

- [54] **PARTICLE COUNTER HAVING REMOVABLE APERTURE SLIDE**
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- [51] **Int. Cl.** G01m 27/00, G01m 27/02
- [58] **Field of Search** 324/71, 30 B; 73/432

- [56] **References Cited**
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Attorney—David S. Kane et al.

[57] **ABSTRACT**
 An aperture slide receptacle has a top and a bottom plate spaced apart. Each plate has a circular depression formed therein for receiving an O-ring. Said depressions and O-rings are juxtaposed so that the O-

rings contact each other and form a seal between the top and bottom plates. A pair of hollow tubes are mounted in the top and bottom plates so that they are in axial alignment having ends spaced apart and terminating at the center of the O-rings. The first of said tubes extends downwardly into a fluid source, while the second of said tubes is connected to a means for drawing the fluid from the source through the tubes.

A thin Mylar slide has a jewel pressed into a hole formed in the slide. The jewel has an aperture formed therein which is positioned between the ends of the hollow tubes by inserting the Mylar slide between the spaced top and bottom plates. The O-rings forming a seal between the slide and the top and bottom plates.

The tubes form electrodes upon which an rf signal is imposed to develop a voltage across the fluid which is drawn 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 suspended in the fluid passes through the aperture, the rf signal intensity increases in relationship to the rf signal intensity when the low resistance fluid is passing through the aperture. The rf signal is processed to provide pulses corresponding to the particles passing through the aperture and said pulses are counted to provide an indication of the number of particles passing through the aperture.

7 Claims, 6 Drawing Figures

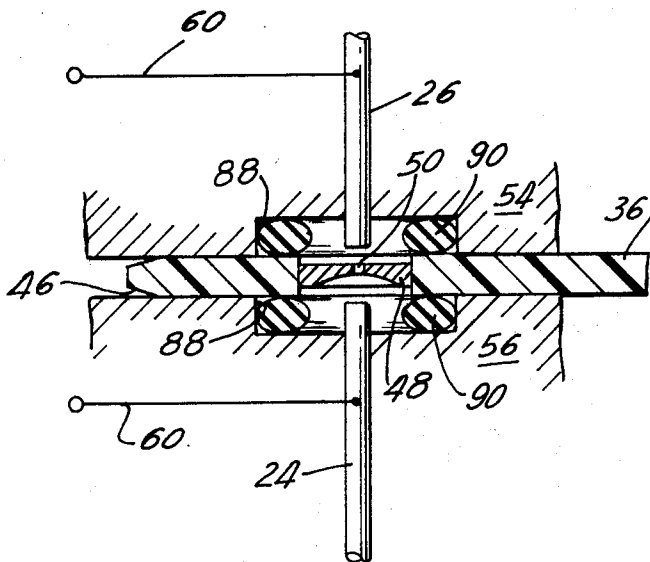


FIG. 1

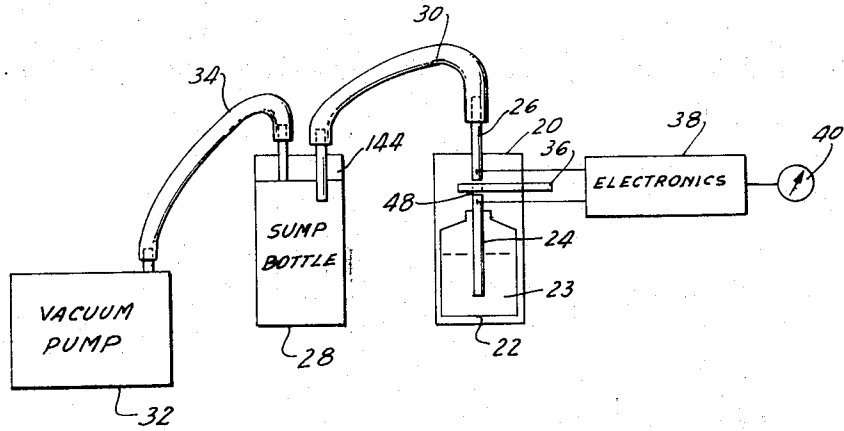


FIG. 6

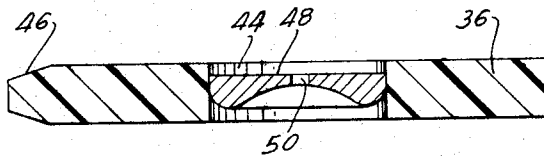
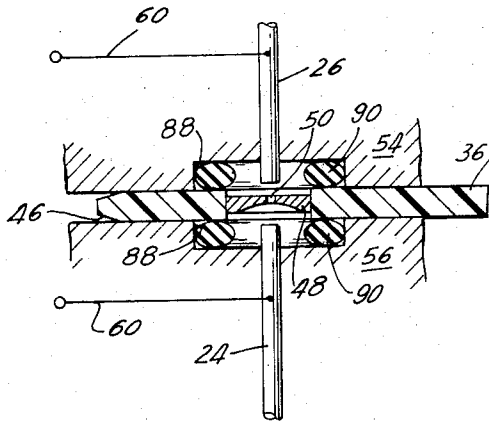


