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(54) **Determining the degree of cooking in a sulphite digester delignification.**

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(73) Proprietor: **THE BABCOCK & WILCOX COMPANY**
1010 Common Street P.O. Box 60035
New Orleans Louisiana 70160 (US)

(72) Inventor: **Johnson, Ralph K.**
652 Lander Drive
Highland Heights Ohio 44143 (US)
Inventor: **Keyes, Marion A. IV**
120 Riverstone Drive
Chagrin Falls Ohio 44022 (US)
Inventor: **Kaya, Azmi**
2365 Woodpark Road
Akron Ohio 44313 (US)

(74) Representative: **Cotter, Ivan John et al**
D. YOUNG & CO. 10 Staple Inn
London WC1V 7RD (GB)

Courier Press, Leamington Spa, England.

Description

This invention relates to methods of and apparatus for determining the degree of cooking in a sulphite digester for delignification. The invention can be used, for example, in the pulp industry.

Lignin is the major noncarbohydrate constituent of wood. It functions as a natural plastic binder for the cellulose fibres. Its exact formula is unknown. Lignin is removed from wood by both the sulphite and sulphate pulp processes.

It is known that the rate of delignification is a function of cooking liquor composition and cooking temperature, and that this rate increases rapidly with temperature and is affected by acid concentration. It is further known that the rate of deliginification for acid pulping varies with temperature in accordance with the known Arrhenius equation. The velocity factor reaction rate (k) can be determined from this equation and subsequently substituted in the standard rate of delignification equation to determine this latter rate.

US Patent No. US—A—3 941 649 (Wallin) describes a method of obtaining a predetermined Kappa number (a measure of the degree of cooking) in a sulphate pulping process by taking a sample of the pulping liquor at a stage when the preliminary alkali-consuming reactions are substantially complete but before any substantial delignification has taken place, and analysing the sample to establish the alkali content. The alkali content is then adjusted by addition of alkali until a predetermined alkali content per unit mass of wood is achieved. This additional alkali content can then be used to calculate the pulping conditions necessary to obtain the required Kappa number. The pulping time and temperature are then controlled on the basis of this information during delignification.

According to the invention there is provided a method of determining the degree of cooking in a sulphite batch digester for delignification reactions, the method being characterised by:

sensing the digester temperature T;

sensing the digester pressure P_d;

providing values corresponding to an energy of activity constant E for the digester reaction, the gas constant R and a further constant A;

continuously calculating the digester reaction rate k of the sulphite digester according to the Arrhenius equation to obtain values therefor over time;

obtaining a value corresponding to the partial pressure of sulphur dioxide as a function of digester temperature T and pressure P_d;

multiplying the partial pressure value by the reaction rate value to obtain a delignification rate value; and

integrating the delignification rate value over time to obtain a Kappa number for cooking in the digester which corresponds to the degree of cooking therein.

The invention also provides apparatus for accomplishing the foregoing method including individual function blocks which are connected together to achieve the various calculations.

According to another aspect of the invention there is provided apparatus for determining the degree of cooking in a sulphite batch digester for delignification, the apparatus being characterised by:

a first sensor for sensing a digester temperature T;

a second sensor for sensing a digester pressure P_d;

a first controller module connected to the first and second sensors and having means for providing values corresponding to an energy of activity constant E for the digester reaction, the gas constant R and a further constant A;

means in the first controller module for continuously calculating a digester reaction rate k of the digester according to the Arrhenius equation to obtain values therefor over time;

means in the first controller module for obtaining a value corresponding to the partial pressure of sulphur dioxide in the digester as a function of the digester temperature T and pressure P_d;

at least one multiplier in the first controller module for multiplying the partial pressure value by the digester reaction rate value to obtain a delignification rate value; and

a second controller module connected to the first controller module for receiving the delignification rate value and integrating the delignification rate value over time to obtain a Kappa value of cooking in the digester.

A preferred embodiment of the present invention described hereineblow provides a method and apparatus for calculating sulphite digester rate of delignification and determining the completion of cooking, utilising function blocks to continuously solve the so-called Arrhenius equation for the velocity factor reaction. This calculation takes place in the first controller module with the second controller module being provided with function blocks to obtain a value corresponding to the rate of delignification. The delignification rate is continuously computed and monitored, and when the cook has been brought up to a desired set point, an indication, such as an alarm, is provided to an operator to terminate the cooking process. By using simple function blocks, a digital computer, with its corresponding expensive programming and equipment, is avoided. An analog computer or device, known to have accuracy and flexibility problems, is also avoided.

