March 16, 1948. C. E. THORP ET AL 2,437,715

CONSISTENCY CONTROL

Filed Nov. 29, 1943 4 Sheets-Sheet 1

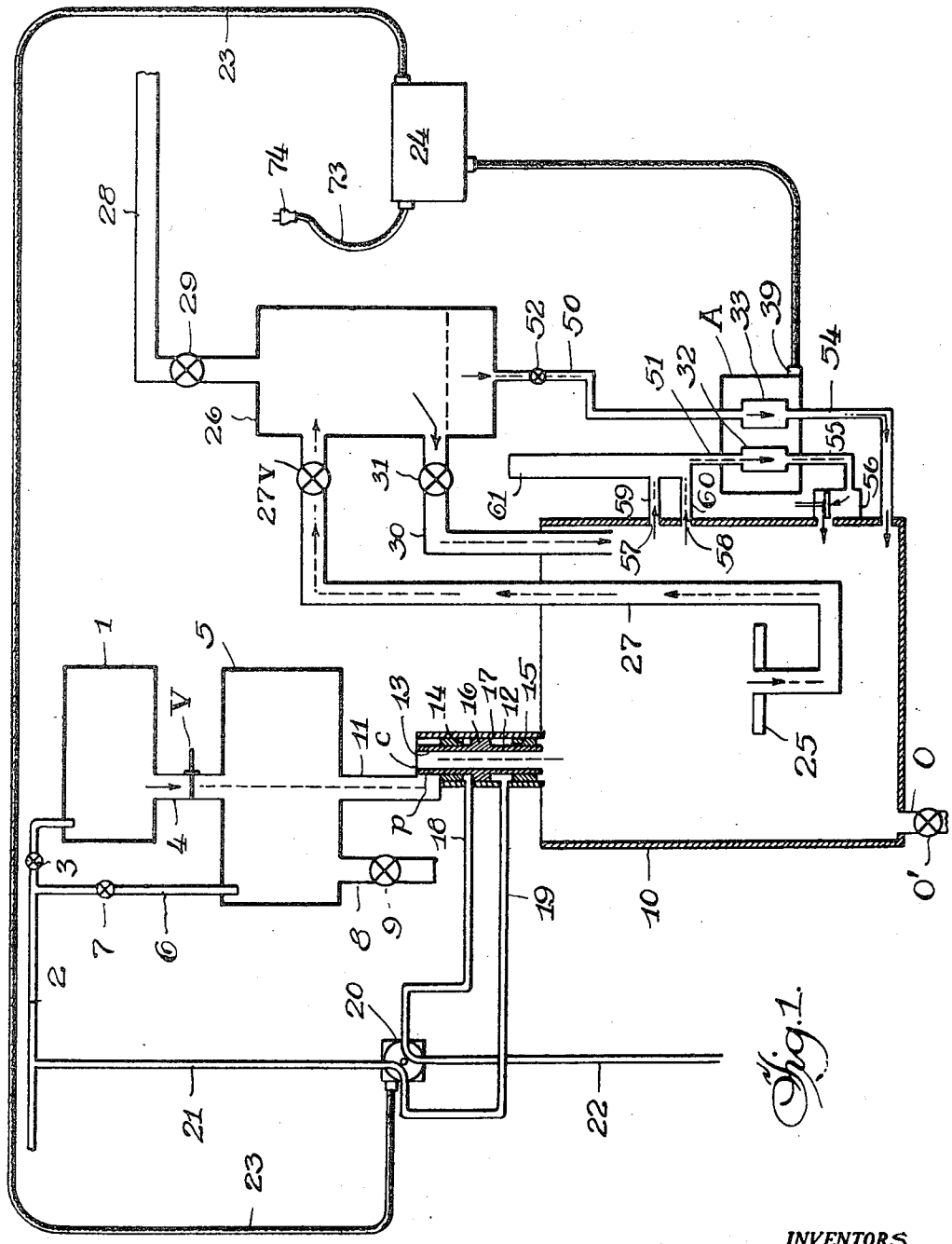


Fig. 1.

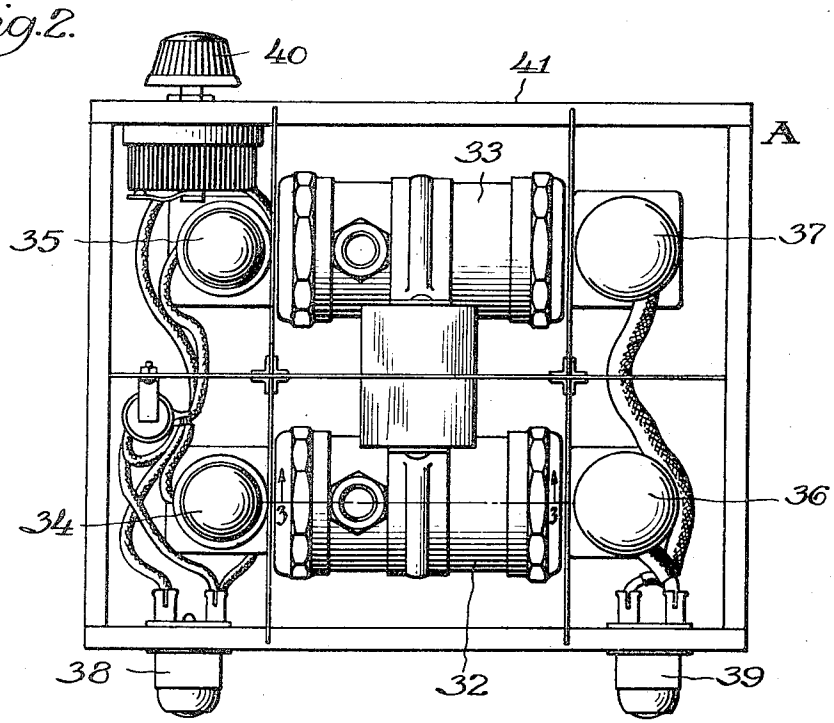
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CONSISTENCY CONTROL

Filed Nov. 29, 1943 4 Sheets-Sheet 2

Fig. 2.



