

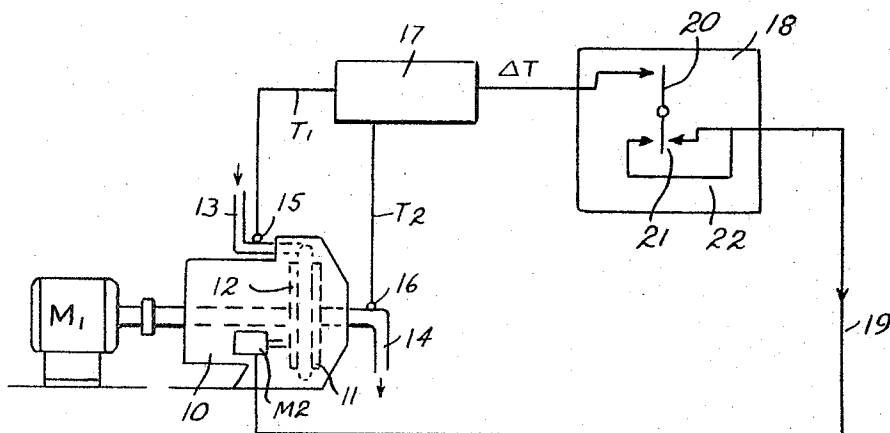
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R. F. McMAHON ET AL

3,309,031

MATERIAL WORKING APPARATUS

Filed Dec. 9, 1964



PRIOR ART

Fig. 1

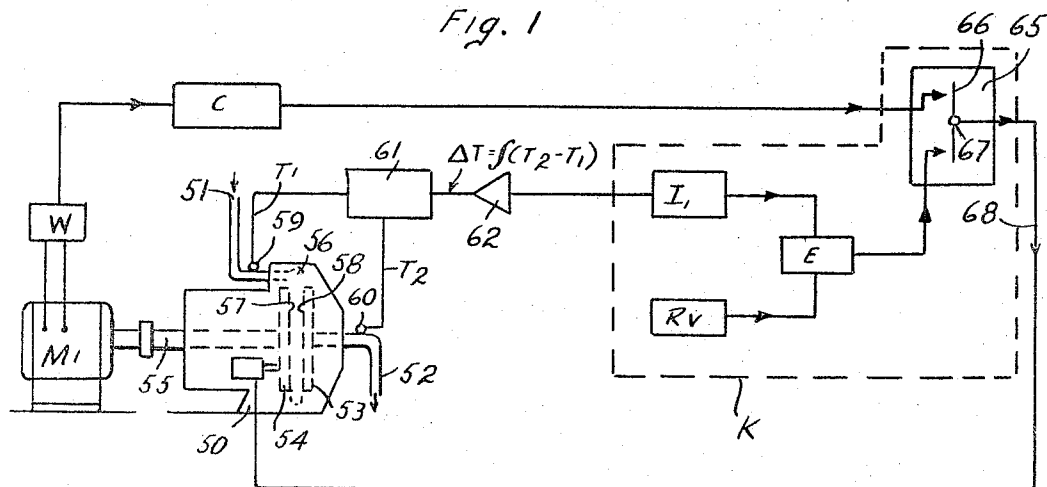


Fig. 2

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3,309,031

MATERIAL WORKING APPARATUS

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This invention relates to a new and improved method and apparatus for controlling the operation of a material working device. More specifically, the present invention relates to a new method of refiner process control in which a process variable is measured to obtain a first control signal which is then used in conjunction with a second instantaneous control signal obtained from the refiner or final control element itself and wherein said first control signal is used to control or modify the corrective action obtained from said second instantaneous control signal.

The present invention is particularly applicable to material defibrating or refining devices for materials such as paper pulp in which the refining operation is controlled in accordance with the amount of work absorbed by the material in the refiner as measured by a condition change of the material which is passed through the refiner.