The preferred apparatus for and methods of determining the degree of cooking in a sulphite digester are simple in design, rugged in construction, and economical to manufacture.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of one embodiment of the invention showing the use of two modules having plural function blocks;

Figure 2 is a block diagram of an Arrhenius equation module shown in the diagram of Figure 1; and

Figure 3 is a curve showing reaction rate plotted against time, graphically illustrating how the area under this curve is calculated for establishing a degree of cooking in a sulphite digester.

The drawings show apparatus embodying the invention for determining the degree of cooking in a delignification sulphite digester.

The rate of delignification is primarily a function of the cooking liquor composition and cooking temperature. Since there are established mathematical expressions for the rate of delignification, it is possible to determine how much cooking time is required based upon the cooking temperature for a particular pulp quality. See Pulp and Paper Manufacture, 2nd Ed., Volume I, *The Pulping of Wood*, pp 282 to 285.

The rate of delignification increases rapidly with increasing temperature, but the effect is altered by the acid concentration. The rate of delignification for acid pulping varies with temperature in accordance with the Arrhenius equation:

$$\log k = A - \frac{E}{2.303}RT \qquad (1)$$

where:

k=measure of the reaction rate;

A=constant;

E=energy of activity (approximately 21 Kcal);

T=digester temperature (Kelvins); and

R=gas constant (1.987 Cal/°C).

The rate of reaction is a little more than doubled by an increase of 10°C in temperature. Cooking is extremely slow at temperatures below 100°C.

Figure 1 illustrates how calculation of the digester rate of delignification and Kappa (K) Number can be implemented in a Bailey Network 90 (Trade Mark) system. The entire delignification rate and K-number calculation can be accomplished using two Network 90 controller modules 10, 30 for a particular digester. Information concerning the Network 90 can be found in Bailey Controls Company Application Guide 260-2 and Bailey Controls Company Product Specification E93-906.

In the first controller module 10, the Arrhenius equation can be continuously solved for the velocity factor reaction rate (k), by means of a calculator unit or module 23 shown in greater detail in Figure 2. The calculation is based upon digester temperature measurement as determined by a digester temperature transmitter 12 which provides one of a plurality of inputs to the unit 23.

The rate of delignification (dL/dt) at any instant for a sulphite batch digester is expressed as follows:

$$\text{Rate} = k\,(pSO_2)^n \qquad (2)$$

where:

k=velocity factor reaction rate varying with temperature according to the Arrhenius equation;

n=constant less than unity; and

pSO_2=partial pressure of sulphor dioxide in the digester (digester pressure minus steam pressure at digester temperature).

The partial pressure of sulphur dioxide in the digester is approximated by measuring the difference between steam pressure at the digester temperature and the actual digester pressure. This partial pressure is linearised and corrected for the assumption that the digester pressure is that of only steam and sulphur dioxide in equilibrium with the digester acid. Steam pressure is calculated as a function of temperature in a unit 14 and the actual pressure is supplied by a digester pressure transmitter 15. The difference between the steam pressure and digester pressure is taken in a comparator unit 16. The n power factor in Equation (2) is provided by a function generator 17 and provides a means for compensating for the foregoing assumption. The constants A, E, 2.303 and R of Equation (1) are provided to the unit 23 by units 18, 19, 20 and 21, respectively. An output (log k) from the unit 23 is integrated to provide k and multiplied by the partial pressure output value from the function generator 17 to provide an output from the controller module 10 which represents the rate of delignification at any instant for the sulphite digester, in accordance with Equation (2), and is directed to the second controller module 30.

The digester cook operator manually enters total SO_2 and free SO_2 acid strength chemical tests as inputs to the controller module 30 over units 32 and 33, respectively. The controller automatically subtracts the difference, which become the combined SO_2 content, in a comparator unit 34. The delignification rate can then have acid strength SO_2 correction applied over a function generator 35 and multipliers 36, 37.

The delignification rate will be integrated for each cook, in a unit 38, with respect to time, for totalising the area under the reaction curve of Figure 3.

This area totalisation is related to a degree of cooking (Kappa Number) set point for the particular grade. When the cook has been brought up to the desired set point, an alarm will sound for the digester cook operator's final decision on when to terminate the cook.

