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Haynes

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[54] **PARTICLE COUNTER HAVING A CLOG AND BUBBLE ALARM**

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[52] **U.S. Cl.** .... **340/243,** 235/92 PC, 324/71 CP

[51] **Int. Cl. G08b 19/00,** G06m 11/00, G01n 27/00

[58] **Field of Search** .... 340/243, 239; 235/92 PC; 324/71 CP; 317/DIG. 3

[56] **References Cited**

UNITED STATES PATENTS

2,656,508	10/1953	Coulter	317/DIG. 3
3,083,909	4/1963	Glaser et al.	235/92 PC
3,114,257	12/1963	Foster et al.	324/71 CP
3,165,692	1/1965	Isreeli et al.	324/71 CP
3,603,875	9/1971	Coulter et al.	235/92 PC

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[57] **ABSTRACT**

A fluid containing disbursed particles having a conductivity substantially different than the fluid is pumped through an aperture. A pair of electrodes are mounted so that one electrode is on each side of said aperture and an *rf* signal is imposed upon the electrodes to develop a voltage across the fluid passing through the aperture. The *rf* signal is modulated by the conductivity of the fluid instantaneously passing through the aperture so that when a high resistance particle passes through the aperture, the *rf* signal intensity increases in relationship to the *rf* signal intensity when fluid is passing through the aperture. The *rf* signal is then detected, filtered and amplified to provide pulses corresponding to the particles passing through the aperture. Means are provided for counting the pulses and for providing a readout indicating the number of particles contained in a unit volume of the fluid.

A clog alarm driver circuit is connected to receive the filtered rf signal and in response to a constant high level filtered signal provides an output to an alarm for indicating a clogged aperture. The amplified signal is directed to an amplifier clipper which further amplifies the signal and establishes a base line at 8 volts DC with pulses having an amplitude of approximately 4 to 6 volts. The presence of bubbles at the aperture causes an erratic signal which appears as base line noise and includes excursions below the 8 volt DC base line output. These excursions intermittently turn on a transistor which provides an output signal to a bubble alarm driver which in response thereto provides an output to the previously-mentioned alarm. A continuous alarm indicates a clogged aperture while an intermittent alarm indicates the formation of bubbles at the aperture.

