United States Patent [19]

Blume

[11] **3,816,241**

[45] **June 11, 1974**

[54] **METHOD AND APPARATUS FOR FEED-FORWARD CONTROL OF WOOD PULP REFINERS**

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[52] **U.S. Cl.** **162/198,** 162/253, 162/254, 162/261, 162/263, 241/33

[51] **Int. Cl.** **D21b 1/14,** D21f 7/00

[58] **Field of Search** 162/254, 253, 263, 261, 162/198; 241/30, 28, 33, 37

[56] **References Cited**

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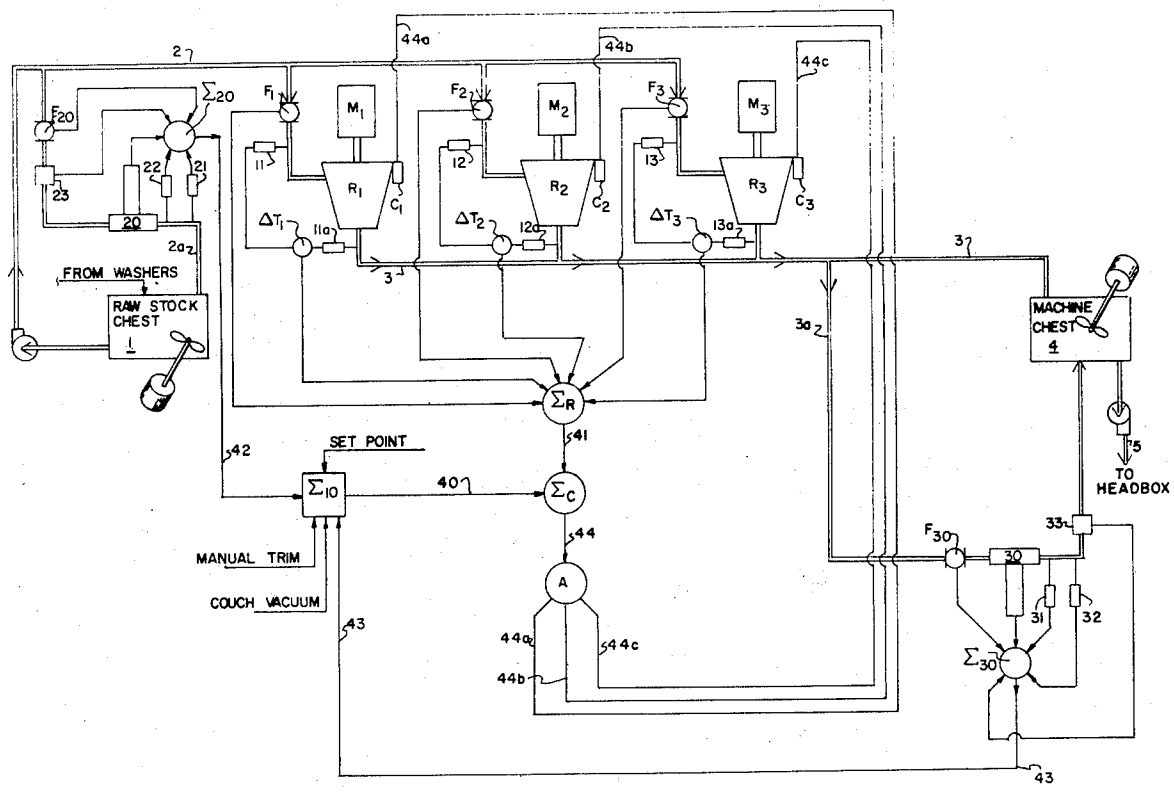
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Attorney, Agent, or Firm—Richard L. Schmalz; W. Allen Marcontell

[57] **ABSTRACT**

Method and apparatus for producing wood pulp stock having substantially constant drainage characteristics from raw stock, that is drainage rate variable, by making a laboratory determination of the functional relationship between drainage rate and refiner applied specific energy for the desired stock furnish. Using the functional relationship to coordinate signals from a continuous or rapidly cycling drainage rate measurement meter on the raw stock line as an automatic, feed-forward set-point control to a stock refiner control system, where the control system is capable of altering the magnitude of specific energy applied to the stock so as to accommodate the set-point as a variable reference standard.

