United States Patent [19]

Fasching et al.

[11] **3,868,509**

[45] **Feb. 25, 1975**

[54] **METHOD OF STABILIZING SINGLE CHANNEL ANALYZERS**

[75] Inventors: **George E. Fasching; George H. Patton,** both of Morgantown, W. Va.

[73] Assignee: **The United States of America as represented by the Secretary of the Interior**

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[21] Appl. No.: **422,052**

[52] **U.S. Cl.** **250/336,** 250/358, 250/369

[51] **Int. Cl.** **G01t 1/20**

[58] **Field of Search** 328/105, 115, 116, 117; 250/253, 262, 263, 358, 336, 369

[56] **References Cited**

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Primary Examiner—Harold A. Dixon

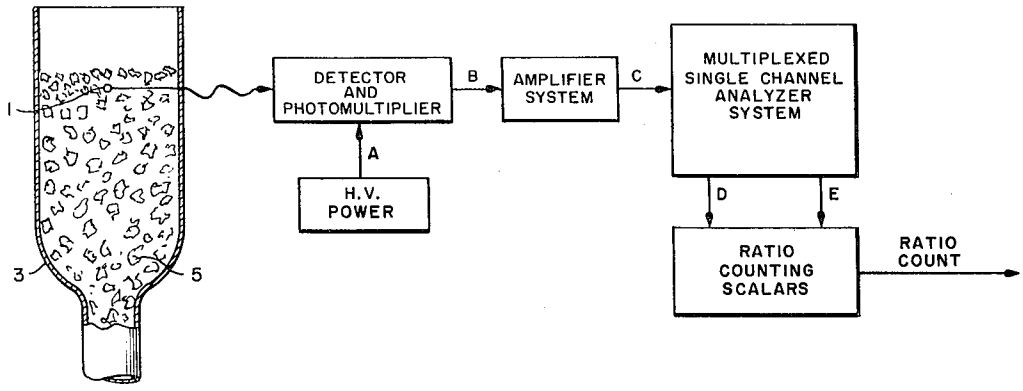
Attorney, Agent, or Firm—Thomas Zack

[57] **ABSTRACT**

A method and the apparatus to practice the method in which the drift of single channel analyzers is reduced. Essentially, this invention employs a time-sharing or multiplexing technique to insure that the outputs from two single channel analyzers (SCAS) maintain the same count ratio regardless of variations in the threshold voltage source or voltage changes. the multiplexing technique is accomplished when a flip flop, actuated by a clock, changes state to switch the output from the individual SCAS before these outputs are sent to a ratio counting scalar.

In the particular system embodiment disclosed that illustrates this invention, the sulfur content of coal is determined by subjectiong the coal to radiation from a neturon producing source. A photomultiplier and detector system equates the transmitted gamma radiation to an analog voltage signal and sends the same signal, after amplification, to a SCA system that contains our invention. Therein, at least two single channel analyzers scan the analog signal over different parts of a spectral region. The two outputs may then be sent to a digital multiplexer so that the outputs may then be sent to a digital multiplexer so that the output from the multplexer contains counts falling within two distinct segments of the region. By dividing the counts from the multiplexer by each other, the precentage of sulfur within the coal sample under observation may be determined.