7 Claims, 3 Drawing Figures

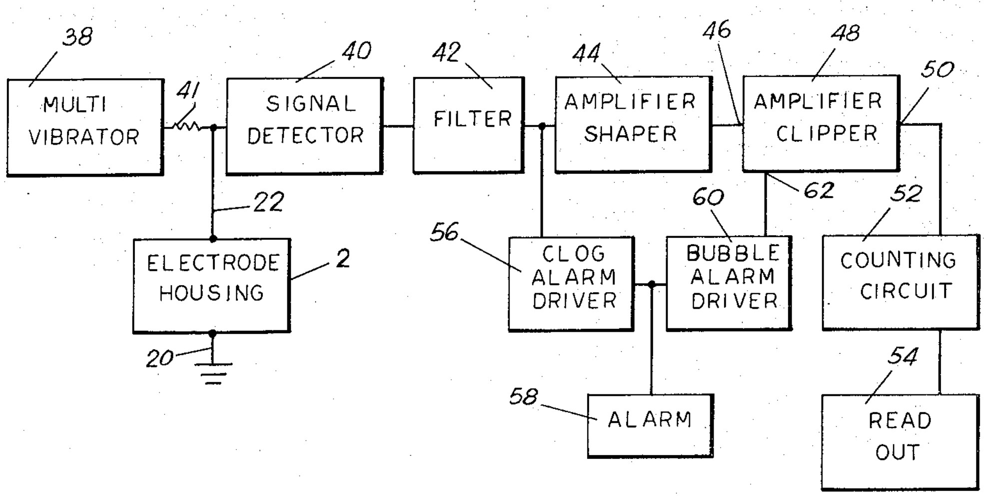


Fig. 1

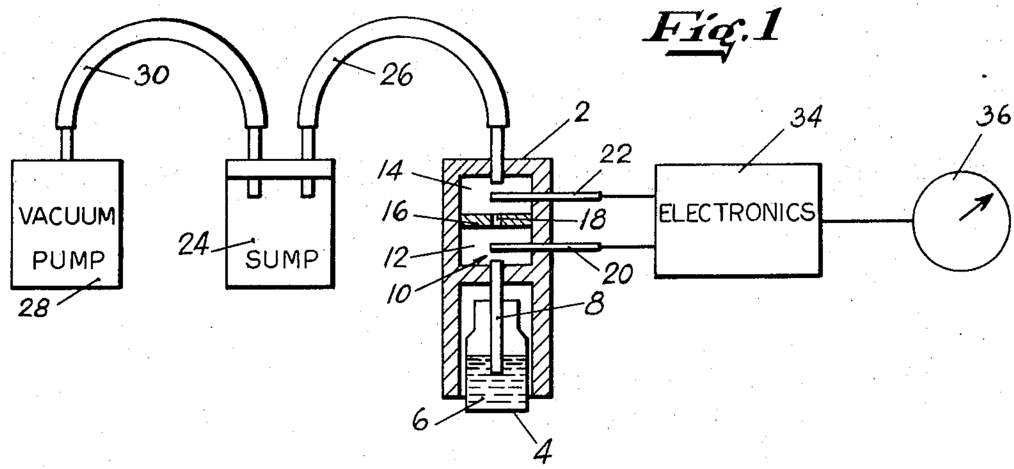


Fig. 2

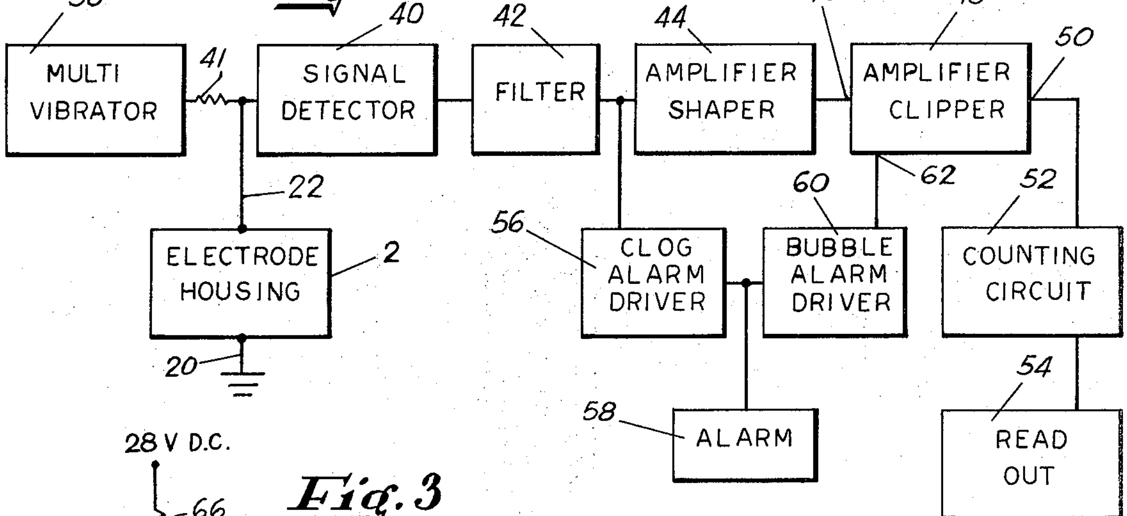
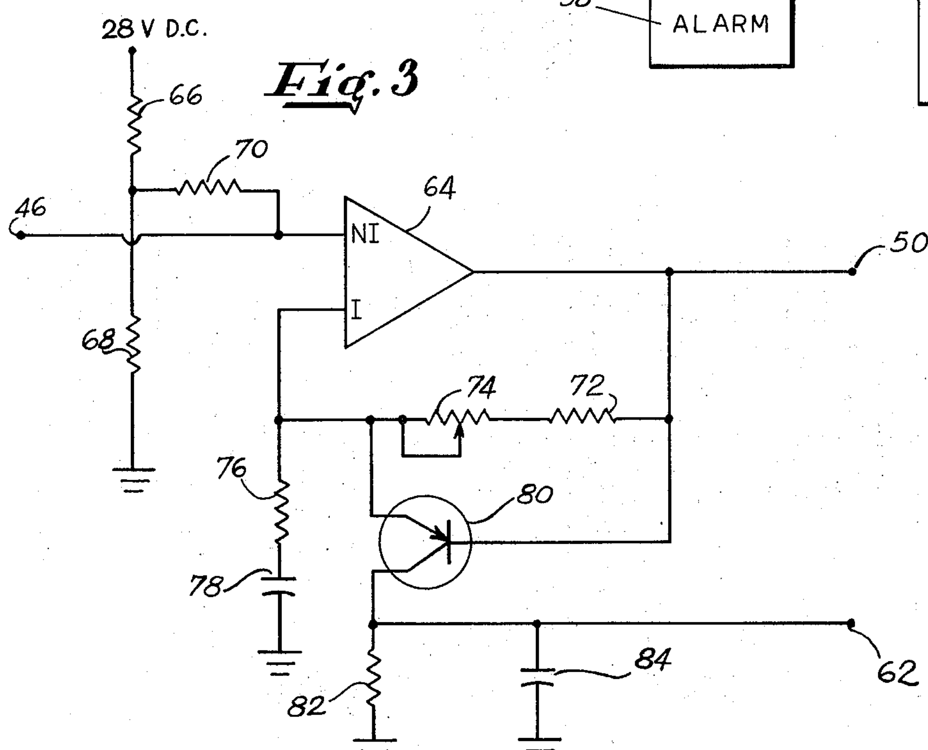


