AUTOMATIC IRON ORE ASSAYER

Filed April 14, 1966 Sheet 1 of 2

FIG. 1

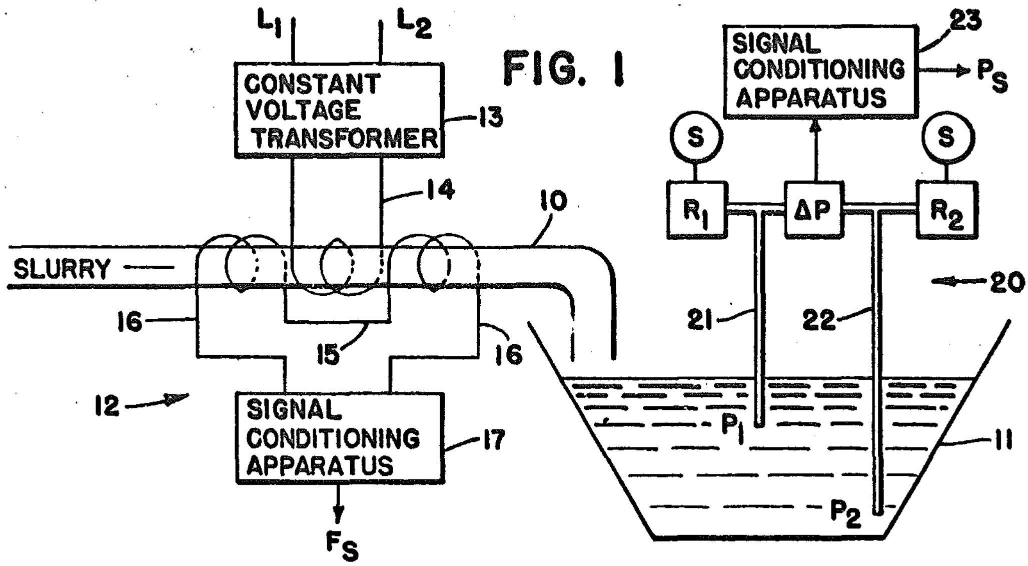

FIG. 2

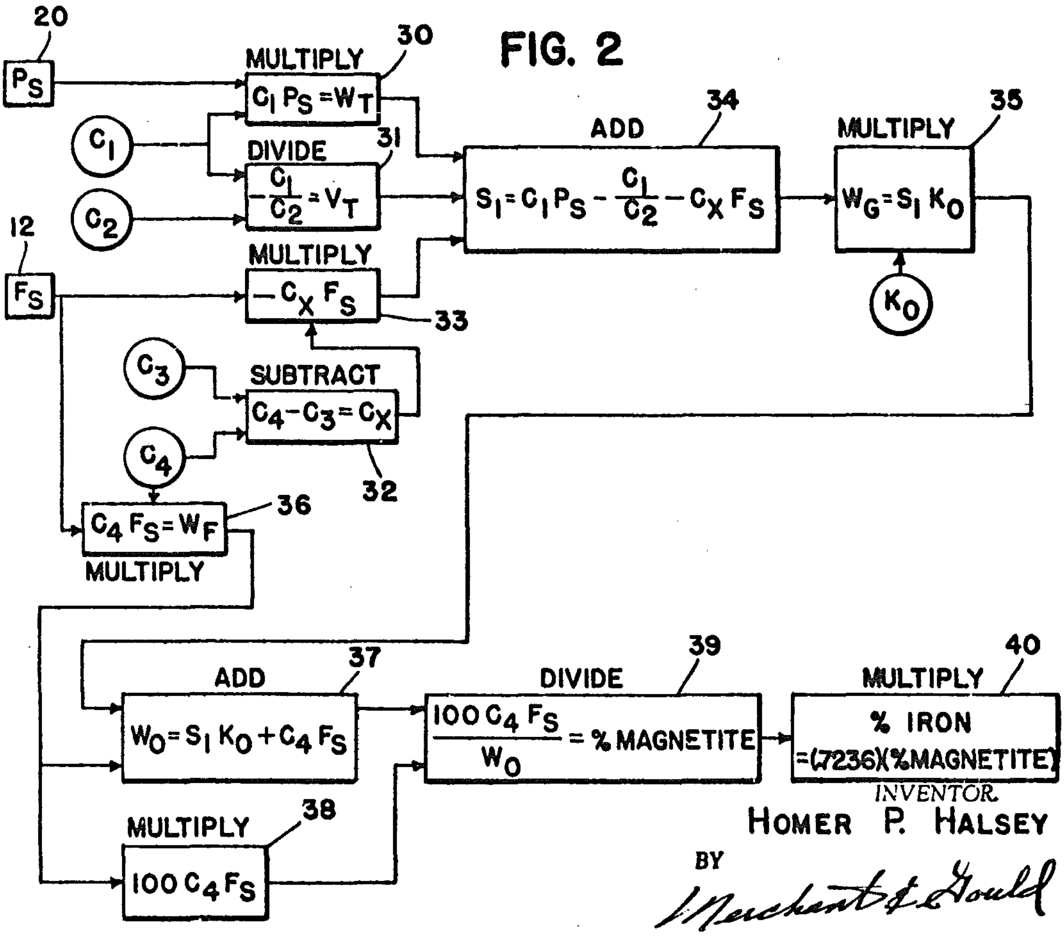

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FIG. 4