The equation for this calculation is as follows:

$$\frac{dL}{dt} = e^{(A-(E/2.303)RT)}[P_d - P_s]^n \qquad (3)$$

where:

P_d=digester pressure; and

P_s=steam pressure.

The degree of cooking (CD) is derived as follows:

$$CD=\int \alpha L=\int\{e^{(A-E/2.303)RT)}[Pd-Ps]^{n}\}dt \qquad (4)$$

The equation used in actually obtaining the total area under the curve as shown in Figure 3 is as follows:

$$(CD)_N=\sum_{i=1}^{N}(\text{rate})_i \qquad (5)$$

Claims

1. A method of determining the degree of cooking in a sulphite batch digester for delignification reactions, the method being characterised by:

sensing (12) the digester temperature T;

sensing (15) the digester pressure P_d;

providing values corresponding to an energy of activity constant E for the digester reaction, the gas constant R and a further constant A;

continuously calculating the digester reaction rate k of the sulphite digester according to the Arrhenius equation to obtain values therefor over time;

obtaining a value corresponding to the partial pressure of sulphur dioxide as a function of digester temperature T and pressure P_d;

multiplying the partial pressure value by the reaction rate value to obtain a delignification rate value; and

integrating the delignification rate value over time to obtain a Kappa number for cooking in the digester which corresponds to the degree of cooking (CD) therein.

2. A method according to claim 1, wherein steam pressure P_s in the digester is calculated (14) as a function of digester temperature T and a difference is taken (16) between the steam pressure P_s and the digester pressure P_d, which difference is proportional to the partial pressure of sulphur dioxide.

3. A method according to claim 1 or claim 2, including selecting a desired Kappa number for a desired degree of cooking in the sulphite digester, comparing the desired Kappa number with the obtained Kappa number, and, when the desired Kappa number corresponds to the obtained Kappa number, generating a signal.

4. Apparatus for determining the degree of cooking in a sulphite batch digester for delignification, the apparatus being characterised by:

a first sensor (12) for sensing a digester temperature T;

a second sensor (15) for sensing a digester pressure P_d;

a first controller module (10) connected to the first and second sensors (12, 15) and having means (18 to 20) for providing values corresponding to an energy of activity constant E for the digester reaction, the gas constant R and a further constant A;

means (23) in the first controller module (10) for continuously calculating a digester reaction rate k of the digester according to the Arrhenius equation to obtain values therefor over time;

means (14, 16, 17) in the first controller module (10) for obtaining a value corresponding to the partial pressure of sulphur dioxide in the digester as a function of the digester temperature T and pressure P_d;

at least one multiplier in the first controller module (10) for multiplying the partial pressure value by the digester reaction rate value to obtain a delignification rate value; and

a second controller module (30) connected to the first controller module (10) for receiving the delignification rate value and integrating the delignification rate value over time to obtain a Kappa value of cooking in the digester.

5. Apparatus according to claim 4, wherein the first and second controller modules (10, 30) including a plurality of function blocks each for conducting one of a comparison function, an arithmetic function, or a plurality of arithmetic functions.

6. Apparatus according to claim 4 or claim 5, wherein the first controller module (10) includes a first function generator (14) for receiving a signal from the first sensor (12) and generating a value corresponding to a steam pressure P_s of the digester, a comparator (16) connected to the first function generator (14) and the second sensor (15) for obtaining a difference between the steam pressure P_s and digester pressure P_d, a second function generator (17) connected to the comparator (16) for generating a value corresponding to the partial pressure of sulphur dioxide in the digester, the second function generator (17) being connected to said at least one multiplier of the first controller module (10), and an Arrhenius equation unit (23) connected to the first sensor (12) and connected to the means (18 to 20) for providing the values corresponding to the constants for generating the digester reaction rate value.

7. Apparatus according to claim 4, claim 5 or claim 6, wherein the second controller module (30) includes means (32, 33) for manually setting a percent total sulphur dioxide value and a percent-free sulphur dioxide value and a comparator (34) connected to the total and free sulphur dioxide setting means (32, 33) for obtaining a difference therebetween, the comparator (34) being connected in the second controller module (30) through a multiplier (37) for multiplying said difference with the delignification rate.