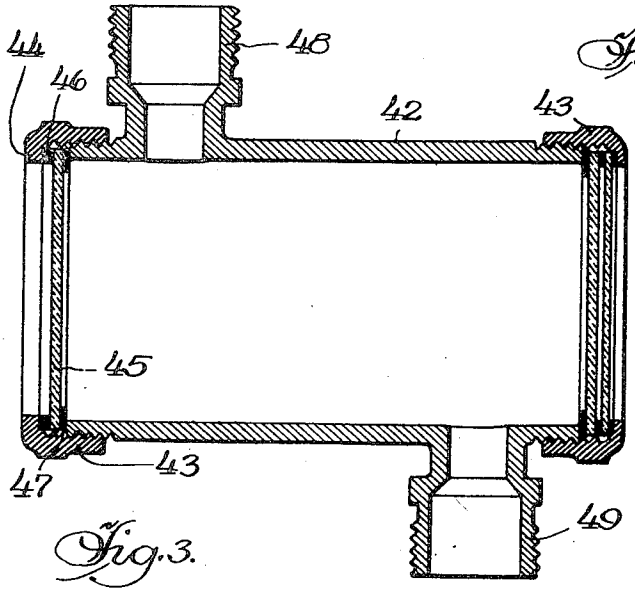
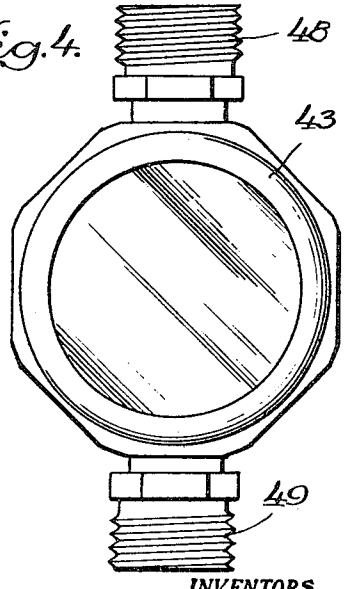


Fig. 3.

Fig. 4.



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CONSISTENCY CONTROL

Filed Nov. 29, 1943 4 Sheets-Sheet 3

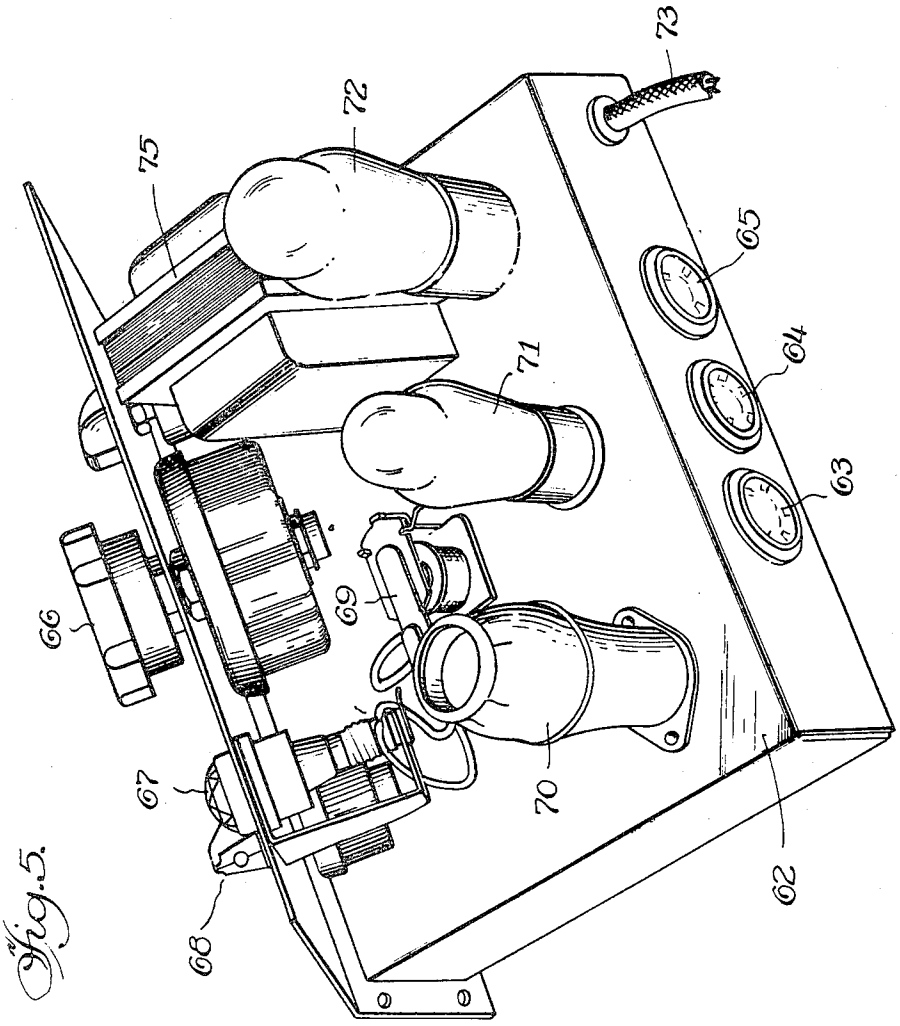


Fig. 5.