8 Claims, 4 Drawing Figures



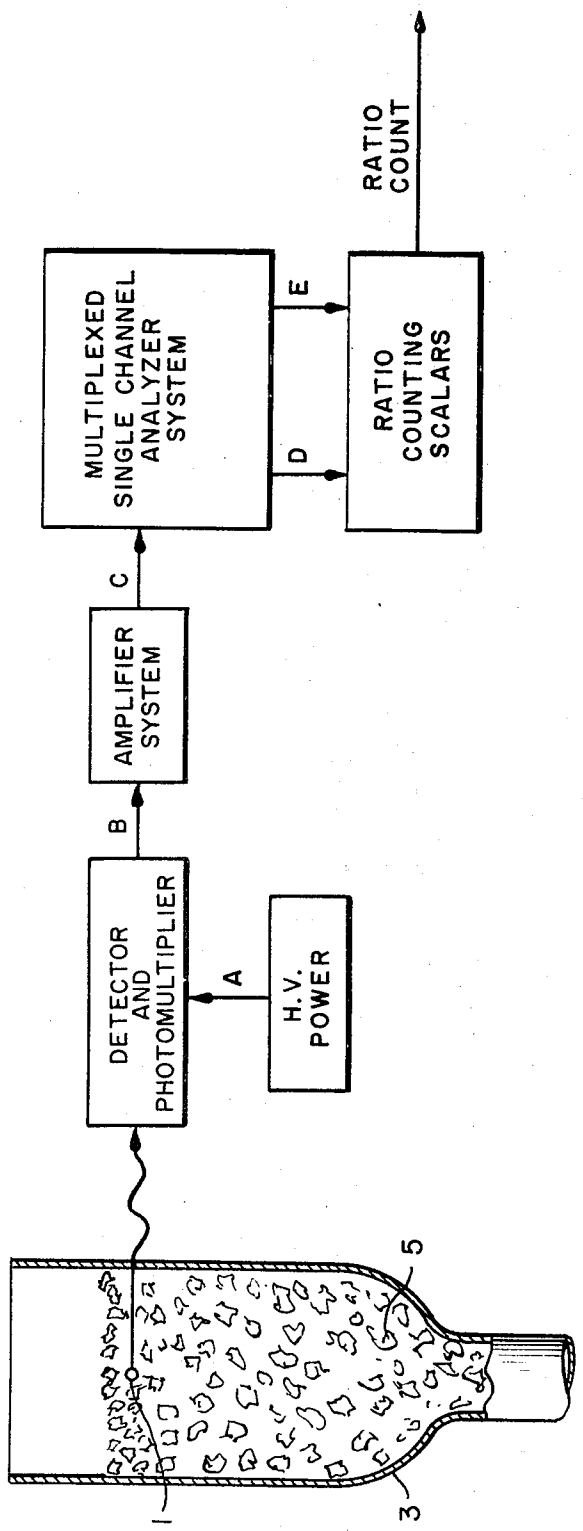

RATIO COUNT
MULTIPLEXED SINGLE CHANNEL ANALYZER SYSTEM
RATIO COUNTING SCALARS
E
D
C
AMPLIFIER SYSTEM
B
DETECTOR AND PHOTOMULTIPLIER
A
H.V. POWER
5
1
3

FIG. 1.