Patentansprüche

1. Verfahren zur Bestimmung des Kochgrades in einem Sulfitsatzkocher für Delignifizierungsreaktionen, wobei das Verfahren dadurch gekennzeichnet ist, daß

man die Kochertemperatur T abfühlt (12),

den Kocherdruck P_d abfühlt (15),

Werte entsprechend einer Aktivitätsenergiekonstante E für die Kochkerreaktion, die Gaskonstante R und eine weitere Konstante A bekommt,

kontinuierlich die Kocherreaktionsgeschwindigkeit k des Sulfitkochers gemäß der Arrheniusgleichung berechnet, um hierfür Werte über der Zeit zu erhalten,

einen Wert entsprechend dem Partialdruck von Schwefeldioxid als eine Funtion der Kochertemperatur T und des Kocherdruckes P_d erhält,

den Partialdruckwert mit dem Wert der Reaktionsgeschwindigkeit multipliziert, um einen Wert für die Delignifizierungsgeschwindigkeit zu erhalten,

und den Wert für die Delignifizierungsgeschwindigkeit über der Zeit integriert, um eine Kappa-Zahl für das Kochen in dem Kocher zu erhalten, die dem Kochgrad (CD) darin entspricht.

2. Verfahren nach Anspruch 1, bei dem man den Dampfdruck P_s in dem Kocher als eine Funktion der Kochertemperatur T berechnet (14) und eine Differenz zwischen dem Dampfdruck P_s und dem Kocherdruck P_d nimmt (16), wobei diese Differenz proportional dem Partialdruck des Schwefeldioxids ist.

3. Verfahren nach Anspruch 1 oder Anspruch 2, bei dem man einer erwünschte Kappa-Zahl für einen erwünschten Kochgrad in dem Sulfitkocher auswählt, die erwünschte Kappa-Zahl mit der erhaltenen Kappa-Zahl vergleicht und, wenn die erwünschte Kappa-Zahl der erhaltenen Kappa-Zahl entspricht, ein Signal erzeugt.

4. Vorrichtung zur Bestimmung des Kochgrades eines Sulfitansatzkochers für Delignifizierung, gekennzeichnet durch

eine erste Abfühleinrichtung (12) zum Abfühlen einer Kochertemperatur T,

eine zweite Abfühleinrichtung (15) zum Abfühlen eines Kocherdruckes P_d,

ein erstes Steuerbauteil (10), das mit der ersten und der zweiten Abfühleinrichtung (12, 15) verbunden ist und Einrichtungen (18 bis 20) besitzt, die Werte entsprechend einer Aktivitätsenergiekonstante E für die Kocherreaktion, die Gaskonstante R und eine weitere Konstante A liefern,

Einrichtungen (23) in dem ersten Steuerbauteil (10) für kontinuierliche Berechnung einer Kocherreaktionsgeschwindigkeit k des Kochers gemäß der Arhheniusgleichung, um Werte hierfür über der Zeit zu erhalte,

Einrichtungen (14, 16, 17) in dem ersten Steuerbauteil (10), die einen Wert entsprechend dem Partialdruck von Schwefeldioxid in dem Kocher als eine Funktion der Kochertemperatur T und des Kocherdruckes P_d erhalten,

wenigstens eine Multipliziereinheit in dem ersten Steuerbauteil (10) zum Multiplizieren des Partialdruckwertes mit dem Kocherreaktionsgeschwindigkeitswert, um einen Wert für die Delignifizierungsgeschwindigkeit zu erhalten,

und ein zweites Steuerbauteil (30), das mit dem ersten Steuerbauteil (10) verbunden ist, um den Wert für die Delignifizierungsgeschwindigkeit aufzunehmen und den Wert für die Delignifizierungsgeschwindigkeit über der Zeit zu integrieren und so einen Kappa-Wert für das Kochen in dem Kocher zu erhalten.

5. Vorrichtung nach Anspruch 4, bei der das erste und zweite Steuerbauteil (10, 30) mehrere Funktionsblöcke enthalten, um jeweils eine Vergleichsfunktion, eine arrhythmetische Funktion oder mehrere arrhythmetische Funktionen durchzuführen.

