Sept. 3, 1968 J. F. SCHMAENG 3,399,565

STOCK VELOCITY MEASUREMENT DEVICE

Filed Dec. 8, 1965 4 Sheets-Sheet 1

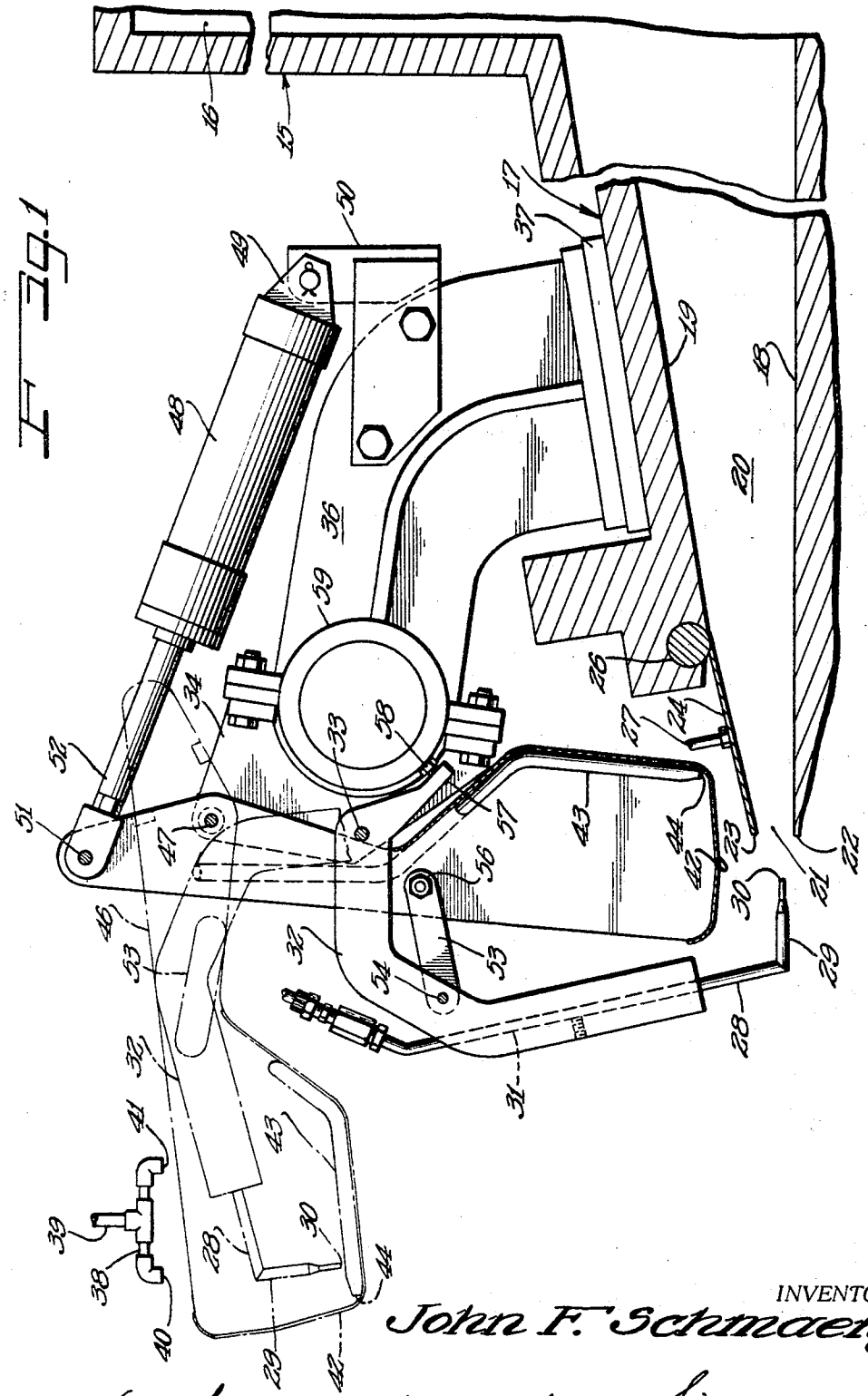


Fig. 1

INVENTOR.
John F. Schmaeng

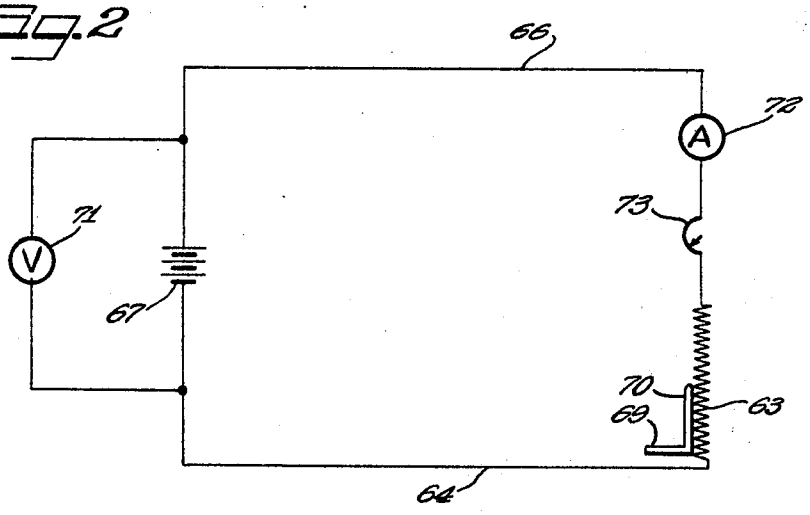
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STOCK VELOCITY MEASUREMENT DEVICE