Fig. 3



PARTICLE COUNTER HAVING A CLOG AND BUBBLE ALARM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to particle counters for counting particles suspended in a fluid medium and more particularly to a counter having an alarm for indicating the existence of an aperture clog or the formation of bubbles adjacent the aperture.

2. Description of the Prior Art

The prior art in the field of particle counting may be described by considering the more limited field of blood cell counting. Pure electronic blood cell counters have been developed wherein changes in conductivity of a diluted blood sample were sensed to provide an output corresponding to the number of blood cells in the sample. The more sophisticated of these pure electronic blood cell counters passed a known volume of diluted blood through an aperture and a DC electric signal was applied to electrodes positioned at each side of the aperture to develop a voltage corresponding to the instantaneous conductivity of the blood sample passing through the aperture. Since blood cells have extremely low conductivity as compared to the diluent used to dilute the blood, each time a blood cell passed between the electrodes, the voltage between the electrodes would increase and provide a pulse output. The pulses were counted to provide an output corresponding to the number of blood cells in the sample.

The problems experienced with aperture-type systems included clogged apertures resulting from the accumulation of lint and dust in the aperture and the formation of bubbles which appeared as blood cells as they bounced around the aperture. In order to detect aperture clogging and bubble formation, the devices of the prior art included an oscilloscope to view a trace of the voltage developed across the aperture so that any abnormality could quickly be detected. The oscilloscope had to be continuously observed to determine if clogging was taking place.

Thus, the devices of the prior art required the use of an oscilloscope to determine if any abnormalities existed that would adversely effect the blood cell count provided by the instrument. The inclusion of an oscilloscope in the prior art made their cost prohibitive and restricted their use to major hospitals and large laboratories.

SUMMARY OF THE INVENTION

The present invention contemplates a particle counter that may also be used as a blood cell counter that provides practicing physicians, veterinarians and laboratories with a simple, reliable and accurate instrument for counting white and red blood cells. The instrument automates the tedious task of physically counting individual blood cells and provides circuitry for automatically warning the user of such a device when an abnormality is present that may adversely affect the blood cell count.

The operational concept of the counter is based upon the difference in electrical conductivity between particles to be counted and the fluid in which the particles are suspended. When used as a blood cell counter, the device depends upon the difference in conductivity between blood cells and the diluent used to prepare blood samples. The diluted blood sample is drawn through an aperture so that as individual blood cells pass through the aperture, the resistance across the aperture abruptly increases. An rf signal is applied to electrodes on each side of the aperture so that the signal is modulated by the variation of the resistance between the electrodes as blood cells pass through the aperture. The modulated rf signal is coupled to a signal detector where it is demodulated to provide pulses corresponding to the blood cells passing through the aperture. The rf frequency is greatly attenuated by passing the signal through a low-pass filter after which the pulses are amplified and shaped and then processed through an amplifier clipper which amplifies the pulses and clips the base line at a DC bias level. The pulses are then processed through a counting circuit which includes means for accumulating and counting pulses and for providing an output corresponding to the number of blood cells per unit volume which is displayed on a readout means.