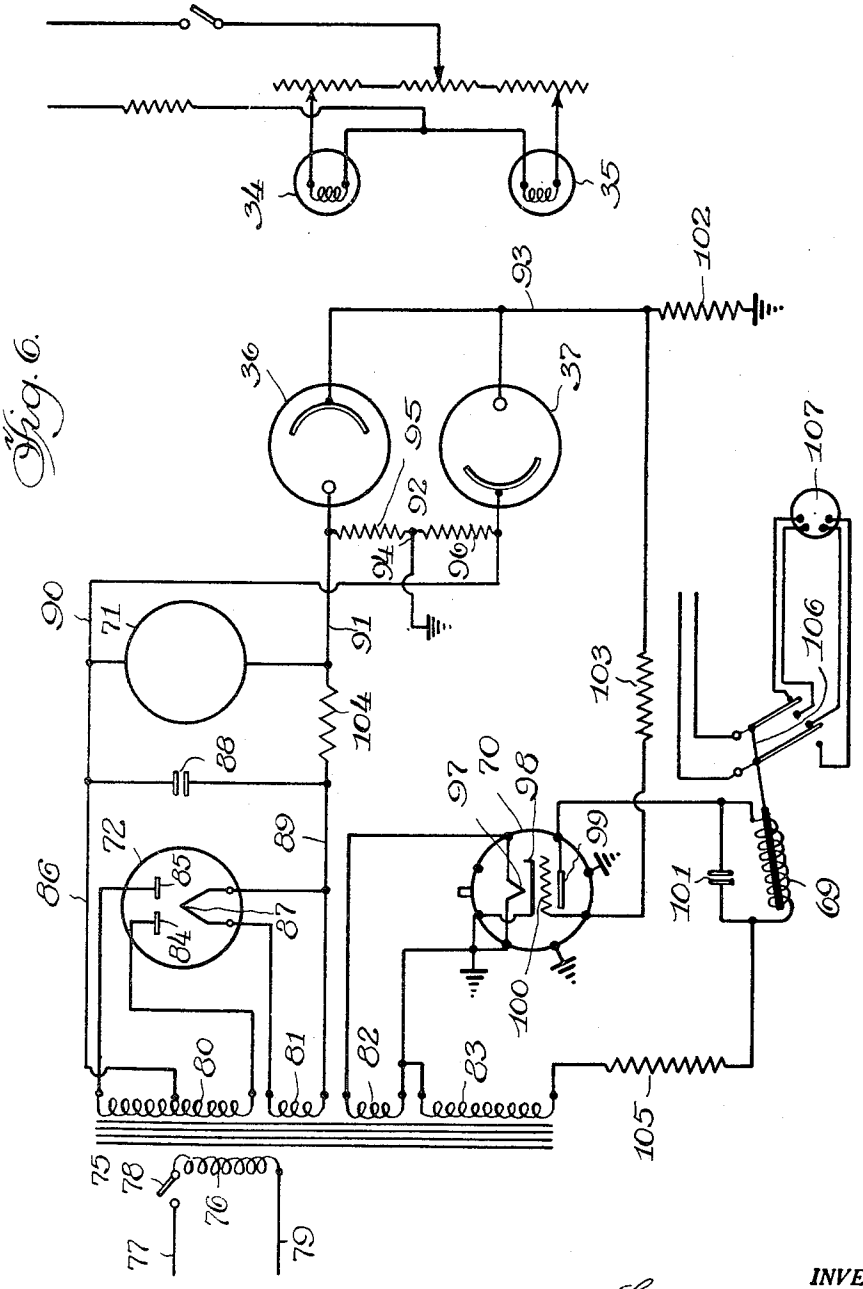
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CONSISTENCY CONTROL

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Fig. 6.



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UNITED STATES PATENT OFFICE

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CONSISTENCY CONTROL

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Application November 29, 1943, Serial No. 512,122

9 Claims. (Cl. 92—46)

1

This invention relates to a method and apparatus for controlling the consistency of a mixture of liquid and other material. While not limited thereto, this invention is particularly useful in automatically controlling the consistency of a pulp-liquid mixture consisting of a mixture of liquid and fibers, for use in accreting onto a porous former, in a fibrous pulp bath, various forms of fibrous articles, as well as being useful in the paper-making industry.

"Consistency" is the term used by the paper and pulp industry to express the per cent pulp contained in a pulp-liquid mixture, and is usually given as grams of dry pulp contained in 100 grams of total pulp-liquid mixture. The quantitative deposition of pulp from a pulp-liquid mixture onto a filtering medium such as an accreting former, or on a screen, depends upon many factors, but one of the most important is the consistency of the pulp-liquid mixture. The accuracy with which pulp can be quantitatively deposited, holding all other factors constant, depends upon the accuracy with which the consistency can be controlled.

In most felting processes the deposition of pulp must be controlled within extremely close limits. Because of the absence of a satisfactory automatic controlling device, an empirical manual control has been used to regulate consistency, in which if the deposition of pulp onto the former or screen is too high the consistency is decreased, and conversely, if the deposition is too low the consistency is increased. This manual control is entirely inadequate because no operator can accurately judge consistency, and as a result the consistency in the felting tanks is continually being adjusted back and forth between wide limits. This causes a wide variance in weight of the deposited pulp form.

While some devices have been heretofore proposed for automatically controlling consistencies 1.0 per cent and higher, such as encountered in beaters and storage tanks, such devices depend upon the change of viscosity or density with consistency, and do not give accurate results below 1.0 per cent consistency. At the point where deposition takes place, the consistency is less than 1.0 per cent and usually is less than .25 per cent.

In the present invention we have developed an automatic consistency control which will accurately control consistencies in the range of from .001 per cent to .25 per cent. We use the principle of light absorption variance with consistency, and the present system is unusual in

2

that it takes its own sample continuously, and automatically adds the correct amount of pulp to keep the consistency at any desired point regardless of how much pulp is removed by other operations.

Among the objects of our invention are to overcome the disadvantages, and utilize the advantages, referred to above.

A further advantage is to provide a novel method and apparatus for automatically controlling consistency, having desired sensitivity, and capable of accuracy at consistencies below 1 per cent.

A still further advantage is to provide for obtaining the light absorption value for the pulp alone, by measuring the amount of light absorbed by the white water and subtracting its value from the total absorption value obtained for the pulp-white water suspension.

Another object is to provide a novel form of light absorption cell unit and associated parts for obtaining the light absorption value for the pulp.