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Fig. 2



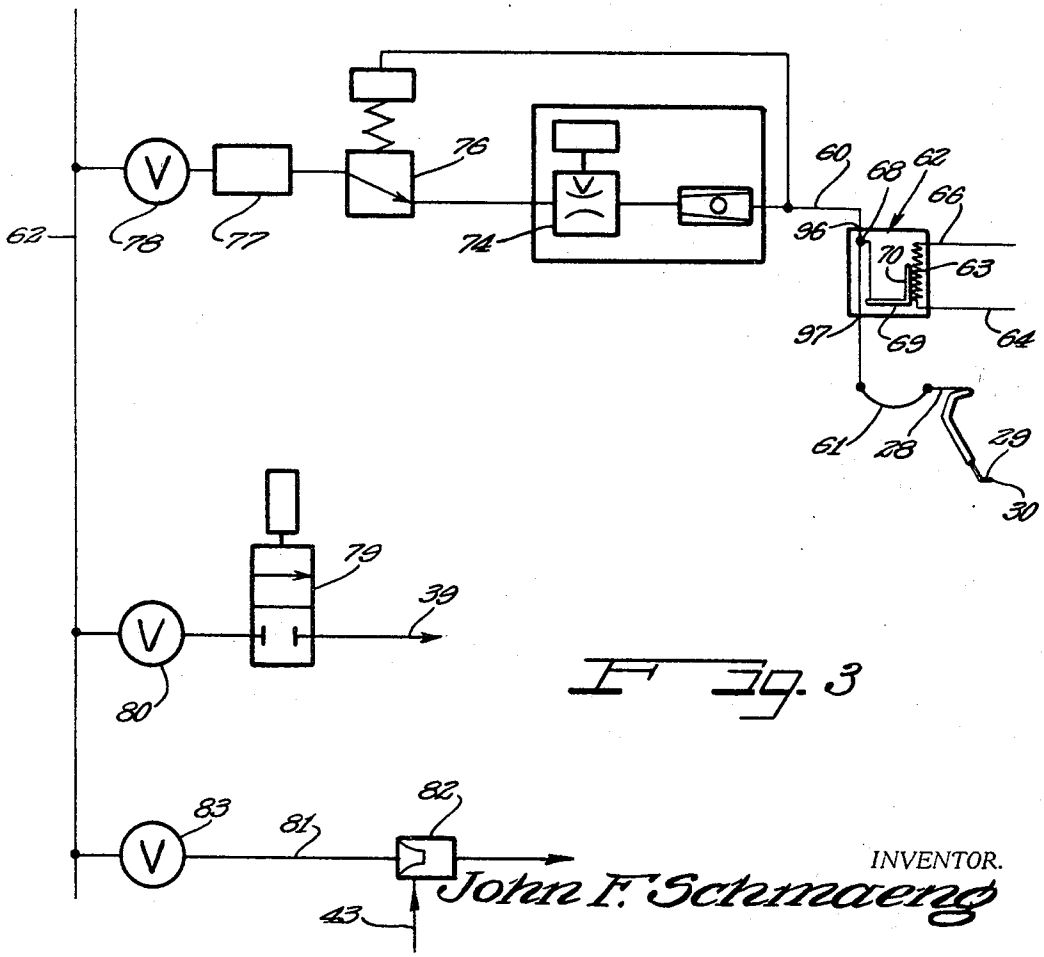


Fig. 3

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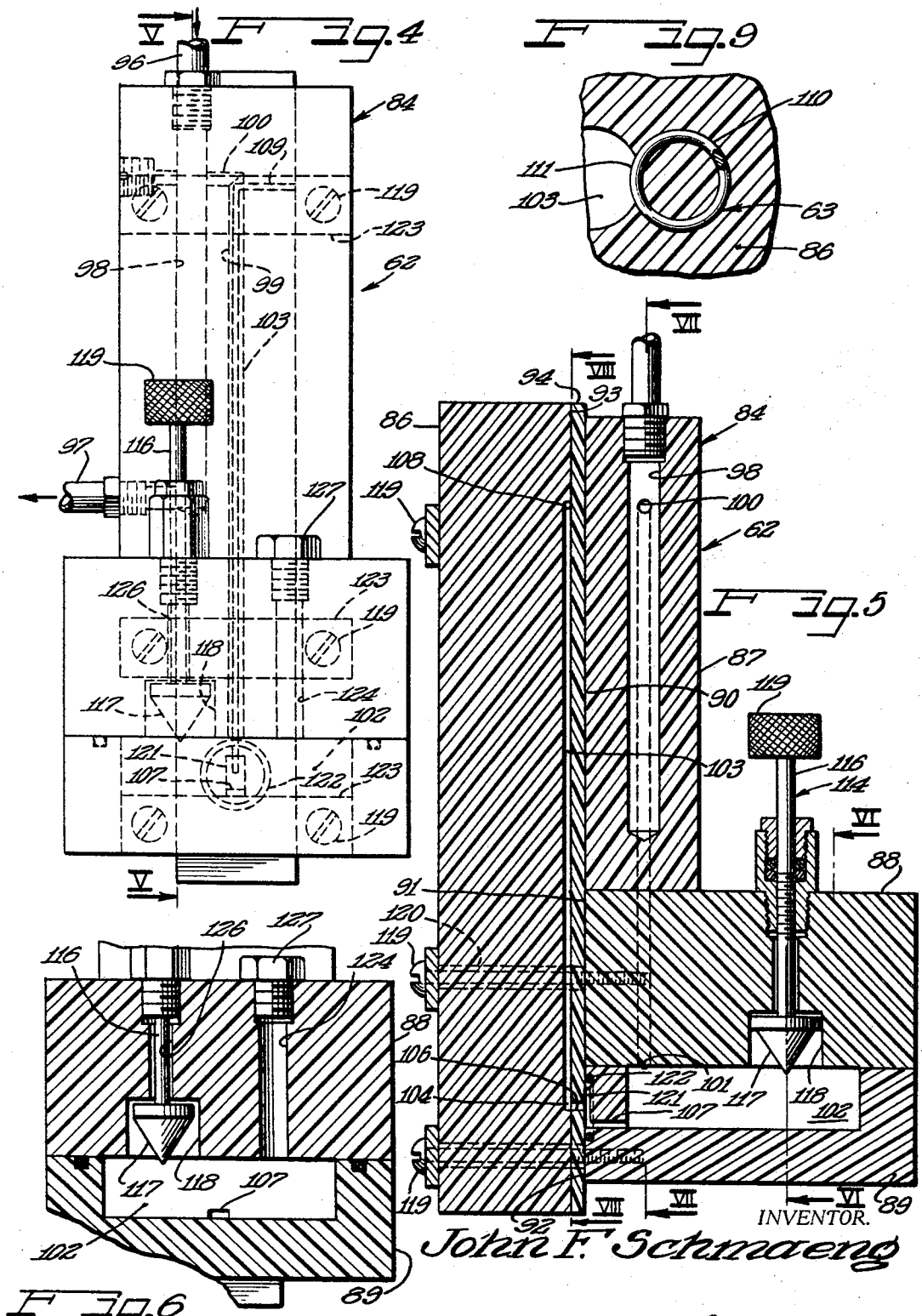
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STOCK VELOCITY MEASUREMENT DEVICE

Filed Dec. 8, 1965 4 Sheets-Sheet 3



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Sept. 3, 1968 J. F. SCHMAENG 3,399,565