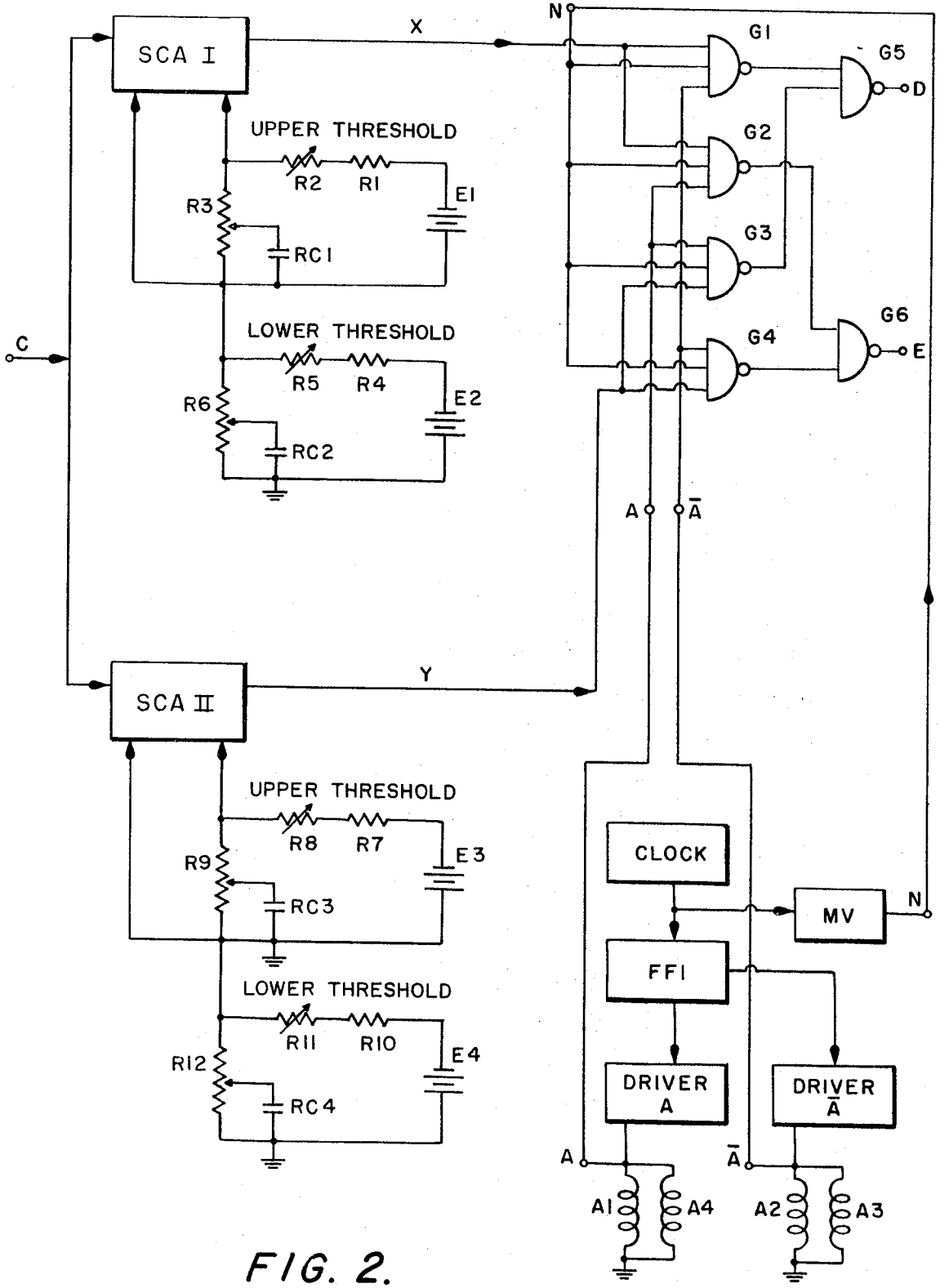

SCA I
X
N
G1
G5
D
G2
UPPER THRESHOLD
R2
R1
E1
R3
RC1
G3
G6
C
LOWER THRESHOLD
G4
E
R5
R4
R6
E2
RC2
A
Ā
SCA II
Y
UPPER THRESHOLD
R8
R7
E3
R9
RC3
CLOCK
MV
N
FF1
LOWER THRESHOLD
R11
R10
R12
E4
RC4
DRIVER A
DRIVER Ā
A
Ā
A1
A4
A2
A3

FIG. 2.