A further object is to provide novel means for measuring the light absorption value of a pulp-liquid suspension, by passing light beams through the suspension, and utilizing the emergent light to set up electrical energy which in turned is used to control parts for automatically effecting consistency control and maintain any consistency to which the circuit is adjusted.

A still further object is to provide novel method and apparatus for automatically controlling consistency by photometric methods.

An additional object is to make use of a thyratron or similar device to effect the automatic consistency control contemplated herein.

Another object is to provide a complete control consisting of two sections comprising a consistency cell unit located near the point where the consistency is to be regulated, and a consistency control unit that may be placed at any convenient location free of moisture and vibration.

A further object is to provide an automatic consistency control comprising amongst other things an electronic control and a thyratron circuit for controlling pulp addition to the system.

A still further object is to provide a consistency control system that, is accurate and reliable in action, eliminates manual control, is sensitive in operation, economical to construct, of especial value for low consistency percentages, and when once set will maintain the consistency at the desired point without further attention.

Other objects, advantages and capabilities, inherently possessed by our invention, will later more fully appear.

Our invention further resides in the combination, construction and arrangement of parts illustrated in the accompanying drawings and while we have shown therein a preferred embodiment, we wish it understood that the same is susceptible of modification and change without departing from the spirit of our invention.

In the drawings:

Fig. 1 is a diagrammatic view of the automatic consistency control of the present invention.

Fig. 2 is a face view showing the interior of the consistency cell unit with the cover removed.

Fig. 3 is an enlarged longitudinal section, taken on the line 3—3 of Fig. 2, through one of the consistency cells.

Fig. 4 is an end elevation of the consistency cells of Fig. 3.

Fig. 5 is a perspective view of the consistency control unit with its housing removed and showing the position of its major part.

Fig. 6 is a wiring diagram of the consistency control unit, and of the photo-tubes and the lighting source of the consistency cell unit, and of the relay for the valve operating solenoid.

While for purposes of illustration only, we have shown in the drawings our invention as applied to the control of the consistency of a pulp-liquid suspension, we wish it understood that it is not limited thereto, but is capable of use in any type of consistency control to which it may be applicable.

If a beam of light is passed into an absorption cell containing a liquid suspension of pulp a certain proportion of the light will be absorbed and a certain portion reflected within the cell. The quantity of light emerging from the cell will be a function of the consistency of the pulp suspension (c), the cell length (l), the character of the pulp (P), the character of the liquid (a), and the character of the entering light beam (y). When the consistency is zero, i. e. no pulp present in the cell, the per cent of light lost in the cell

$$\left(\frac{I_0}{I}\right)$$

may be expressed by the formula (Lambert's law):

$$\log_{10}\left(\frac{I_0}{I}\right)=yal$$

With consistencies greater than zero, i. e. pulp present, the equation must be expanded to include all of the above factors. No exact theoretical equation has yet been derived to express the relation of consistency to all these factors, and therefore the theoretical aspects of the consistency control must be limited to empirical data as obtained in its use.

An approximate equation which relates absorption with consistency has been given by P. V. Wells to be:

$$\log\left(\frac{I_0}{I}\right)=\frac{ceP}{P^4+ay^4} \qquad (1)$$

In preliminary work done in the development of the consistency control the above formula was evaluated and proven correct for the consistency range 0 to .25 per cent.

Beer's formula, well known in colorometric work, states:

$$\frac{I_0}{I}=e^{-Kcl} \qquad (2)$$

This is the Wells formula where

$$K=\frac{-2.303kP}{P^4+ay^4}$$

K can be evaluated for pulps of different character and some work was done in that direction during the initial states of the development of a consistency control. Kraft F–8 with a freeness of 19 was found to have a K of 7.1 whereas sulphite F–16 had a K of 10.6 when at a freeness of 19.

Although no practical use for the evaluation of K has been suggested the above work showed that consistency measurement by means of light absorption was not entirely dependent on empirical data and that certain well known turbidimetric laws held true within the limits for which the control was designed.

If

$$\left(\frac{I_0}{I}\right)$$

is set equal to X then from Formula (2).

$$X=e^{-Kcl}$$

dX/dc is the sensitivity and is equal to $-KlX$.

This indicates that the sensitivity is directly proportional to the length of the absorption cell, i. e. doubling the length of the cell will double the sensitivity. This is an important factor in the design of the absorption cell, and shows that if the cell is of the correct length any sensitivity required may be obtained.

The absorption constant, K depends, as previously stated, on four major constants, but each of these in turn is dependent on a great many other characteristics of the pulp. It is not practical to theoretically calculate the value of K, but if required it can be obtained empirically. The value of K is only necessary in the development of the basic principles of the consistency control, and need not be considered in the operation of the automatically controlled consistency control.

In a pulp-liquid suspension, light will be absorbed not only by the pulp, but also by the liquid. A consistency control using only one absorption cell will therefore give the additive result of both pulp and liquid absorption factors. Hence if the light absorbing components of the liquid do not remain constant they will cause corresponding inconstancy in the consistency control.

The liquid generally used to form a pulp suspension is water which, if re-used, contains a variable amount of turbidity and color. As used herein, the term "white water" designates the water which has passed through the accreting former or screen and from which the greater portion of the pulp fibers has been removed, and the term "tank water" designates the pulp-liquid mixture in the tank prior to its passage through the accreting former or screen. Provision must be made to measure the amount of light absorption by the white water and subtract its value from the total absorption value obtained for the tank water. The net result will then be an absorption value for the pulp alone. This measurement and subtraction of white water absorption values is, in the present invention, done continuously and automatically so that the white water

variations will be compensated for at all times, as later more fully described.

As previously stated, a light beam passing through the suspension will be decreased in intensity, this decrease being directly proportional to the consistency. If the emergent light impinges on a photoelectric cell, or other suitable light sensitive device, the light intensity and its variations will be converted into electrical energy. While any suitable light sensitive device desired may be used, we, in the present disclosure for illustrative purposes only, and not as limiting our invention, have shown and described a phototube which regulates an external current source in direct proportion to the light intensity. The amount of current which a phototube or the like will emit is only large enough to operate a sensitive meter, and therefore, in order to convert a consistency control into an automatic control unit we have used an electronic circuit to develop larger currents from the minute current of the phototubes.