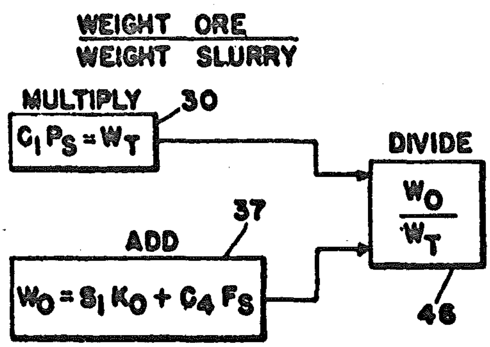


FIG. 3

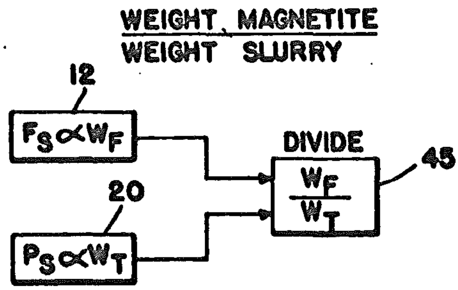


FIG. 5

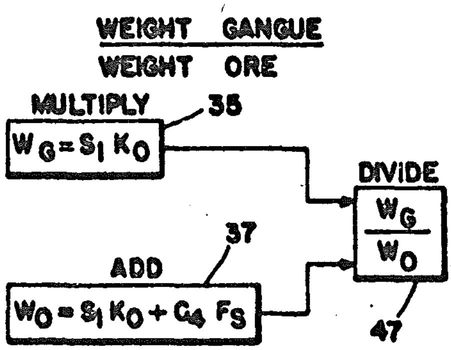


FIG. 6

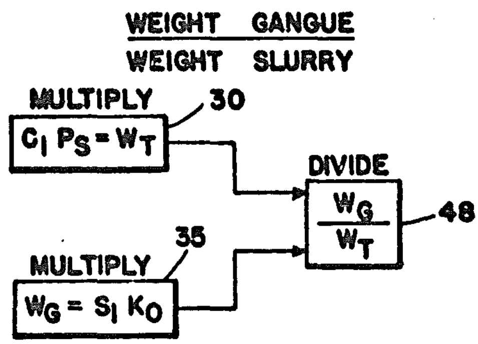
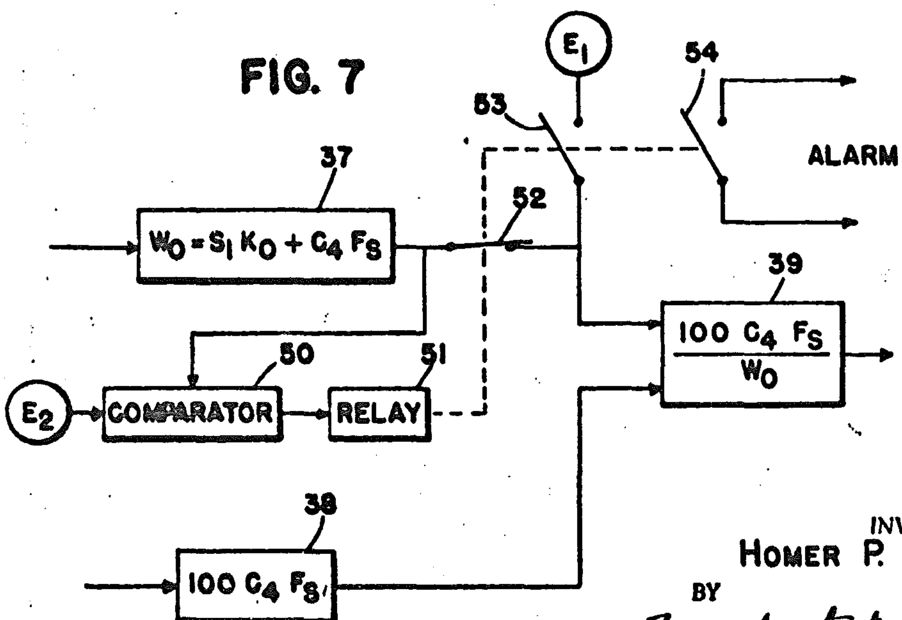


