out of the bottom of the measuring box **60** through the outlet **64**.

The embodiment of FIGS. **4** and **5** is highly desirable because it greatly reduces the effect of the water droplets on the sensing head **49**. The velocity of the air in chamber **44** is kept sufficiently low so that heavy water drops are not carried over to the measuring elements. However, the embodiment of FIG. **7** may be used in high speed machines wherein the pressure differential applied is below 2 inches of mercury. Desirably the sensing heads **62** have temperature compensation means to diminish the effect of water droplets falling thereon. On higher speed machines, the horizontal movement of the sheet **17** will tend to force the water droplets closer to the trailing edge of the slice lip **46**. A single sensing head **62** may also be used and mounted for traverse movement in a manner similar to the sensing head **49** illustrated in FIGS. **8** and **8A**.

USE OF THE METHOD AND APPARATUS OF THIS INVENTION IN THE PRESS SECTION OF A PAPER MAKING MACHINE

As illustrated in FIGS. **1** and **2**, the method and apparatus of this invention may be used in modified form in the press section **18** of a paper making machine in a manner similar to that described for the Fourdrinier section, however, as the air permeability of the felt belt **19** is measured there is, of course, no dry line formed before the measuring box. As mentioned above in order to have uniform water removal from the sheet **17** in the press section **18**, it is important that the felt be maintained uniformly clean. For this purpose this invention is used to measure the permeability of the felt belt **19** across its width.

As shown in FIG. **2** a suction box **150** is located under the felt belt **19** prior to a measuring box **151** of the present invention, following the movement of the felt from the press nip. The suction box **150** and measuring box **151** are constructed and operated in a similar manner to the boxes **15A** and **44** for the Fourdrinier section. The vacuum level, within both slice boxes **150** and **151** can vary for instance from 5 inches to 20 inches mercury depending on what type of felt material is used. The suction box **150** functions to remove water uniformly from the felt belt **19** prior to the permeability measurement at the measuring box **151**.

The volume of air can vary from few cubic feet per minute to approximately 20 cubic feet per minute per inch of width. The sensing head desirably has a functional compensation for shower water temperature and ambient air temperature. The water cleaning showers to wash the felt belt **19** include an elongated low pressure flooding shower **152** and a high pressure cleaning shower **153** having a traveling shower head which moves across the width of the felt belt in response to conventional control apparatus operating on signals derived from the measuring box **151** indicating locations of the felt belt **19** having the least permeability, i.e., restricted air flow areas. If, for a short period, the showers and vacuum to the suction box **150** is disconnected, the profile measured by the measuring box **151** will indicate the linearity of the press nip at the existing roll nip loading.

THE SENSING HEAD

The sensing device generally consists of the air flow sensing head **49** and **62** which may be in the form of a conventional hot wire anemometer or a thermal hot wire anemometer which measures the air flow to indicate a change in sheet permeability. In the hot wire anemometer the sensing element's temperature is kept above the temperature of the air flow and the cooling effect is measured. A constant temperature anemometer may be used as the sensing device. In a constant temperature anemometer circuit a heated wire which is the sensing element is cooled by the air flow and the current required to maintain the temperatue constant is measured. Since variation in the cooling of the sensing element is influenced by variations in ambient air temperature above the sheet as well as variation in water and sheet temperature, a temperature compensation sensor is included in the anemometer sensing head and control circuit. Beside compensating for temperature variations it will also compensate for variation in moisture level in the air flow. With the addition of conventional linearized circuitry which will achieve a linear output the above system will measure changes of the mass air flow and will directly indicate changes in the air permeability of the sheet **17**.

Referring to FIG. **4**, as the flow of moist air, which is at a lower temperature than the sensor **49**, passes

through the orifice **50**, a cooling of the sensor **49** takes place. To maintain a constant temperature, the amount of heat supplied to the sensor coil can be ascertained by measuring the current. This is known as constant temperature anemometer circuit. Another type of anemometer circuitry can apply a known amount of heat to the heating coil and measure the temperature difference. This type of anemometer circuitry is called constant current circuit. Both the constant temperature anemometer and the constant current anemometer measure the cooling effect of the moist air flow and thus give a direct indication of the quantity of air flow indicating air permeability. The sensors **49** must be calibrated under known conditions and a curve developed. The read-out can then be made as a permanent measurement record for the machine.

