United States Patent [19]

Klein

[11] **3,863,056**

[45] **Jan. 28, 1975**

[54] **METHOD AND APPARATUS FOR MULTICHANNEL VOTING**

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[73] Assignee: **Coulter Electronics, Inc.,** Hialeah, Fla.

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[52] **U.S. Cl.**..... **235/151.3,** 235/92, 328/146, 328/147

[51] **Int. Cl.**..... **G06f 7/38,** G06g 7/12, G01n 15/00

[58] **Field of Search**..... 235/151.3, 92 PC, 184, 235/195; 324/71 CP; 328/146, 147, 150, 173; 340/172; 307/235

[56] **References Cited**

UNITED STATES PATENTS

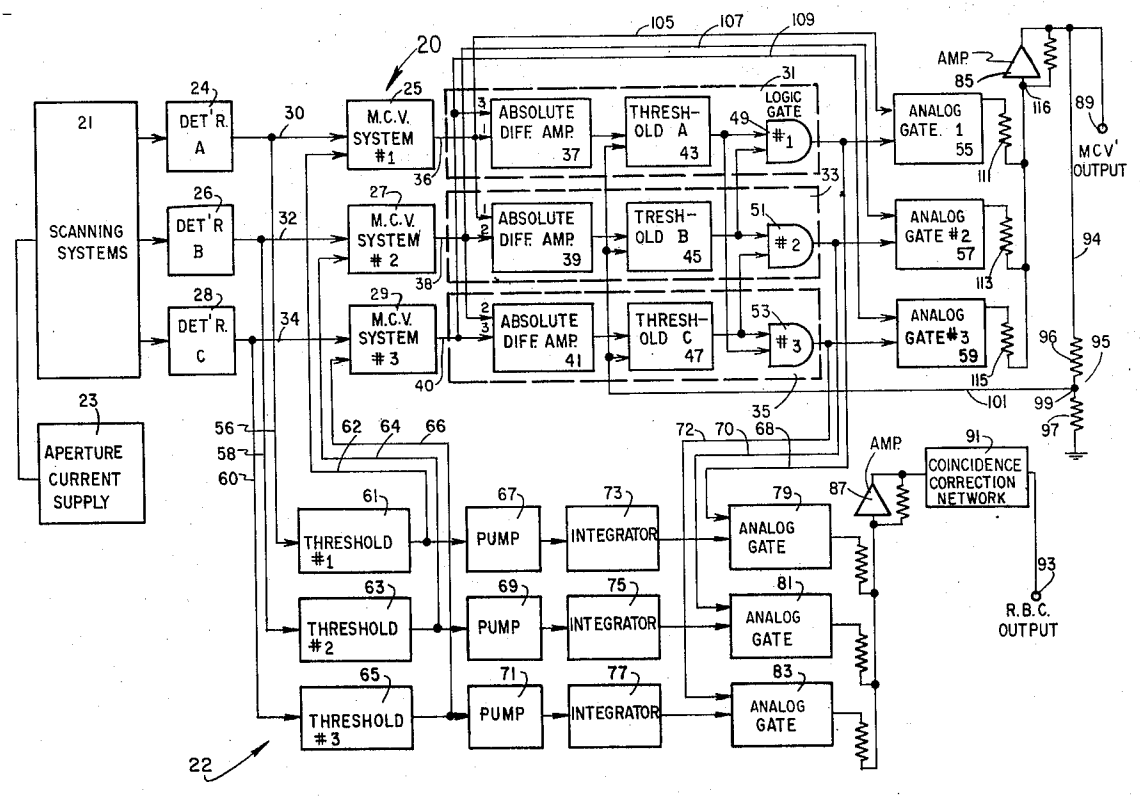
3,420,993	1/1969	Chamberlain et al.	328/147 X
3,444,463	5/1969	Coulter et al.	324/71
3,530,381	9/1970	Hogg et al.	324/71
3,557,352	1/1971	Hogg et al.	324/71 CP X
3,603,875	9/1971	Coulter et al.	235/92 PC X
3,668,531	6/1972	Hogg	328/150
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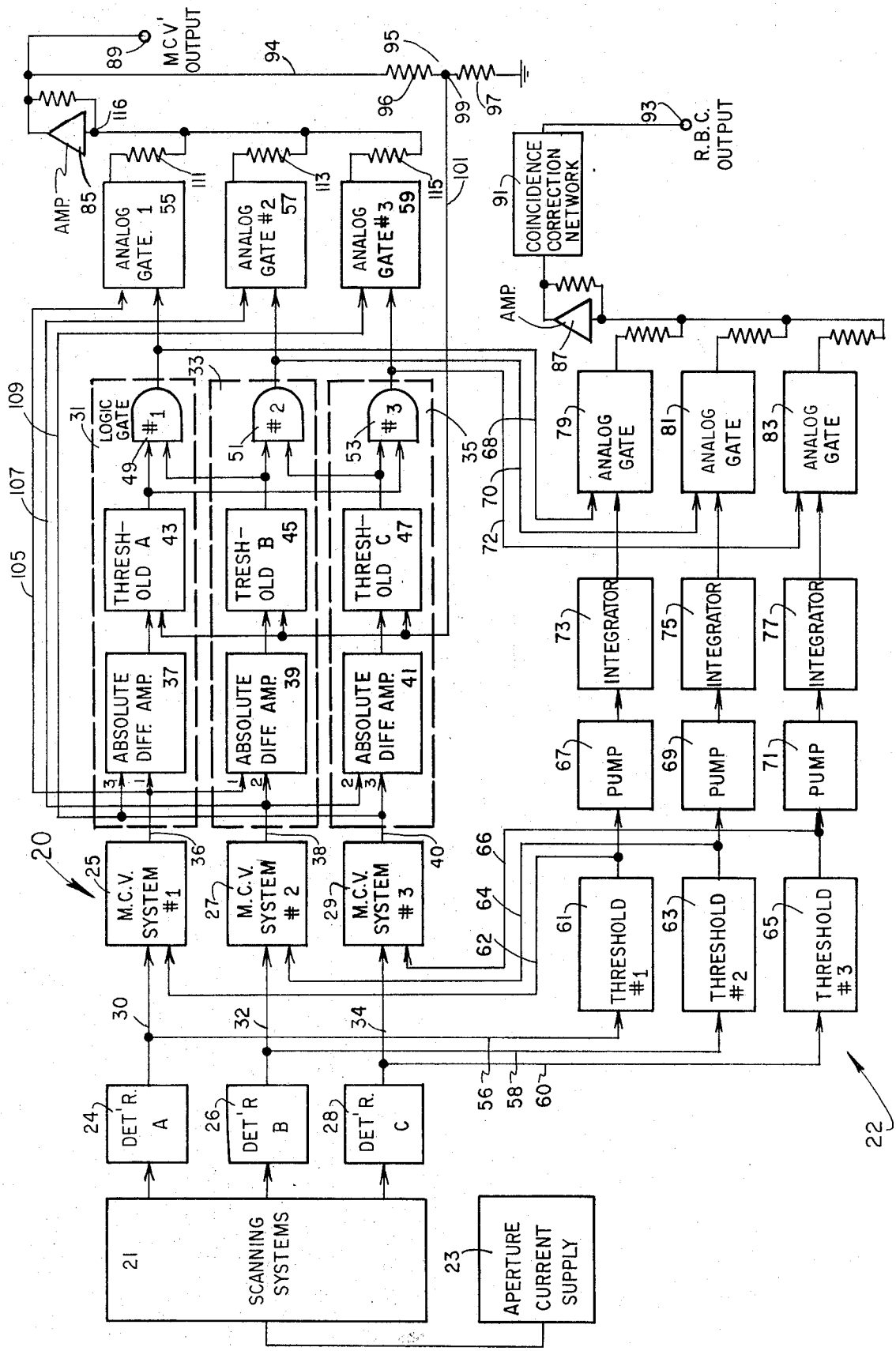
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[57] **ABSTRACT**