The control of the quality of the end product of a refining operation may be accomplished by various control methods such as for example described in United States Patent Re. 24,185 and United States Patent 2,699,095. U.S. Patent Re. 24,185 describes a control system in which the power consumed by the driving motor is measured and in which the spacing between the refining elements is adjusted according to the power consumption variation of the motor. The refining elements are adjusted in such a manner as to hold the power consumption of the motor constant. The disadvantage of this system is that it does not compensate for changes in motor load occasioned by variations in flow through the refiner. Furthermore, holding the motor power constant does not take into account the effect of wear of the refining elements or variations in consistency and/or other variables of the material fed to the refining apparatus. The above mentioned patent also suggests independent adjustment of the spacing between the refining elements according to a measure of stock freeness in a subsequent stage of the process. The long time delay in making such a stock freeness measurement is not tolerable in present day refining operations.

U.S. Patent 2,699,095 proposes the measurement of temperature rise of the papermaking stock as it passes through the refiner whereby the refining elements are spaced relative to each other as a function of the temperature rise. The disadvantage of this system is that control by temperature rise alone does not take into account changes in the rate of flow through the refiner and changes of the papermaking stock consistency. A further disadvantage of refiner control by temperature rise is that the response time is unduly long mainly because of the inability to instantaneously measure a change in temperature which is mainly due to the inefficiency of the heat transfer from the papermaking stock or other material to the temperature measuring device.

A third method of refiner control is known as the constant pressure control system. The constant pressure control system operates on the principle of maintaining a pre-set pressure between the refiner elements to give a uniform intensity of refining action. However, variations in refiner inlet pressure and changes in flow through the refiner require a change in the pressure control set point to maintain uniform refining conditions.

An ideal control system for a paper stock refiner would

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not only adjust the refining element spacing as a function of process variables but would also control the amount and rate of adjustment by a direct measure of the element spacing as the spacing is adjusted. Such an element spacing measurement could be made by attaching a slide wire potentiometer to the element itself or to its adjusting mechanism. However, such a measurement of element spacing is impractical because of the wear on the refining elements and other dynamic variables and design considerations.

From the above three described control system practical experience with papermaking stock refiners has shown that refiner control by temperature rise appears to be the most promising. As pointed out previously, however, the measurement of temperature rise is a time consuming proposition and can only be used effectively when means are provided for producing an instantaneous corrective signal obtained from the refiner or final control element itself and of which the intensity and duration is ultimately controlled by the rise in temperature of the papermaking stock.

The concept of refiner control by temperature rise utilizes the principle that a given amount of energy will raise the temperature of a material being processed by a definite amount. Since papermaking stock as processed in the stock preparation area is at a definite consistency in the range of from three percent (3%) to five percent (5%) fiber in solution with water, the amount of energy required per unit weight of volume of fiber can be calculated by knowing the consistency. As the flow through the refiner is increased, the amount of additional energy required to maintain a given temperature rise of the fiber and water mixture will be in direct proportion to the increase in flow. We may for practical purposes assume that the consistency (fiber to water ratio) of the solution is relatively constant since the material is normally pumped to the refiner from a large holding chest with good agitation and through a consistency regulator ahead of the refiner so that the consistency variations can be kept to a minimum.

In a temperature differential control system as presently known in the art, temperature measuring elements are located in the stock inlet and outlet lines of the refiner and such measuring elements are preferably located as close as possible to the inlet and outlet ports of the refiner housing. The two temperature signals obtained from the temperature measuring elements are fed to a temperature difference converter which produces an output signal proportional to the temperature rise of the stock across the refiner. This signal is fed to a controller which compares the signal from the temperature difference converter with a predetermined set point signal value, and causes the controller to reposition refiner elements whenever there is a difference between these two signals. In accordance with normal control practices such a controller has a built-in feedback network which feeds a signal back into the controller as a function of the output signal of the controller. This feedback signal is not influenced by the actual or physical corrective movement of the correcting device nor by the actual physical change in refiner element spacing. In principle, the controller will send a corrective signal to the corrector and the built-in feedback network will notify the controller that the corrective signal has been dispatched to the corrector. Upon being thus notified by the internal feedback signal the controller will be balanced and its corrective signal will be reduced to some predetermined constant value to which the corrector does not respond. However, due to the effects of inertia and friction of the moving parts in the corrector, a corrective signal sent by the controller may not have been sufficient to obtain the corrective action