FIG. 7



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United States Patent Office

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1

3,433,057

AUTOMATIC IRON ORE ASSAYER

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U.S. Cl. 73—61 11 Claims
Int. Cl. G01n *11/00*

ABSTRACT OF THE DISCLOSURE

Apparatus for continuously and automatically computing the amount of magnetic iron relative to the amount of ore in a slurry of ore and water. The ore itself is a mixture of gangue and magnetite, with the magnetite containing a known percentage of magnetic iron. The present system continuously measures two characteristics of the constantly changing slurry, the specific gravity of the slurry and the amount of magnetite in the slurry. These two characteristics are represented as usable signals, and apparatus is provided to combine these signals with various constants, including a constant representative of the specific gravity of the gangue, to develop the desired information.

Taconite is a low grade magnetic iron ore in the form of hard rock in its natural state. The taconite ore includes not only the desirable magnetic iron but also includes undesirable nonmagnetic material, referred to herein as gangue. The magnetic iron is present in taconite in the form of magnetite (Fe_3O_4). Taconite itself is approximately 23% magnetic iron while magnetite is 72.4% magnetic iron.

To be of value as a blast furnace feed, the ore must be concentrated to upgrade the beneficiated concentrate to above 60% magnetic iron. Therefore, it is necessary to separate and then discard the gangue from the magnetite. This separation of the gangue from the magnetite is normally accomplished by dry crushing the ore and then wet grinding and wet separating the magnetic particles from the gangue particles. There are several stages of magnetic separation in the process of upgrading the taconite. During this process, it is desirable, and often necessary, to obtain an analysis of the percentage of magnetic iron relative to the weight of ore, both before and after the various separation stages. The efficiency of a particular stage in the upgrading process can be measured by obtaining the magnetic iron content both before and after the stage.

During much of the upgrading process, the pulverized taconite is included in a water slurry. The slurry is thus a mixture of water, gangue, and magnetite.

The prior art method of analyzing the amount of magnetic iron in the ore required that a sample of the slurry be taken to a laboratory to be analyzed. At the laboratory, the water was evaporated from the sample, and the remaining ore was then analyzed by conventional means to determine the percentage of magnetic iron in the ore. Since this is a time-consuming process, an undesirable amount of time often elapsed between the time the sample was taken and the time the results of the analysis were available. A particular stage of the upgrading process could therefore operate improperly for a long period of time because of the time lag in obtaining the analysis.

Because of the undesirable features of the prior art practice, I have designed a system that provides an "On Line" continuous output signal that is proportional to the percentage of magnetic iron relative to the ore in a mixture of gangue, magnetite and water. My invention will accurately indicate the percentage of magnetic iron even where there are large variations in the relative proportions of the water, gangue and magnetite. This new and unique system uses only two easily obtainable signals; a signal to indicate the specific gravity of the slurry, and a signal to indicate the amount of magnetic iron. These two signals can be obtained with commercially available devices. My invention lies in designing a system that will combine these signals with various constants to develop the desired information.

2

This assayer apparatus can be used to analyze slurry flowing through a pipe or slurry located in a tank. Different sensing devices might be required to obtain the two necessary signals, depending upon the location of the slurry. The basic system, however, would not change. Further, the assayer can be mechanized with either electrical or pneumatic components.

It is therefore a primary object of the present invention to provide apparatus for automatically and continuously computing the percentage of magnetic iron relative to the amount of ore in a slurry of water, gangue and magnetite.

Further objects of the present invention will become apparent from the specification and claims when considered in connection with the accompanying drawings, in which:

FIG. 1 illustrates schematically a pair of devices that will provide the two necessary input signals;

FIG. 2 is a block diagram of the assayer system according to my invention;

FIG. 3 discloses a variation of the system for determining the ratio of magnetite weight to slurry weight;

FIG. 4 is a variation of the system in which the ratio of ore weight to slurry weight is computed;

FIG. 5 is a variation of the system for computing the ratio of the gangue weight to ore weight;

FIG. 6 is a variation of the system for computing the ratio of gangue weight to slurry weight; and

FIG. 7 discloses a variation of the basic system in which means is provided to stabilize the system under abnormal operating conditions.