Apparatus and method for voting out a malfunctioning channel in a system of channels carrying electric pulses. The pulses may be produced by particles passing through a sensing zone. The pulses are conducted through comparison and exclusion stages. A device for producing mean size values of the pulses is placed ahead of the comparison stage so that comparison and exclusion are performed on the basis of the mean size values of the pulses. In another embodiment, channels for counting the pulses are provided with count threshold circuits of the counting channels being positioned ahead of the devices for producing the mean size values of the pulses.

18 Claims, 1 Drawing Figure




M.C.V. OUTPUT
89
94
95
96
99
97
116
AMP.
85
111
113
115
101
ANALOG GATE. 1 55
ANALOG GATE #2 57
ANALOG GATE #3 59
COINCIDENCE CORRECTION NETWORK
91
93
R.B.C. OUTPUT
AMP.
87
109
107
105
31
LOGIC GATE
#1
#2
#3
33
49
51
53
35
68
70
72
THRESH-OLD A 43
TRESH-OLD B 45
THRESH-OLD C 47
ABSOLUTE DIFF. AMP. 37
ABSOLUTE DIFF. AMP. 39
ABSOLUTE DIFF. AMP. 41
ANALOG GATE 79
ANALOG GATE 81
ANALOG GATE 83
INTEGRATOR 73
INTEGRATOR 75
INTEGRATOR 77
PUMP 67
PUMP 69
PUMP 71
20
25
M.C.V. SYSTEM #1
27
M.C.V. SYSTEM # 2
29
M.C.V. SYSTEM # 3
36
38
40
66
64
62
61
THRESHOLD #1
63
THRESHOLD #2
65
THRESHOLD #3
30
32
34
56
58
60
22
24
DET'R A
26
DET'R B
28
DET'R C
21
SCANNING SYSTEMS
23
APERTURE CURRENT SUPPLY

METHOD AND APPARATUS FOR MULTICHANNEL VOTING

CROSS REFERENCES TO RELATED APPLICATIONS OR PATENTS

The method and apparatus of the invention utilize the teachings of several patents to which reference may be had for detailed information concerning the particular structure referred to.

In the preferred form of the apparatus, use is made of a multiple aperture arrangement in which there is a plurality of aperture tubes of the Coulter type immersed in a single vessel, which also is called a bath in the prior art. The structure which comprises the multiple aperture arrangement includes fittings which are disclosed and claimed in U.S. Pat. No. 3,444,464 entitled "Multiple Aperture Fittings For Particle Analyzing Apparatus." The scanning means and circuitry for the multiple aperture arrangement, including voting circuits to discard data which are apparently invalid, are disclosed and claimed in U.S. Pat. No. 3,444,463 entitled "Particle Analyzing Apparatus and Method Utilizing Multiple Apertures." In U.S. Pat. No. 3,549,994 there is a detailed discussion of significant parameters of blood analysis.

A study of the properties of blood calls for a study of the cells themselves as well as a study of the whole blood, and for this purpose over a period of time there have been a group of measurements or parameters which have been recognized by workers in the field, as providing information considered characteristic of a given sample for its maximum description. The most important parameters are six in number, all relating to the red blood cells and their contents, size, and so on. These parameters are important in the diagnosis, study, and treatment of anemia. A seventh parameter which is used primarily in diagnosing infection and in general health studies is related to the white blood cells.

The first six parameters are classically referred to as the red blood cell count (RBC), the hematocrit (HCT), the hemoglobin (HGB), the mean corpuscular volume (MCV), the mean corpuscular hemoglobin (MCH) and the mean corpuscular hemoglobin concentration (MCHC). The seventh parameter is the white blood cell count (WBC).

As noted earlier, one of the significant parameters is the mean corpuscular volume or MCV. One apparatus for determining the MCV utilizes structure which is disclosed in a patent entitled "Apparatus and Method for Determining Mean Particle Volume," U.S. Pat. No. 3,473,010.