19 Claims, 6 Drawing Figures



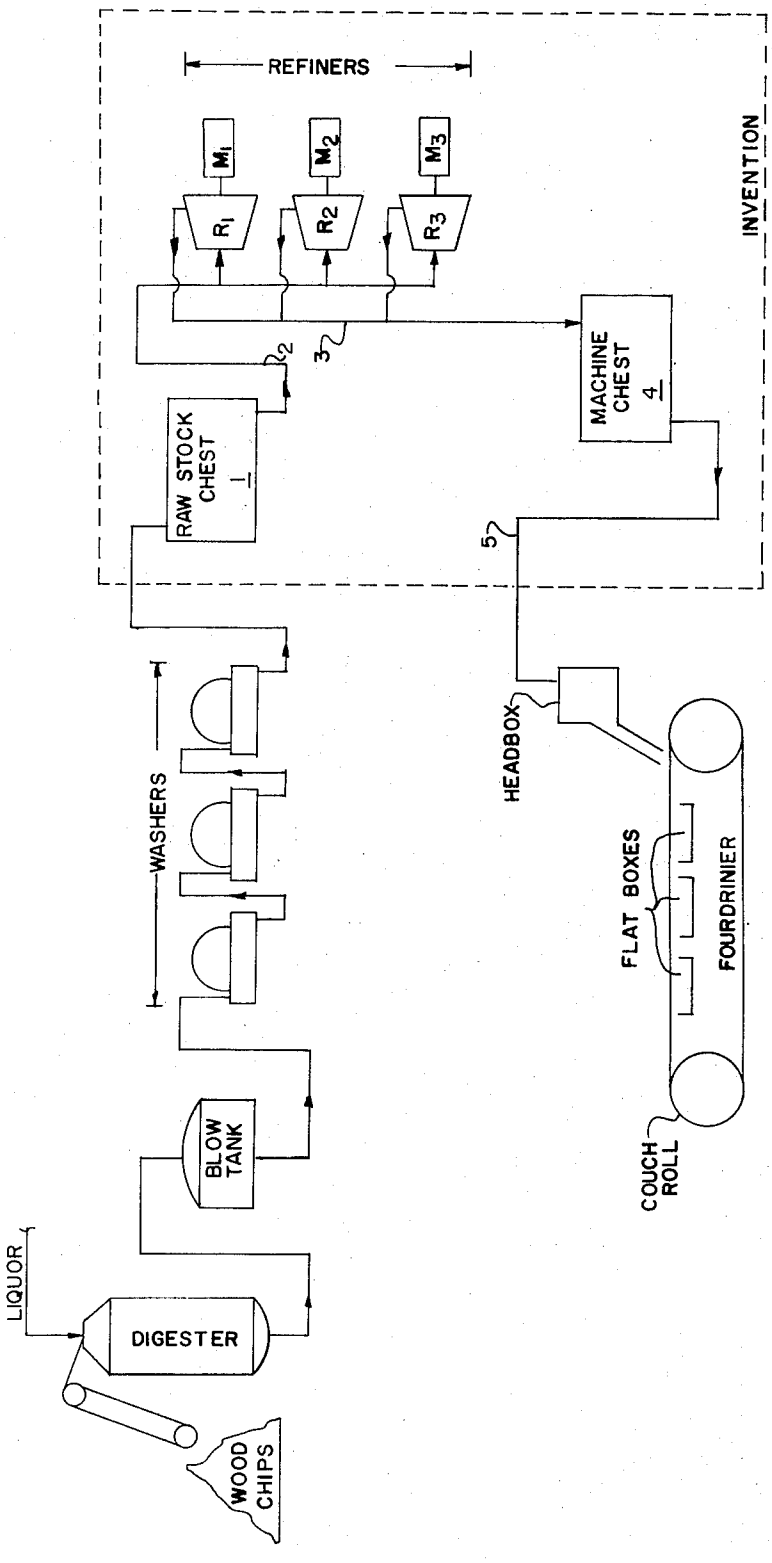

REFINERS
M1
M2
M3
R1
R2
R3
INVENTION
2
3
MACHINE CHEST 4
RAW STOCK CHEST 1
5
WASHERS
HEADBOX
FLAT BOXES
FOURDRINIER
COUCH ROLL
BLOW TANK
LIQUOR
DIGESTER
WOOD CHIPS