In FIG. 1, a slurry of water, gangue and magnetite flows through a pipe **10** into a tank **11**. This schematic representation could represent any stage of the upgrading process. Pipe **10** is normally full of slurry and tank **11** is normally filled with slurry to a preferred level as shown.

Disclosed generally at **12** is a sensing system designed to provide an output signal F_8 that is proportional to the amount of magnetite passing through pipe **10**. Sensing system **12** includes a constant voltage transformer **13** that takes power from L_1 and L_2, a source of alternating current. The constant voltage output from transformer **13** is impressed across a primary coil **14** that surrounds or is otherwise mounted adjacent to pipe **10**. Mounted on opposite sides of primary coil **14** are two secondary coils **15** and **16**. Secondary coils **15** and **16** are connected to a signal conditioning apparatus **17** that develops the desired signal F_8.

When primary coil **14** is energized by an alternating current, a current is induced in coils **15** and **16**. The output from coils **15** and **16** varies with the amount of magnetic material passing through pipe **10** so that the voltage applied to signal conditioning apparatus **17** is proportional to the amount of magnetic material that intersects the flux field of the coils. Changes in the secondary output therefore accurately reflect changes in the magnetic content of the slurry. The signal F_8 is therefore proportional to the amount of magnetite in the slurry in pipe **10**.

Signal conditioning apparatus **17** can be any device such as an amplifier, rectifier or pulse generator that is necessary to convert the signal from coils 15 and 16 into the desired signal F_s.

The signal P_s is developed by a sensing means generally designated at 20. Sensing means 20 includes a pair of bubbler tubes 21 and 22 that extend into the slurry in tank 11. Tube 21 terminates near the top of the slurry while tube 22 extends to a point near the bottom of tank 11. A source of air pressure S is supplied to a pair of relays or pressure regulators R_1 and R_2. Relays R_1 and R_2 regulate the amount of air supplied to tubes 21 and 22 respectively so that each tube receives the same amount of air. A differential pressure transmitter (ΔP) is connected across tubes 21 and 22. Transmitter ΔP is in turn connected to a signal conditioning apparatus 23 that provides the desired output signal P_s.

Sensing apparatus 20 operates as follows. The pressure in tube 21 (P_1) will be lower than the pressure in tube 22 (P_2) because of the different amounts of pressure exerted by the different depths of liquid. The pressure differential between tubes 21 and 22 is indicative of the density or specific gravity of the slurry in tank 11 since P_1 and P_2 are both indicative of the weight of the liquid above the tubes. As the specific gravity of the slurry increases, the difference in pressure will also increase. Transmitter ΔP monitors this differential pressure and produces a signal proportional to it. The signal from transmitter ΔP is sent to signal conditioning apparatus 23 where it is converted into a usable signal P_s. Apparatus 23 can be an amplifier, transducer or any other device necessary to convert the signal from transmitter ΔP into a usable signal P_s. Output signal P_s will therefore be proportional to the specific gravity of the slurry in tank 11.

FIG. 1 was designated to show schematically two possible systems for obtaining the necessary signals F_s and P_s. Other device may be employed to genearte these same signals without departing from the invention.

FIG. 2 is a block diagram of the system for computing the percentage of magnetic iron relative to the weight of ore in the slurry. Before discussing the operation of the system disclosed in FIG. 2, however, it will be necessary to understand the derivation of an equation that equates the percentage of magnetic iron as a function of the two measured variables P_s and F_s and certain constants. Set forth below is a list of symbols that are used in deriving the equation. Following the list of symbols is the equation derivation.

Symbols

P_s=Specific gravity signal
F_s=Magnetite signal
W_t=Total weight of slurry
W_f=Magnetite weight
W_g=Gangue weight
W_w=Water weight
W_{gw}=Weight of gangue and water
W_o=Weight of ore
V_t=Total volume (a constant for a given system)
V_g=Volume of gangue
V_w=Volume of water
V_{gw}=Volume of gangue and water
V_f=Volume of magnetite
SG_w=Specific gravity of water=1
SG_f=Specific gravity of magnetite=5.18
SG_g=Specific gravity of gangue=K
SG_t=Specific gravity of slurry
C_1, C_2, C_3, C_4=System constants