6. Vorrichtung nach Anspruch 4 oder Anspruch 5, bei dem das erste Steuerbauteil (10) einen ersten Funktionserzeuger (14), um ein Signal von der ersten Abfühleinrichtung (12) aufznehmen und einen Wert entsprechend einem Dampfdruck P_s des Kochers zu erzeugen, einen mit dem ersten Funktionszeuger (14) und der zweiten Abfühleinrichtung (15) verbundenen Komparator (16), um einen Unterschied zwischen dem Dampfdruck P_s und dem Kocherdruck P_d zu erhalten, einen zweiten mit dem Komparator (16) verbundenen Funtkionserzeuger (17), um einen Wert entsprechend dem Partialdruck von Schwefeldioxid in dem Kocher zu bekommen, enthält, wobei der zweite Funktionszeuger (17) mit wenigstens einer Multipliziereinheit des ersten Steuerbauteils (10) verbunden ist und eine Arrheniusgleichungseinheit (23) mit der ersten Abfühleinrichtung (12) und mit der Einrichtung (18 bis 20) zur Erzeugung des Wertes entsprechend den Konstanten verbunden ist, um den Wert für die Kocherreaktionsgeschwindigkeit zu erzeugen.

7. Vorrichtung nach Anspruch 4, Anspruch 5 oder Anspruch 6, bei der das zweite Steuerbauteil (30) Einrichtungen (32, 33) zur manuellen Einstellung eines prozentualen Gesamtschwefeldioxidwertes und eines prozentualen Wertes für freies Schwefeldioxid und einen Komparator (34), der mit der Einstelleinrichtung für Gesamtschwefeldioxid und freies Schwefeldioxid (32, 33) verbunden ist, einschließt, um eine Differenz zwischen beiden zu erhalten, wobei der Komparator (34) in dem zweiten Steuerbeauteil (30) über eine Multipliziereinheit (37) verbunden ist, um diese Differenz mit der Delignifizierungsgeschwindigkeit zu multiplizieren.

Revendications

1. Procédé pour déterminer le degré de cuisson dans un lessiveur en discontinu au bisulfite destiné à des réactions de délignification, procédé caractérisé en ce qu'il consiste:

à capter (12) la température T du lessiveur;

à capter (15) la pression P_d du lessiveur;

à fournir des valeurs correspondant à la constante d'énergie d'activation E de la réaction dans le lessiveur, à la constante des gaz R et à une autre constante A;

à calculer en continu la vitesse de réaction k du lessiveur au bisulfite selon l'équation d'Arrhénius, pour en obtenir des valuers en fonction du temps;

à obtenir une valeur correspondant à la pression partielle de l'anhydride sulfureux en fonction de la température T et la pression P_d du lessiveur;

à multiplier la valeur de la pression partielle par la valeur de la vitesse de réaction pour obtenir une valeur de la vitesse de délignification; et

à intégrer la valeur de la vitesse de délignification par rapport au temps pour obtenir un indice kappa pour la cuisson dans le lessiveur, indice qui correspond au degré de cuisson (CD) à l'intérieur de ce dernier.

2. Procédé selon la revendicution 1, dans lequel la pression de vapeur P_s dans le lessiveur est calculée (14) en fonction de la température T du lessiveur, et une différence est prise (16) entre la pression de vapeur P_s et la pression P_d du lessiveur, laquelle différence est proportionnelle à la pression partielle de l'anhydride sulfureux.

3. Procédé selon la revendication 1 ou la revendication 2, consistant à sélectionner un indice kappa voulu, correspondant à un degré voulu de cuisson dans le lessiveur au bisulfite, à comparer l'indice kappa voulu à l'indice kappa obtenu et, quand l'indice kappa voulu correspond à l'indice kappa obtenu, à produire un signal.

4. Appareillage pour déterminer le degré de cuisson d'un lessiveur en discontinu au bisulfite destiné à une délignification, appareillage caractérisé par

un premier capteur (12) pour capter une température T du lessiveur;

un deuxième capteur (15) pour capter une pression P_d du lessiveur;

un premier module régulateur (10) connecté au premier et au deuxième capteurs (12, 15) et possédant un moyen permettant de fournir de valeurs correspondant à une constante d'énergie d'activation E de la réaction dans le lessiveur, la constante des gaz R et une autre constante A;

un moyen (23), dans le premier module régulateur (10), pour calculer en continu une constante spécifique de vitesse de réaction k dans le lessiveur selon l'équation d'Arrhénius, pour en obtenir des valeurs en fonction du temps;

un moyen (14, 16, 17) dans le premier module régulateur (10) pour obenir une valeur correspondant à la pression parteille de l'anhydride sulfureux dans le lessiveur en fonction de la température T et de la pression P_d du lessiveur;

au moins un multiplicateur dans le premier module régulateur (10) pour multiplier la valeur de la pression partielle par la valeur de la vitesse de réaction dans le lessiveur, pour obtenir une valeur de la vitesse de délignification; et