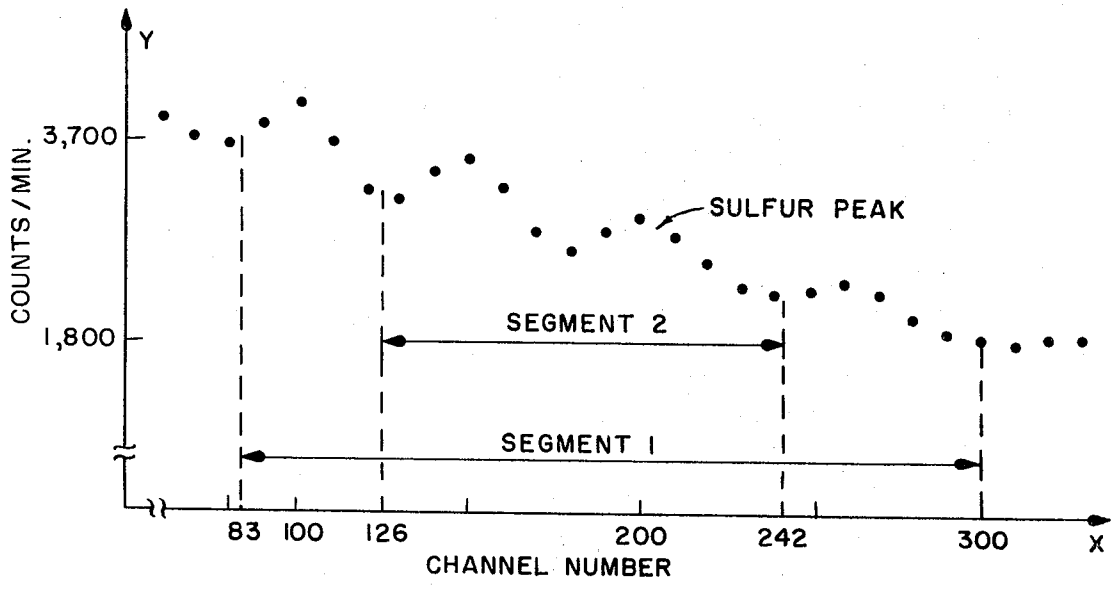

Y
3,700
1,800
COUNTS / MIN.
SULFUR PEAK
SEGMENT 2
SEGMENT 1
83
100
126
200
242
300
X
CHANNEL NUMBER

FIG. 3.

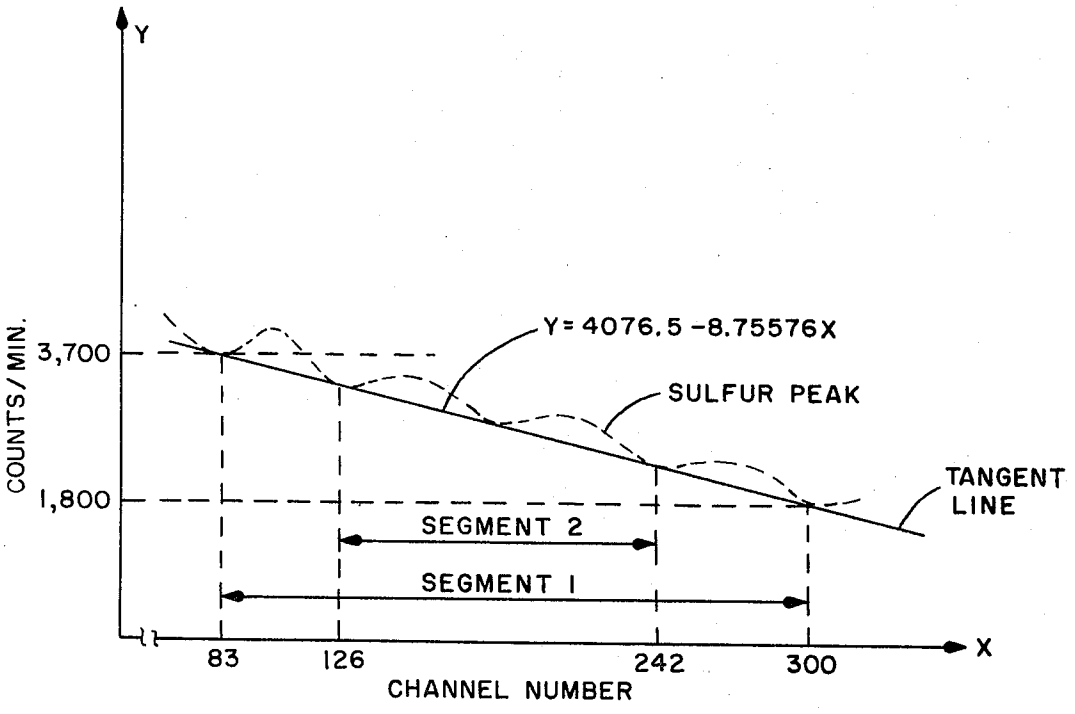

Y
3,700
1,800
COUNTS / MIN.
Y= 4076.5 -8.75576X
SULFUR PEAK
TANGENT LINE
SEGMENT 2
SEGMENT 1
83
126
242
300
X
CHANNEL NUMBER

FIG. 4.

METHOD OF STABILIZING SINGLE CHANNEL ANALYZERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The method and apparatus to practice the method described herein relates to a stabilization technique for two single channel analyzers. More specifically, this invention stabilizes the relative threshold levels of single channel analyzers by a time sharing technique such that their count ratio remains constant.