FIG. 1

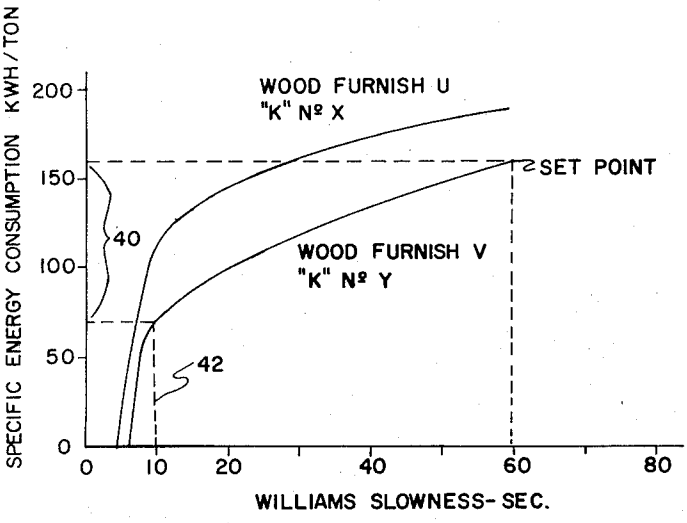


Fig. 2

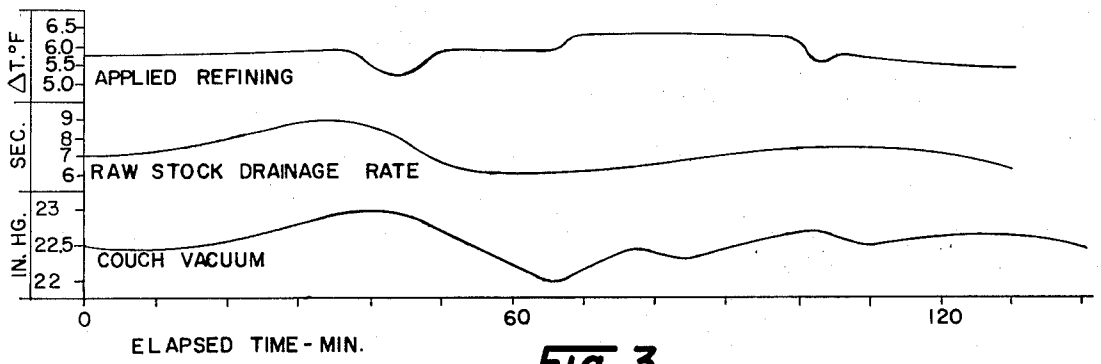


Fig. 3

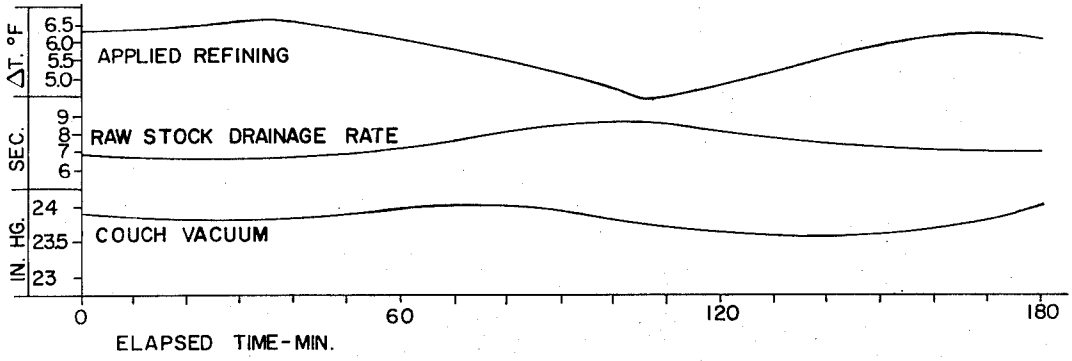


Fig. 4

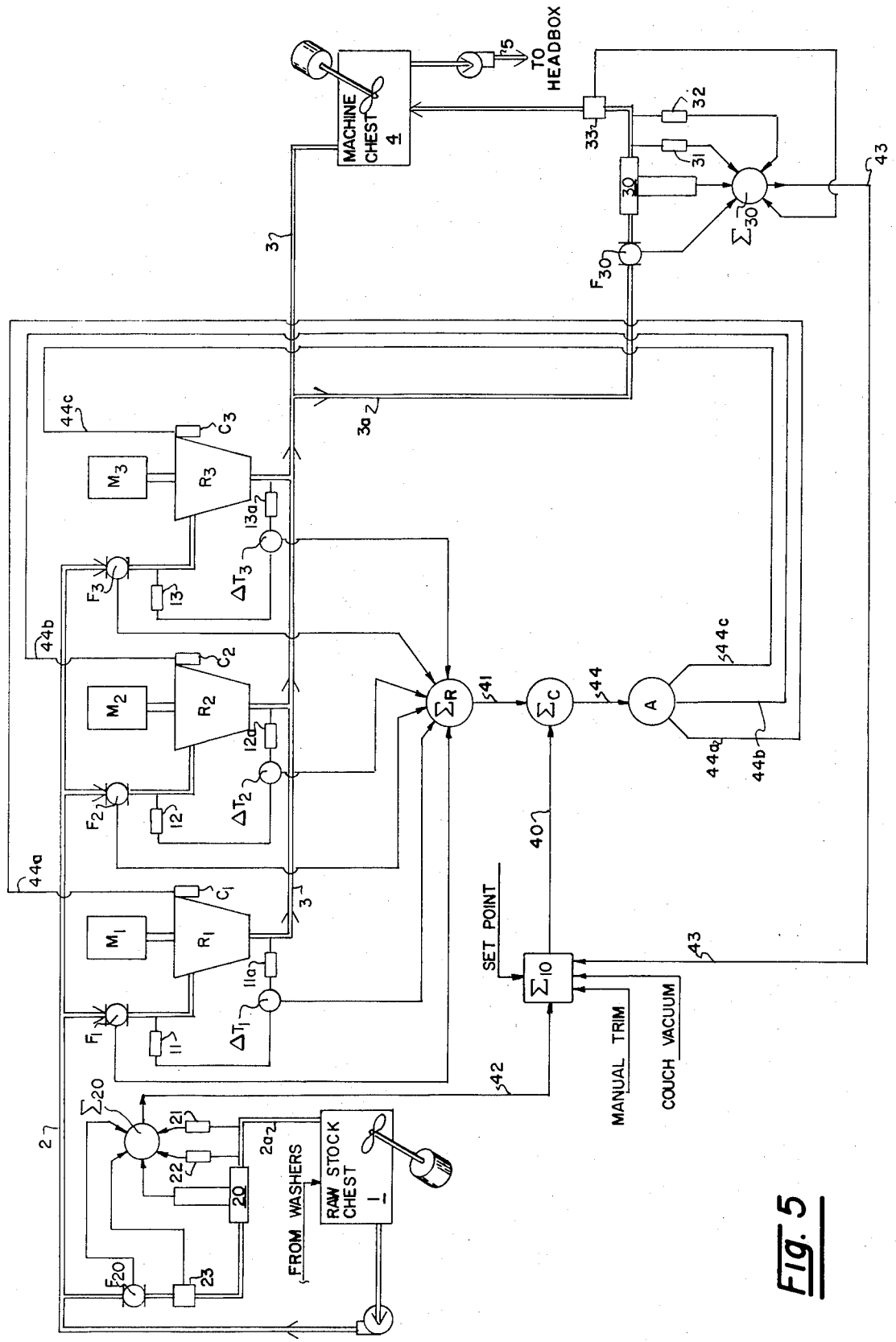

MACHINE CHEST 4
TO HEADBOX
15
32
33
31
30
43
3
F30
Σ30
44c
C3
M3
R3
13a
ΔT3
F3
13
3a
44b
C2
M2
R2
12a
ΔT2
F2
12
ΣR
41
ΣC
44
A
44a
44b
44a
C1
M1
R1
11a
ΔT1
F1
11
3
40
SET POINT
Σ10
MANUAL TRIM
COUCH VACUUM
43
42
Σ20
21
22
20
23
E20
2a
FROM WASHERS
RAW STOCK CHEST 1
2

Fig. 5

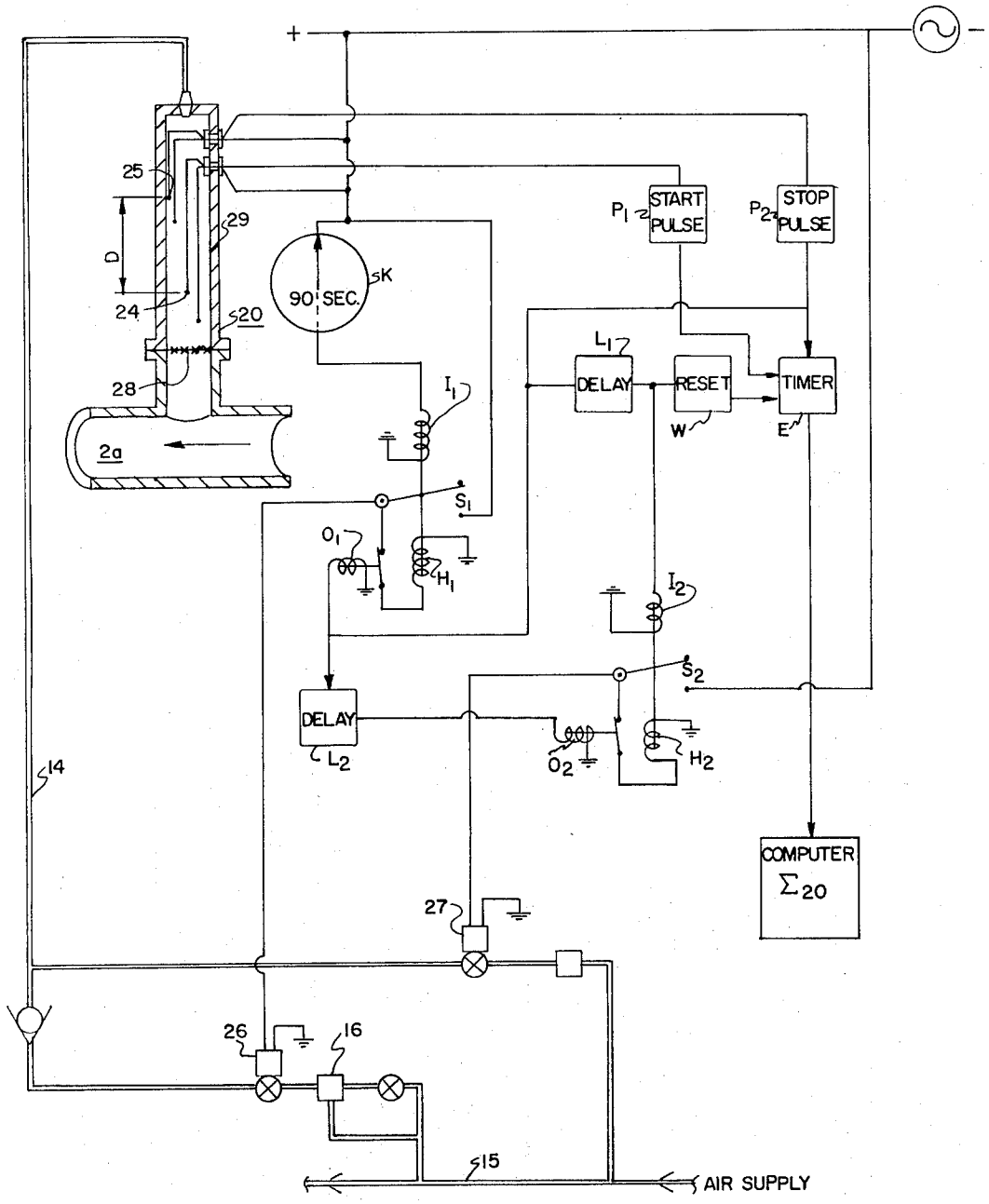

+
25
29
D
24
20
28
2a
90 SEC.
K
I_1
S_1
O_1
H_1
P_1
START PULSE
P_2
STOP PULSE
L_1
DELAY
RESET
W
TIMER
E
I_2
S_2
DELAY
L_2
O_2
H_2
COMPUTER
Σ_{20}
14
27
26
16
15
AIR SUPPLY

Fig. 6

METHOD AND APPARATUS FOR FEED-FORWARD CONTROL OF WOOD PULP REFINERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to automated control of wood pulp refining engines.