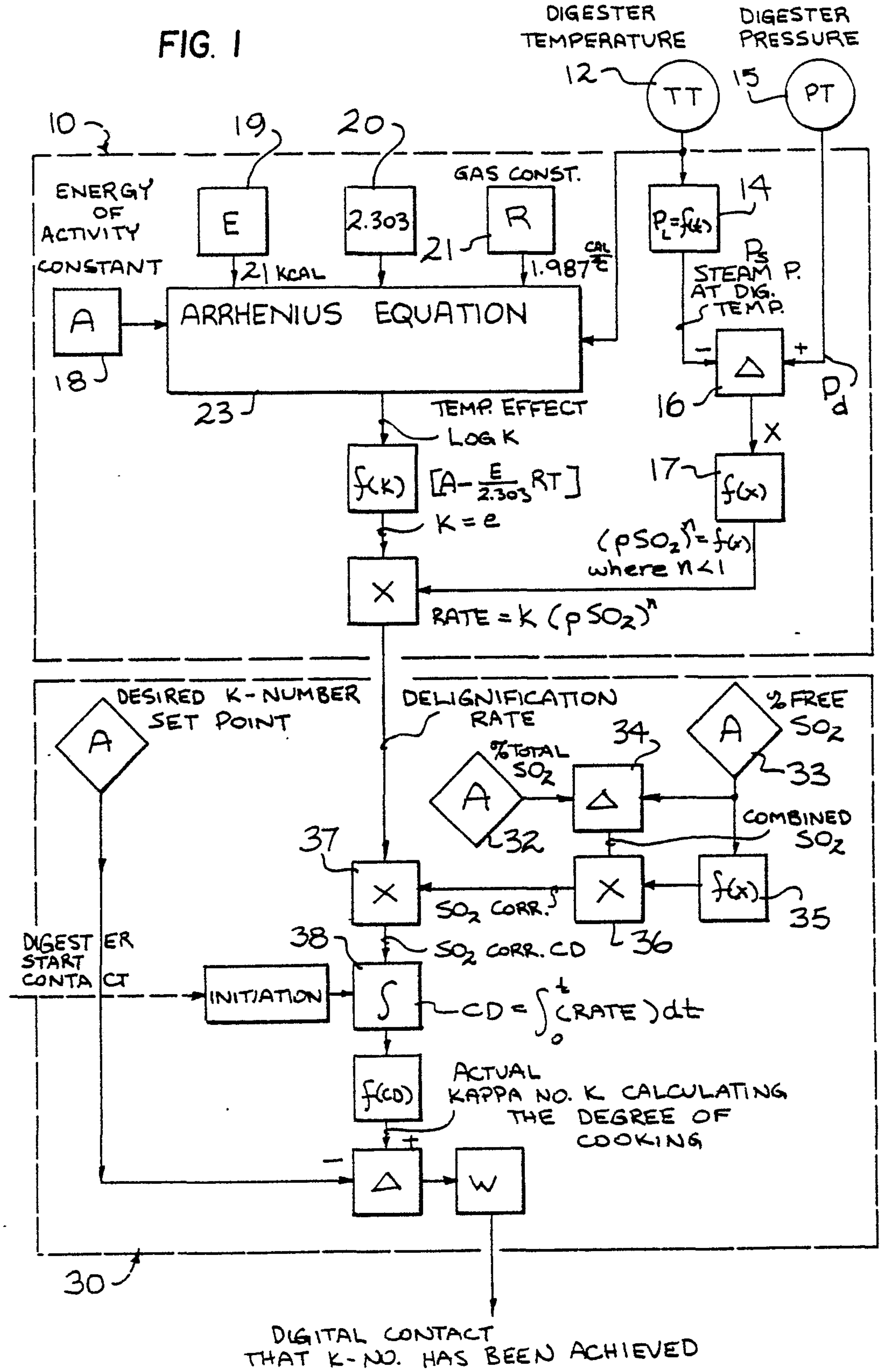
un deuxième module régulateur (30) connecté au premier mdoule régulateur (10) pour recevoir la valeur de la vitesse de délignification et intégrer la valeur de la vitesse de délignification en fonction du temps pour obtenir un indice kappa de cussion dans le lessiveur.