2. Description of the Prior Art

Stabilization of the output signals from single channel analyzers is a problem caused by variations in the circuit components and voltage drifts in the reference source networks and comparators. One solution has been to use multichannel analyzers in place of the single channel analyzers in a ratio counting system. However, because of the cost, slowness, and complexity of these units, the results have been limited. Phase differences between two signals have been analyzed in such patents as the Miller reference having U.S. Pat. No. 3,631,340. In none of the known prior art references is the voltage amplitude discrimination of random pulses that is being sent to two single channel analyzers stabilized by using a time-sharing technique.

SUMMARY

In our invention, the same analog voltage is fed to two single channel analyzers operating between two different upper and lower operating ranges. The discriminator thresholds and output counts from the analyzers are switched by a digital multiplexer such that the output pulse counts from one range always appear at the same output terminal. Next, a comparison is made of the counts from the outputs of the two ranges to determine a desired result.

The primary object of our invention is an improved method and apparatus to stabilize the outputs from two single channel analyzers.

A secondary object of our invention is an improved detecting system to detect specific components of a material under observation.

FIG. 1 is a block diagram of the system set up.

FIG. 2 is a circuit diagram of the multiplexer system.

FIG. 3 is a graph of detected sulfur and other peaks based on the counts per minute detected.

FIG. 4 is a graph similar to the FIG. 3 graph showing a graphical representation of a formula and its relation to the sulfur peaks.

The system set up of FIG. 1 shows an actual working embodiment incorporating the principles of our invention. A neutron producing substance 1 sends its rays into the material under observation 5 that is held in a hopper 3. The radioactive source element selected was Californium (Cf) 252 and the material under observation was coal. As these neutrons strike the coal atoms, gamma rays from the coal atoms' nuclei are produced and transmitted as a natural occurring phenomena to the ambient air. What this experiment sought to determine was the sulfur content of the coal. After the rays pass through the coal and hopper, a photo-multiplier detector powered from a high voltage (HV) source, via signal A, detects the transmitted gamma wave portion and changes it into an electrical representation. Next, this detected wave form is sent as signal B to an amplifier system where it is amplified electronically and emitted as signal C.

Signal C is an analog random voltage pulse whose amplitude can be correlated to the energy of the detected gamma rays. It is sent to a multiplexed single channel analyzer (SCA) system shown as a single block in FIG. 1. The essence of our invention resides in the performance and structure of this multiplexing system and how it processes the analog signal C.

When coal is subjected to neutron radiation, the peak height of signal C is proportional to the energy of a detected gamma ray. When this signal enters the multiplexer system of FIGS. 1 and 2, it is sent to the two SCAs I and II. These SCAs deliver a fixed pulse at their outputs if signal C falls within a spectral region or energy window individually for each SCA. The SCA pulses X and Y are fixed in height and width at their respective outputs but each SCA pulse is not necessarily in phase with the other. Each SCA consists basically of a pair of discriminators which send a signal to a comparator and certain pulse forming circuitry. The two output signals from these discriminators comparator, and associated circuitry are sent to common logic circuitry to obtain the desired fixed pulse that falls within a window or voltage range. These SCAs may be substantially identical in construction although such is not necessary as long as the desired function of sending fixed pulses X and Y is accomplished. The actual SCAs used by us were custom designed and built by United States Bureau of Mines personnel. These SCAs would be very similar to the SCA having Model No. 33-14A built by Radiation Instrument Development Laboratory a division of Nuclear Chicago Corporation.

Two reference voltage generator circuits are operatively connected to each SCA to determine the voltage ranges or windows they will operate in. For example, the window for SCA I is set by adjustable resistors R_2, R_3, R_5, and R_6. For SCA II, adjustable resistors R_8, R_9, R_{11}, and R_{12} would perform the same function. Thus, the window for each SCA is defined upper and lower threshold limits. Normally these two windows are different from each other and overlap each other as do the designated segments 1 and 2 is FIG. 3. In addition to the mentioned adjustable resistors, each generator circuit has two fixed or supply voltage sources (E1 and E2; E3 and E4), two fixed resistors R1 and R4; R7 and R10), and two relay coil contacts (RC1 and RC2; RC3 and RC4).