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actually required to correct the erratic process variable. Accordingly, since the erratic variable has not been entirely corrected the sensor will continue to send a signal to the controller which on receipt of the feedback signal is in physical balance. The delayed error signal will build up in intensity as time goes by and will again upset the controller after which the cycle is repeated. Therefore, a controller which is equipped with a built-in feedback signal will require several cycles to obtain the desired corrective action for this type of control system. In addition, it should be borne in mind that a substantial amount of time may lapse before the corrective signal (which is a function of temperature rise of the material in the refiner) comes to a peak value and thus produces the amount of correction actually required due to a change of operating conditions.

Since the most common variable in a stock refining system is a change in flow rate through the refiner, such a change in flow will not only result in a variation of the temperature in the refiner but also in a change in the power consumption of the motor which drives the refiner since more or less work will be absorbed by the stock.

Such a change in power consumption of the driving motor can be considered instantaneous and a corrective signal obtained therefrom will activate the corrector immediately and substantially earlier than would be possible with a corrective signal obtained as a function of a temperature variation in the refiner. Such an instantaneous corrective signal would eliminate the transfer lag inherent in a temperature control system.

We have discovered that an ideal refiner control process can be obtained by combining the temperature change variable with the power change variable into a single closed control loop. By thus combining temperature change with its associated power change of the drive motor we are able to obtain an immediate corrective signal as a function of the power change. The temperature change signal which develops at a later time and at a slower rate can be used to control the instantaneous power change signal as soon as the refiner element spacing has been properly adjusted.

Accordingly, an important object of the present invention is to provide an automatic closed loop control system which embodies a process variable measuring device, an automatic proportional control device, and an external feedback measuring device for closing the control loop.

Another object of the invention is to provide a closed loop control system for a paper stock refiner comprising means for measuring a process variable and continually comparing said variable with a predetermined set point value to obtain a first control signal, means operatively connected to said refiner to obtain a second instantaneous control signal which is in direct proportion to said process variable and said first control signal, network means for computing the algebraic sum of said first and second signals to obtain a final control signal, and means operatively connected to said refiner for adjusting said refiner as a function of said final control signal.

A further object of the invention is to provide a closed loop control system for a paper stock refining device which includes a first temperature responsive means operatively connected to the inlet portion of said refining device whereby the inlet temperature of the material processed by said device is continuously measured, second temperature responsive means operatively connected to the outlet of said refining device whereby the outlet temperature of the material is continuously measured, means connected to said first and second temperature responsive means to develop a first signal proportional to the signal as a function of the power change. The temperature change signal which develops at a later time and at a slower rate can be used to control the instantaneous power change signal as soon as the refiner element spacing has been properly adjusted.

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A feature of the present invention is to provide a closed loop control system for a continuous flow paper stock refining apparatus which includes means directly sensing the work absorbed by the paper making stock, means for measuring the temperature rise of the papermaking stock as it flows through the refining apparatus, and a controller responsive to said temperature and work sensing means for adjusting the effect of the refiner on the stock so as to maintain the operating conditions of the refiner at predetermined constant values.

Other objects and advantages will appear from time to time as this specification proceeds with the reference to the accompanying drawings in which

FIG. 1 is a diagrammatic representation of a control system for a paper stock refiner as used in the prior art; and

FIG. 2 is a diagrammatic representation of a control system in accordance with the principles of the present invention.

FIG. 1 shows a prior art temperature control system in which a refiner 10 having a stationary refining element 11 and a rotating auxiliary refining element 12 is shown as being utilized for the refining of paper making stock which enters into the refiner through an inlet 13. The refined paper making stock is discharged from the refiner 10 through an outlet 14. The rotating refining element 12 is driven by means of a motor M_2 .