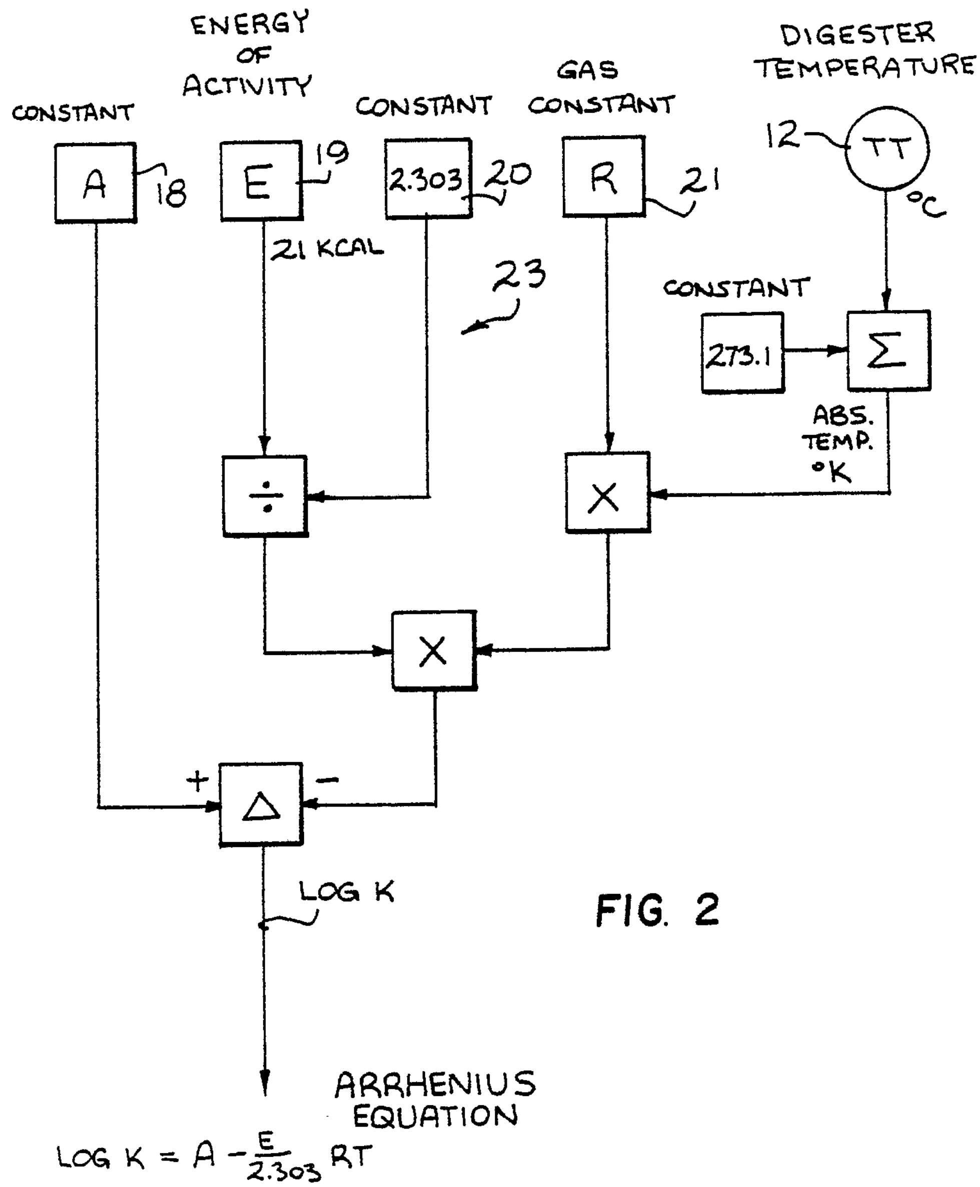
5. Appareillage selon la revendication 4, dans lequel le priemer et le deuxième modules régulateurs (10, 30) comprennent une pluralité de blocs fonctionnels, chacun effectuant une fonction de comparaison, une fonction arithmétique ou une pluralité de fonctions arithmétiques.