U.S. Pat. No. 3,530,381 entitled "Voting Circuit Control Apparatus for Multiple Aperture Particle Analyzing Device" discloses improvements upon the voting structure of apparatus disclosed in the previously mentioned U.S. Pat. No. 3,444,463.

U.S. Pat. No. 3,678,382 discloses a system for using a part of the output voltage for controlling a threshold.

All of the above patents are owned by the assignee of the instant application.

To the extent that it might be necessary to understand fully the teachings of the invention the above noted patents are incorporated by reference, i.e. U.S. Pat.

No. 3,444,463
No. 3,444,464
No. 3,473,010

No. 3,530,381
No. 3,549,994, and
No. 3,678,382.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to voting circuitry, and in particular for systems of channels carrying electric pulses in which a malfunctioning channel is detected and its data excluded on the basis of the mean size values of the pulses, a parameter which has not been used for such purpose in the prior art.

2. Description of the Prior Art

The devices disclosed in the patents mentioned in the preceding paragraphs have been used quite successfully in analysis of particles in liquid suspension. In particular, good results have been obtained by utilizing voting arrangements for discarding data which apparently were invalid.

However, in operating the devices of the prior art, problems have arisen which were caused in certain instances by the failure of voting circuits to exclude data of a channel which did not operate properly. Observations of such failures have pointed to a particular course of trouble, i.e. a build-up of scum within the opening of the aperture in the scanner element. In carrying out a great number of tests, it was found that the voting systems did not take account of such scum build-up, although it is quite an obvious fact that the scum formation causes a change in dimension of the aperture, namely a diminution of its cross section. In considering the effect of such scum formation it is readily noted that the result is a partial blockage of the aperture. However, despite such partial blockage, it has often been observed that the voting section of the apparatus did not react thereto, or, expressed otherwise, the voting part did not show any sensitivity to such changed conditions of the aperture.

Through further investigation of the problem of such lack of sensitivity, it now has been established that the problem has its roots in a basic feature of the voting systems of the prior art.

The basic feature referred to is to be seen in the fact that the prior art voting is based on the principle of counting the pulses without having regard to their amplitudes. It is well known that the amplitude of a pulse produced by a particle passing through the aperture is a function of the ratio between the particle size and the cross-section of the aperture, i.e., for the same particle size, the larger the cross-section the smaller the pulse amplitude will be, and vice versa.

The conclusion is that when scum builds up at the aperture, and the cross-section of the aperture is diminished thereby, the pulses will have greater amplitudes.

Since, as previously indicated, the voting systems of the prior art operate on the principle of merely counting the pulses, changes of pulse amplitudes due to scum formation are not sensed by the prior voting systems. Those voting systems therefore are insensitive to scum formation at the aperture.

SUMMARY OF THE INVENTION

The present invention represents a departure from principles of the prior art in that it provides for a voting system that is sensitive to changes of pulse amplitudes, such as occasioned by a scum build-up of the aperture.

Such voting system has a plurality of channels carrying electric pulses comprising structure for permutatively comparing data of two channels and excluding apparently invalid data, wherein a device for producing an indication representing the mean size of pulse amplitudes is used as a basis for said comparison and exclusion.

The voting system of the present invention attains the desirable sensitivity by using a method of sensing pulse amplitude values which is described in the above mentioned U.S. Pat. No. 3,473,010. This patent discloses method and apparatus for determining the mean corpuscular volume (MCV) of a blood cell, and is based on the principle of measuring the averaged amplitudes of pulses produced by blood particles passing through a sensing zone.

Since the MCV method takes account of pulse amplitudes rather than pulse counts, it follows that a voting system using the MCV method will be sensitive to a change of aperture cross-section caused by build-up of scum within the aperture.