STOCK VELOCITY MEASUREMENT DEVICE

Filed Dec. 8, 1965 4 Sheets-Sheet 4

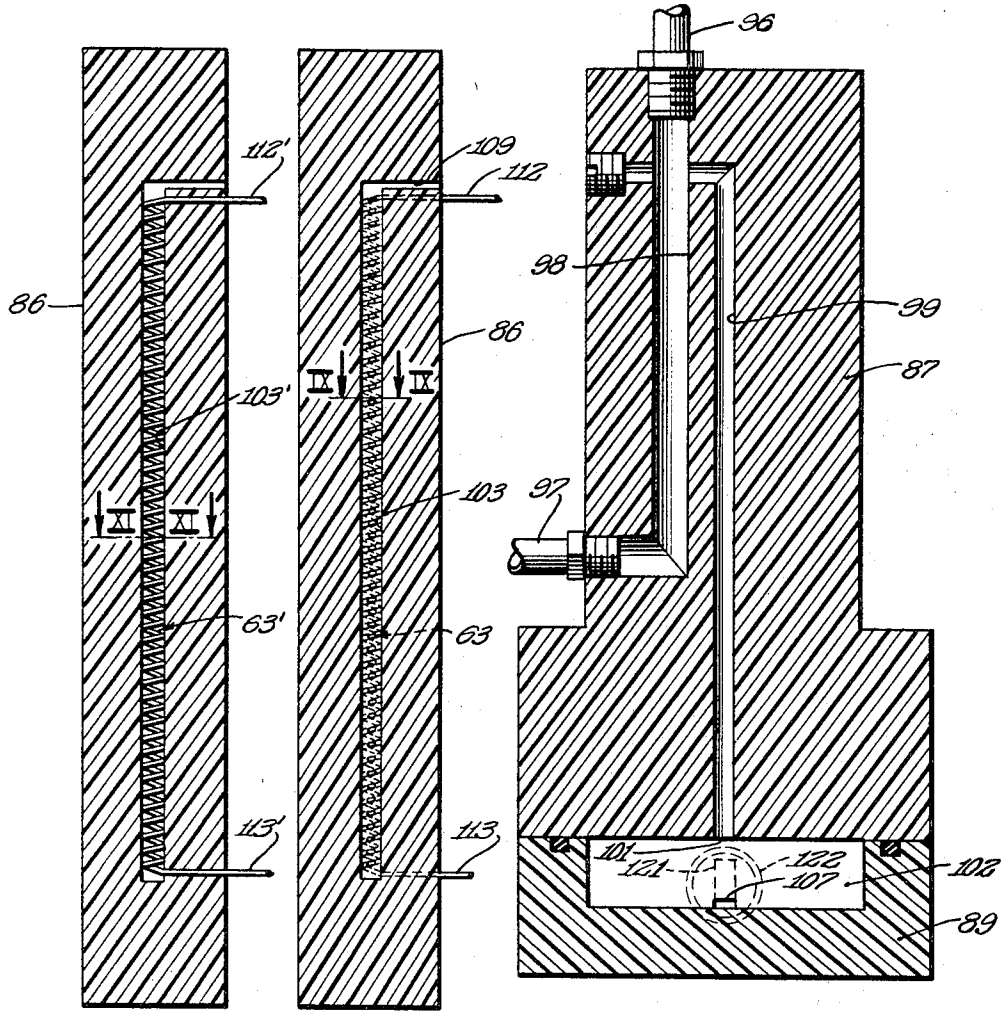


Fig. 8

Fig. 7

Fig. 10

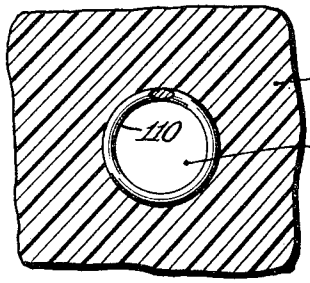


Fig. 11

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United States Patent Office 3,399,565 Patented Sept. 3, 1968

3,399,565

STOCK VELOCITY MEASUREMENT DEVICE

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Filed Dec. 8, 1965, Ser. No. 512,399
4 Claims. (Cl. 73—194)

ABSTRACT OF THE DISCLOSURE

Apparatus for determining the velocity of stock as it flows from the slice opening in the head box of a papermaking machine. The apparatus includes an impact tube movable into the flow of stock at the slice opening and from which issues a jet of fluid against the flow of fluid against the flow of stock. The fluid which issues from the impact tube is maintained at a constant velocity. An indicator is provided to indicate the static pressure of the fluid in the impact tube, the static pressure varying as a function of variations in the velocity of the stock flowing from the slice opening.

This invention relates generally to papermaking apparatus and more particularly to improvements for ascertaining the velocity of the stock as it flows out of the slice opening of a head box of a papermaking machine onto a traveling forming surface.

Many papermaking machines comprise a head box onto which a stock slurry is delivered and a traveling forming surface which receives a stream of the stock from the slice opening of the head box and upon which the paper web is initially formed.

It is generally considered desirable for the formation of quality web that the velocity of the stock as it flows from the head box and is delivered to the forming surface be correlated with the velocity of the forming surface. While it is possible to provide a degree of correlation merely by a visual observation of the relative velocities, this may be quite unreliable and a more consistently accurate means of measurement is indicated.

The speed of the forming surface, whether it be a Fourdrinier wire, the peripheral surface of a cylinder, or the like, is not difficult to ascertain. Measuring the velocity of the stock, however, presents a different and more difficult problem.

The present invention provides a means for determining the stock velocity through the utilization of a variable electrical resistance mechanism connected into an electric circuit across which is applied a fixed E.M.F. The electrical resistance mechanism comprises a coil of high resistance wire exposed to the interior of a core formed in a non-conductive housing. A reservoir filled with mercury is formed in the housing at the base of the core.