Derivation

(1) $W_t \alpha P_s$
Therefore
(2) $W_t = C_1 P_s$
(3) $SG_t \alpha P_s$
Therefore
(4) $SG_t = C_2 P_s$
(5) $$V_t = \frac{W_t}{SG_t} = \frac{C_1}{C_2}$$
(6) $V_f \alpha F_s$
Therefore
(7) $V_f = C_3 F_s$
(8) $W_f \alpha F_s$
Therefore
(9) $W_f = C_4 F_s$
(10) $$SG_f = \frac{C_4}{C_3} = 5.18$$
(11) $V_t = V_f + V_g + V_w$
(12) $V_{gw} = V_g + V_w$
(13) $V_{gw} = V_t - V_f$
Substituting 5 and 7 into 13
(14) $$V_{gw} = \frac{C_1}{C_2} - C_3 F_s$$
(15) $W_{gw} = W_w + W_g$
Therefore
(16) $W_{gw} = SG_w V_w + KV_g$
(17) $W_{gw} = V_w + KV_g$
(18) $V_w = V_{gw} - V_g$
Substituting 18 into 17
(19) $W_{gw} = V_{gw} - V_g + KV_g$
(20) $W_{gw} = W_t - W_f$
Substituting 2 and 9 into 20
(21) $W_{gw} = C_1 P_s - C_4 F_s$
From 19 & 21
(22) $C_1 P_s - C_4 F_s = V_{gw} - V_g + KV_g$
Substituting 14 into 22
(23) $$C_1 P_s - C_4 F_s = \frac{C_1}{C_2} - C_3 F_s - V_g + KV_g$$
(24) $$V_g = \left[\frac{1}{K-1}\right]\left[\left(C_1 P_s - \frac{C_1}{C_2}\right) - F_s(C_4 - C_3)\right]$$
Multiplying both sides of Equation 24 by K
(25) $$KV_g = \left[\frac{K}{K-1}\right]\left[\left(C_1 P_s - \frac{C_1}{C_2}\right) - F_s(C_4 - C_3)\right]$$
But $KV_g = W_g$; also $C_3 = C_4/5.18$
Therefore $C_4 - C_3 = .807 C_4$
Therefore
(26) $$W_g = \left[\frac{K}{K-1}\right]\left[C_1 P_s - \frac{C_1}{C_2} - .807 C_4 F_s\right]$$
Let
$$K_o = \left[\frac{1}{K-1}\right]$$
Then
(27) $$W_g = K_o\left[C_1 P_s - \frac{C_1}{C_2} - .807 C_4 F_s\right]$$
(28) $W_o = W_g + W_f$
(29) $$W_o = K_o\left[C_1 P_s - \frac{C_1}{C_2} - .807 C_4 F_s\right] + C_4 F_s$$
(30) $$\text{Percent iron} = \left[\frac{W_f 100}{W_o}\right](.72356)$$
(31) Percent iron =
$$\left[\frac{C_4 F_s 100}{K_o\left(C_1 P_s - \frac{C_1}{C_2} - .807 C_4 F_s\right) + C_4 F_s}\right](.72356)$$
Let
$.807 C_4 = C_x$
Then
(32) Percent iron
$$\left[\frac{C_4 F_s 100}{K_o\left(C_1 P_s - \frac{C_1}{C_2} - C_x F_s\right) + C_4 F_s}\right](.72356)$$

Equations 1 and 3 show that the signal P_s is proportional to both the total weight of the slurry and the specific gravity of the slurry. From these two relationships, the constants C_1 and C_2 are developed. From Equations 6 and 8, it can be seen that the volume of the magnetite and the weight of the magnetite are both proportional to the signal F_s. From these relationships, the constants C_3 and C_4 are developed. Other constants are known such as the specific gravity of the magnetite and the specific gravity of water. It is also assumed that the total volume of the system is a constant. The other equations gradually lead to Equation 32 in which the percentage of magnetic iron relative to the weight of ore is expressed only in terms of F_s, P_s and the various constants. With regard to Equation 32, it is noted that the multiplier .72356 is a decimal representing the amount of magnetic iron in magnetite.

In FIG. 2, the input signals include P_s and F_s, which have been developed with systems such as disclosed in FIG. 1. The constants C_1, C_2, C_3 and C_4 are also presented as usable signals. These constants would be determinable with respect to any given system in accordance with the relationships set forth earlier.

A first multiplying device 30 is connected to sensing means 20 and to the source of C_1 to develop a signal C_1P_s which is equivalent to the total weight of the slurry (W_t). A first dividing means 31 is connected to the sources of signals C_1 and C_2 for developing a signal

$$-\frac{C_1}{C_2}$$

which signal is indicative of the total volume of the slurry (V_t). A subtracting device 32 is connected to the sources of C_3 and C_4 for developing a signal C_4-C_3 which is set equal to a constant C_x.