Assuming now that a thin film has formed at the aperture opening, such as expressed in a change of radius of 1 percent, this will result in a large change in aperture cross-section since the cross-section is in the nature of an area, and therefore, mathematically, has a quadratic magnitude as compared with the linear magnitude of the radius. Such change of area certainly will cause an appreciable change in pulse amplitude, thereby increasing sensitivity of the voting system.

A further advantage may be seen in the use of the MCV method by the fact that several significant parameters in particle analysis are derived and computed from MCV values, as described in the above noted patents. With the use of such MCV values, the derivative values are improved as well.

BRIEF DESCRIPTION OF THE DRAWING

In order that the invention may be clearly understood and readily carried into effect, apparatus and method in accordance therewith will now be described by way of example with reference to the drawing comprising one FIGURE.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The circuitry illustrated schematically in the drawing is similar to systems disclosed in U.S. Pat. Nos. 3,444,463, FIG. 2, and 3,549,994, FIG. 12.

It will be appreciated that the voting circuitry of the invention comprises an upper branch **20** of three channels and a lower branch **22** also having three channels. To the left of the upper branch **20** a box **21** indicates scanning systems for the three channels which include apparatus with fluid suspension, aperture tubes, devices for moving the fluid suspension, amplifiers, etc. as used in the well known Coulter apparatus of various designs. Electric current is supplied to the apertures from an aperture current supply **23.** Detectors **24, 26** and **28** are provided respectively at the outputs of the scanning systems.

In the two previously mentioned U.S. Pat. Nos. 3,444,463 and 3,549,994, the outputs of the three detectors are conducted in series to threshold circuits, to integrators and to voting circuits. The present invention provides for three MCV systems **25, 27** and **29** coupled to the outputs of the detectors. The outputs of the MCV systems are connected to three voting circuits **31, 33** and **35** which comprise absolute differential amplifiers **37, 39** and **41,** threshold circuits **43, 45** and **47,** and logic gates **49, 51** and **53.** The outputs of the voting circuits **31, 33** and **35,** are series-connected to analog signal gates or electronic switches **55, 57** and **59.**

Each MCV system can be of the same structure of the MCV system disclosed in U.S. Pat. No. 3,473,010 and therefore is not described here.

In addition to lines **36, 38** and **40** extending from the MCV systems **25, 27** and **29** and through the voting circuits **31, 33** and **35** to the analog gates **55, 57, 59** as set forth above, there are three lines **105, 107** and **109** going directly from the MCV systems **25, 27** and **29** to the analog gates **55, 57, 59.**

Analogously, the components of the voting circuits can be structured in accordance with the voting circuits in FIG. 2 of U.S. Pat. No. 3,444,463 and therefore no details are required in this description. It is to be noted that while the last mentioned patent employs differential amplifiers, blocks **37, 39** and **41** are absolute differential amplifiers known in the art.

The lower branch **22** also includes three channels which are branched off from the upper channels at the output sides of the detectors **24, 26** and **29,** leading over lines **56, 58** and **60** to the channels of the lower branch **22.** The channels of the lower branch comprise threshold circuits **61, 63** and **65** electric pump circuits **67, 69** and **71,** integrators **73, 75** and **77** and analog gates or electronic switches **79, 81** and **83,** all series connected and in that order.

The output ends of the upper three channels are the outputs of the three analog gates **55, 57** and **59,** and are coupled over resistors **111, 113** and **115** to the input **116** of an amplifier **85.** The lower three channels lead over resistors **117, 119** and **121** to an amplifier **87.**

In operation, signals leaving the detectors **24, 26, 28,** travel in the three upper channels through the MCV systems **25, 27** and **29,** the voting circuits **31, 33** and **35** to the analog gates **55, 57** and **59.**

On the other hand, MCV signals leaving the MCV systems **25, 27** and **29** reach via lines **105, 107, 109** the analog gates **55, 57** and **59** and are processed there, i.e., allowed to pass or not depending on the results arrived at in voting circuits **31, 33** and **35.** The signals passing the analog gates **55, 57** and **59** are combined in the amplifier **85** which at its output terminal **89** gives an output designated as MCV'.