Flow restrictions caused by particulate matter caught in the aperture cause the resistance across the aperture to approach exceedingly high levels so that the signal output from the low-pass filter approximates a DC signal of substantial amplitude sufficient to trigger a clog alarm driver which has an output to an alarm for providing a continuous indication which represents a clogged aperture.

When bubbles form about the aperture, they tend to vibrate back and forth, causing the resistance across the aperture to fluctuate up and down by extremely small amounts. This fluctuation results in an erratic signal output which appears as base line noise and includes excursions below the 8 volt DC bias level of the amplifier output. These excursions are used to trigger a transistor that provides an output for driving a bubble alarm driver. The bubble alarm driver provides an output to the previously-mentioned alarm which provides intermittent indications corresponding to the negative excursions previously mentioned. Thus, a single alarm is used to indicate a clogged aperture when a constant indication is provided and is also used to indicate the presence of bubbles when intermittent indications are provided.

The main objective of the present invention is to provide a blood cell counter having an alarm system for providing indications of aperture clogging and the presence of bubbles.

Another objective of the present invention is to provide a blood cell counter that uses a single indicator to indicate either a clogged aperture or the presence of bubbles adjacent the aperture.

Another objective of the present invention is to provide a blood cell counter wherein a single indicator provides a constant indication when the aperture is clogged and an intermittent indication when bubbles are present adjacent the aperture.

The foregoing objectives and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein one embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for illustrative purposes only and are not to be considered as defining the limits of the invention.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating the system of the present invention.

FIG. **2** is a schematic block diagram showing the electrical system of the present invention.

FIG. **3** is an electrical schematic showing the amplifier clipper circuit shown in FIG. **2.**

DESCRIPTION OF THE INVENTION

The present invention pertains to devices for counting particles suspended in a fluid medium, wherein the medium and the particles have substantially different conductivities. The invention will be described as a blood cell counter, but it is to be understood that it could be used for counting other types of particles such as dust or pollution.

Referring to FIG. **1**, there is shown a diagrammatic representation of the system of the present invention. An electrode housing **2** receives a reservoir bottle **4** containing a diluted blood sample **6.** A dip tube **8** extends downwardly from the electrode housing into the blood sample **6** contained in bottle **4.** A cavity **10** is formed in the upper portion of the electrode housing and is divided into first and second chambers **12** and **14** by a partition **16** having an aperture **18** formed therein for connecting the first and second chambers. Dip tube **8** extends into the first chamber **12** of cavity **10** for communicating bottle **4** with chamber **12.** Aperture **18** has a diameter of **90** microns, a diameter that was chosen because of its relationship to the size of a normal red blood cell. Electrodes **20** and **22** are mounted in the electrode housing **2** and extend into the first and second chambers respectively. The electrode housing and the partition **16** are formed of nonconductive material so that the electrodes remain electrically isolated from each other and do not short out through the electrode housing.

A sump bottle **24** has a hollow interior which is in communication with the second chamber **14** through a flexible tube **26.** A vacuum pump **28** is pneumatically connected with the interior of sump bottle **24** through a flexible tube **30** for evacuating sump bottle **24** so that the pressure within the bottle is maintained below atmospheric pressure and the diluted blood sample **6** from the reservoir bottle **4** is drawn through dip tube **8** and into the first and second chambers **12** and **14** so as to establish a flow of blood sample through aperture **18.**

Electronic circuitry **34** impresses an rf signal across the electrodes to develop a voltage across the electrodes dependent upon the instantaneous conductivity of the diluted blood sample passing through the aperture.

Blood cells have substantially lower conductivity than the diluent used for diluting the sample and therefore, abrupt voltage increases or pulses are generated each time a blood cell passes through the aperture. The electronic circuitry **34** senses the pulses and processes them to provide an output corresponding to the number of blood cells per cubic millimeter of blood sample passing through the aperture. This output is displayed on a readout device **36,** such as a meter.

Referring to FIG. **2,** there is shown a schematic diagram of the overall electronic circuitry of the instrument of the invention. A multivibrator **38** provides a squarewave output at a frequency of 330 KHz with a 20 volt peak output. The output of multivibrator **38** is connected to a signal detector **40** through a resistor **41.** The input of the signal detector is connected to electrode **22** of the electrode housing **2** while electrode **20** is connected to ground.