Pulp feed to accreting or felting tank

Referring more in detail to the drawings, Fig. 1 shows a diagrammatic or schematic layout of one form of automatic consistency control embodying our invention, and in which pulp and liquid are first treated in a beater 1 into which the desired amount of fibers are introduced, water being added thereto as required through pipe-line 2 having a valve 3 for regulating the amount of water, or other liquid, so introduced. From the beater 1 the mixed and beaten pulp and liquid are passed through pipe 4 to the dilution and storage tank 5, there being provided in pipe 4 a quick opening valve V for controlling the amount of material passed into tank 5. Extending from the pipe line 2 and leading to the interior of tank 5 is a pipe 6, having a valve 7, for introducing into tank 5 in desired amount, water or other liquid, for effecting the required dilution of the pulp-liquid mixture in this tank. Pipe 8, which has a valve 9, provides for outflow of all or part of the contents of tank 5 as desired.

The accreting or felting tank 10 is positioned at a lower level with relation to storage tank 5, and receives therefrom at controlled intervals pulp-liquid mixture through pipe 11 in which is mounted a control valve 12. While any suitable type of valve may be here used, we have shown for illustrative purposes only, and not by way of limitation, a tubular valve sleeve 13 longitudinally slidable in a tubular seat having a pair of fixed, spaced apart shoulders 14 and 15, forming stops to limit the longitudinal movement of the collar 16 fixed on the exterior of the valve sleeve. Collar 16 is longitudinally slidable within an outer wall 17 which in effect forms a cylinder within which collar 16 acts as a piston. Fixed into openings at one side of the tubular wall 17 (which has a closed top c) are two spaced apart pipes 18 and 19 which at their opposite end are secured to the opposite sides of a four-way solenoid valve 20, which when in the position shown in Fig. 1 admits water (or other liquid) from pipe 19 to the under face of collar piston 16 and forces it to its upper position to move valve 12 to close port p in pipe 11, thus preventing flow of pulp-liquid mixture from storage tank 5 into the accreting or felting tank 10. When the valve 20 is rotated clockwise (as viewed in Fig. 1) ninety degrees, as will be understood, the liquid will be conducted from pipe 21 through valve 20, and pipe 18 to the upper face of collar piston 16 and force it to its lower position to move valve 12 to open port p in pipe 11 and admit flow of pulp-liquid mixture from storage tank 5 into the accreting or felting tank 10. This enables us to feed to the mixture materials of such constituency as to maintain the consistency of the mixture constant at any desired point.

As will be understood in Fig. 1, when liquid flows from pipe 21 through pipe 19 to move the collar piston upwardly, the liquid formerly above this collar will be relieved through pipe 18, valve 20 and discharge pipe 22 to any suitable place of discharge. When the valve 20 is rotated clockwise ninety degrees, to pass liquid from pipe 21 through pipe 18 to move the collar piston 16 downwardly, the liquid therebelow will be relieved through pipe 19, valve 20 and discharge pipe 22. Valve 20 is preferably operated by means of a solenoid through the medium of an electric current through a pair of wires (see Figs. 1 and 6) within the cable 23 from the consistency control box 24 later more fully described. It is thus seen that by opening and closing of valve 12 pulp-liquid mixture will be added to the accreting or felting tank 10, or prevented from entering thereinto, as required to maintain the consistency of the pulp-liquid mixture in the felting tank constant. From the foregoing it will be understood that the solenoid in valve 20 may be operated to rotate this valve in one direction to add pulp to the felting tank, or in the opposite direction to stop the flow of pulp to the felting tank, as required. Details of this solenoid action are not shown as the general construction of solenoids for operating valves are well known to any one skilled in the art, but it will be sufficiently understood by referring to Fig. 6.

Accreting or felting tank operation

Vertically movable in the felting tank is a felting carriage 25 connected from which to the white water header 26 is a tubular member 27 (having a check valve 27V) which may be in the form of a coiled or bent flexible hose, a telescoping pair of slidable pipes, or any other suitable construction that will permit the felting carriage to be lowered into and raised out of the pulp-liquid bath in this tank. As will be understood a porous felting former of the desired contour will be mounted upon the felting carriage in such manner as to enable a fibrous carcass to be accreted or felted thereon.

A suction will be created within the header 26 by means of a pipe 28 leading from this header to any suitable source of suction and controlled by a quick opening hand valve 29 which will be closed when felting is not desired. Connected to the side of the header at a suitable height above the bottom thereof is an overflow pipe 30 for flowing white water from within the header back into the felting tank, which flow is controlled by a check valve 31. The position of pipe 30 above the bottom of the header is such that a substantial amount of white water is provided for therein not subject to overflow through pipe 30.

During an accreting or felting operation the valve 29 will be open and suction will draw white water through pipe 27 into header 26, which as explained above overflows back into the felting tank through pipe 30, except for that portion below the inlet end of this outlet pipe which portion as will be later explained continuously and slowly drains to and through the white water

absorption cell and back into the felting tank. It is also pointed out that if desired for any special reason, additional liquid may be added to the felting tank by a pipe, hose or the like (not shown) or any other means, although this is not done in normal automatic operation of the system. An outlet pipe O, having a valve O', is connected with the bottom of this tank for use as desired. The check valves 27V and 31 insure the correct uni-directional flow from the felting tank to the header through pipe or hose 27, and from the header to the felting tank through pipe 30.

