

Dec. 22, 1959

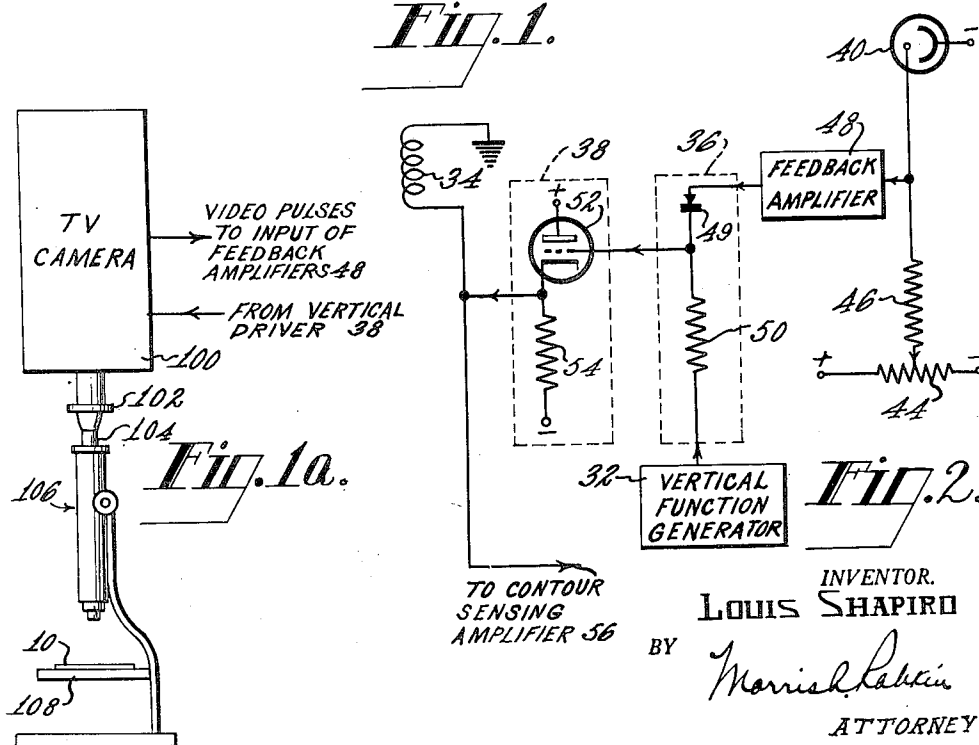
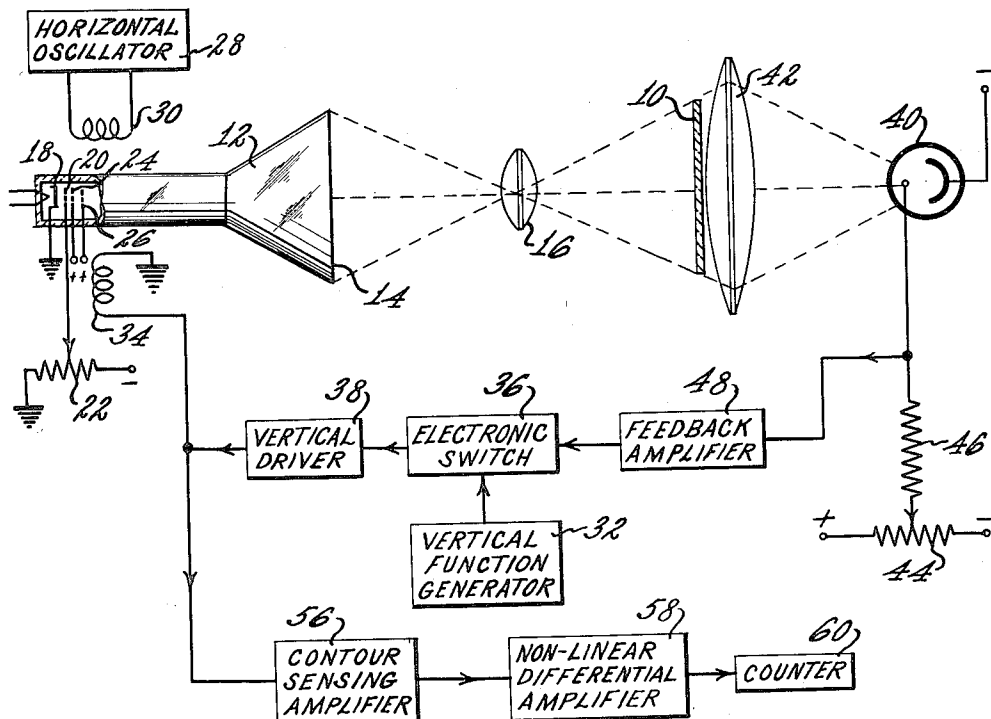
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2,918,216