A voltage divider is formed by resistor **41** and the resistance across electrodes **20** and **22** so that the 330 KHz signal supplied by multivibrator **38** is modulated as the resistance across the electrodes increases when a blood cell passes through the aperture. Signal detector **40** functions as a demodulator and amplifier to provide a rectified signal to a low-pass filter **42** which eliminates the rf component of the signal. The low-pass filter is a 6 pole Butterworth Filter which passes frequencies below 33 KHz; therefore, the output of the low-pass filter is a series of pulses corresponding to blood cells passing through the aperture. The filter output pulses are provided to an amplifier shaper **44** for pulse amplification. The output of amplifier shaper **44** is connected to the input **46** of an amplifier clipper **48** which has an output **50** for providing pulses having an amplitude of approximately 4 to 6 volts at a bias of 8 volts DC.

The output so of amplifier clipper **48** is connected to a counting circuit **52** which includes a counting means for accumulating and counting the pulses received from the amplifier clipper and for providing an output signal corresponding to the number of pulses counted. The output of counting circuit **52** is connected to a readout device **54,** such as a meter for providing an indication corresponding to the number of blood cells per unit volume of blood sample.

A clog alarm driver **56** is connected to the output of the low-pass filter **42** and comprises a transistor biased to turn on at a predetermined voltage level. The clog alarm driver has an output connected to an alarm **58,** such as an indicator light which in response to the output provides an indication. When the aperture becomes clogged, the resistance across the aperture increases substantially so that the rf carrier signal increases in amplitude resulting in a high level DC signal from the low-pass filter that exceeds the predetermined voltage level at which the clog alarm driver turns on. Since a clog is a constant condition, the DC level remains constant and the alarm provides a constant indication.

Amplifier clipper circuit **48** has a second output **62** which is connected to a bubble alarm driver **60** which in response to an output signal from the amplifier clipper provides an output to alarm **58** causing the alarm to provide an indication. The bubble alarm driver is a standard driver circuit that provides an output in response to an input signal.

Referring to FIG. **3,** there is shown a schematic diagram of the amplifier clipper circuit **48** shown in FIG. **2.** Terminal **46** is connected to the non-inverting input of an operational amplifier **64.** Series connected resistors **66** and **68** are connected between a **28** volt DC source and ground to form a voltage divider for establishing a DC bias level at the junction between the two resistors. A resistor **70** connects the junction between the resistors **66** and **68** to the non-inverting input of amplifier **64.** The output of amplifier **64** is connected to terminal **50** of the amplifier clipper circuit and in addition thereto, it is connected to the inverting input of amplifier **64** by a feedback loop consisting of a resistor **72** and a potentiometer **74** for providing a variable resistance in the feedback loop. A series connected resistor 76 and capacitor 78 are connected between the inverting input of amplifier 64 and ground. A transistor 80 has an emitter connected to the inverting input of amplifier 64, a base connected to the output of amplifier 64 and a collector connected to output 62 of the amplifier clipper circuit. A resistor 82 and a capacitor 84 are connected in parallel between the collector of transistor 80 and ground.

In operation resistors 66 and 68 are adjusted to that an 8 volt DC bias is established at the output of amplifier 64 and potentiometer 74 is adjusted so that the pulses are 4 to 6 volts in amplitude above the 8 volt DC base line. In normal operation, transistor 80 remains in a cut off condition since the base is subjected to a higher voltage than is the emitter. When bubbles are formed adjacent the aperture, they tend to vibrate about the aperture prior to passing through the aperture. The vibrating bubbles cause the aperture resistance to fluctuate by an extremely small amount such as 0.1 per cent. This fluctuation appears as base line noise on output 50 of amplifier clipper 48. The noise includes excursions below the 8 volt DC base line. The negative excursions cause transistor 80 to turn on thereby clipping the negative going signals. The current through transistor 80 when it turns on is sensed by resistor 82 and capacitor 84 and causes capacitor 84 to become charged. If a oscillating bubble is present, a continuous train of negative going signals is produced so that capacitor 84 receives a continuous train of charges and develops a voltage which appears on terminal 62 of the amplifier clipper circuit and is used to drive the bubble alarm driver 60 when a specified threshold voltage is exceeded.

Thus, when bubbles are formed adjacent the aperture, intermittent output signals are provided to the bubble alarm driver so that the alarm 58 provides an intermittent flashing indication indicative of the presence of bubbles as distinguished from the constant indication which is indicative of a clogged aperture. The present invention provides an inexpensive circuit for providing alarms that indicate the presence of bubbles adjacent the aperture or the existence of a clogged aperture and thereby eliminates the necessity for the use of an oscilloscope as required by the prior art devices. The circuit makes it possible to use a single alarm indicator for providing indications of both aperture clogging and bubble formation.