Consistency cell unit

The consistency cell unit contains only the parts which should be located near the point where the consistency is to be regulated. Fig. 2 shows an interior view of the consistency cell unit, and the location of its component parts. This unit is designated generally at A and comprises two absorption cells 32 and 33, light sources 34 and 35 (one for each cell), phototubes 36 and 37 (one for each cell), light control input 38, shielded cable output 39 for the phototubes, range adjustment 40, which parts are mounted in and on a box or cabinet 41 having suitable partitions (see Fig. 2) for separating the lights of the light source from each other and from the absorption cells (except for openings to permit the light from each light source to pass into its respective absorption cell), and to separate the absorption cells from each other and from the phototubes (a hole being provided in each of the partitions between the absorption cell and phototube to permit light emerging from each absorption cell to pass to and strike its respective phototube), and to separate the two phototubes from each other. The cabinet or box, and its parts are constructed and arranged to provide complete isolation of the absorption cells and tubes to prevent stray light interference, to give adequate ventilation of the light source, to provide adequate space for the component parts to allow ease of inspection and removal, and to afford rigidity of the parts with relation to each other and to the cabinet to prevent vibrational misalignment of critical dimensions.

The wiring in the consistency cell unit is such as to provide isolation of phototube wiring from the light source wiring, give adequate shielding of the phototube wiring, and to afford adequate heat and electrical insulation of light source wiring.

The absorption cell 33 is for receiving white water and the absorption cell 32 is for receiving tank water. These cells will hereinafter be referred to as the white water cell and the tank water cell respectively. As they are of identical construction, one of them only need be described. This cell is shown in detail in Figs. 3 and 4 and comprises a tubular body portion 42, of opaque material such as metal (although other suitable material may be used), and at each end is provided with a removable clamping member 43 screwed or otherwise secured to the body portion. At the light source end (which in Fig. 3 is the left hand end) there is clamped between the end of the body portion and the flange 44 a pane of glass 45 of the appropriate marginal contour, suitable gaskets 46 and 47 being used under compression to prevent leakage of moisture around this glass from the interior of the cell. This is the end adjacent the light source and will not have dew or moisture deposited on the exterior face because of the heat from the light source.

The opposite end of the tube is closed in a similar manner except that two glass panes are used, laterally spaced apart, to form a dead air space therebetween and provided with gaskets to prevent leakage of moisture from within the cell. This dead air space prevents deposit of dew on the outer face of the outer glass pane, which dew or moisture might interfere with the passage of light to the adjacent phototube. Near one end of the cell body portion is a tubular outstanding threaded nipple 48 to which will be connected a suitable hose, pipe or the like from the white water header in the case of the white water cell, and from the felting tank in the case of the tank water cell, in order to pass the white water or the tank water (as the case may be) into the cell. Adjacent the opposite end of the cell and projecting from the opposite side of the body portion is a similar nipple 49 to which a hose, pipe or the like will be connected back to the felting tank to enable the respective liquid to flow through the cell. The inlet pipe from the header to the white water cell 33 is shown at 50 in Fig. 1, and the inlet pipe from the felting tank to the tank water cell 32 is shown at 51, while the return pipe for the white water cell is indicated at 54 and the return pipe for the tank water cell is indicated at 55. A check valve 52 is provided in pipe 50 to insure uni-directional flow from the header to the absorption cell.

From the above it is seen that white water will continually be fed through the white water cell by gravity, and tank water will be continually fed through the tank water cell. This latter feed from the felting tank of the tank water through pipe 51 and back to the felting tank, will preferably be positively effected by a suitable motor operated pump (not shown in detail) located in the pump chamber 56 (see Fig. 1).

In order to avoid drawing air bubbles through the tank water cell (which might interfere with the accuracy of the system) the tank water is drawn from the felting tank through two openings 57 and 58 and pipes 59 and 60 to pipe 51 which is provided with an upstanding vent pipe 61 through the open upper end of which the air from such air bubbles will escape. It is thus seen that we have provided for continuous sampling, in the absorption cells, of tank water and white water, through which samples in the respective cells light will be passed, and the unabsorbed portion of which light will pass out of the farther end of the cells onto the phototubes to effect operation of the consistency control unit.

Consistency control unit

The consistency control unit is shown, with the housing removed, in Fig. 5. The parts are mounted upon the hollow base 62, and in this view 63 designates the shielded cable control inlet, 64 designates the light control outlet, and 65 the solenoid control outlet. The rough adjustment is indicated at 66, the solenoid function indicator at 67, and the fine adjustment at 68. The relay is designated at 69, the thyratron at 70, the voltage regulating tube at 71 and the full wave type 80 rectifier tube at 72. The wiring diagram of the consistency control unit will now be described.

Wiring diagram of consistency control unit

The wiring diagram of the consistency control unit is shown in Fig. 6. The cable 73 (see Figs.

1 and 5) carrying at its outer end a wall plug or the like 74 (to be connected to a 110 volt A. C. source) leads into the consistency control box 24 (see Fig. 1) to the transformer 75 shown in Figs. 5 and 6. As seen in Fig. 6, the transformer comprises the primary 76 (having the incoming current line 77, with a switch 78, and the outgoing current line 79), the secondary 80, the two filament secondaries 81 and 82, and the secondary 83 for the thyratron plate voltage. The wiring forming the secondary 80 leads to the plates 84 and 85 of the full wave rectifier 72 and connected midway of secondary 80 is the direct current line 86. The wiring forming the filament secondary 81 leads to the cathode 87 which under the action of the alternating currents rapidly emits electrons alternately to the plates 84 and 85 of the "80" full wave rectifier. As will be understood from this type of rectifier tube and hookup, this produces a direct current in line 86, a small amount of which passes to the condenser 88 to smooth the direct current in lines 86 and 89.

The D. C. current in lines 86 and 89 and the condenser 88 is connected in parallel to give a smoothing action on the current to eliminate ripple voltage. In parallel with the condenser and lines 86 and 89 is a voltage regulating "V. R. 150/30" tube designated at 71 (in Fig. 6), of the well known gas filled diode type to maintain constant voltage across points 90 and 91. In the present arrangement this gives a constant voltage of 150 volts which is the supply voltage for the Wheatstone bridge of which each of the tank water phototube 36 and the white water phototube 37 acts as one arm of the bridge. The other two arms of the bridge are obtained by a potentiometer or ballast 92, see Fig. 6. When the Wheatstone bridge is balanced there is no voltage between 93 and 94. Phototube 36, phototube 37, arm 95 and arm 96 form the four arms of the Wheatstone bridge.