The reservoir is in fluid communication with a selected point in a fluid-carrying conduit which has mounted at one end thereof a small pitot tube, which is referred to hereinafter as an impact tube. The outlet of the impact tube is arranged to eject a small jet of fluid into the stock stream, preferably in a direction substantially opposite to the direction in which the stock is flowing.

The conduit at the other end thereof is connected to a source of pressurized fluid. The fluid may preferably be water, although it will become manifest herein that other pressurized fluids are also suitable. The static pressure of the fluid in the conduit at the point thereof which is in communication with the mercury reservoir will vary in proportion to the velocity of the stock flowing across the outlet of the impact tube. As the static pressure increases a portion of the mercury in the reservoir rises in the core, thereby shunting out a portion of the coil of wire and causing an increase in the flow of current through the circuit. As the static pressure decreases the level of mercury in the core falls, thereby having the effect of decreasing the current flow in the circuit. An ammeter can be connected in the circuit for reading such variations in current, and the current reading, of course, can be calibrated to directly reflect velocity of the stock.

The variations in the current flowing in the circuit can also be utilized through suitable apparatus to regulate the slice opening of the head box, the flow rate of the stock supply pump, etc., whereby to maintain a predetermined velocity of the stock at the slice opening.

The impact tube is swingably mounted such that it can be periodically pivoted into the stock stream for measurement of the stock velocity, and pivoted out of the stock stream when not in use. Shower means and associated apparatus are also provided for cleaning the impact tube when it is positioned out of the stock stream.

It is, therefore, an object of the present invention to provide improved means for measuring the velocity of stock at the slice opening of a head box of a papermaking machine.

Another object of the invention is to provide means for measuring stock velocity with minimal physical disturbance of the flow of the stock.

A further object of the invention is to measure stock velocity as a function of its effect on the pressure of another fluid being injected into the stock.

Still another object of the invention is to measure stock velocity by means of a variable electrical resistance mechanism connected into an electrical circuit having a fixed voltage applied thereacross and means for varying the effective resistance of the mechanism and therefore the current flowing through the circuit as a function of the stock velocity.