Continuing with the explanation of FIG. 2, the six NAND gates G1, G2, G3, G4, G5 and G6 form part of a digital multiplexer system which receive input gate drive signals A and $\overline{A}$ as well as, an inhibit signal N, and signals X and Y from SCA I and SCA II. The outputs from gates G5 and G6 have been designated as signals D and E, respectively. Each of these outputs consist only of counts falling within a specific window. The four NAND gates G1, G2, G3, and G4 each have three input terminals and one output terminal. These three input terminals may receive signals from either one of the two SCAs, from a multivibrator MV, or from driver gates A and $\overline{A}$. Their single output terminals are connected to either of the NAND gates G5 or G6.

The remaining multiplexer system circuit elements of FIG. 2 consist of a pulse clock connected to a flip flop FF1 and a multivibrator MV, two driver circuits A and $\overline{A}$ connected to FF1, and two sets of relay coils A1–A4 and A2–A3, with one set being connected to and oper-

able by each driver circuit. The clock operates at a low frequency (about 1 pulse per second) to send its output to FF1 and the multivibrator MV. On each cycle as the clock pulse is sent to the multivibrator, a 4 millisecond noise gating signal N is outputted to the four NAND gates G1, G2, G3 and G4 to inhibit switching transients of FF1 and to allow circuit voltages to settle. When the clock pulse triggers FF1, alternating complementary control square waves are sent to drivers A and $\overline{A}$. These drivers, which are high output logic gates, in turn drive the relay coil pairs A1–A4 and A2–A3. Two relay coils are used for each driver to provide isolation for switching at two different locations in the circuit for each set of SCA discriminators. Relay contacts RC1 and RC2 of the reference voltage generators are actuated by relay coils A1 and A2 for SCA I. The contacts RC3 and RC4 are actuated by relay coils A3 and A4 for SCA II.

When a periodic pulse is set by the clock to FF1 and multivibrator MV a chain of events is sent in motion. The pulse N exists for only 4 millisecond which by experience has been shown as long enough to inhibit "relay bounce," which is always less than 4 milliseconds in duration in our set up. During this time interval, from 0 to 4 milliseconds, all of the gates G1 to G4 (and hence gates G5 and G6) are inoperative even through pulses are inputted on their other two input terminals. The flip flop circuit alternately drives A and $\overline{A}$. As it does this its connected relay coils actuate at least one contact in each reference voltage generator e.g., when driver A is actuated contacts RC2 and RC3 are completed. This results in pulses X and Y being set to gates G1, G2, G3 and G4 from SCA I and SCA II within their present window voltages. The part of these SCA pulses and the pulses A and $\overline{A}$ from driver A and $\overline{A}$ that occur after inhibit signal N has passed are what give output multiplexed pulses D and E from gates G5 and G6.

FIG. 3 is a graph of the coal under observation wherein the Y axis represents the counts per minute observed at the output and the X axis represents the channel number. This channel number corresponds to energy received in a pulse height analyzer having a sodium iodine (NaI) crystal and photomultier tube which detects the gamma rays and converts them to electrical pulses. Certain pulse amplitudes indicative of the energy of the sulfur that are referred to as "sulfur peaks" are observed on the graph. Theoretically and empirically it can be shown that if the count collected over a period of time from segment 1 are divided by two and then divided by the counts in segment 2, a relation is found that can be correlated to the percentage of total sulfur in the sample. While it is not of critical importance to this invention on how the result was formulated, the formula relating the output counts to each other was developed by United States Bureau of Mines personnel based both on theoretical considerations and empirical work.

FIG. 4 is a graph very similar to the graph of FIG. 3 except that it is an approximation that has been slightly distorted to make the minimums for the four sulfur peaks such that they fall on a straight tangent line. The purpose of this graph is to allow a simplified comparison of the stability achieved by our invention with the state-of-the-art method. Since the purpose of our invention is to achieve relative stability at the outputs of the SCAs, the comparison can be made first when the threshold supply voltage shifts and then when the window width of one of the SCAs (segments 1 and 2 of FIGS. 3 and 4) change due to a change in the window supply voltage. Before, however, these two cases are looked at in detail, it should be noted that our improvement gained by switching the SCAs not only applies to compensate for changes in the threshold supply voltages and upper window voltage, but also to voltage changes due to variations in the resistances of any or all the resistors R_1 to R_{12}.