2. Description of the Prior Art

Refining engines, as characterized by the papermaking art are wood pulp preparation machines that induce fibrillation along the surface of the cellulose fiber. When bonded together, the intertwined fibrils increase the structural tenacity between adjacent fibers to improve the tensile and bursting characteristics of the finished paper. However, tear resistance of the finished paper is diminished by such fibrillation. Consequently, to achieve an optimum balance between these contradictary effects of refining, the degree of fibrillation must be carefully controlled.

For any given paper, each of these characteristics, tensile, bursting and tear strength, may be related, by a determinable function, to the magnitude of refiner work imparted to the pulp stock (specific energy) from which the paper is formed.

Specific energy consumption is a work per unit of stock mass relationship and is usually determined in kilowatt-hours per ton of stock or some equivalent thereof such as BTU per ton of stock. Specific energy may be the calculated product of such measurable parameters as stock flow rate, stock consistency and refiner motor current supply or stock flow stream temperature differential across the refiner engine.

Also related by a determinable function to the refiner work on the pulp stock are the water holding properties of the stock. These properties describe the ease with which water passes through papermaking fibers while they are being forced into a wet mat on the fourdrinier screen of a paper machine. A "free" pulp drains readily whereas a "slow" pulp drains its water slowly. Consequently, for the given pulp stock, a measure of such water retention properties may provide a direct indication of tensile, bursting and tear characteristics of a paper to be produced from the pulp stock.

Numerous tests have been devised to quantify pulp stock properties of water retention. Typical among such tests are the Canadian Standard Freeness Test wherein a 1 liter sample of standard consistency stock is allowed to flow freely into a funnel. Flow from the funnel is restricted by an orifice of select size. A side outlet is selectively positioned in the funnel wall. That portion of the 1 liter sample not accommodated by the flow rate of the orifice is drawn off for volumetric measurement as a quantity of the pulp freeness. A low volume represents a "free" stock whereas a high volume represents a "slow" stock.

Another type of water retention property test is that for "drainage factor." This quantity may be determined by forming sheets on a British standard sheet machine under standard conditions and taking the drainage time and weight of the test sheets. The drainage factor is the slope of the line produced when drainage time is plotted against weight of stock added to the sheet machine. Units for drainage factor are in seconds per gram.

A third test for pulp water retention, the Bolton-Emerson test, is a variation of the drainage factor test wherein the weight of the test sheet is standardized for

a test series. In the Bolton-Emerson test, standardized volume of pulp slurry having a standardized consistency is passed through a screen of such mesh as to allow the passage of water but not fiber. The test sample is subjected to standardized pressure differential conditions across the screen. These conditions leave only the time factor as a variable in the test, the weight of pulp, quantity of water and pressure drive being standardized. Accordingly, to obtain a quantitative measure of "freeness" or "slowness," one need only measure, in seconds, the time interval required to separate the fiber from the water. A low time interval indicates a "free" stock whereas a high time interval is indicative of a "slow" stock.

Lacking in all the above described water retention property tests is consideration for the vibratory dynamics actually present on the fourdrinier wire. Since the drainage performance of a pulp on the fourdrinier wire is generally characterized, in the art, as "drainage rate," any test for pulp water retention properties independent on the fourdrinier shall be characterized for purposes of this disclosure, as a test for "static drainage rate."

If, in a particular mill, producing a particular pulp, the raw stock, direct from the digesters or defiberizing engines, had consistent water retention properties, it would be a relatively simple matter to merely control, in a direct manner, the magnitude of refining energy applied to the stock in order to consistently achieve the desired retention property at the paper machine headbox.

However, many uncontrollable factors influence the raw stock retention property such as the moisture content and species characteristics of the raw wood furnish to the digester. Accordingly, the degree of digestion and defiberization necessary to yield a constant raw stock retention property is continuously changing for practicably indeterminate reasons.

Consequently, it is of limited value to the papermaker to know exactly how much refining energy he will or has applied to the raw stock since he doesn't know exactly how much energy is necessary for the run of stock, then flowing, to yield the desired retention property as an end result.

If the papermaker knew, precisely, the retention properties of the presently flowing raw stock, at the time the power setting of the refiners must be determined, he could do so with confidence. However, the known and accepted tests for such properties are, definitively, of a batch or incremental nature, usually performed under the exact conditions of a laboratory. Such test procedures are much too slow and cumbersome to provide the papermaker with refiner control information at the time it is needed.

In lieu of a timely water retention property test of the stock, papermakers have relied on the indicated vacuum drawn from the flat box or couch roll of the paper machine fourdrinier section as a continuous measure of these properties. U.S. Pat. No. 2,699,095, Re. No. 24,185 and No. 3,654,075 are examples of automatic refiner control systems that are monitored by vacuum measurements taken at the fourdrinier section.

Although fourdrinier section vacuum is related to the final water retention properties of the stock, it is also related, unfortunately, to numerous other mechanical characteristics of the paper machine and web that are independent of water retention or drainage rate as it is

called in connection with the fourdrinier. Disturbances or changes in the couch roll vacuum, therefore, may or may not be related to a change in the stock drainage rate. For example, an undetected mechanical change in the headbox slice lip opening of unobvious magnitude could cause a shift in the couch roll vacuum. If the vacuum shift is assumed to be drainage rate related, correction of the vacuum indication may be obtained by an appropriate alteration of the refiner energy application. This action, however, will establish a new balance between the adjusted drainage rate and the quantity of stock deposited by the new slice opening on the fourdrinier screen. Hence, the finished paper will be over or under refined for the desired mechanical characteristics and, moreover, will have an undesired basis weight.

Accordingly, couch roll or flat box vacuum offers an unreliable alternative to direct water retention property monitoring for refiner control.

Even if it were possible to reliably isolate fourdrinier section vacuum measurements due to stock drainage rate from those due to other sources, as is attempted by the teaching of U.S. Pat. No. 3,654,075, for example, there would yet remain the wasted effort problem attendent with a "feed-back" control system. Whether practiced manually or automatically, any control system which monitors one or more quality characteristics of a product subsequent to the operational station responsible for the characteristics inherently tolerates the production of a small amount of error for the benefit of the larger amount. Of course, small and large are relative quantities and in years past, when a typical paper machine would produce approximately 2 tons of paper per hour, there would only be approximately 1 ton of refined pulp fiber in storage between the refiner and the fourdrinier wire. In other words, from the time the inferior quality condition was detected to the time it could be corrected, only 1 ton of inferior quality product need be produced.

By contemporary standards, a typical paper machine is supplied with 30 tons of pulp fiber per hour from as many as 15 parallel flow refiners to produce as much paper product per hour. At this production rate, 5 tons of refined pulp fiber may be in storage between the refiners and the fourdrinier wire. If this storage stock is of inferior quality, the production of 6 tons of inferior and possibly unmarketable paper product must be produced before correction of the condition may be effected by the prior art "feed-back" control systems.