Signal C_x and signal F_s are multiplied by a second multiplying device 33 to provide a signal $-C_xF_s$. At this point it is noted that the signals being developed are those necessary to solve Equation 32.

The output signals from multiplying device 30, dividing device 31, and multiplying device 33 are all added together by a first summing means or device 34. Summing device 34 therefore provides an output signal S_1 which is equal to

$$C_1P_s-\frac{C_1}{C_2}-C_xF_s$$

A third multiplying device 35 is connected to summing device 34 to multiply the output signal S_1 by a constant K_0. K_0 is equal to $K/K-1$ where K is the specific gravity of the gangue. The specific gravity of the gangue is a known quantity normally having a value in the range of 3.2. The signal S_1K_0 that is developed by multiplying device 35 is equivalent to the weight of the gangue (W_g).

A fourth multiplying device 36 is connected to sensing means 12 and to the source of C_4. Multiplying device 36 provides a signal C_4F_s which is equivalent to the weight of the magnetite (W_f).

A second summing means 37 is connected to multiplying means 35 and multiplying means 36 to add S_1K_0 to C_4F_s. Summing device 37 provides an output signal equivalent to the weight of the ore (W_0).

A fifth multiplying device 38 is connected to multiplying device 36 to provide an output signal $100C_4F_s$. The figure 100 is necessary if the output from the system is desired in terms of percentage rather than in terms of a ratio.

A second dividing device 39 is connected to summing device 37 and multiplying device 38. Dividing means 39 provides an output signal $100C_4F_s/W_0$ which is equivalent to the percentage of magnetite in the ore.

A sixth multiplying device 40 is connected to dividing means 39 to multiply the percentage of magnetite by a constant .7236 to arrive at the percentage of magnetic iron in the ore. The figure .7236 is a specific figure that is derived from the formula for magnetite (Fe_3O_4).

From FIG. 2 it can be seen that many useful signals are provided by the system. For example, if the weight of the gangue is desired, the signal from multiplying means 35 can be utilized. If the weight of the ore is desired, the signal from summing means 37 can be utilized. If the percentage of magnetite in the ore is the desired quantity, multiplying device 40 can be dropped from the system.

The exact mechanization of the system in terms of electrical or pneumatic circuitry is not disclosed herein since such mechanization is well within the capacity of anyone skilled in the art. If an electrical system is used, for example, the arithmetic computations can be performed by high-gain DC amplifiers associated with other well known components. Such an amplifier with feedback and input resistors can perform active multiplication. Such an amplifier can also perform the summing functions required herein. A high-gain amplifier together with a servo can perform the desired division. There are thus many well known means of computing the necessary functions that can be incorporated into my system without difficulty.

FIG. 3 discloses a variation of my system in which an additional dividing means 45 is connected to sensing means 12 and sensing means 20 for developing a signal W_f/W_t which is equivalent to a ratio of the magnetite weight to the total slurry weight. If desired, this ratio could be multiplied by 100 to obtain a percentage figure.

FIG. 4 discloses a variation of my system in which an additional dividing means 46 is connected to multiplying means 30 and summing means 37. Dividing means 46 provides a signal W_0/W_t which is equivalent to the ratio of the ore weight to the total slurry weight. Again, this figure could be multiplied by 100 to obtain a percentage figure.

FIG. 5 is a variation of my invention in which an additional dividing means 48 is connected to multiplying means 35 and summing means 37 to develop an output signal W_g/W_0 which is equivalent to the ratio of the gangue weight to the ore weight. This signal can be multiplied by 100 to obtain a percentage figure.

FIG. 6 is a variation of my invention in which additional dividing means 48 is connected to multiplying means 30 and multiplying means 35 to develop a signal W_g/W_t which is equivalent to the ratio of the gangue weight to the total slurry weight. This ratio can be multiplied by 100 to obtain a percentage figure.

From the above examples, it is apparent that many significant relationships can be obtained from the available signals. My invention is therefore not limited to merely a system for deriving the percentage of magnetic iron.

FIG. 7 discloses a system for insuring stability in the system in case of abnormal operating conditions such as the starting up or shutting down of the concentrating process. The divisor (W_0) in the dividing means 39 would normally go to zero when the system was shut down because the pipes and tanks would have only water in them.