The slope of the tangent line plotted in FIG. 4 is directly related to the stability of the SCAs. As the slope increases, the stability decreases for both of the cases under observation. As the slope approaches zero, the stability would approach infinity. In the example shown, the slope would be about −8.7556 counts/min.-channel. The equation for this line is approximately as shown, i.e., $y=4076.5-8.75576x$. By recognizing that the spectrum window widths is small compared to the width of the valleys shown in FIG. 4, the tangent line can, as an approximation, be used to represent the actual spectrum.

The number of counts in any given segment on the FIG. 4 graph can be determined by integrating the area under the tangent line between the segment limits and multiplying the answer by the count interval. Thus, for segments 1 and 2 of FIG. 4 in a 2 minute count interval, the results would be: (1) Counts in segment

$$1=2\int_{83}^{300}(4076.5-8.756x)dx$$

which equals 1,041,481 counts; (2) Counts in segment

$$2=2\int_{126}^{242}(4076.5-8.756x)\,dx$$

which equals 571,972 counts. If the sulfur content in coal is determined by the formula $\bar{x}=$ (½ counts in seq. 1)/(counts in segment 2) then the ideal case would yield a $\bar{x}$ value of 0.910430.

If the lower threshold voltage of SCA I was to shift to cause a decrease of ½ channel while its window width remained constant, then the counts in segment 1 would be 1,043,381. Assuming SCA II and the segment 2 values remain constant (i.e., 571,972 counts), then this ½ channel shift in one SCA results in an $\bar{x}$ of 0.912091 or an error of 1661 μ units from the ideal value of 0.910430. Now if our invention is used to switch SCA I and SCA II such that each of their outputs alternately occupies segment 1 and 2, a comparison of the errors can be made. With our invention, the count interval would be one minute from each of the SCAs for each segment, thus:

$$\text{Counts in segment } 1=\int_{82.5}^{299.5}(4076.5-8.756x)dxt+\int_{83}^{300}(4076.5-8.756x) = 1{,}042{,}431 \text{ and}$$

$$\text{counts in segment } 2=\int_{126}^{242}(4076.5-8.756x)dxt+\int_{125.24}^{241.24}(4076.5-8.75x)dx = 572{,}744. \text{ Hence,}$$

Hence, $\bar{x}$ is [½ (1,042,431)]/572,744 or 0.910032. This is an error of 398 μ units (0.910430 – 0.910032). Comparing this to the error of 1,661 units when there is no switching, the result is an error reduction of a factor of 4.17 (1661/398) when the error is due to relative threshold drift.

The type of error causing a change in the window width of one of the SCAs will be considered next. If the window width of SCA I decreases by ½ channel while the lower threshold remains constant and the SCA of segment 2 also remains constant then:

$$\text{Counts in Segment 1} = \int_{83}^{299.5} (4076.5-8.756x)dx = 1{,}040{,}029 \text{ counts}$$

and $\bar{x}$ = [½ (1,040,029)]/571,972 = 0.909161 comparing this to the ideal value of 0.910430 the error is −1269 μ units. This would correspond to a change in the voltage source E_1 (see FIG. 2) of the upper threshold voltage of SCA I without any switching. Should our invention be employed with SCA I, alternating for 1 minute each between segment 1 and segment 2 and SCA II alternating vice-versa, then:

$$\text{Counts in segment 1} = \int_{83}^{299.5} (4076.3-8.756x)dx + \int_{83}^{300} (4076.5-8.756x)dx = 1{,}040{,}755 \text{ counts}$$

over a 2 minute count interval.