What is claimed is:

1. An instrument for counting particles suspended in a fluid medium, wherein the fluid medium and the particles have different conductivities, comprising:

an aperture;

means for passing the fluid through the aperture;

means for applying an electrical signal across the aperture;

detecting means for detecting changes in the electrical signal level across the aperture and for providing an output having pulses corresponding to the changes in the electrical signal which result from a change in impedance across the aperture as particles pass through the aperture;

means for counting the pulses from the detecting means that exceed a predetermined level and for providing an indication corresponding to the number of particles per unit volume of the fluid;

clog detecting means responsive to the output from the detecting means for sensing when the detecting means provides a constant output exceeding a predetermined level resulting from a clogged aperture and for providing a steady state signal output in response thereto;

bubble detecting means responsive to the output from the detecting means for detecting erratic and rapidly changing pulses which result from the formation of bubbles adjacent the aperture and for providing an intermittent signal output in response thereto; and

indicator means, responsive to the signal outputs from the clog and bubble detecting means, for providing a con-stant indication when a clogged aperture exists and for providing an intermittent indication when bubbles are formed adjacent the aperture.

2. An instrument as described in claim 1, wherein the clog detecting means comprises a driver circuit biased to provide a signal output when the output of the detecting means exceeds a predetermined level.

3. An instrument as described in claim 1, wherein the bubble detecting means comprises:

an amplifier clipper circuit for providing an output signal corresponding to the output of the detecting means but biased at a DC level; and

means for detecting when the amplifier clipper circuit output signal drops below the DC bias level as a result of errotic and rapidly changing pulses and for providing the intermittent signal output in response thereto.

4. An instrument as described in claim 3, wherein the amplifier clipper circuit comprises:

an operational amplifier having a first input for receiving the output from the detecting means;

a biasing circuit connected to the first input for establishing a DC bias level; and

a feedback loop connecting the amplifier output to a second input, so that the amplifier provides an output signal biased at a DC level.

5. An instrument as described in claim 4, wherein the means for detecting when the output signal drops below the DC bias level includes a transistor having the base to emitter junction connected between the output and the second input of the operational amplifier so that the transistor is turned on when the output signal drops below the DC bias level.

6. In a particle counting apparatus of the type, wherein a fluid medium containing particles having a conductivity different from the fluid is passed through an aperture and electrodes positioned at each side of the aperture are energized to develop a signal corresponding to the impedance across the aperture so that the particles cause signal changes as they pass through the aperture and the changes are detected and counted to provide a readout corresponding to the number of particles per unit volume of the fluid medium, the improvement comprising:

clog detecting means for detecting a steady state electrical signal across the electrodes that exceeds a predetermined level and for providing a constant output in response thereto;

bubble detecting means for detecting erratic signal changes across the electrodes and for providing an intermittent output in response thereto; and

indicator means connected to the last two mentioned means and responsive to the outputs therefrom for providing a constant indication in response to the output of the first mentioned means and an intermittent indication in response to the output of the second mentioned means so that the constant indication is provided when an aperture clog exists and an intermittent indication is provided when bubbles are formed adjacent the aperture.

7. An instrument for counting the number of particles per unit volume suspended in a fluid medium, said fluid medium having a conductivity different than the particles, comprising:

an aperture;

means for passing the fluid through the aperture;

means for applying an electronic signal across the aperture;

detecting means for detecting changes in the electronic signal level across the aperture and for forming pulses corresponding to the changes which result from an increase in impedance across the aperture as particles pass through the aperture;

means for counting the pulses that exceed a predetermined level and for providing an indication corresponding to the number of particles per unit volume of the fluid;

a clog alarm driver responsive to the output of the detecting means for providing a steady state output when the aperture is clogged;

a bubble detector and alarm driver responsive to the pulses from the detecting means for providing an intermittent output when bubbles are formed adjacent the aperture; and

an alarm indicator connected to the output of the clog alarm driver and bubble detector and alarm driver and responsive to the signals therefrom for providing a constant indication when the aperture is clogged and an intermittent indication when bubbles are formed adjacent the aperture.

* * * * *