FIG. 4

FIG. 5

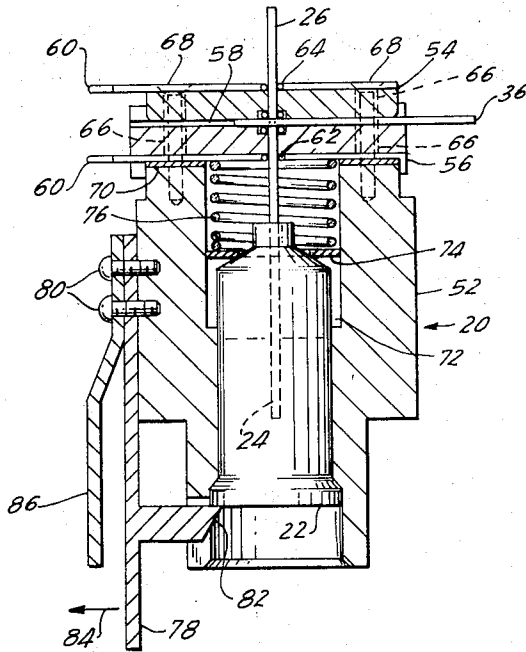


FIG. 2

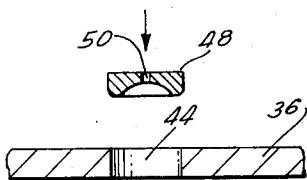
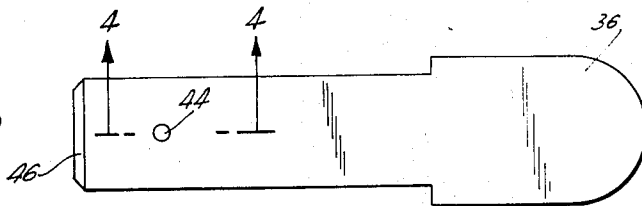


FIG. 3

PARTICLE COUNTER HAVING REMOVABLE APERTURE SLIDE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to particle counters and more particularly to particle counters for counting particles suspended in a fluid having a conductivity substantially different than the conductivity of the particles being counted.

2. Description of the Prior Art

The prior art related to the counting of particles suspended in a fluid medium, wherein the fluid has a conductivity substantially different than that of the particles may best be described by describing the blood cell counting art. Heretofore, blood cell counting was accomplished in three distinctly different ways. Firstly, a sample of diluted blood was placed under a microscope and the blood cells were individually counted to determine the blood cell count. Secondly, a more sophisticated blood cell counting system utilized optics and photoelectric cells to provide a count of the number of blood cells passing through a light beam. Thirdly, pure electronic blood cell counters were utilized, 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.

Some of the less sophisticated pure electronic blood cell counters merely applied a signal across a volume of diluted blood and utilized the voltage developed across the blood sample as an indication of the number of blood cells present. This type of device was inaccurate and did not prove satisfactory.

A more sophisticated type of pure electronic blood cell counter was developed, wherein a known volume of diluted blood was drawn through an aperture and a DC electric signal 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 in which they are diluted, each time a blood cell passed between the electrodes, the voltage between the electrodes would increase and provide a pulse output. When the pulses exceeded a predetermined threshold level, a blood cell was counted.

The DC type devices suffered from unique problems relating to electrode stability. Base line instability occurred because of bubble formation and the devices were sensitive to polarization potentials. These problems were partially the result of electrode instability, and as a result, it was necessary to use precious metals in the formation of the electrodes, this resulted in high cost.

Problems experienced with aperture type systems included the accumulation of lint and dust in the aperture resulting in clogged apertures 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 provided an oscilloscope to view a trace of the voltage generated across the aperture so that any abnormality could quickly be detected and a viewing screen was provided so that the aperture could be continuously observed to determine if clogging was taking place. After detecting a clogged aperture, it was difficult to gain access to the aperture in order to clean it, since the aper-

tures of the prior art were not easily removed for cleaning.