For segment 2, the window width will be decreased one-half the time by the same percentage as above to give equal window widths of 116 channels and 115,733.

$$\text{Counts in segment 2} = \int_{126}^{242} (4076.5-8.756x)dx + \int_{126}^{241.7332} (4076.5-8.756x)dx = 571{,}449 \text{ counts.}$$

This means $\bar{x}$ = [½ (1,040,755)]/571,449 = 0.910628. Comparing this to the ideal value of 0.910430, we see that there is an error of +198 μ units. Our invention would, thus, reduce the error due to the window width changes, a factor of 6.4 (1,269/198) under the conditions stated.

It is readily understood from the above examples that the errors which result from changes in the reference voltages (E_1 through E_4), the reference network resistors (R_1 through R_{10}) and the offset voltages of the comparators in SCA I and SCA II are transferred nearly equally into each output channel by the time sharing of these circuits and voltages. The overall effect of time sharing then is to produce a change in the count of segment 2 that is proportional to any change (error) in the count induced in segment 1 due to variations in voltages and circuit parameters, and visa-versa. Thus, in the formula for sulfur, the errors in each count tend to cancel. That is, since the error count occurring in segment 1 is proportional to the count in segment 2 and the error in the count of segment 2 is equally proportional to that count in segment 2 then in the quotient (½ setment 1 count divided by segment 2 count) cancellation of the errors occur.

It should be apparent that our invention is not limited to the specific system discussed in FIGS. 1 to 4, but may be used in any system requiring a comparison of the counts in two areas of a count spectrum that requires SCAs with a high degree of relative stability. It could be used to replace a multiple channel pulse height analyzer and a small computer in a simpler and less costly way. Other variations are also apparent as a person skilled in the art should realize. None of these variations should be used to limit the scope and extent of our invention which is to be measured only by the scope of the claims that follow.

We claim:

1. A method for stabilizing the analog output signals from two single channel analyzers that are to be fed to a comparator comprising the steps of:

detecting an analog signal representative of some physical phenomenon;

amplifying said representative signal and transmitting the result to a multiplexer system;

splitting said amplified signal in the multiplexer system into two analog signals and sending each signal to one of two separate single channel analyzers that output fixed pulses and normally operate between different specific output ranges;

switching and gating the outputs from said single channel analyzers so that each analyzer alternately operates at one of two outputs with the same specific range output signals always appearing at the same gate output; and

comparing the outputs from the gating circuitry after switching and gating takes place to obtain the desired results.

2. The method of claim 1 wherein said detection step detects radiate energy from a radioactive source that is transmitted through a material under investigation.

3. The method of claim 1 wherein said switching step is accomplished by actuating a flip flop and gating means by a clock pulse.

4. A stable output multiplexed single channel analyzer system comprising:

means for receiving an analog signal representative of a physical phenomenon;

two single channel analyzers operable within different specific ranges to receive said analog signal and to output fixed pulse signals when operative;

a multiplexer system to time share by switching and gating the output signals from said analyzers such that the output signals from the analyzers are continuously switched and the same range always appears at the same gate output; and

a comparator to compare the multiplexed signals outputted from the multiplexer system.

5. The system of claim 4 wherein said multiplexer system comprises:

a clock to generate a pulse;

a flip flop connected to said clock; and

a plurality of gating elements operatively associated

with said single channel analyzer and said flip flop to alternately switch the output pulses from the single channel analyzers.

6. A system for accurately determining the sulfur content of coal comprising:

a radioactive ray source to transmit neutrons through coal;

a gamma ray detector to detect the created gamma rays transmitted and convert these detected rays into electrical representations;

circuitry to amplify the electrical representations;

two substantially identical single channel analyzers normally operable within different specific ranges to receive said electrical representations;

a multiplexer system connected to the outputs of said two substantially identical single channel analyzers to analyze the electrical representations from said analyzers between certain specific ranges, said system including switching and gating means to continuously switch the analyzed signals from the analyzers and to gate these switched signals so that the signals from the same specific ranges always appear at the same gate output; and

comparator and scalar circuitry to compare the switched and gated outputs with each other and to output a scaled answer of their ratio.

7. The system of claim **6** wherein said multiplexer system switching means has a plurality of gating members actuated by drivers.

8. The system of claim **7** wherein said drivers are switched by a clock pulse actuated flip flop.

* * * * *