PARTICLE COUNTING APPARATUS

Filed Aug. 31, 1956

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

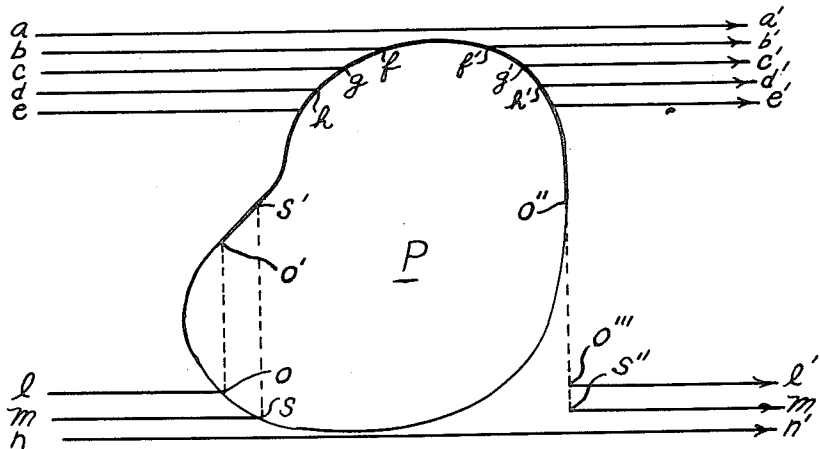


Fig. 3.

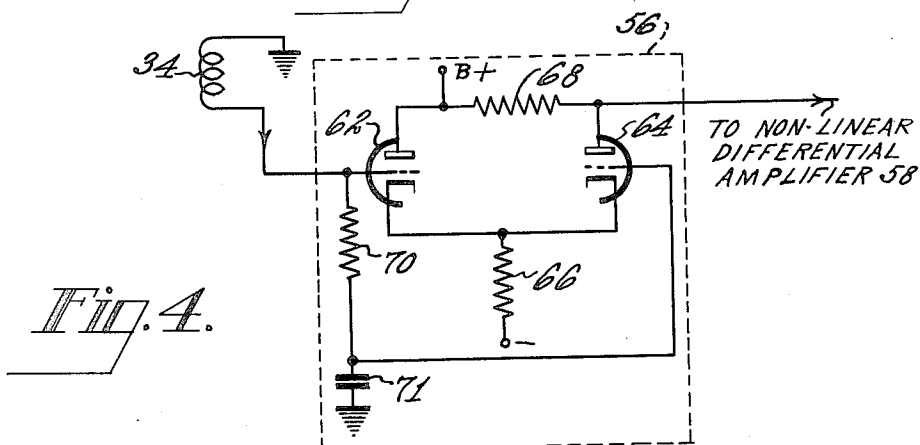


Fig. 4.

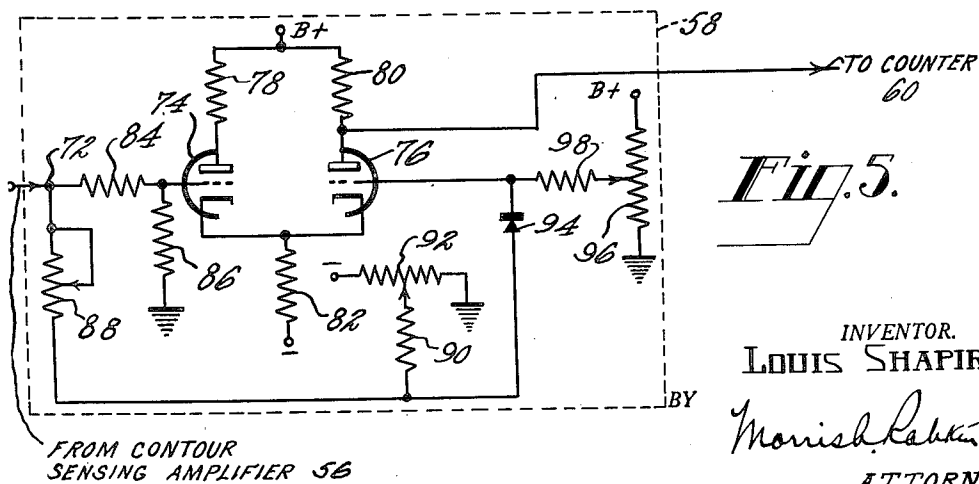


Fig. 5.

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2,918,216

PARTICLE COUNTING APPARATUS

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7 Claims. (Cl. 235—92)

This invention relates to improvements in particle counting apparatus, and more particularly to a novel arrangement of apparatus and a novel system for counting particles by electronic means. By "particles" is meant not only physical entities having three dimensions, but any discrete areas or spots, in a field of view, having an appearance contrasting with that of a general background. The particle counting apparatus of the present invention is useful not only for counting particles of relatively uniform shape, such as red blood cells, but is also particularly useful for counting particles of non-uniform shape, such as dust particles. The apparatus and system of the present invention may also be used to count and sort particles of a predetermined size when distributed among particles of many different sizes.