For more accurate measurement the anemometer sensing device **49** may include circuitry for compensating for variations in the temperature of the stock, the ambient air above the sheet and other variables. Such hot wire anemometers referred to above for use as a sensing head **49** are well known as is the circuitry for temperature compensation linearizing. Other suitable sensors can be an electric thermocouple measuring device, thermistor measuring device, a liquid filled probe or container, or a gas or vapor probe or container, where the expansion or contraction of the liquid, gas or vapors are measured to indicate changes in air flow.

It will be understood that the foregoing description with the details of exemplary structure is not to be construed in any way to limit the invention, but that modifications may be made thereto without departing from the scope of the invention as set forth in the following claims.

Having thus described the invention what is claimed is:

1. A method for continuously measuring the porosity of a moving wet porous continuous sheet including removing water from the sheet by a first uniform application of a pressure differential across the sheet through a suction slice having a uniform opening extending in a direction generally perpendicular to the direction of sheet movement, subsequently subjecting the moving sheet to a second uniform application of a pressure differential across the sheet in a direction generally perpendicular to the direction of the sheet movement and passing the flow of water and air created by the second pressure differential into a measuring box through a measuring slice having a uniform opening extending across the sheet in a direction generally perpendicular to the direction of movement of the sheet, expanding the air after it passes through the measuring slice as by lowering the velocity of air and water and separating the air from water droplets, and sensor means measuring the changes in flow of the air passed through the measuring slice.

2. The method of claim **1** wherein the flow of air and water created by the second pressure differential passes through a diverging measuring slice, and wherein the air is expanded to lower the velocity of the air and water to below 1,500 feet per minute, and wherein the flow of air is passed through an orifice in the side of the measuring box at a velocity below 15,000 feet per minute, and wherein the changes in the flow of air through the orifice are measured by said sensor means.

3. The method of claim **2** wherein the velocity of the flow of air and water passed through the measuring slide into the measuring box is first directed downwardly and then reversed to a generally upward direction before the air passes out through the orifice for measurement.

4. The method of claim **1** wherein said second pressure differential applied is below two inches of mercury and wherein the flow of the air and water passes through a diverging measuring slice and wherein measurement of the changes in the flow of air through the slice occurs at a point on the upstream side of the diverging measuring slice.

5. The method of claim **4** wherein the first uniform application of a pressure differential to remove water uniformly from the sheet is applied by moving the sheet over a suction box having a diverging slice with a uniform opening extending generally perpendicular to the direction of the sheet movement.

6. A method for continuously measuring the porosity of a moving wet porous continuous uncompacted fiber sheet being formed on the forming section of a paper making machine including removing water from the uncompacted sheet by a first uniform application of a uniform pressure differential across the sheet in a direction perpendicular to the direction of sheet movement by passing the sheet over a suction box having a diverging suction slice with a uniform opening extending across the sheet, creating a dry line on the sheet at the suction slice, and subjecting the moving sheet to a second uniform pressure differential across the sheet in a direction perpendicular to the direction of the sheet movement, and passing the flow of water and air created by the second pressure differential into a measuring box through a diverging measuring slice, expanding the air as after it passes through the diverging measuring slice as by lowering the velocity of the water and air below 1,500 feet per minute, and separating the air from water droplets, and measuring the changes in flow of the air passed through the diverging measuring slice after separation of water droplets from the air as it passes out of the measuring box.

7. The method of claim **6** wherein the flow of air after water droplet separation is passed through an orifice in a side of the measuring box at a velocity below 15,000 feet per minute, and wherein changes in the flow of air are measured when the air flows through the orifice.

8. The method of claim **7** wherein the direction of flow of the air in the measuring box is first downwardly and then reversed to a generally upward direction before the air passes out through the orifice for measurement.

9. The method of claim **8** wherein the first uniform application of a pressure differential to remove water from the sheet is applied by moving the sheet over a plurality of suction boxes each having a diverging slice with a uniform opening extending generally perpendicular to the direction of the sheet movement.

10. The method of claim **6** wherein measurement of the changes in flow of the air passed through the diverging measuring slice occurs at a point on the upstream side of the outlet of the measuring slice.