Although some effort has been given of late to continuous, on-line, measurement of pulp stock water retention properties as represented by U.S. Pat. No. 3,655,980 and the Aug. 21, 1961, publication in the Paper Trade Journal of an article entitled "Continuous Freeness Measurement and Control," such teachings have not been widely adopted by the industry. Furthermore, no teaching is found to suggest that the specific energy input of stock refiners may be directly controlled by such prior art stock water retention measurement systems. More particularly, no teaching is found to suggest that pulp refiners may be directly controlled most advantageously by sampling the stock water retention property before refining for "feed-forward" control of the refiner energy input.

It is, therefore, an object of the present invention to teach the construction of a simple, on-line, rapidly cycling static drainage rate measuring device having reliability of performance characteristics comparable to laboratory determinations.

Another object of the present invention is to teach an automatic refiner control strategy pursuant to direct, static drainage rate measurement.

A further object of the present invention is to teach a feed-forward automatic refiner control stragegy.

SUMMARY OF THE INVENTION

These and other objects of the invention may be achieved by electrically pacing and measuring the pneumatic control cycle of a Bolton-Emerson type of water retention property test meter disposed for continuously sampling raw pulp supply stock to refiners. Simultaneous with a water retention test, tests are also taken of stock temperature, consistency and pH. If test conditions are within predetermined limits, a signal proportional to measured water retention may be accepted as a reliable measure of static drainage rate. Said static drainage rate signal is processed, either manually or by computerized logic, to determine, from a laboratory and operationally developed history of the stock type, the magnitude of refiner work needed of the approaching stock to achieve a desired final static drainage rate. Signals proportional to the needed refiner work are then entered as set-point control signals to an automatic refiner control system such as is disclosed in U.S. Pat. No. 3,568,939.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow diagram of the papermaking process between the digester vessel and the fourdrinier section of the paper machine.

FIG. 2 is a graphic plot of refiner applied specific energy as a function of static drainage rate for two pulp stocks distinct in furnish, as to wood species, and degree of cooking, as to Kappa number.

FIG. 3 is a composite plot against elapsed time of a typical change in the static drainage rate of raw stock to illustrate the consequent effect on couch roll vacuum and applied refining energy pursuant to a feedback corrective control system.

FIG. 4 is a composite plot against elapsed time of a typical change in the static drainage rate of raw stock to illustrate the consequent effect on couch roll vacuum and applied refining energy pursuant to the feedforward refiner control system of the present invention.

FIG. 5 is a stock flow piping schematic of the overall refiner control system of the present invention having superimposed thereon an integrated control logic flow schematic representative of the invention.

FIG. 6 is an integrated electrical-pneumatic circuitry diagram for the static drainage rate sampling device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For orientation, reference is first made to FIG. 1 showing the primary operational stations of a typical pulp mill. The present invention is most suitably exploited to control pulp stock refining engines operative between the pulp washers and the paper machine headbox.

Referring next to FIG. 5, details are shown relative to the raw stock chest 1; the refiners R_1, R_2, R_3; the ma-

chine chest **4**; and, the interconnecting stock flow piping **2** and **3**, also seen in FIG. **1**.

To the raw stock chest **1**, raw pulp stock is delivered from one or more pulp washers for blending. Subsequently, the greater bulk of blended raw stock is pumped through conduit **2** for distribution to one or more refiners as represented by R_1, R_2, R_3. A sample portion of blended raw stock is taken from the chest **1** through conduit **2***a* in parallel flow with the trunk line **2** as a continuously flowing source reservoir for the static drainage rate meter **20.** Instruments **21** and **22** in the test sample shunt **2***a* are a pH meter and a thermometer, respectively. Instruments **23** and F_{20} provide electrical signals proportional to stock consistency and flow rate, respectively.

Before entering the refiners R_1, R_2, and R_3, respectively driven by motors M_1, M_2, and M_3, the stock flow rate respective to each refiner is measured by flow meters F_1, F_2, and F_3. The stock flow stream temperature to each refiner is taken by thermometers **11, 12,** and **13.**

Refined stock emerges from the refiners into pipeline **3** to be measured of heat content again by thermometers **11***a*, **12***a*, **13***a* and thence carried to the machine chest **4** for further blending and storage before delivery to the paper machine head box.

Refined stock flow shunt **3a** provides a sampling reservoir for a second static drainage rate meter **30** and attendant instrumentation including flow meter F_{30}, pH meter **31,** thermometer **32** and consistency gauge **33.** Although data from the static drainage rate meter **30** is not necessary to the feed-forward feature of this invention, such accessory data may be used advantageously for calibration and control trim purposes in a manner to be described subsequently.

Alternatively, data from the static drainage rate meter **30** may be used exclusively or primarily for a most efficient feed-back control system, if desired.

Elements ΔT_1, ΔT_2, and ΔT_3 represent logic circuitry for receiving and comparing signals from respective pairs of thermometer **11-11***a*, **12-12***a*, and **13-13***a*. Responsive to the comparison, computers ΔT_1, ΔT_2, and ΔT_3 transmit original signals proportional to respective stock temperature differentials.

Computer Σ_R receives the temperature differential signals from computers ΔT_1, ΔT_2, and ΔT_3 for mathematical combination and processing with signals proportional to the respective stock flow rates from meters F_1, F_2, and F_3. All of these signals are combined by computer Σ_R pursuant to the relation:

$$F_1 \cdot \Delta T_1 + F_2 \cdot \Delta T_2 + F_3 \cdot \Delta T_3 / F_1 + F_2 + F_3 = \Sigma F_i \cdot \Delta T_i / \Sigma F_i = E_3$$

The calculated product of this relation is proportional to the specific energy (E_S) applied by the several refiners to the stock, units being corrected to BTU per ton of stock. If units are desired in terms of kilowatt-hours per ton of stock, the temperature differential signals from computers ΔT_1, ΔT_2, and ΔT_3 may be corrected by the appropriate mathematical equality for heat and power. Alternatively, current and voltage signals may be transmitted from the motors M_1, M_2, and M_3 in lieu of the stock temperature measurements for direct calculation of specific energy in units of kilowatt-hours per stock ton. This calculation would take the form:

$$E_s = I_1 \cdot V_1 \cdot F_1 + I_2 \cdot V_2 \cdot F_2 + I_3 \cdot V_3 \cdot F_3 / F_1 + F_2 + F_3 = \Sigma I_i \cdot V_i \cdot F_i / \Sigma F_i$$

Signal **41** is an original emission from computer Σ_R proportional to the momentary specific energy application of all refiners R_1, R_2, and R_3, collectively.