Apparatus has been proposed to count particles in a field of view by scanning the particles with a beam of energy, and by obtaining pulses resulting from any changes in the energy of the beam every time the beam scans a particle. The pulses derived from a single raster scan are counted. Since the same particle may be, and usually is, scanned several times by the beam during a single raster scan, the average pulse width must be determined as a measure of the average particle size. The pulse width information is then used as a correction factor to minimize the error in the particle count resulting from variations in the particle size. While the particle count thus obtained may be reasonably accurate for most purposes, the count is an estimated one, and the accuracy of the count depends upon the accuracy of the correcting factor used. When the particles to be counted are non-uniform in size and shape, the accuracy of the particle count is relatively decreased.

Accordingly, it is a general object of the present invention to provide improved and novel particle counting apparatus adapted to count particles of non-uniform size and shape, as well as particles of uniform size and shape, quickly and accurately.

A more specific object of the present invention is to provide improved particle counting apparatus by means of which an accurate particle count may be obtained quickly, and accurately, and without the need of a correcting factor because of variations in the size of the particles.

Another object of the present invention is to provide novel means for checking and/or counting particles of a predetermined size among particles of different sizes.

The term "raster scanning," as used herein and in the appended claims, is intended to mean the repeated movement of a beam of energy along a multiline pattern, with each line in the pattern being parallel to and slightly displaced from the preceding line. Such a scanning pattern is well known in the television art and allied fields. Other types of scan patterns are, of course, possible and applicable to the invention herein described.

In accordance with the present invention, the foregoing objects and related advantages are attained in novel and improved particle counting apparatus wherein a beam

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of energy is made to scan a field of view in which the particles to be counted appear. The energy of the beam, which may be a beam of light, as in a flying spot scanner, or an electron beam, as in a "Vidicon" television camera tube, changes when it impinges upon the particle scanned. Detecting means are provided to derive signal pulses from such changes in energy. Feedback means, responsive to the detected signal pulses, are provided to modulate the beam transversely and to cause it to scan a portion of the contour of the particles when they are encountered by the beam. Thus, the line scanning voltage is modulated by the signal pulses resulting from the changes in the energy of the beam when impinging on the particles to be counted. The modulating pulses are first separated from the scanning line pulses, and then applied to a non-linear differential amplifier. The circuitry of the non-linear differential amplifier comprises means to provide output pulses of one polarity when the input pulses are within predetermined critical range of amplitudes, and to provide output pulses of an opposite polarity when the input pulses are greater than the critical range of amplitudes. Since the usual distance between adjacent scanning lines of the raster scan is such that a plurality of scanning lines will probably scan the contour of a single particle, it will be understood that every particle scanned will have only one modulating pulse of critical amplitude if the range of amplitudes of critical modulating pulses is greater than that represented by the distance between two adjacent scanning lines but no greater than the distance between three consecutive scanning lines. Therefore, by counting pulses of this critical amplitude only, an accurate count of the particles within the field of view scanned may be obtained.

A more complete understanding of the invention can be had by reference to the following description of illustrative embodiments thereof when considered in connection with the accompanying drawings, in which similar reference characters represent similar components, and in which:

Fig. 1 is a schematic diagram, partially in block form, illustrating particle counting apparatus arranged in accordance with the system of the present invention;

Fig. 1a shows an alternative form of pulse generating means suitable for use in the system of the type shown in Fig. 1;

Fig. 2 is a schematic diagram of the electronic switch and vertical driver circuits shown in block form in Fig. 1;

Fig. 3 is a schematic diagram illustrating the contour scanning of a particle by individual lines of a raster scan, in accordance with the present invention;

Fig. 4 is a schematic diagram of the contour sensing amplifier illustrated in block form in Fig. 1; and

Fig. 5 is a schematic diagram of the non-linear differential amplifier illustrated in block form in Fig. 1.

Referring now to Fig. 1, there is shown an arrangement of apparatus for counting particles (not shown) within a field of view of a transparency 10, in accordance with the system of the present invention. The transparency 10 may comprise actual particles such as blood cells on an unruled counting chamber, for example, or the transparency may be a transparent slide wherein the particles to be counted, such as stained bacteria, for example, appear against a uniform background of contrasting color. Means are provided to raster scan the transparency with a beam of light. To this end, a cathode ray tube 12 is disposed in front of the transparency 10 in a manner whereby a moving spot of light, resulting from the electron beam of the cathode ray tube 12 impinging on the screen 14 thereof, is focussed onto the transparency 10 by a lens system 16, shown illustratively as a single lens. The electron gun of the cathode ray tube 12 comprises an indirectly heated cathode 18 con-

nected to ground, and a control grid 20 connected to the movable arm of a potentiometer 22. The potentiometer 22 is connected between a source of negative voltage and ground for providing the control grid 20 with a negative bias with respect to the cathode 18. A focussing anode 24 and an accelerating anode 26 are connected to suitable sources of operating potentials.