The control system shown in FIG. 1 consists of an input temperature measuring element 15 and an output temperature measuring element 16 which form a part of a bridge circuit. An unbalanced condition due to differences in temperature at inlet 13 and outlet 14 will cause the bridge circuit to produce a signal proportional to the

temperature difference sensed by the elements 15 and 16. The signal produced by temperature difference is applied to a converter 17, which can be either a conventional differential amplifier, or a high impedance direct current amplifier. The amplified signal from the converter 17 is then sent to a controller 18 which, in turn, converts the electrical signal to a corresponding pneumatic signal. The newly derived pneumatic signal is linearly proportional to the electrical signal from the converter 17. The pneumatic control signal is then applied to a motor M_2 through a pneumatic line 19. The motor M_2 is connected to the movable refining element 12 whereby the spacing between the refining elements 11 and 12 may be controlled to maintain the temperature differential between the inlet and outlet ports of the refiner at a pre-selected constant value.

The operation of this prior art control system may be best understood by assuming that the temperature difference of the material between the inlet and outlet 13 and 14 respectively is disturbed by a sudden change of flow rate through the refiner 10. Such a change in flow rate will result in a temperature difference signal ΔT being developed by the temperature difference converter 17. The converter 17 will send a proportional signal to the controller 18. The operation of the controller 18 may be best described by assuming that it contains a pivotally mounted flapper 20 which will be caused to pivot in a clockwise direction due to the signal sent to it by the converter 17. As the flapper 20 rotates in a clockwise direction it will move away from an orifice 21 in the line 19 thus causing a change in air pressure in said line 19. However, the controller 18 contains an internal feedback control line 22 which sends an appropriate signal to the other side of the flapper 20 thus causing it to resume its balanced position. The internal feedback signal is directly proportional to the signal transmitted to the refiner element positioning device M_2 via the line 19. It will be appreciated that if the disturbance in flow rate through the refiner is relatively small the change in disparity between the inlet and outlet temperature of the refiner will be relatively small and may not be sufficient to overcome the backlash in the gear mechanism used for moving the refiner element 12. Such a gear backlash is inherent in every mechanical positioning device and is in effect a built-in dead band within which the change in temperature between the inlet and outlet of the refiner is not controllable and may vary at random. Furthermore, it will be appreciated that the internal feedback signal is not influenced by the actual or physical corrective movement of the correcting device M_2 . In principle, the controller 18 sends a corrective signal to the correcting device M_2 and the feedback network 22 will notify the controller that the corrective signal has been dispatched to the corrector M_2 thereby balancing the controller and counteracting its corrective signal. With this type of control system, which is entirely based on a control signal obtained from a variation between the inlet and outlet temperature of the refiner, it will be readily apparent that the corrective action is not instantaneous and may require a substantial amount of time due to the slow response of the temperature sensing elements 15 and 16.

Referring to the improved mechanism of the present invention, as shown in FIGURE 2, the inlet 51 has a temperature sensing device 59 attached thereto whereby the inlet temperature of the stock being processed is continuously measured. The outlet 52 has a temperature measuring device 60 attached thereto whereby the outlet temperature of stock is continuously measured. The temperature measuring devices 59 and 60 form an integral part of a conventional bridge circuit, with the remaining two legs of the bridge built into the converter 61. The converter 61 is of a type which will be recognized to those skilled in the art from the foregoing description, preferably such as a Leeds and Northrup differential tem-

perature thermohm transmitter No. 4-1901-1-1-9997-6-0.

Upon comparing the respective temperatures of elements 59 and 60, the converted 61 will develop a control signal which has a value proportional to the temperature difference sensed by the input element 59 and output element 60.

As mentioned hereinabove, the converter 61 may be in the form of a commercially available resistance to current converter which may also include an amplifier 62 for amplifying signals applying thereto.

Connected to the motor M_1 is an external power sensing means W, which will be recognized from the foregoing description, preferably of a type such as a Lincoln Thermoconverter, Leeds and Northrup catalog No. 10-730. The function of the power sensor W is to produce corresponding voltage signals which are proportional to the power consumption of the motor M_1 . The power input to motor M_1 is proportional to the work absorbed by the stock in the refiner 50 and hence proportional to the temperature rise of the stock. It can be seen therefore that the sensor W develops an instantaneous signal which is proportional to the input power to the motor M_1 , and which signal is proportional to the temperature rise of the stock. Connected to the power sensor W is a converter C for converting the voltage signal from power sensor W to a current signal similar to the current signal obtained from the comparator 61 and amplifier 62. The converter C is of a type which will be recognized from the foregoing description preferably such as a Leeds and Northrup converter, catalog No. 4-1901-3-1-0045-6-0.