Receiving signal **41** is refiner correction computer Σ_c for comparison to a set-point or reference signal **40.** Computer Σ_{10} is the source of signal **40** and generates it in response to data received from the static system and processed as a function of laboratory and other applied data. In essence, signal **40** represents the magnitude of collective refiner applied specific energy that is needed to work the stock to the desired final water retention property. Accordingly, computer Σ_c compares the magnitude of specific energy that the refiners are momentarily delivering, as represented by signal **41,** to the magnitude of energy necessary for the desired drainage rate, as represented by signal **40,** and derives and emits a signal **44** proportional to the necessary change, if any, to the refiner engine effort needed to match the objective.

Although the aforedescribed system is perfectly adaptable to the control of a single refiner, such systems are more commonly utilized to control a multiplicity of refiners, in which case, it becomes necessary to allocate the energy correction signal **44** among the several refiners since some may be larger or more efficient than others and can take a disproportionate share of the needed change. Such allocation is the function of computer A which keeps an accounting of the present loading and capacity of each refiner. Operatively then, allocation computer A assigns that portion of the total needed correction, represented by signal **44,** to each refiner R_1, R_2, R_3 according to its individual need or capacity.

Signals **44***a*, **44***b*, and **44***c*, then, are individually assigned portions of signal **44** and dictate the refiner disc or plug setting via respective refiner controller C_1, C_2, and C_3.

Heretofore has been described a prior art refiner control system such as that more completely described in U.S. Pat. No. 3,568,939 except for the briefly described contribution of the static drainage rate responsiveness of set-point signal **40.** It should be understood, however, that most of numerous other single and multiple refiner control systems are responsive to an externally provided reference signal to which the refiner control system can relate for control orientation. Consequently, the present invention may be adapted to any of such refiner control systems.

Regressing now, to focus on the static drainage rate measurement system in stock flow shunt **2***a*, it is seen from FIG. **6** that test meter **20** is merely a blind spur from shunt **2***a* having a sample barrel **29** separated from the shunt conduit **2***a* by a screen **28** of appropriate mesh as to permit the passage of water but prohibit the passage of pulp fibers.

Entering at the top of barrel **29** is a pneumatic conduit **14** having controlled communication with an air supply line **15.**

Internally of barrel **29** are lower and upper liquid level switches **24** and **25,** the respective contact levels being separated by a precisely determined distance D to specify the desired test volume.

Pacing the entire operation of the static drainage rate test is a timing device K, set to transmit a single starting

impulse to the initiating winding I_1 for the purpose of closing starting switch S_1. Timer K emits such a starting impulse at regular, periodic intervals determined by the desired cycle rate of the draining test, each 90 seconds, for example. The starting impulse is of selected magnitude and duration as is sufficient to close the contacts of switch S_1 long enough to establish sufficient electromagnetic force in winding H_1 to hold the switch S_1 closed. Thereafter, the starting impulse stops.

When winding I_1 is energized by the starting impulse from K, switch S_1 closes to energize holding winding H_1 and open solenoid valve **26.** Communication of pneumatic conduit **14** is thereby established with the air supply subject to pressure controls **16.** Pressure controller **16** holds the pressure in conduit **14** and, consequently, in barrel **29** at a constant, predetermined level that is slightly less than the pressure prevailing in shunt **2***a* so as to allow a fixed, pressure differential drive of the stock into barrel **29.**

As the stock rises into barrel **29,** the water vehicle thereof passes through screen **28** but not the fiber constituent. A fiber mat is established on the shunt side of screen **28** which inhibits continued transfer of water to a rate proportional to the water retention properties of the fibers. When sufficient water has passed the screen **28** to reach the lower reference level **24,** the fibrous mat on screen **28** has grown with sufficient accumulation to provide a reliable water retention test. This event closes the contacts of lower level switch **24** to energize starting pulse circuit P_1.

Starting circuit P_1 is of a prior art type that, in response to an energized input, emits a single signal pulse of select magnitude and duration. Thereafter, the pulse energy stops and will not flow again until the input energy stops and starts again. Therefore, so long as switch **24** is closed, starting circuit P_1 will not emit a second pulse.

The single pulse from starting circuit P_1 starts the running of a prior art elapsed time measuring device E. As the water continues to rise in barrel **29,** the timer E accumulates data proportional to the elapsed interim.

When the water level has risen the prescribed distance D in the barrel **29,** upper level switch **25** closes to energize a second single pulse transmitting circuit P_2 and stop the running of elapsed timer E. Also energized by the P_2 pulse are time delays L_1, L_2, and switch S_1 reset relay O_1.

When reset relay O_1 is energized, the holding circuit of switch S_1 is immediately opened to allow the mechanical bias of the moving contact point of S_1 to open the solenoid valve **26** holding circuit thereby closing the valve **26** and disrupting fluid communication between line **14** and the pressure controller **16.** There being no energized bias on the switch S_1, the contacts thereof remain in the open position awaiting the next pulse from timer K.

In response to the stop pulse from circuit P_2, time delays L_1 and L_2 merely retard the signal for respective, predetermined time periods before passing it on.

The signal from time delay L_1 initiates a reset circuit W in timer E to transmit the accumulated time signal stored therein and clear the storage circuit for the next starting pulse from circuit P_1. The transmitted signal is proportional to the measured static drainage rate of the tested stock and enters computer Σ_{20} as such.

Also energized by the delayed L_1 signal is initiating winding I_2 for the switch S_2. When closed, switch S_2 conducts energy to a holding relay H_2 to keep the switch S_2 closed and to the actuating winding of solenoid valve **27.** When open, valve **27** places pneumatic conduit **14** into controlled fluid communication with the air supply source again but at a pressure greater than the pressure of shunt line **2a.** This pressure differential drives the test charge of water standing in barrel **29** down through the screen **28** and back into the flow stream of shunt **2***a*, cleaning the accumulated fiberous mat against screen **28** in the process.

Adequate time for the foregoing barrel purge is allowed by time relay L_2 before transmission of the stop pulse from circuit P_2 on to the reset relay O_2 to open the holding circuit H_2 of solenoid valve **27** holding switch S_1. Valve **27** closes to interrupt communication between line **14** and the air supply, thereby stopping the purge of barrel **29.**

Due to the falling liquid level in barrel **29,** switches **24** and **25** have opened thereby resetting the start and stop pulse circuits P_1 and P_2 in preparation of the next level switch closure due to rising fluid.

At this point, all circuits are quiet and open except for the continuing advancement of pace timer K. When the prescribed period has elapsed, the timer K issues another starting pulse to initiating winding I_1 to start the cycle over again for another static drainage rate signal to computer Σ_{20}.

If correct static drainage rate was consistently equivalent to the raw measure signal, it would be sufficient to by-pass computer Σ_{20} for direct receipt of the timer E signal by computer Σ_{10}. However, due to stock variations of pulp consistency, temperature and pH, a static drainage rate measure thereof may not be exactly equal to a true measure. For this reason, signals proportional to these parameters are also transmitted by instruments **23, 22,** and **21,** respectively, to computer Σ_{20}.