SUMMARY OF THE INVENTION

5 The present invention relates to particle counters and in particular to devices for counting particles suspended in a fluid medium, wherein the fluid medium has a conductivity substantially different than that of the particles. While the present invention has many applications, including the monitoring of pollution levels, the invention will be described in the embodiment of a blood cell counter. The invention contemplates 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. The operational concept of the blood cell counter is similar to many of those used in the prior art and it is based upon the difference in electrical conductivity between the blood cells and the diluent used to prepare blood samples. The diluted blood sample is passed through an aperture formed in a jewel and as the 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 and the signal is modulated by the variation of the resistance between the electrodes. The signal is then processed to provide pulses corresponding to the blood cells passing through the aperture and to provide an indication of the number of blood cells contained in the blood sample.

The present invention employs several features which make it a reliable and trouble-free instrument. The jewel in which the aperture is formed is pressed into a hole formed in a slide formed of a thin sheet of Mylar. The Mylar slide slides into a receptacle which also houses tubes that form the previously-mentioned electrodes. The Mylar slide is slid between two juxtaposed O rings which seal a portion of the slide and the jewel into the blood flow path and contact each other to prevent leakage from the path when the Mylar slide is removed.

Most flow restrictions caused by particulate matter caught in the aperture, can be cleared by simply flicking the flexible Mylar slide while it is in place in the receptacle. Massive aperture clogging does not present a serious problem as the Mylar slide may be easily removed for cleaning and reinserted without the need for disassembling the instrument. In most cases, the wiping action of the O rings passing the aperture causes the clog to be removed.

The present invention also overcomes many of the problems resulting from bubble formation and electrode instability by the use of electrodes formed of Hastelloy C, a type of stainless steel that is less expensive and more durable than either platinum or gold, which was used in the prior art devices.

Thus, the present invention provides a blood cell counter that has better maintainability and reliability than the devices heretofore provided.

The main objective of the present invention is to provide a blood cell counter that is less expensive, more reliable and easier to maintain than those heretofore provided so that it will be available for use in doctors' offices and in small laboratories.

Another objective of the present invention is to provide a blood cell counter that is of smaller size than those heretofore provided.

Another objective of the present invention is to provide a blood cell counter having means to facilitate the cleaning of a clogged 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 plan view of an aperture slide for use with the present invention.

FIG. 3 is a sectional view taken along lines 3—3 of FIG. 2 showing how the jewel is inserted into the slide. FIG. 4 is a sectional view taken along lines 3—3 of FIG. 2 showing the jewel inserted into the slide.

FIG. 5 is a vertical section of an aperture slide receptacle assembly.

FIG. 6 is a vertical section showing in detail a portion of the assembly of FIG. 5.

DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is shown a schematic representation of the system of the present invention. An aperture slide receptacle 20 receives a blood source such as a reservoir bottle 22 containing a diluted blood sample 23 into which is inserted a dip tube 24 which also functions as an electrode. A tube 26 is aligned with the dip tube 24 and spaced therefrom to function as a second electrode. A sump bottle 28 has a hollow interior which is in communication with the interior of the reservoir bottle 22 through flexible tubing 30, dip tube 24 and tube 26. A vacuum pump 32 evacuates sump bottle 28 through a flexible tube 34 and as a result, diluted blood from reservoir bottle 22 is drawn through dip tube 24 and tube 26 to establish a flow of blood between the electrodes formed by tubes 24 and 26. It is to be understood that any other conventional pumping means could also be used to establish a blood flow through the tubes.

An aperture slide 36 having an apertured jewel 48 mounted therein is positioned between the spaced tubes 24 and 26 so that the jewel aperture is in line with the tubes. Electronic circuitry 38 impresses an rf signal across the electrodes formed by tubes 24 and 26. The rf signal develops a voltage across the electrodes dependent upon the conductivity of the diluted blood sample 23 passing through the aperture.

Blood cells have substantially less conductivity than does the diluent used in the sample and therefore, abrupt voltage increases or pulses are generated each time a blood cell passes through the aperture. The electronics circuitry 38 senses these pulses and processes them to provide an output signal corresponding to the number of blood cells per cubic millimeter of blood sample passing through the aperture. This output signal is displayed on an indicator 40, such as a meter.