Yet another object of the invention is to provide a pressure responsive, mercury column, variable resistance mechanism comprising a coil of high resistance wire exposed to the interior of a core and fluid mercury riseable within the core a distance proportionate to the value of a pressure applied to the mercury for shunting out a proportionate portion of the coil to vary the resistance thereof as a function of the pressure applied to the mercury.

Another object of the invention is to provide a papermaking machine having a head box for supplying a stream of stock to a traveling forming surface with improved means for measuring the velocity of the stock being applied to the forming surface, such means comprising a conduit connected to a source of pressurized fluid and having an impact tube mounted thereon for directing a jet of the fluid into the stream of stock, means in communication with the conduit at a selected point thereof and responsive to the pressure of the fluid at said selected point for providing a signal which varies in accordance with variations in the fluid pressure at said selected point, means for moving the impact tube selectively into and out of the stock stream and means for cleaning the impact tube.

Many other features, advantages and additional objects of the present invention will become manifest to those versed in the art upon making reference to the detailed description which follows and the accompanying sheets of drawings, in which preferred structural embodiments incorporating the principles of the present invention are shown by way of illustrative example only.

On the drawings:

FIGURE 1 is a fragmentary vertical sectional view of a head box of a papermaking machine having mounted thereon a stock flow measurement device constructed in accordance with the principles of the present invention;

FIGURE 2 is a wiring diagram showing the electrical circuitry of the present invention;

FIGURE 3 is a plumbing diagram showing the hydraulic circuitry of the present invention;

FIGURE 4 is a front elevational view of a variable electrical resistance mechanism constructed in accordance with the principles of the present invention;

FIGURE 5 is a vertical sectional view of the mechanism of FIGURE 4 taken substantially along lines V—V of FIGURE 4;

FIGURE 6 is a vertical sectional view taken along lines VI—VI of FIGURE 5;

FIGURE 7 is a vertical sectional view taken along lines VII—VII of FIGURE 5;

FIGURE 8 is a vertical sectional view taken along lines VIII—VIII of FIGURE 5;

FIGURE 9 is a horizontal sectional view taken along lines IX—IX of FIGURE 8;

FIGURE 10 is similar to FIGURE 8 but shows a slightly modified version of the element disclosed in FIGURE 8; and

FIGURE 11 is an enlarged fragmentary horizontal sectional view taken along lines XI—XI of FIGURE 10.

Although the principles of the present invention are of utility in measuring the characteristics of any fluid a particularly useful application is made to the measurement of stock velocity in a papermaking machine which, in an illustrative embodiment thereof shown herein in FIGURE 1, comprises a head box **15** having formed therein a tank **16**, which head box receives stock slurry from a suitable source and discharges or deposits the stock on a traveling web forming surface as, for example, a Fourdrinier wire.

A front portion **17** of the head box **16** comprises an apron **18**, which constitutes a forward projection of the bottom wall of the head box, and a downwardly and forwardly sloping wall **19** which, in conjunction with the apron **18**, forms a tapered passageway **20** for conveying the stock from the tank portion of the head box **15** to a slice opening **21** formed between vertically spaced distal ends **22** and **23** of the apron **18** and the wall **19**. The stock flows from the slice opening **21** to a traveling web forming wire situated below the slice opening.

In the manufacture of quality web it is generally considered desirable to correlate the speed of the web forming surface with the velocity of the stock as it is deposited on the forming surface. In the illustrated embodiment of the head box **15** the velocity of the stock as it emerges from the slice opening **21** can be varied through the provision of means for varying the area of the slice opening **21**. Thus a forward end portion **24** of the wall **19** is hinged as at **26** to the remaining portion of the wall and an adjustment rod **27** is mounted on the end portion **24**. Movement of the rod **27** can be controlled by any suitable means which may be of the manual or automatic type. It will be appreciated that correlation of the velocities of the stock emerging from the slice opening and of the forming wire by means of varying the area of the slice opening **21** has its practical limitations since there are, of course, generally preferred maximum and minimum velocities of the stock at the slice opening **21**. In addition the thickness of the web formed on the wire is a function of the area of the slice opening and the desired thickness of the web may therefore also enter into limitations placed upon the adjustment of the slice opening. The speed of the forming wire is, of course, adjustable.

In correlating the velocities of the stock and forming wire visual observation can be quite inaccurate and therefore quite unsatisfactory. It is desirable to provide means for determining with a relatively high degree of accuracy the respective velocities of the forming wire and of the stock leaving the slice opening. As noted, the speed of the forming wire can be determined through the utilization of any number of suitable and well known means. In determining the velocity of the stock, however, the following considerations render this a different and a more difficult problem.

First of all, the stock should not be unduly agitated as it emerges from the slice opening in the interest of a quality web. This consideration places a limitation on the physical size of any measurement member situated directly in the stock stream.

Further, any measurement member situated within the stock stream should be designed to prevent flocculations and agglomerations of the fibers of the stock.

In accordance with the principles of this invention means are provided for accurately measuring the velocity of the stock without the formation of substantial and quality-reducing flocculations and agglomerations. The invention comprises the utilization of a relatively small Pitot tube **28** having a lower neck portion **29** open at a distal end **30** thereof for discharging a relatively small jet of fluid into the stock stream at the slice opening **21** of the head box **15**. The tube **28** may be more descriptively referred to as an impact tube since it is the force or impact of the stock acting upon the jet of fluid being emitted from the tube **28**, and the effect upon the pressure of the fluid being discharged from the tube **28** as a result of the velocity of the stock, which results indirectly in a measurement of the velocity of the stock.