These auxiliary signals from **21, 22** and **23** may be handled in either of two ways. Each may be received by a respective limit circuit whereby if one or more of the auxiliary signals exceeds a predetermined value range, such as to render the signal from meter **20** unreliable, transmission of the static drainage rate signal to computer Σ_{10} is interrupted.

Alternatively, computer Σ_{20} may be programmed with laboratory determined process data whereby a static drainage rate signal corrected to standardized conditions may be derived by computer Σ_{20} from the auxiliary signals notwithstanding the excursion of any one or more auxiliary signals from the standard value range.

Computer Σ_{10} constitutes the interface between the automatic refiner control system and the automatic static drainage rate determination system. Pursuant to this function, Σ_{10} is programmed with data such as that represented by the graphs of FIG. **2.** Static drainage rate signals from computer Σ_{20} are compatible with the scale of one graph axis, the Williams Slowness Scale along the abscissa in this example, and needed refining energy signals **40** to computer Σ_c are compatible with the other axis of the plot.

Σ_{10} must also be programmed with data concerning the desired end result. Such is the set-point input of FIG. **5** and may take the form of either a target specific energy value or a target static drainage rate value. Unlike the program data that is definitive of the specific

energy consumption to static drainage rate function for the wood furnish and cook type, the set point is an operator entered variable needed by the computer to establish a presently desired end point on the characteristic curve. A typical event to dictate the operator's change of the set-point input would be the desire for a grade change in the finished paper.

A representative operation of computer Σ_{10} may be thusly: Relative to FIG. **2**, wood of furnish V is to be cooked to a "K" number of Y. Accordingly, data that is definitive of the typical specific energy relation to static drainage rate for that furnish and cook is made available to the active control circuit.

The grade characteristics of the finished paper that is desired suggests the final static drainage rate which, in this example, constitutes a set-point value proportional to a Williams Slowness of 60 seconds. A corresponding total specific energy input of 160 kw-hr./ton will need to be applied to the stock. Accordingly, the operator enters a set-point value of 60 seconds into the manual entry station of computer Σ_{10} control console. Responsively, the computer reviews the programmed data stored within the active control circuit and determines that 160 kw-hr./ton is the refining energy target.

Due to the fact that the stock may have been previously "worked," to some degree, by defiberizing engines at an earlier flow station, for example, signal **42** from the drainage rate computer Σ_{20} informs computer Σ_{10} that the stock in transit has a raw static drainage rate of 10 seconds. From the internally stored data relative to the active stock curve, computer Σ_{20} determines that the static drainage rate signal **42** corresponds to an applied specific energy value of 70 kw-hr./ton.

From the foregoing determinations, computer Σ_{10} further determines that the magnitude of additional refining energy needed by the stock in transit to reach the desired total is 90 kw-hr./ton (160 kw-hr./ton desired minus 70 kw-hr./ton received).

A signal proportional to the needed addition of 90 kw-hr/ton constitutes the substance of signal **40** from computer Σ_{10} and becomes the set-point signal for the automatic refiner control computer Σ_c.

To continue the example, assume that specific energy averaging computer Σ_R is emitting a signal **41** to the effect that the average specific energy currently being applied to the stock flow is 85 kw-hr./ton. Upon receipt of signal **40** representing a need of 90 kw-hr./ton, computer Σ_c compares this need value to the presently applied average value of 85 kw-hr./ton and determines that an additional 5 kw-hr./ton should be applied by the refiners. Such is the substantive value of signal **44.**

Allocation computer A receives the 5 kw-hr./ton increase dictate of signal **44** and determines how the 5 kw-hr./ton increase shall be apportioned among the several refiners.

If desired, the static drainage rate testing system in shunt *3a* may be used as a feed back alternative to the feed forward system in shunt *2a* described above. In this case, however, an initial assumption must be made relative to the static drainage rate of raw stock received at the refiner. Nevertheless, such a system may be more efficient than other, prior art, feed back systems, since the post refiner static drainage rate is sampled directly, no opportunity being given for the introduction of irrelevant parameters. Moreover, the post refiner stock sample is taken from the refiner discharge manifold **3** or machine chest **4** before the accumulation of large quantities of nonconforming stock.

As to the applied logic of computer Σ_{10} in the feed back example, it may generally be characterized as the reverse of the feed forward system with an initial condition raw stock static drainage rate assumed and entered by the operator at the console manual entry station. The desired finished stock static drainage rate is also entered as in the case of the feed forward system. Actual or measured finished stock static drainage values are fed back to computer Σ_{10} for comparison to the assumed, initial condition, values with the assumed raw stock rate being corrected as the consequence of an increase or decrease in the refining energy demand signal **40** as is found necessary for the conformity of the actual or measured post refiner static drainage rate to the desired or set-point value.

As a third and preferred alternative, static drainage rate signals **42** and **43** from both test systems are offered to computer Σ_{10} simultaneously. Such data provides a reservoir of actual line information to correct the laboratory derived data forming the substance of the static drainage rate to refining energy function curves of FIG. **2.** As operational time accumulates, the internally stored program data is corrected and honed to accuracy by the actual line measurements thereby increasing the corrective action response time of the refiner to a transient excursion of the raw stock static drainage value.

The significance of rapid response time and of the invention, generally, may be appreciated by a comparison of FIGS. **3** and **4.** Therein, the couch vacuum is given as the reference value of performance rather than finished stock static drainage rate since the former parameter is more familiar to those of ordinary skill in the art. In both cases of FIGS. **3** and **4,** couch vacuum disturbances are attributed exclusively to water retention property changes in the stock.

The control relation between the measured couch vacuum and refining engine response of FIG. **3** is a simple feed back system comprising an alert and skilled papermachine tender taking note of an initial departure of the couch vacuum from an established norm. Responsively, the machine tender informs a skilled refiner operator of the changes which, in the personal judgment of the machine tender, are needed.

In contrast, FIG. **4** represents a system under group refiner control referenced by a feed forward static drainage rate set-point as described herein but without feed back correction of the internal program parameters. The reduced degree of couch vacuum departure from norm, as shown from a comparison of FIGS. **3** and **4,** is typical of system performance from the present invention. Not only is the degree of couch vacuum disturbance reduced by the present invention but, as a comparison of the FIGS. **3** and **4** time scales will substantiate, the invention eliminates the disturbance result more quickly.

The foregoing numerical examples are merely representative of several methematical manipulations that may be performed with the various accumulated data, measured, derived and assumed, to achieve the desired end result of assuring that the refiners, collectively, will apply sufficient work to the particular stock in transit so the average water retention properties of the machine chest **4** blend will remain at the desired level. To summarize, however, it will be appreciated that basic

to the invention are at least one measured value of the stock static drainage rate; at least one assumed value of the desired stock static drainage rate; and, at least one derived value representative of a differential in average specific energy applied to the stock. Further, laboratory or experience derived data is necessary to relate the static drainage rate values to specific energy values or vice versa. From such data, the differential energy exerted by the refiners may be related in a quantitative manner, to the total or absolute energy adsorption level for the stock that is desired. From this relation, a quantitative value representative of change from a present refiner energy exertion level to a future energy exertion level may be derived. This change value offers a quantitative reference for refiner adjustment.