In a similar manner, signals for the RBC counts, upon leaving the detectors **24, 26** and **28,** transfer over leads **56, 58, 60** to the lower branch **22** and pass in its three channels through the thresholds **61, 63, 65,** the pump circuits **67, 69** and **71,** the integrators **73, 75** and **77,** the analog gates **79, 81** and **83** and are combined in the amplifier **87.** The output of the amplifier **87** is connected to a coincidence correction network **91** as known in the prior art which on its output side gives the RBC value at the output terminal **93** which may include a readout device such as a counter.

Aside from the above described two pathways of signals along the upper and lower branches **20, 22,** there is provided an additional pathway as set forth herein below. Signals leaving detectors **24, 26** and **28** for the lower branch **22,** on lines **56, 58, 60** enter the thresholds **61, 63** and **65** and return to the upper branch **20** on line **62, 64** and **66** to arrive at the input sides of the MCV systems **25, 27** and **29.** They, then continue to

travel on the upper branch **20** through all components of the upper branch channels as previously described, ending up in the MCV' output terminal **89.**

This arrangement offers the advantage that the MCV systems are triggered by the same thresholds that are used to make the count of the red cells. Thus besides eliminating a set of threshold circuits, it is also insured that the MCV measurements are made on the exact same pulses which are counted.

Another pathway is provided by lines **68, 70** and **72** which branch off from the upper branch **20** at the output side of the logic gates **49, 51** and **53** to lead to the inputs of analog gates **79, 81** and **83** in the lower branch **22.** This last pathway has the task of providing the control inputs to the analog gates **79, 81** and **83** and carry the voting data thereto.

A line **94** is connected to the output of the amplifier **85** and leads to a potentiometer **95** having segments **96** and **97.** A tap **99,** dividing the voltage of the potentiometer, is connected over a feedback line **101** to the input sides of the threshold circuits **43, 45** and **47.** This arrangement of controlling the threshold by a portion of the output voltage is similar to an arrangement in the above noted U.S. Pat No. 3,678,382 for a "Malfunction Detection Circuit and Method." Therefore no further details are given here.

In summarizing the invention, in contradistinction to the voting circuitry of the prior art in which a malfunctional channel was excluded on the basis of wrong pulse counts, the inventive concept is based on the exclusion of a channel showing deviations from mean pulse amplitudes rather than pulse counts.

This goal is attained by arranging at the input sides of the voting circuits **31, 33** and **35** MCV systems **25, 27** and **29** which determine average amplitude sizes, so that the voting circuits **31, 33** and **35** compare pulse amplitude values and exclude a channel having wrong amplitude values of pulses which travel on direct lines **105, 107** and **109** between the MCV systems **25, 27** and **29** and the analog gates **55, 57** and **59.**

The pulse amplitude voting system is capable of solving the problem created by scum formation within the aperture which causes no changes in the counting of pulses but leads to changes in pulse amplitudes.

The invention, therefore, provides sensitivity to the formation of scum within the aperture which sensitivity was absent in the prior art.

Additionally the novel amplitude voting system may be combined with the old counting system by providing counting component in the parallel branch of channels whereby the amplitude voting can be triggered by the same thresholds that are used for conducting the pulses to the counting component.

It is believed that the foregoing adequately will enable those skilled in the art to appreciate and practice this invention, and if necessary, make modifications which would fall within the scope of the invention as defined by the accompanying claims.

I claim:

1. A voting method for excluding data output from a malfunctioning electrical channel within a system having at least three parallel channels, each channel cumulatively carrying substantially the same electrical pulse data, comprising the steps of: producing cumulatively in each channel an indication representative of the mean size of the pulses carried in that channel, comparing the mean size indications of all of the channels, and excluding the pulse data output from any channel from which the mean size indication does not compare favorably with the remaining channels.

2. The method according to claim **1** in which said indication producing is accomplished by ascertaining electrically the amplitude of each data pulse and obtaining cumulatively the mean value thereof.