Ballast 92 compensates for differences in phototubes and related wiring, and places the bridge circuit at the optimum sensitive point of operation.

The thyratron is a mercury-vapor, hot cathode tube with a controlling grid especially well suited for use in phototube circuits. A small change in its grid potential can cause its plate current to change from zero to a comparatively large value, and therefore it is essentially a relay. It may also be described as a gaseous electronic conduction device. The plate current from the thyratron is used to operate a magnetic relay which in turn controls a valve or any other large current-requiring equipment desired. The grid circuit of a thyratron is extremely sensitive and provision must be made to prevent stray electrical currents being set up in it. One millivolt grid variation is sufficient to cause the thyratron to fire or cease firing, and this sensitivity is responsible for the extreme sensitivity of our present consistency control. Adequate shielding of the thyratron and its grid circuit prevents stray electrical fields from disturbing this sensitivity.

Both alternating and direct current are used in the control unit. Alternating current is supplied to the plate circuit of the thyratron and the relay from a separate winding of the power transformer, while direct current, maintained constant by the voltage regulator tube 71, is supplied to the phototubes by the type 80 rectifier tube 72.

The operation of the thyratron will be readily understood from an inspection of the circuit diagram in Fig. 6. In the main the thyratron comprises the filament 97, the cathode 98, the plate or anode 99, and the grid 100, connected up in the circuit shown. The thyratron tube is gas filled. The relay for the thyratron is shown at 69 and is connected up with a condenser 101 to prevent the relay from chattering.

Proper grid bias for the thyratron is obtained through the use of the 8 meg. resistor 102 (see Fig. 6). One end of the phototube bridge circuit is connected to this 8 meg. resistor and the other end to the thyratron cathode. Thus, any lack of balance created in the phototube bridge circuit by variance in light intensity will cause the grid bias on the thyratron to change and cause the tube to fire or unfire. The grid line also includes the 2 meg. resistor 103. Suitable resistance will be used where desired. For example we have in successful operations used a resistance of 4200 ohms at 104 in Fig. 6, a resistance of 800 ohms at 105, a resistance of 10,000 ohms in the ballast 92 of the Wheatstone bridge and a resistance of 5000 ohms in the relay 69. We, however, do not wish to be limited to these specific amounts as by varying one or more of the various conditions, others will be varied accordingly, without departing from the spirit of our invention.

As will be understood in Fig. 6, operation of the relay 69 from the thyratron 70, will operate a switch 106 to in turn operate the solenoid 107 for effecting operation of the four way valve 20 for opening or closing valve 12 for adding, or stopping the addition of, pulp to the felting tank 10 for automatically controlling and maintaining constant the consistency of the pulp-liquid mixture in this tank. As stated, the present invention is capable of accurately controlling consistencies in the range from .001 to .25 per cent.

The light source control circuit is shown at the right hand side of Fig. 6, and will be readily understood as shown therein. Desired consistency settings are obtained by adjustment of the ratio of the white water light source intensity to that of the tank water light source intensity. This adjustment is obtained by the use of a simple light source balance or dimmer circuit as shown, whereby regulation of light intensity through this circuit, as compared to regulation of the operation of the photo-cells, overcomes loss of sensitivity of the control mechanism throughout a variation between relatively wide ranges of consistency. The function of the light source control may be explained as follows:

If more light falls on the tank water phototube than on the white water phototube, the bridge becomes unbalanced, the thyratron fires and pulp is added to the tank until the light intensities on the phototubes again become equal. Therefore, it can be seen that by varying the original light source intensities the above function can be simulated and control of the thyratron accomplished. After the ratio of the light intensities has been adjusted as referred to above, the consistency control will operate automatically.

While not wishing to be limited thereto, we have used two type 75 AV phototubes in the consistency cell unit for white water and tank water determination respectively. These tubes act as varying resistances under varying light intensities. Advantage of this fact is taken by using each tube as one arm of a Wheatstone bridge circuit in such a way that the output of the white water tube is subtracted from the out-

put of the tank water tube. In other words, the output of the bridge circuit is always the difference in outputs of the two phototubes and thus compensation for white water changes is obtained. Another advantage obtained by such a bridge circuit is the control of sensitivity. Effectively the tubes act as load resistances for each other. It is important to note that a small change in the load line of either of the tubes will cause a very large change to occur in the bridge output. This high sensitivity may be controlled by varying the ratio of the fixed resistances in the bridge.

The light source consists of two 100-watt projector lamps, one for each cell. These lamps are so arranged as to give practical results, but we wish it understood that modifications may be made without departing from the spirit of our invention.

While we have shown and described our control as preferably comprising two absorption cells, if maximum sensitivity is not desired a single cell may be used alone by proper adjustment of the electronic circuit as the other major component parts will function independently of whether one or two absorption cells be used. For example the grid bias of the thyratron obtained by the combination of resistors 102 and 95 and the additive resistances of tubes 36 and 37 of Fig. 6 may be changed by shorting out the white water tube 37, disconnecting resistor 95 and proportionately increasing resistor 102 to compensate for the loss of resistance 95. However we consider the use of the two absorption cells to be of great value in obtaining the extreme sensitivity of this control as previously described.

Having described our invention, we claim:

1. In consistency control apparatus, a vessel for containing a pulp-liquid mixture, a light absorption cell for continuously receiving liquid from which pulp has been removed, a light absorption cell for continuously receiving pulp-liquid mixture, a separate light source for each cell, a separate light sensitive device for each absorption cell for receiving light emerging from its respective absorption cell, a consistency control unit controlled by the light sensitive devices and having electronic means and a relay, and electrically operated means controlled by said relay for governing the admission of pulp-liquid mixture to the vessel to automatically control the consistency of the pulp-liquid mixture in the vessel.