The impact tube **28** is mounted on the front portion **17** of the head box **15** for movement of the neck **29** thereof selectively into and out of the path or stream of the stock. Accordingly the conduit or tube **28** is mounted at a central portion **31** thereof on a generally inverted U-shaped arm **32** which, in turn, is pivotally mounted on a stationary shaft **33**. The pin **33** is fixedly mounted on a flange **34** connected in fixed assembly to an elbow bracket **36**. A lower end **37** of the bracket **36** is secured to the wall **19** of the head box **15**.

Since it is not necessary to continuously measure the velocity of the stock, the impact tube **28** need only periodically be lowered or dipped into the stock stream. From the lower or operating position of the impact tube as indicated in the full lines in FIGURE 1, the tube may be pivoted or raised to a second or inoperative position thereof indicated by the dashed lines in FIGURE 1.

When the tube **28** is raised to its inoperative position it is desirable to clean the tube, and particularly the neck portion **29** and outlet **30** thereof, to prevent stock build-up thereon. For this purpose an impact tube shower is indicated at reference numeral **38** as being disposed above the impact tube **28** in its inoperative position. The shower **38** is connected by means of a conduit **39** to a suitable source of water and to provide a spraying effect a pair of spray nozzles **40** and **41** may be mounted on the shower **38**.

In order to collect the spray water, a shower pan **42** houses the impact tube at the inoperative position thereof. The collected spray water is removed from the shower pan **42** by means of a drain line **43** which is open at a lower end **44** thereof. A vacuum or siphon effect is applied to the drain line **43** in order to draw the collected spray water from the shower pan **42**.

The pan **42** is formed at one end of an arm **46** which is also pivotally mounted on the flange **34** by means of another stationary pin or shaft **47**. In order to pivot the arm **46** about the shaft **47** a pressurized fluid cylinder **48** is provided having one end **49** thereof pivotally mounted on a bracket **50** which extends from the elbow bracket **36** and having an opposite end **51** thereof, which is actually the distal end of a telescopic arm **52** of the cylinder, pivotally connected to the arm **46** on a side of the shaft **47** opposite the side at which the pan **42** is formed.

Thus the shower pan **42** can be moved from a raised position thereof as indicated by the dashed lines to a lowered position thereof as indicated by the solid lines in FIGURE 1. The arm **32** which mounts the impact tube **28** is also connected to the shower pan **42** by means of a linkage **53** which is pivotally connected at one end **54** thereof to the arm **32** and at an opposite end **56** thereof to the shower pan **42**. As a result of this linkage, as the pressure cylinder **48** is operated to pivot the shower pan

42 to the raised position thereof the impact tube 28 is also raised thereby to its inoperative or raised position. By operating the cylinder 48 in an opposite direction, the impact tube 28 is lowered to its operative position and the shower pan 42 is also lowered so as to avoid interference with the tube 28.

In order to prevent overtravel of the tube 28 one end 57 of the arm 32 is provided with a threadedly adjustable bolt 58 which abuts the peripheral surface of a collar 59 of the elbow bracket 36 when the tube 28 reaches its operating position.

In the hydraulic circuit shown in FIGURE 3 the impact tube 28 is disclosed as being connected to a conduit 60 through a flexible conduit 61 in order to accommodate the pivotal movement of the impact tube. The conduit 60 is, in turn, connected to a suitable source of pressurized fluid as, for example, a pressurized water pipe 60*a*.

As noted, it is the effect on the pressure of the fluid in the conduit 60 and the impact tube 28 as a result of the force of the stock acting on the jet of fluid being discharged from the impact tube 28 into the stock stream which affords a variable for measuring the velocity of the stock. In accordance with the invention this variable serves to vary a signal which in turn provides a means for measurement. Accordingly, a variable electrical resistance mechanism indicated generally at reference numeral 62 is connected into the conduit 60. Generally, the mechanism 62 comprises a resistor element 63 connected at opposite ends to wiring 64 and 66 shown in the wiring diagram of FIGURE 2 to provide a circuit across which is applied a voltage provided by suitable means as indicated diagrammatically at 67.

The conduit 60 is tapped as at 68 for fluid communication with a reservoir 69 filled with fluid mercury. The mercury can rise in a column or core 70 into engagement with the resistor element 63 whereby that portion of the resistor 63 which is engaged with the column of mercury 70 is effectively shunted out. The greater the water pressure at tap 68 the higher will rise the column of mercury 70 and the greater will be that portion of the resistor 63 shunted out. A decrease in water pressure at tap 68 conversely has the effect of reducing the pressure in reservoir 69 lowering the level of the mercury column 70 and decreasing the shunted out portion of the resistor 63.

The electric power source 67 is adapted to apply a fixed E.M.F. to the circuitry 64, 66. A voltmeter 71 may be applied across the power source 67 to indicate this fixed E.M.F.

As the shunted out portion of the resistor element 63 increases and decreases as a result of pressure variations of the water in conduit 60 the current in the electric circuit decreases and increases accordingly as indicated by an ammeter 72 connected in the circuit. A manually adjustable rheostat 73 is also provided in the circuit to establish manually a maximum current flow through the circuit.