In FIG. 2, there is shown a plan view of the aperture slide 36, which is formed of a polyester film such as Mylar, having a thickness of approximately 0.015 inch and a length of approximately 2 inches. It is to be understood that any thin plastic material having flexibility and cold flow characteristics similar to Mylar could be used. A hole 44 is formed near one end of the aperture slide and this hole is precisely positioned so as to be aligned with the tubes 24 and 26 of the aperture slide receptacle 20. The forward edge of the aperture slide is beveled at 46 to facilitate insertion of the slide into receptacle 20. A jewel 48 shown in FIG. 3 is press fit into hole 44 of slide 36 as shown in FIG. 4 and is retained therein by the cold flow of Mylar around the jewel edge. The jewel 48 is preferably a ruby having a thickness of 0.25 mm and an outside diameter of 1.20mm. An aperture 50 is formed in the jewel and has a diameter of 90 microns.

It is desirable that the electrodes of the system be placed as close to the jewel aperture as possible in order to reduce the generation of electronic noise and to increase the signal pulse level. Therefore, the aperture slide had to be constructed of a material closely approximating the thickness of the jewel. A polyester film (ethylene glycol terphthalate) such as Mylar was chosen as the preferred material because it was available in the proper thickness and displays cold flow characteristics which simplified jewel mounting. Mylar is also flexible so that the slide may be bent without breaking or without dislodging the jewel from hole 44.

Referring now to FIG. 5, there is shown a sectional view of an aperture slide receptacle 20 having a base member 52, a top plate 54 and a bottom plate 56 all formed of acrylic plastic. Plates 54 and 56 are very precisely machined and have centrally located openings formed therein for receiving and retaining tubes 26 and 24 which are formed of hollow Hastelloy C or other suitable material having similar characteristics to function as electrodes and conduits for the diluted blood sample stream. Hastelloy C was chosen because of its resistance to corrosion especially in a saline solution which is normally used for the diluent of the blood. In addition, Hastelloy C is less expensive and more durable than both platinum or gold, the metals used in the prior art. Top and bottom plates 54 and 56 are machined to be keyed together by way of an upstanding collar formed on plate 56 so that the electrodes are axially aligned within 0.010 inch of each other and are spaced within 0.030 inch of each other. Horizontal grooves 58 are machined in both the top and bottom plates for receiving the aperture slide 36. Again it is emphasized that the plates and the slide must be machined so that aperture 50 of the jewel is within 0.010 inch of the center line of the tubes 24 and 26. Electrodes 60 extend across horizontal grooves formed in the top and bottom plates and are electrically connected to tubes 24 and 26 at 62 and 64 respectively.

Through holes 66 are formed in plates 54 and 56 for receiving screws 68 which thread into base 52 for mounting the plates to the base. A poly washer 70 is provided between the base and bottom plate 56 to prevent moisture from making an electrical contact between screws 68 and the electrodes. If such contact were made, an antenna would be formed and noise introduced into the system.

The interior of the base 52 has a generally cylindrical opening formed therein with a stepped shoulder 72

forming a stop for a washer 74 which retains a stainless steel spring 76 in position between the lower plate 56 and itself. The reservoir bottle 22 is inserted through an opening in the lower portion of base 52 and is pushed up to compress spring 76 to a position where the dip tube 24 is well beneath the level of the diluted blood sample 23 contained in reservoir 22. Reservoir 22 is preferably a Unopette reservoir bottle which is a commercially available item manufactured by Becton, Dickinson and Company. A latch 78 formed of a hard resilient plastic material such as Delrin is attached to base 52 by mounting screws 80 and has a protrusion 82 which engages the bottom of reservoir bottle 22 after it is inserted into base 52. When the reservoir bottle is to be released, latch 78 is pressed in a direction shown by arrow 84 to release the reservoir bottle 22 which is ejected under the force of spring 76. A stop member 86 formed of stainless steel is provided to limit the movement of latch 78 and to prevent breakage due to excessive bending.

The base may be adapted to receive a conduit for connection to a blood source for an in-line type of operation where the instrument provides an indication of the blood count of the blood passing through the aperture at that time. This type of device is particularly adaptable for pollution monitoring where a continuous supply of fluid is available.

Referring to FIG. 6, there is shown in detail the connection between aperture slide 36 and aperture slide receptacle 20. Both the top and bottom plates 54 and 56 have circular depressions 88 machined therein for receiving O rings 90 which seal the blood flow path. The O rings are formed of silicone rubber to provide the required resiliency so that the O-rings are compressed and engage each other when slide 36 is removed and remain sufficiently resilient to allow aperture slide 36 to be inserted therebetween. O-rings of a harder and more durable material would undoubtedly have a greater life but would not provide the required resiliency to allow slide 36 to be easily slid between the O-rings. Beveled edges 46 of aperture slide 36 also facilitate insertion of the slide between the O-rings. It is essential that depressions 88 and the O-rings 90 be only slightly larger than hole 44 so that the volume of the enclosed space on both sides of the aperture is kept to a minimum. This is essential because blood from a previous sample remains in the space and must be completely purged by the flow of new blood before a count can be made. The smaller the space, the quicker the purging is completed.