The signal from amplifier 62 and the signal from the converter C are applied to a controller K, which is preferably a type such as a Leeds and Northrup Model C controller. The controller K is further provided with a variable reference signal generator R_v for generating a predetermined desired signal as a function of the desired mechanical energy to be absorbed by the fibrous material as it is being processed by the refiner 50. It can be seen, therefore, that the mechanical energy absorbed by the fibrous material in the refiner 50 is a direct function of the temperature increase of the fibrous material. The reference signal from the network R_v together with the signal from the input I_1 are fed to an error signal generator E, which is a differential amplifier. The error signal generator E develops a signal corresponding to the algebraic sum of the signals received from the input network I_1 and the reference generator R_v . The error signal generator E will develop a signal as soon as the value of the signal fed into the input network I_1 deviates from the predetermined value of the signal applied to the error signal generator E by the variable reference signal generator R_v .

The signal from converter C, which also corresponds to the instantaneous power change of the motor M_1 , is fed to a power responsive signal computing device or network 65. The computing network 65 is an integral part of the controller K, and which computing network includes variable proportional and automatic reset circuits whereby the value of the input signal generated therein is linearly proportional to the external power signal or external intelligence and is further linearly proportioned to the time integral of said external intelligence. The computing network 65 includes means for comparing the error signal from the converter C with the error signal from the generator E. The means for comparing the error signals from the converter C and the generator E may schematically be represented by means of a flapper member 66 which is pivotally mounted at 67. The signal from the converter C (which is instantaneous) will cause the flapper 66 to rotate in a clockwise direction thus causing an imbalance of the flapper 66 which in turn will result in an immediate signal 68 to be sent to the refining element positioning motor M_2 . The signal from the error generator E (which is a function of the change in

disparity between the inlet temperature T1 and the outlet temperature T2 of the refiner 50) will attempt to balance the flapper member 66 thus reducing the output signal 68 and thereby the action of the refiner element positioner M₂. However, as previously indicated the signal from the generator E is developed at a slower rate than the signal from the converter C. Moreover the signal from the converter C is instantaneous in nature and directly proportional to the change in flow rate through the refiner 50. This change in flow rate will ultimately result in an increase in temperature differential in the inlet and outlet temperature of the refiner.

It will thus be seen that with our improved control system we obtain an immediate corrective action from an external feedback or intelligence source and we have eliminated the time delay which is unavoidable when the temperature change in the refiner is used as the primary control means.

In summary, it will be appreciated that after the instantaneous power change signal is received by the flapper element 66 from the converter C there will be a change in the feedback side of the controller K and a signal 68 will be sent to the refining element positioner M₂. As long as the upset remains in the controller the signal to the corrector M₂ will continue. Therefore, the controller must be balanced which balance is achieved by the change in the signal received by the flapper element 66 from the amplifier 62. As soon as the signal from the amplifier balances the flapper 66 the corrective action by the positioner M₂ becomes zero. The main function therefore, of the external feedback signal from the power source M₁ is to stabilize the controller and to control the amount and rate of adjustment of the refining element spacing by a direct measure of the element spacing as the spacing is adjusted.

With external feedback of actual change in work absorbed by the stock or power input into the drive motor M₁, the controller is immediately notified of a change in flow condition through the refining machine which results in instantaneous corrective action. In addition, the controller is notified of the actual corrective action that has taken place because as soon as the corrector M₂ changes the spacing between the discs 53 and 54 the power input into the motor M₁ will change thereby changing the signal sent to the controller K by the converter C. This external feedback signal from the converter C therefore notifies the controller of the actual corrective action that has taken place and controls the amount and rate of the corrective action. With an internal feedback system as previously described with respect to FIGURE 1 the controller is notified of the corrective action that has been demanded by the error signal from the temperature difference converter 17. With the use of external feedback from the final control element itself our invention therefore results in fast and effective return to normal operating conditions without having to rely on time consuming temperature measuring cycles as described above with respect to the prior art control system of FIGURE 1.