6. Appareillage selon la revendication 4 ou la revendication 5, dans lequel le premier module régulateur (10) comprend un premier générateur de fonctions (14) destiné à recevoir un signal du premier capteur (12) et produisant une valeur correspondant à une pression de vapeur P_s du lessiveur, un comparateur (16) connectée au premier générateur de fonctions (14) et au deuxième capteur (15) pour obtenir une différence entre la pression de vapeur P_s et la pression P_d du lessiveur, un deuxième générateur de fonctions (17) connecté au comparateur (16) pour produire une valeur correspondant à la pression partielle de l'anhydride sulfureux dans le lessiveur, le deuxième générateur de fonctions (17) étant connecté audit au moins un multiplicateur du premier module régulateur (10), ainsi qu'une unité "équation d'Arrhénius" (23), connectée au premier capteur (12) et connectée au moyen (18 à 20) pour fournir les valeurs correspondant aux constantes, dans le but de produire la valeur de la vitesse de réaction dans le lessiveur.

7. Appareillage selon la revendication 4, la revendication 5 ou la revendication 6, dans lequel le deuxième module régulateur (30) comprend un moyen (32, 33) pour ajuster manuellement une valeur de la concentration de l'anhydride sulfureux total, en pourcentage, et une concentration, en pourcentage, de l'anhydride sulfureux libre, et un comparateur (34) connecté au moyen d'ajustage de la concentration de l'anhydride sulfureux total et de l'anhydride sulfureux libre (32, 33) pour en calculer une différence, le comparateur (34) étant connecté au deuxième module régulateur (30) par l'intermédiaire d'un multiplicateur (37), pour multiplier ladite différence par la vitesse de délignification.

FIG. 1


DIGESTER TEMPERATURE
DIGESTER PRESSURE
TT
PT
GAS CONST.
ENERGY OF ACTIVITY
CONSTANT
E
2.303
R
21 KCAL
1.987 CAL/E
ARRHENIUS EQUATION
A
STEAM P. AT DIG. TEMP.
TEMP. EFFECT
LOG K
f(K)
K = e
f(x)
X
RATE = K (pSO2)^n
where n<1
DESIRED K-NUMBER SET POINT
DELIGNIFICATION RATE
% FREE SO2
% TOTAL SO2
COMBINED SO2
SO2 CORR.
SO2 CORR. CD
DIGESTER START CONTACT
INITIATION
CD = ∫ (RATE) dt
f(CD)
ACTUAL KAPPA NO. K CALCULATING THE DEGREE OF COOKING
W
DIGITAL CONTACT THAT K-NO. HAS BEEN ACHIEVED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ENERGY
OF
ACTIVITY
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GAS
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DIGESTER
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EQUATION
LOG K = A − E/2.303 RT

FIG. 2

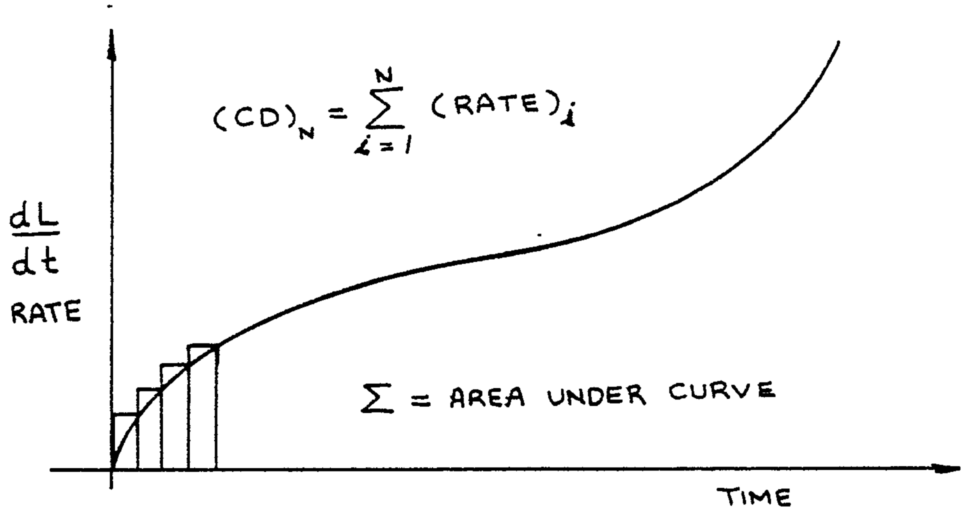

FIG. 3