The improved system of FIG. 7 includes a comparator device 50 that is connected to the output from summing means 37. Comparator 50 compares the signal W_0 from summing means 37 with a predetermined constant signal E_2. If W_0 drops below E_2, indicating that the amount of ore in the lines is approaching zero, comparator 50 energizes a relay 51 having a plurality of switches 52, 53 and 54 operated thereby. Switch 52 is a normally closed switch connected in series with the output of summing means 37. Switch 53, a normally open switch, is connected in series between the source of a constant signal E_1 and the input of dividing means 39. Switch 54, a normally open switch, is connected to an alarm circuit.

When the ore in the lines drops below a certain minimum point, signal W_0 drops below the value of signal E_2. Comparator 50 then energizes relay 51. Switch 52 opens to disconnect summing means 37 from dividing means 39. At the same time, signal E_1 is substituted for signal W_0 when switch 53 closes. Switch 54 also closes to initiate an alarm to alert an operator or system supervisor. Signal E_1 has a large value as compared to signal W_o so that the output of dividing means 39 indicates zero percent of magnetite in the system.

It is apparent from the above description that I have invented a new and unique magnetic iron ore assayer. Since the invention has been described in connection with a preferred system, certain variations in the system will undoubtedly occur to those skilled in the art. For that reason, I intend to limit my invention only as required by the scope of the appended claims.

What is claimed is:

1. Apparatus for providing a continuous output signal indicative of the percentage of magnetite relative to the amount of ore in a slurry of ore and water, said ore being a mixture of gangue and magnetite, comprising:

(a) first sensing means for monitoring the differential pressure across said slurry to develop an electrical signal (P_s) that is related to the total weight (W_t) of a given volume of said slurry by the equation $W_t=C_1P_s$, and to the specific gravity (SG_t) of said slurry by the equation $SG_t=C_2P_s$, where C_1 and C_2 are constants that are determinable with respect to a given system and that can be represented by electrical signals;

(b) second sensing means for inductively monitoring the slurry to develop an electrical signal (F_s) that is related to the total magnetite weight (W_f) by the equation $W_f=C_4F_s$, and is related to the total volume of magnetite (V_f) by the equation $V_f=C_3F_s$, where C_3 and C_4 are constants that are determined with respect to a given system and that can be represented by electrical signals; and where the specific gravity of the magnetite (SG_f) is equal to C_4/C_3;

(c) first multiplying means connected to said first sensing means for developing an electrical signal C_1P_s;

(d) second multiplying means connected to said second sensing means for developing an electrical signal equivalent to $-C_xF_s$ where $C_x=C_4-C_3$;

(e) first dividing means for developing an electrical signal $-C_1/C_2$, where C_1/C_2 is equal to the total volume (V_t) of the slurry;

(f) first summing means connected to said first and second multiplying means and to said first dividing means for developing an electrical signal (S_1) equivalent to $C_1P_s-C_1/C_2-C_xF_s$;

(g) third multiplying means connected to said first summing means for multiplying S_1 by a constant K_o, where K_o is an electrical signal corresponding to K/K_{-1} where K is the specific gravity of the gangue, the signal S_1K_o being equivalent to the weight of the gangue (W_g);

(h) fourth multiplying means connected to said second sensing means for developing an electrical signal C_4F_s;

(i) second summing means connected to said third multiplying means and to said fourth multiplying means for developing an electrical signal equivalent to the weight of the ore (W_o), where $W_o=S_1K_o+C_4F_s$;

(j) fifth multiplying means connected to said fourth multiplying means for developing an electrical signal $100C_4F_s$; and

(k) second dividing means connected to said second summing means and to said fifth multiplying means for developing an electrical signal $100C_4F_s/W_o$ which corresponds to the percentage of magnetite in said ore.

2. Apparatus according to claim 1 in which a sixth multiplying means is connected to said second dividing means for multiplying the signal corresponding to the percentage of magnetite by .7236 to obtain an electrical signal corresponding to the percentage of magnetic iron in said ore.

3. Apparatus for providing a continuous output signal indicative of the weight of gangue in a slurry of ore and water, said ore being a mixture of gangue and magnetite, comprising:

(a) first sensing means for monitoring said slurry to develop a signal (P_s) that is related to the total weight (W_t) of a given volume of said slurry by the equation $W_t=C_1P_s$, and to the specific gravity (SG_t) of said slurry by the equation $SG_t=C_2P_s$, where C_1 and C_2 are constants that are determinable with respect to a given system and that can be represented by appropriate signals;