The mechanics of such mathematical manipualtions, whether performed manually or by electronic data process equipment, are well known to those of skill in the art. Accordingly, it is of no significance that the set-point value for the target or objective refining level is: entered as a slowness value or a total specific energy of refining value; combined first with the value represented by either of signals **41, 42,** or **43**; or, entered by the console of computer Σ c or Σ_{10}.

It will also be apparent to those skilled in the art that other changes may be made in the preferred embodiments described herein without departing from the spirit of my invention as set forth in the appended claims. Therefore, having now disclosed my invention, what I claim as new and unobvious and desire to secure by Letters Patent is:

1. A method of controlling the magnitude of energy applied to an aqueous slurry of pulp stock by at least one refining engine, said method comprising the steps of:

A. determining a quantitative first differential value of the average refining energy applied to said stock by refiner engine means;

B. determining a desired total quantitative value of average refining energy to be applied to said stock;

C. determining a quantitative value of total refining energy actually absorbed by said stock prior to working by said refiner engine means;

D. mathematically combining said determined values to derive a second differential value representative of a change in the magnitude of average refining energy application required of said refiner engine means for the average total value of refining energy actually absorbed by said stock as discharged by said refiner engine means to substantially equal said desired value; and,

E. adjusting the application of refining energy to said stock by said refiner engine means pursuant to the magnitude of said second differential value.

2. A method as described by claim **1** wherein the value of total refining energy actually absorbed by said stock is derived from a known functional relationship that a static drainage rate value bears to total absorbed refining energy for a stock sample that is representative of the subject stock.

3. A method as described in claim **2** wherein said value of total refining energy actually absorbed is derived from a measured value of static drainage rate for said subject stock.

4. A method of controlling the magnitude of energy applied to a flow stream of aqueous slurry pulp stock by pulp refining engine means, said method comprising the steps of:

A. obtaining a functional relationship between static drainage rate and total absorbed refining energy that is relevant to said stock;

B. measuring the static drainage rate of said stock at a point in said flow stream before said engine means;

C. deriving a first quantitative value from said measured drainage rate and said functional relationship that is representative of the total average specific energy that has been absorbed by said stock;

D. selecting a second quantitative value that is representative of a desired total average specific energy to be absorbed by said stock;

E. deriving a third quantitative value from the mathematical combination of said first and second values that is representative of a change in the magnitude of average specific energy delivered to said stock by said engine means necessary for said first value to substantially equal said second value; and

F. controlling said engine means in response to said third value.

5. A method of controlling pulp refining engine means as described by claim **4** additionally comprising the steps of:

A. producing signals proportional to said first and second values;

B. combining said first and second value signals to produce a third value signal; and

C. controlling said refining engine means responsively to said third value signal.

6. A method of controlling pulp refining engine means as described by claim **5** wherein said first value signal is proportional to the measured time interim of a stock slowness test.

7. A method of controlling at least one pulp refining engine means comprising the steps of:

A. obtaining from measured parameters a first quantitative value representative of the average specific energy applied to a pulp stock flow stream by said engine means;

B. obtaining from measured parameters a second quantitative value representative of the average static drainage rate of said flow stream stock prior to working by said engine means;

C. selecting a third quantitative value representative of a desired total average specific energy to be absorbed by said stock;

D. obtaining a functional relationship between static drainage rate and total absorbed refining energy that is relevant to said stock;

E. deriving a fourth quantitative value from said second value and said functional relationship that is representative of the total average specific energy that has been absorbed by said stock;

F. deriving a fifth quantitative value from the mathematical combination of said first, third and fourth values that is representative of a change in said first value for the total average specific energy absorbed by said stock, as discharged by said refining engine means, to substantially equal said third value; and,

G. controlling said refining engine means in response to said fifth value.

8. A method of controlling pulp refining engines means as described by claim **7** wherein said fifth value

is proportional to the difference between said third value and the sum of said first and fourth values.

9. A method of controlling pulp refining engine means as described by claim **7** additionally comprising the steps of:

A. producing signals proportional to said first, second and third values;

B. processing said second value signal pursuant to said functional relationship to produce a fourth value signal;

C. combining said first, third and fourth value signals to produce a fifth value signal; and,

D. controlling said refining engine means responsively to said fifth value signal.

10. A method of controlling pulp refining engine means as described by claim **9** wherein said second value signal is proportional to the measured time interim of a stock slowness test.

11. A system for controlling the magnitude of energy applied to an aqueous pulp slurry flow stream by refiner engine means, said system comprising:

A. means for quantitatively measuring the static drainage rate of said slurry at a station in said flow stream prior to said refiner engine means;

B. means for relating said drainage rate measurement to a first quantitative value of the total average specific energy absorbed by said slurry at the drainage rate measuring station;

C. means for comparing said first value to a second quantitative value representative of a desired total average specific energy to be absorbed by said slurry; and,

D. means for controlling the magnitude of energy applied to said slurry by refiner engine means responsive to a third quantitative value representative of a differential including said first and second values.

12. A system as described by claim **11** further comprising means for determining a fourth quantitative value representative of the average specific energy applied to said slurry by said refiner engine means.

13. A system as described by claim **12** wherein said third value represents a differential including the algebraic sum of said first and fourth values and said second value.

14. A system for controlling the magnitude of energy applied to an aqueous pulp slurry flow stream by refiner engine means, said system comprising:

A. means for quantitatively measuring the static drainage rate of said slurry at a point in said flow stream prior to said refiner engine means;

B. means for comparing said measured quantity to a second quantity representative of the static drainage rate desired for said slurry;

C. means for functionally relating the comparative differential including said measured quantity and said second quantity to a magnitude and direction of change in average specific energy applied to said slurry by refiner engine means; and,

D. means for controlling said refiner engine means responsive to the change determined by said functionally relating means.

15. A system as described by claim **14** further comprising means for determining a third quantity representative of the average specific energy applied to said flow stream by said refiner engine means.

16. A system as described by claim **15** wherein said comparing means compares the algebraic sum of said measured quantity and said third quantity to said second quantity.

17. In a pulp stock refiner engine control means having means for quantitatively measuring the average specific energy applied to a flow stream of pulp stock by refiner engine means, means to compare said applied energy measurement to a quantitative reference value and means to alter the energy applied by said refiner engine means responsive to said comparison, the improvement comprising:

A. means to quantitatively measure the static drainage rate of said pulp stock at a point in said flow stream prior to said refiner engine means; and,

B. means to relate said drainage rate value to said reference value.

18. Control means as described by claim **17** wherein said reference value represents a desired total average specific energy applied to said flow stream and said relating means determines the average total specific energy actually absorbed by said flow stream from said measured drainage rate value.

19. Control means as described by claim **18** wherein said comparison means derives the algebraic sum of said refiner engine applied energy measurement and said actually absorbed energy value and obtains the differential between said sum and said reference value.

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