2. In consistency control apparatus a storage tank for pulp-liquid mixture, an accreting tank, means for enabling controlled passage of mixture from the storage tank to the accreting tank, a consistency cell unit having a white water absorption cell and a tank water absorption cell, a white water header, means for continuously passing white water from the white water header through the white water absorption cell and thence to the accreting tank, means for continuously passing tank water from the accreting tank through the tank water absorption cell and back to the accreting tank, a separate light source for each of said cells, a separate phototube for receiving light emerging from said cells, a consistency control unit operated from said phototubes, and means operated by the consistency control unit for operating the mixture passage control means to maintain the consistency of the mixture constant.

3. A consistency control for maintaining substantially constant the consistency of a mixture of liquid and a material to be operated upon, comprising a vessel containing the mixture, valve means for controlling admission and stoppage of mixture with relation to the vessel, a sampling device comprising a pair of absorption cells, each of said cells having a separate light source and a light sensitive device, a light source balance circuit for regulating the light intensity of the light sources, and electronic means operated by the light sensitive device for controlling operation of the valve means for automatically controlling the consistency of the mixture.

4. A control apparatus for controlling the consistency of a suspension of solids in a liquid in a system in which solids are removed from a solids-liquid suspension leaving a substantially light transmissive liquid substantially free of solids, said apparatus comprising a pair of light transmissive vessels adapted to receive samples of the liquid mixture, one of said vessels being adapted to receive a sample of a liquid containing solids whose consistency is to be controlled, and the other of said vessels being adapted to receive a control sample of said liquid from which said solids have been substantially removed, a light-sensitive device adjacent each of said vessels, means for passing separate light rays through each of said vessels to its associated light-sensitive device, means for varying the intensity of said light rays passing through said respective vessels one with respect to the other, electrical circuit means interconnecting said light-sensitive devices in a Wheatstone bridge, and means forming an operating circuit connected to the output of said bridge circuit comprising a gaseous conduction electronic device for actuating a relay circuit to add a liquid mixture containing more solids to control the consistency of said liquid-solid mixtures in response to imbalance in said bridge circuit.

5. A control apparatus for controlling the consistency of a suspension of pulp in a liquid in a system in which pulp is removed from a pulp-liquid suspension leaving a substantially light transmissive liquid substantially free of pulp, said apparatus comprising a pair of light transmissive vessels adapted to receive samples of the liquid mixture, one of said vessels being adapted to receive a sample of a liquid containing pulp whose consistency is to be controlled, and the other of said vessels being adapted to receive a control sample of said liquid from which said solids have been substantially removed, means for circulating said liquids from a main body of liquid through said vessels and back to said main body of liquid, a phototube adjacent each of said vessels, means for passing separate light rays through each of said vessels to its associated phototube, means for varying the intensity of said light rays passing through said respective vessels one with respect to the other, circuit means interconnecting said light-sensitive device in a Wheatstone bridge, and means forming an operating circuit connected to the output of said bridge comprising a gaseous conduction electronic device for actuating a relay circuit to add a liquid mixture containing more pulp to control the consistency of said liquid-pulp mixtures.

6. The method of controlling the consistency of a liquid mixture having not more than about 1% of a solid material suspended therein, which comprises simultaneously passing separate light beams through a sample of said liquid mixture and through a sample of said liquid from which said solids have been substantially removed, ad-

justing the intensity of said light beams unequally one with respect to the other for a given concentration of solids in said liquid mixture, directing light emerging from said samples into separate light-sensitive electrical devices interconnected in a Wheatstone bridge circuit including bridge balancing means, balancing said bridge circuit at its optimum sensitive point of operation, whereby said liquid mixture compensates for the imbalance in the light intensity and keeps said bridge circuit in balance so long as the consistency of the liquid mixture remains the same, connecting an electronic circuit to the output of said bridge circuit to operate in response to imbalance in said bridge circuit and operating control means in response to the operation of said electronic circuit to control the addition of solids and liquid to said liquid mixture until said imbalance is restored.

7. The method of controlling the consistency of a liquid mixture having not more than about 1% of a solid material suspended therein which comprises simultaneously passing separate light beams of unequal intensity through a sample of said liquid mixture and through a sample of said liquid from which said solids have been substantially removed, directing light emerging from said samples into separate phototubes interconnected in a Wheatstone bridge circuit including bridge balancing means balanced at the optimum sensitive point of operation, connecting a gaseous conduction electronic device to the output of said bridge circuit to operate in response to imbalance in said bridge circuit, actuating a relay circuit in response to the operation of said gaseous conduction electronic device and causing said relay circuit to operate control means to control the addition of solids and liquid to said liquid mixture until said imbalance is restored.

8. The method as claimed in claim 6 in which said liquid mixture is a pulp-liquid mixture having a consistency in the range of from 0.001% to 0.25%.

9. The method of forming articles from pulp which comprises establishing a main body of a pulp-liquid mixture having a substantially constant consistency in the range from 0.001% to 0.25% of pulp, accreting pulp from said liquid mixture onto a pulp former, adding additional

quantities of pulp-liquid mixture to said main body of pulp-liquid mixture, continuously withdrawing from said main body a sample of said pulp-liquid mixture, withdrawing white water from said accreting pulp former to form a body of white water, withdrawing continuously a sample of said white water from said body of white water, simultaneously and continuously passing separate light beams of unequal intensity through said samples of liquid-pulp mixture and white water, directing the light emerging from said samples into separate phototubes interconnected in a Wheatstone bridge circuit including bridge balancing means balanced at the optimum sensitive point of operation, connecting a gaseous conduction electronic device to the output of said bridge circuit to operate in response to imbalance in said bridge circuit, actuating a relay circuit in response to the operation of said gaseous conduction electronic device and causing said relay circuit to operate a valve to control the addition of said additional quantities of liquid-pulp mixture to said main body until said imbalance is restored, thereby maintaining a substantially constant consistency in said main body of said pulp-liquid mixture.

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