(b) second sensing means for monitoring the slurry to develop a signal (F_s) that is related to the total magnetite weight (W_f) by the equation $W_f=C_4F_s$, and is related to the total volume of magnetite (V_f) by the equation $V_f=C_3F_s$, where C_3 and C_4 are constants that are determined with respect to a given system and that can be represented by appropriate signals, and where the specific gravity of the magnetite (SG_f) is equal to C_4/C_3;

(c) first multiplying means connected to said first sensing means for developing a signal C_1P_s;

(d) second multiplying means connected to said second sensing means for developing a signal equivalent to $-C_xF_s$ where $C_x=C_4-C_3$;

(e) first dividing means for developing a signal $-C_1/C_2$; where C_1/C_2 is equal to the total volume (V_t) of the slurry;

(f) first summing means connected to said first and second multiplying means and to said first dividing means for developing a signal (S_1) equivalent to

$$C_1P_s-C_1/C_2-C_xF_s$$

and

(g) third multiplying means connected to said first summing means for multiplying S_1 by a constant K_o, where K_o is a signal corresponding to

$$\frac{K}{K-1}$$

where K is the specific gravity of the gangue, the signal S_1K_o being indicative of the weight of the gangue (W_g).

4. Apparatus according to claim 3 in which an additional dividing means is connected to said first multiplying means and to said third multiplying means to develop a signal W_g/W_t which is indicative of the weight of gangue with respect to the total weight of said slurry.

5. Apparatus according to claim 3 in which a fourth multiplying means is connected to said second sensing means for developing a signal C_4F_s, and in which a second summing means is connected to said third and fourth multiplying means to develop a signal (W_o) indicative of the weight of said ore, where $W_o=S_1K_o+C_4F_s$.

6. Apparatus according to claim 5 in which an additional dividing means is connected to said first multiplying means and to said second summing means to develop a signal W_o/W_t which is indicative of the weight of ore with respect to the total weight of said slurry.

7. Appar tus accordin gto claim 5 in which an additional dividi g means is connected to said third multiplying means and to said second summing means to develop a signal W_g/W_o which is indicative of the weight of gangue with respect to the weight of ore in said slurry.

8. Apparatus according to claim 5 in which a fifth multiplying means is connected to said fourth multiplying means for developing a signal $100C_4F_s$, and in which a second dividing means is connected to said second summing means and to said fifth multiplying means for developing a signal $100C_4F_s/W_o$ which is indicative of the percentage of magnetite in said ore.

9. Apparatus according to claim 8 in which a sixth multiplying means is connected to said second dividing means to multiply the signal from said second dividing means by a constant equivalent to the percentage of magnetic iron in magnetite to develop a signal indicative of the percentage of magnetic iron in said ore.

10. Apparatus according to claim 8 in which: first source means is provided to develop a constant signal E_1 that corresponds to a high value of W_o; second source means is provided to develop a constant signal E_2 that corresponds to a predetermined minimum value of W_o; a comparator device is connected to the output from said second summing means and to the source of signal E_2 to compare W_o with E_2; a relay having a plurality of switches operated thereby is connected to the output of said comparator device; said comparator device providing an output signal to energize said relay upon the value of W_o decreasing below that of E_2; a first normally closed switch of said relay is connected in series with the output from said second summing means to disconnect said second summing means from said second dividing means upon the energization of said relay; and in which a second normally open switch of said relay is connected in series between said source of E_1 and said second dividing means to substitute signal E_1 for signal W_o upon the energization of said relay.

11. Apparatus for providing a signal indicative of the amount of magnetite relative to the amount of ore in a slurry of ore and water, said ore being a mixture of gangue and magnetite, comprising:

(a) first sensing means for monitoring a slurry of ore and water to develop a first signal that is proportional to the weight and to the specific gravity of a given volume of said slurry, said ore being a mixture of gangue and magnetite;

(b) second sensing means for monitoring said slurry to develop a second signal that is proportional to the weight and to the volume of magnetite in said slurry;

(c) first computing means including means for introducing a constant signal proportional to the specific gravity of the gangue connected to said first and second sensing means for developing a signal indicative of the weight of gangue in said slurry;

(d) second computing means connected to said first computing means and to said second sensing means for developing a signal indicative of the weight of said ore in said slurry; and

(e) third computing means connected to said second computing means and to said second sensing means for developing a signal indicative of the weight of magnetite with respect to the weight of ore.

References Cited

UNITED STATES PATENTS

2,687,037	8/1954	Saxe	73—433
2,760,769	8/1956	Onstand.	
3,139,578	6/1964	Henderson et al.	324—41 X

FOREIGN PATENTS

1,358,655	3/1964	France.	

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73—32, 194; 235—151.35; 324—34; 325—335