It will be appreciated that in order to provide a linear relationship between the static pressure of the water in conduit 60 and the flow of current through the electric circuitry 64, 66 without the necessity of an electrically compensating mechanism the velocity of the water through conduit 60 must be maintained at a fixed level regardless of the velocity of the stock and the effect thereof on the jet of water being discharged from the impact tube 28. In order to provide a fixed flow rate of the water through conduit 60 a flow meter 74 is mounted in conduit 60, ahead of which is mounted a water pressure compensator 76. The flow meter 74 may be of the fixed orifice type and the compensator 76 automatically adjusts the flow rate through conduit 60 so as to maintain a fixed pressure drop, for example, about 3 pounds per square inch, across the flow meter 74. A filter 77 and a water shut-off valve 78 are also mounted in the conduit 60 ahead of the pressure compensator 76.

If desired, water can be supplied to the impact tube shower 38 from the same water line 62 which supplies the water to the impact tube 28. Thus, the conduit 39 is connected to the water line 62 and in order to facilitate the operation of the shower a solenoid operated valve 79 is connected in conduit 39 along with a shut-off water valve 80.

In many papermaking machines of the Fourdrinier type water is also supplied to the wire pit. In FIGURE 3 another conduit 81 is shown connected to water pipe 82 and leading to the wire pit of the papermaking machine. Conduit 81 can be utilized in draining the impact tube shower pan 42 when the impact tube 28 is in its inoperative position and being cleaned, and for that purpose an eductor venturi 82 is mounted in the conduit 81 and is also connected to the drain line 43 which extends into the impact tube shower pan 42. Again, a shut-off valve 83 may be mounted in the conduit 81 for obvious purposes.

Referring to FIGURES 4 and 5, the variable electrical resistance mechanism 62 is more particularly characterized as comprising a housing 84 which includes a vertically upright back member 86, a vertical front member 87, a horizontal front member 88 and a reservoir member 89. Members 87, 88 and 89 have vertically aligned back walls 90, 91 and 92, respectively, which are separated from a vertical wall 93 of member 86 by means of a spacer bar 94.

The vertical front member 87 has formed therein an inlet 96 and an outlet 97 interconnected by means of a bore 98. The inlet 96 and the outlet 97 are connected to the conduit 60 (FIGURE 1) whereby the water flowing through conduit 16 to the impact tube 28 passes through the bore 98.

A reduced diameter vertical bore 99 is also formed in the vertical front member 87 adjacent the bore 98 and in parallel relation thereto. Bore 99 is connected in fluid communication to the bore 98 through a horizontal branch passageway 100 formed at the upper end of bore 99. A lower end 101 of the smaller bore 99 opens into a reservoir 102 formed in member 89. The reservoir 102 is filled with fluid mercury in the operative condition of the mechanism 62 to provide a shunt for the resistor element 63.

The front wall 93 of the vertical back member 86 has formed therein a thin, elongated vertical groove or recess 103 which is in communication with the reservoir 102 at a lower end 104 thereof through an aperture 106 formed in the spacer plate or bar 94 and a passageway 107 formed in the reservoir member 89. Thus, as the static pressure of the water in conduit 60 increases to increase the pressure in bore 99 (which is filled with water), the pressure on the mercury in reservoir 102 increases to urge a quantity of the mercury upwardly in the groove or core 103 formed in the vertical back member 86. An upper end 108 of the core 103 is vented to atmosphere through a branch passageway 109.

Referring to FIGURES 2 and 3 in conjunction with FIGURES 8 and 9, it will be noted that the resistor element 63 comprises a helical coil of wire which is wound vertically upwardly along the groove or core 103. In the embodiment of the element 63 shown in FIGURES 8 and 9, the windings as indicated at 110 are embedded almost entirely within the back member 86 except for an arcuate portion 111 thereof which is exposed to the interior of the core 103. The back member 86 may be formed of any non-conductive material, such as "plexiglass," and in the embodiment illustrated members 86–89 and 94 of the mechanism 62 are all formed of this material.

Opposite ends 112 and 113 extend through the back member 86 and are connected, respectively, to wires 64 and 66 (FIGURE 2).

The resistor element 63 may be preferably wound of relatively high resistance wire such as Nichrome. Fluid mercury, used in the illustrated embodiment for shunting out portions of the resistor 63, has an electrical resistance

somewhat similar to Nichrome but the cross-sectional area of the fluid mercury in the core **103** is so much greater than the cross-sectional area of the windings of the resistor **63** that the overall resistance afforded by the fluid mercury is substantially less than that of the Nichrome wire. In the illustrated embodiment the wire has about 100 windings per inch with an overall resistance of about 800 ohms.

In the embodiment illustrated in FIGURES 10 and 11 the windings of the resistor **63** are disposed completely within the core **103**. In this embodiment the diameter of the core **103** may be greater than the diameter of the core in the embodiment shown in FIGURE 8 in order to accommodate additional fluid mercury to lessen the electrical resistance thereof.