3. The method according to claim **2** in which said indication producing is accomplished by converting the pulse in each channel into monopolar sequels of generally histogrammic configuration.

4. The method according to claim **1** in which each electrical pulse represents the volume of a particle, and said step of indication producing is accomplished by electrically ascertaining cumulatively the mean volume of the particles in each channel.

5. The method according to claim **4** which further includes the step of generating the data pulses in a particle analyzer of the Coulter type, with each channel receiving its electrical pulse data from a separate particle analyzer of the Coulter type.

6. The method according to claim **1** which further comprises the steps of averaging the outputs from the channels, and employing a small portion of such average for defining an acceptable limit for differences in the mean size indication between channels for said step of comparing.

7. The method according to claim **1** in which said comparing includes permutatively comparing the mean size indication of two channels, for all of the channels.

8. The method according to claim **1** which includes the step of producing separately another indication representative of the data pulses from each channel, and employing said excluding for excluding as an output said another pulse data indication from at least one of the channels.

9. A voting structure for use in pulse analysis apparatus, said voting structure comprising: a plurality of electrically parallel channels, means at the input of each channel for receiving substantially the same pulse data that are directed to all other of said channels, means for producing an indication representing the mean sizes of those pulses in each channel, pulse comparison and exclusion circuitry responsive to the mean size indication of each channel for comparing such mean size indications from said channels against each other and for excluding any pulse-derived output from at least one of said channels subsequent to an unfavorable mean size indication comparison for that channel.

10. A voting structure according to claim **9** in which said mean size indication producing means comprises means for obtaining the mean amplitude of the pulses which have been directed into each respective channel.

11. A voting structure according to claim **9** which said mean size indication producing means comprises an MCV system in each of said channels.

12. A voting structure according to claim **11** in which each said MCV system has an input connected to receive pulses from a particle study apparatus of the type wherein a fluid sample containing particles is passed from one body of electrolyte through a particle scanning aperture to another body of electrolyte.

13. A voting structure according to claim **12** in which said particle study apparatus is of the Coulter type.

14. A voting structure according to claim **9** in which said comparison and exclusion circuitry comprises in each channel: an absolute differential amplifier permu-

tatively coupled to receive the mean size indications for its channel and another of said channels, a threshold circuit coupled to the output of each said amplifier, and logic gate means permutatively connected to the outputs of all of said threshold circuits.

15. A voting structure according to **14** which further comprises; output signal averaging means coupled for receiving the mean size indications of all of said channels, and voltage dividing means coupled between the output of said averaging means and an input to said threshold circuit of each said channel, for establishing a limit of acceptance for the comparison by said comparison and exclusion circuitry.

16. A voting structure according to claim **14** further comprising an analog signal gate coupled at the output end of each said channel, each said analog signal gate having one input coupled to the output of one of said logic gates and another input directly coupled to the output of said mean size indication producing means for that channel.

17. A voting structure according to claim **9** which further comprises an additional plurality of channels, each channel within said additional plurality of channels being connected in parallel to a specific one of the first mentioned plurality of parallel channels and having an input for receiving the pulses that are directed to such one channel, each channel of said additional plurality of channels comprising the series connection of: a threshold circuit, pulse accumulating means and an analog signal gate; each said analog signal gate having another input connected to the output of said pulse comparison and exclusion circuitry of its corresponding first mentioned channel; whereby, the pulse data which are applied to any excluded of said first mentioned channels will be excluded from defining an output from the corresponding associated additional channel.

18. A voting structure according to claim **17** wherein the output of each said threshold circuit also is coupled to an input of said indication producing means of its corresponding channel, for defining an amplitude limit to the pulses received by said first mentioned channels.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,863,056

DATED : January 28, 1975

INVENTOR(S) : Robert Ivan Klein

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 24, change "large" to --larger--. Column 4, line 7, after "structure" change "of" to --as--. Column 6, line 10, change "pulse" to --pulses--; line 54, before "which" insert --in--.

Signed and Sealed this

eighteenth Day of *November 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

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