Although we have herein described our invention as being used in connection with a paper stock refining device it will be apparent that the principles of the invention are by no means limited to such device. Obviously our method may be equally well applicable to grinding or defibrating operations of a wide range of materials and the term "refiner" as used in the claims is meant to include material working devices of the type in which a physical change of the material is a function of the amount of work absorbed by said material, which work absorption can be measured by a differential in temperature, pressure, flow or any other variable.

We claim:

1. A control system for a material working device comprising:

means for measuring a change in temperature rise of the material, and

means for measuring a change in work absorbed by the material and means responsive to said change in temperature rise and said change in work absorbed for adjusting the effect of the material working device on the material toward a predetermined value.

2. A stock refining apparatus comprising:

a refiner having an input and output with a stock solution flowing therethrough,

control means for varying the refining action of said refiner,

an input temperature responsive means and an output temperature responsive means,

means for measuring the work absorbed by said stock, and

control means including said temperature responsive means and said work measuring means to control said control means for said refiner.

3. In a control mechanism for a defibrating device, means defining an inlet and an outlet whereby fibrous material may be introduced into and removed from said defibrator,

means within said defibrator defining opposed close running defibrating surfaces including means for introducing said material therebetween,

first motor means operatively attached to at least one of said surfaces for rotationally driving said surface whereby said material is worked mechanically and resulting in a temperature increase of said material,

first temperature responsive means operatively connected to said inlet whereby the inlet temperature of the fibrous material is continuously measured,

second temperature responsive means operatively connected to said exit whereby the exit temperature of the fibrous material is continuously measured,

means connected to said first and second temperature responsive means to compare the value of said first and second temperatures respectively and to develop a first signal having a value proportional to the disparity of said inlet and exit temperatures respectively and including means for amplifying said first signal, external power sensing means operatively connected to said first motor means for measuring the power input to said first motor means and to develop a second instantaneous signal proportional to said input power and including means for converting said signal to be compatible in nature to said first signal,

second motor means operatively connected to at least one of said defibrating surfaces whereby its relative position with respect to the other of said surfaces can be controllably varied to maintain a relatively constant stock quality under varying flow rates through said defibrator,

a controller having:

an input network for receiving said first signal, a variable reference signal generator having means for generating a predetermined desired signal as a function of desired mechanical energy to be absorbed by said fibrous material,

means operatively connected to said input network and said reference generator for developing an error signal proportional to the algebraic sum of said first signal and said reference signal respectively,

a power responsive signal computing network for receiving instantaneous external intelligence from said external power sensing means and comprising variable proportional and automatic reset circuits whereby the value of said output signal generated by said network is linearly proportioned to said external intelligence and to the time integral of said external intelligence and means for comparing said error signal with said power signal whereby a control response is generated to direct said second motor means thereby controllably varying the relative position of

said defibrating surfaces whereby said first signal is maintained at a predetermined value.

4. A control system for maintaining a variable function at a predetermined value comprising:

first and second motors connected to a processing unit, said variable function being indicative of characteristics of material processed by said processing unit,

means connected to said first motor for developing a primary signal corresponding to changes in the variable function,

control means for receiving said primary signal to provide a control signal therefrom,

said control signal from said control means being applied to said second motor,

and sensing means connected to the processing unit for developing a secondary signal corresponding to changes of the variable function,

said secondary signal being applied to said control means for comparison therein with said primary signal to effectively change said control signal applied to said motor.