In order to provide a zero adjustment of the variable electrical resistance mechanism **62** and the ammeter **72** means are provided for selectively adjustably controlling the level of mercury in the core **103** for any given water pressure. As shown in FIGURES 4–6, a mercury level regulator indicated generally at reference numeral **114** comprises a threaded stud **116** mounted in the horizontal front member **88** and having an enlarged head portion **117** formed at an inner end thereof and disposed in a recess **118** situated above and opening downwardly into the reservoir **102**. A knurled outer end **119** facilitates adjustment of the stud **116**, and as the stud is threaded into the member **88** the enlarged head portion **117**, which is conically shaped in the illustrated embodiment, moves downwardly toward the reservoir **102** to raise the level of the mercury in the core **103**. Conversely, threading the stud **116** outwardly has the effect of raising the enlarged head **117** to lower the level of the mercury in core **103**.

The mercury level may also be regulated by adjusting the upright back member **86** and the spacer **94** vertically with respect to members **87**, **88** and **89**. For this purpose members **86** and **94** are connected in fixed assembly to members **87–89** by means of a plurality of threaded bolts as at **119** housed in oversized bores **120** formed in members **86** and **94**. In order to accommodate such movement, an inner vertical leg **121** is formed in the passageway **107** of the reservoir member **89** and is surrounded by a sealing member such as an O-ring at **122**. As the upright back member **86** and the spacer **94** are adjusted vertically the level of mercury in the core **103** varies accordingly for any given pressure of the water.

A plurality of cross bars **123** interconnect opposite pairs of the bolts **119** in order to rigidify the assembly of the mechanism **62**. In order to fill the reservoir **102** with mercury a bore **124** is formed in the reservoir member **89** adjacent a bore **126** which houses the stud **116**, and a threaded filler plug **127** closes off the bore **124** after the reservoir **102** has been filled with mercury.

It should be understood that it is not essential to the principles of the invention that the fluid discharged from the impact tube **28** be water. Other liquids as well as air and inert gases can also be utilized as a substitute for the water.

Although minor modifications might be suggested by those versed in the art, it should be understood that I wish to embody within the scope of the patent warranted hereon all such modifications as reasonably come within the scope of my contribution to the art.

I claim as my invention:

1. In a papermaking machine having a head box and a slice opening in the head box for supplying a stream of stock from the slice opening to a traveling forming surface, means for providing a measurement relating to the velocity of the stock at the slice opening comprising,
- conduit means having means for connection to a source of pressurized fluid,
- an outlet in said conduit means situated at said slice opening for directing a jet of the fluid from said conduit means into the stream of stock,
- regulator means in said conduit means for maintaining a constant velocity of said pressurized fluid at said outlet regardless of variations in the velocity of the stream of stock, and
- means associated with said conduit means and responsive to variations in the pressure of the fluid in said conduit means at a selected point therein for providing a signal which varies as a function of variations in the pressure of the fluid at said selected point,
  - the pressure of the fluid at said selected point varying as a function of variations in the velocity of the stock at said slice opening, and
  - said signal providing means comprising an electric circuit,
  - means for applying a given E.M.F. across said circuit, and
  - resistance means in said circuit responsive to variations in the pressure of the fluid at said selected point for varying the electrical resistance of said circuit as a function of variations in the pressure of the fluid at said selected point.

2. The papermaking machine as defined in claim **1** wherein said resistance means comprises
- a resistor element connected in said circuit,
- electrically conductive means movable with respect to said resistor element for shunting out portions of said element, and
- means responsive to variations in the pressure of the fluid at said selected point for moving said electrically conductive means with respect to said resistor element as a function of the pressure of the fluid at said selected point,
  - whereby the current of said circuit varies as a function of the pressure of the fluid at said selected point.

3. In a papermaking machine having a head box and a slice opening in the head box for supplying a stream of stock from the slice opening to a traveling forming surface, means for providing a measurement relating to the velocity of the stock at the slice opening comprising,
- conduit means having means for connection to a source of pressurized fluid,
- an outlet in said conduit means situated at said slice opening for directing a jet of the fluid from said conduit means into the stream of stock,
- means associated with said conduit means and responsive to variations in the pressure of the fluid in said conduit means at a selected point therein for providing a signal which varies as a function of variations in the pressure of the fluid at said selected point,
  - the pressure of the fluid at said selected point varying as a function of variations in the velocity of the stock at said slice opening,
  - said conduit means comprising an impact tube,
- means for pivotally mounting said impact tube for selective movement thereof between first and second positions at which the impact tube is disposed within and without the stream stock at the slice opening of the head box, respectively,
- impact tube shower means for spraying cleaning water on the impact tube when the tube is pivoted to said second position thereof,
- an impact tube shower pan associated with said impact tube in said second position thereof for collecting the cleaning water sprayed on the impact tube, and
- a drain pipe in said shower pan for removing the collected cleaning water from the pan.

4. Apparatus for providing a signal which varies as a function of variations in the pressure of a stream of fluid comprising,
- a housing having a vertically extending core and a reservoir at the base of the core,
- a quantity of fluid mercury within the reservoir risable

within the core upon an increase in pressure in said reservoir,

means communicating the stream of fluid with said reservoir for simultaneous change in pressure thereof,

a helical coil of high resistance wire the windings of which are disposed principally outside of said core with only portions of each of the windings being exposed to the interior of said core,

means for applying a fixed E.M.F. across said coil, and

means for measuring the current in said coil.

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