Many of the problems heretofore experienced because of the presence of bubbles at the aperture are eliminated by the unique use of electrodes formed of Hastelloy C which is an extremely stable metal and does not corrode in a saline environment. The aperture assembly provides maintainability and reliability heretofore not experienced in blood cell counters. The aperture slide may be easily removed for cleaning and in many cases, a minor clog in the aperture may be removed by gently flicking the aperture slide with a finger. It is also possible to clear minor clogs by simply pulling the aperture slide slightly out of position so that the O-rings rub across the aperture causing the clogging substances to be dislodged after which the slide is again inserted into the proper position.

Thus, the present invention provides a less expensive, more reliable and more maintainable blood cell counter than was heretofore available.

I claim:

1. An instrument for counting particles suspended in a fluid medium, wherein the fluid medium and particles have different conductivities, comprising:
 - a flexible slide formed of a nonconductive material;
 - a jewel having an aperture formed therein, said jewel being mounted in an opening formed in the slide;
 - a slide receptacle having an opening into which the slide is inserted and being capable of being flicked as a result of said flexibility while in this instrument for clearing flow restrictions caused by particulate matter caught in the aperture;
 - tubular electrodes mounted in said receptacle, the ends of the electrodes being positioned adjacent the aperture in said jewel and spaced from each side of the jewel;
 - means for passing the fluid medium through the tubular electrodes and aperture;
 - means for applying an electrical signal across the electrodes to develop a voltage corresponding to the conductivity of the fluid passing through the aperture, whereby the voltage increases each time a particle of lower conductivity passes through the aperture; and
 - means for detecting the voltage increases and for providing output indication corresponding to the number of particles passing through the aperture.
2. An instrument as described in claim 1, wherein the slide is formed of a thin polyester film.
3. An instrument as described in claim 2, wherein the slide is press fit into an opening in the slide.
4. An instrument as described in claim 1, wherein the slide receptacle comprises:
 - a top plate;
 - a bottom plate; the top and bottom plates having spaced surfaces that form the opening into which the slide is inserted;
 - depressions formed in both the top and bottom plates adjacent the jewel in the slide; and
 - O-rings disposed within the depressions, said O-rings forming a seal between the plates and the surfaces of the slide and forming a seal between the plates when the slide is removed.
5. An instrument as described in claim 4, wherein the slide is formed of a thin polyester film and the jewel is press fit into the opening in the slide.
6. An aperture slide receptacle for a particle counting instrument of the type, wherein a fluid medium is passed through an aperture and an electrical signal is applied to electrodes positioned at each side of the aperture to develop a voltage corresponding to the resistance of the fluid medium passing through the aperture so that high resistance particles cause voltage increases as they pass through the aperture, comprising:
 - a top member;
 - a bottom member, said top and bottom members having spaced surfaces forming a slot between said top and bottom members;
 - juxtaposed depressions formed in the slot forming surfaces of the top and bottom members;
 - O-rings disposed within the depressions, said O-rings forming a seal between the top and bottom members;

tubular electrodes extending through the top and bottom members and having ends positioned so as to be encircled by the O-rings, said ends being spaced apart; and

a flexible slide having an aperture formed therein being inserted into the slot between the top and bottom members so that the O-rings form a seal between the members and the slide and the aperture is disposed between the ends of the tubular electrodes and being capable of being flicked as a result of said flexibility while in this instrument for clearing flow restrictions caused by particulate matter caught in the aperture.

7. An electrode assembly for a particle counting instrument of the type wherein a fluid medium is passed through an aperture and an electrical signal is impressed across the fluid in the aperture to develop a voltage corresponding to the resistance of the fluid medium passing through the aperture so that high resistance particles cause voltage increases as they pass through the aperture, comprising:

- a housing have a cavity formed therein;
- a flexible partition dividing said cavity into first and

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second chambers, said partition having an aperture formed therein connecting the first and second chambers and being capable of being flicked as a result of said flexibility while in this instrument for clearing flow restrictions caused by particulate matter caught in the aperture;

a hollow tubular member extending through said housing into said first chamber and having an end adjacent said aperture;

a second hollow tubular member extending through said housing into said second chamber and having an end terminating adjacent said aperture;

a source of fluid medium connected to one of said hollow tubular members; and

means for establishing a flow of fluid medium through said hollow tubular members and through said aperture, connected to the other of said hollow tubular members, said hollow tubular members being formed of a conductive material and functioning as electrodes positioned on each side of said aperture.

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