5. A control system for a refiner mechanism with a material inlet and outlet and having relatively rotating refiner members for defibrating material comprising:

a drive motor connected for driving one of the refiner members in rotation,

a control motor connected to the members for controlling the refining action of the members,

power means connected to said drive motor for developing primary signals corresponding to changes in motor operation due to changes in characteristics of the material from a predetermined value,

control means for receiving said primary signal to produce signals therefrom,

said control signals being applied to said control motor to change the refining action of the members, sensing means positioned to sense the conditions of the material in the refiner for producing a secondary signal corresponding to changes of said material caused by said control motor, reference signal means producing a constant reference signal,

and means for comparing said reference signal with said secondary signal to produce a feedback signal sufficient to eliminate said control signal when said constituent of material is at said predetermined value.

6. The control system of claim 5 in which said sensing means has a slower speed of response than said power means.

7. In a material refining control system for maintaining a characteristic of material at a predetermined constant value comprising:

a refiner having a work chamber for processing the material,

input and output means connected to said work chamber for supplying raw material to said work chamber and for receiving finished material from said work chamber, stationary means in said work chamber,

rotating means in said work chamber for applying work to the material thereby refining the material as it passes between said stationary means and said rotating means,

a drive motor for rotating said rotating means,

a control motor for controlling the distance between said stationary means and said rotating means,

power means connected to said drive motor for developing primary signals corresponding to changes of the characteristic of the material from a predetermined value,

a control means for receiving said primary signals to produce control signals therefrom,

said control signals applied to said control motor

for changing the distance between said stationary means and said rotating means,

sensing means connected between said input and said output means for producing a secondary signal corresponding to changes of the characteristic of the material in said work chamber,

reference signal means in said control means, and means for comparing said reference signal with said secondary signal to produce a feedback signal,

said feedback signal being applied to the control signal and being sufficient to eliminate the control signal from said control motor when the characteristic of the material is at a predetermined value.

8. The material refining control system of claim 7 in which said characteristic of material which is maintained at a constant value is temperature.

9. A paper stock refiner comprising in combination:

refiner plates positioned to form a refining zone therebetween,

a drive motor connected to one of the plates for driving it in rotation,

a control motor connected to control the distance between said plates,

a first signal means measuring the power input of the drive motor,

a second signal means measuring the temperature differential of stock flowing into and out of the space between the refiner plates, and

means for receiving the signals produced by said first and second signal means and operatively connected to said control motor for controlling the distance between said plates.

10. A paper stock refiner comprising in combination: refiner plates positioned to form a refining zone therebetween,

a drive motor connected to one of the plates for driving it in rotation,

a control motor connected to control the distance between said plates,

a first signal means measuring the power input of the drive motor,

a second signal means measuring the temperature differential of stock flowing into and out of the space between the refiner plates, and

means for receiving the signals from said first and said second signal means and comparing said signals,

said receiving means generating an error signal as a function of the difference between said first and second signals and supplying said error signal to the control motor for controlling the spacing between the plates as a function of said error signal.

11. A paper stock refiner comprising in combination: refiner plates positioned to form a refining zone therebetween,

a drive motor connected to one of the plates for driving it in rotation,

a control motor connected to control the distance between said plates,

a first signal means measuring the power input of the drive motor,

a second signal means measuring the temperature differential of stock flowing into and out of the space between the refiner plates,

means for generating a constant reference signal,

means for comparing said reference signal with the signal received from said second signal means and producing a feedback signal, and

means comparing said feedback signal with the signal received from said first signal means, and connected to said control motor for operating the control motor to change the spacing between said plates until the feedback signal is adequate to eliminate the signal from said first signal means.

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12. The method of controlling the refining operation of a paper pulp refiner by changing the spacing between refining plates which comprises measuring the power input to the refiner, measuring the temperature differential of the stock flowing into and out of the refiner, and controlling the distance between plates as a function of the work input and temperature differential. 5

13. The method of controlling the output of a paper pulp refiner having relatively rotating plates by controlling the distance between plates which comprises the steps of: 10

producing a first signal which is a function of power input to the refiner,

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producing a second signal which is a function of temperature differential between the stock entering and the stock leaving the refiner;
producing a constant signal and comparing it with the second signal of temperature differential to produce a feedback signal, and
comparing the feedback signal with the first signal of power input and controlling the distance between the plates as a function of the difference.

No references cited.

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