11. Apparatus for continually measuring the porosity of a moving wet porous continuous sheet including at least one suction box having a diverging vacuum slice with a uniform opening extending across the sheet generally perpendicular to the direction of sheet movement for water removal from the sheet, means for forming a uniform pressure differential across the vac-

uum slice, a measuring box disposed on the downstream side of the suction box, said measuring box having a measuring slice with a uniform opening extending generally perpendicular to the direction of sheet movement, said measuring slice having a diverging opening to allow the flow of air passing therethrough to rapidly expand in the measuring box for separation of water droplets from the air, means for forming a uniform pressure differential across said measuring slice, and measuring means provided near the air flow outlet in said measuring box for measuring changes in the flow of air passed through the measuring slice after separation of water droplets from the air.

12. The apparatus of claim **11** wherein said measuring means is a compensated hot wire anemometer.

13. The apparatus of claim **11** wherein said measuring box is divided into a plurality of separate compartments each having an orifice for the passage of the air from each compartment, and wherein said measuring means is movable for positioning adjacent the desired orifice for air flow measurement.

14. Apparatus for continually measuring the porosity of a moving wet porous continuous sheet including a suction box having a diverging vacuum slice with a uniform opening extending across the sheet generally perpendicular to the direction of sheet movement for water removal from the sheet, means for forming a uniform pressure differential across the vacuum slice, a measuring box disposed on the downstream side of the suction box, said measuring box having a measuring slice with a uniform opening extending generally perpendicular to the direction of sheet movement, said measuring slice having a diverging opening to allow the flow of air passing therethrough to rapidly expand for separation of water droplets from the air, means for forming a uniform pressure differential across said measuring slice, and measuring means provided in said measuring box for measuring changes in the flow of air passed through the measuring slice after separation of water droplets from the air, and wherein an orifice is provided in a wall of the measuring box for the air to flow therethrough after separation from the water droplets, and wherein said measuring means is provided on the outlet side of said orifice.

15. The apparatus of claim **14** wherein a baffle is disposed in said measuring box between said measuring slice and said orifice, said baffle being mounted on one end of the top of said measuring box, said baffle having its free end extending into said measuring box whereby the flow of air must change its direction and flow around said baffle to reach said orifice.

16. Apparatus for continuously measuring the porosity of a moving wet porous continuous paper sheet being formed on the forming section of a paper making machine including a suction box having a vacuum slice with a uniform opening extending generally perpendicular to the direction of the sheet movement, means for forming a uniform pressure differential across the vacuum slice for water removal across the sheet, said vacuum slice having a diverging opening for expansion of the flow of air as it passes through the orifice, a measuring box provided in the downstream side of the suction box, said measuring box having a measuring slice with a uniform opening extending generally perpendicularly to the direction of the sheet movement, said measuring slice having a diverging opening to allow the air passing therethrough to expand, means for forming a uniform pressure differential across said measuring slice, said measuring box having an orifice provided in a wall for the measuring box for the air to flow therethrough, measuring means on the outlet side of said orifice for measuring the flow of air passed through the measuring slice, and baffle means between said measuring slice and said orifice to aid in changing the direction of the air flow.

17. A method for continuously measuring the porosity of a moving wet porous continuous uncompacted fiber sheet including removing water from the uncompacted sheet by a first uniform application of a pressure differential across the sheet through a diverging suction slice having a uniform opening extending in a direction generally perpendicular to the direction of sheet movement by passing the sheet over a suction box having said diverging suction slice with a uniform opening extending across the sheet, subsequently subjecting the moving sheet to a second uniform application of a pressure differential across the sheet in a direction generally perpendicular to the direction of the sheet movement and passing the flow of water and air created by the second pressure differential into a measuring box through a measuring slice having a uniform opening extending across the sheet in a direction generally perpendicular to the direction of movement of the sheet, expanding the after as it passes through the measuring slice to lower the velocity of air and water below 1,500 feet per minute and separating the air from water droplets, and measuring the changes in flow of the air passed through the measuring slice.

18. A method for continuously measuring the porosity of a moving wet porous continuous uncompacted fiber sheet being formed on the forming section of a paper making machine including removing water from the uncompacted sheet by a first uniform application of a uniform pressure differential across the sheet in a direction perpendicular to the direction of the sheet movement, and passing the flow of water and air created by a second pressure differential into a measuring box through a diverging measuring slice, expanding the air after it passes through the diverging measuring slice to lower the velocity of the water and air below 1,500 feet per minute, and separating the air from water droplets, reversing the flow of air and passing it through a measuring orifice at a velocity below 1,500 feet per minute, and measuring the changes in flow of the air passed through the measuring orifice.

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