Means are provided to raster scan the screen 14 of the cathode ray tube 12 with the electron beam. The output of a horizontal oscillator 28, such as a sawtooth oscillator, is connected to a horizontal deflection coil 30 for providing the electron beam with a repetitive horizontal sweep. Retrace blanking means (not shown) may also be provided in a manner well known in the television and allied arts. A vertical function generator 32, for providing a sawtooth voltage pulse of a relatively much longer duration than the pulses from the horizontal oscillator 28, is connected to a vertical deflection coil 34 through an electronic switch 36 and a vertical driver circuit 38. As will be explained hereinafter in greater detail, the electronic switch circuit 36 and the vertical driver circuit 38 provide direct coupling means for applying a vertical deflection pulse from the vertical function generator 32 to the vertical deflection coil 34. It will now be understood that the electron beam of the cathode ray tube 12 will raster scan the screen 14 and thereby produce a moving spot of light thereon. This spot of light is focussed onto the transparency 10 by the lens system 16 in a manner whereby the spot of light will raster scan the transparency 10.

Light energy transmitted through the transparency 10 is focussed onto a photosensitive device 40 by a lens system 42, represented illustratively as a single lens. The photosensitive device 40 and its associated circuitry comprise means to detect the light energy impinging thereon, and means to provide output signals in accordance with changes in the light energy of the beam. The photosensitive device 40 may be a phototube, for example, whose photocathode is connected to a source of suitable negative voltage and whose anode is connected to the movable tap of a potentiometer 44 through a load resistor 46. The resistor of the potentiometer 44 is connected across a source of suitable operating voltage for supplying the anode of the photosensitive device 40 with a proper positive operating voltage. It will now be understood that if the light beam does not scan a particle, the light beam will pass through the transparency 10 with minimum transmission loss, that is, with a maximum intensity, and impinge upon the photocathode of the photosensitive device 40. This will cause a negative-going signal pulse to appear at the anode of the photosensitive device 40. The negative-going signal pulse is applied to the input of a feedback amplifier 48, and the output of the feedback amplifier 48 is applied to the electronic switch 36.

Referring now to Fig. 2, there are shown the electronic switch 36 and the vertical driver circuit 38 in greater detail. The electronic switch 36 comprises a diode 49 whose anode is connected to the output of the feedback amplifier 48, and whose cathode is connected to the output of the vertical function generator 32 through a resistor 50. The cathode of the diode 49 is also connected to the control grid of a tube 52 of the vertical driver circuit 38. The tube 52 is connected as a cathode follower and functions as a current amplifier. The anode of the tube 52 is connected to a suitable source of operating voltage (not shown), and the cathode is connected to a source of negative voltage (not shown), through a cathode resistor 54. The cathode of the tube 52 is connected to the vertical deflection coil 34.

The diode 49 offers essentially an infinite impedance to negative-going signal pulses from the output of the feedback amplifier 48, but presents substantially no impedance to positive-going signal pulses. Therefore, it will be understood that when the light beam passes

through the transparency 10 and does not impinge upon a particle, the negative-going signal pulse produced at the anode of the photosensitive device 40, and amplified by the feedback amplifier 48, will not pass through the diode 49 of the electronic switch 36. Consequently, the only current flowing through the vertical deflection coil 34, under these conditions, will be that resulting from the pulse of the vertical function generator 32.

When the light beam entering the transparency 10 impinges upon a particle in the field of view of the transparency 10, the intensity of the transmitted light beam will decrease. This decrease in light energy will be detected by the photosensitive device 40 and provide a positive-going signal pulse at the anode thereof. It will now be understood that this positive-going signal pulse will be amplified by the feedback amplifier 48 and will be applied to the grid of the tube 52 of the vertical driver circuit 38 through the diode 49 of the electronic switch 36. A positive-going pulse is now applied to the vertical deflection coil 34 through the cathode of the tube 52. This positive-going pulse is more positive than the pulse already present from the vertical function generator 32 and functions as a modulating pulse to deflect the beam transversely, that is, vertically, to the horizontal scan. The modulating pulse will instantaneously deflect the beam transversely a sufficient amount, during its horizontal scan, to the peripheral edge of the particle being scanned. As soon as a specified portion of the light beam reaches the peripheral edge of the particle, a sufficient portion of the light beam will pass through the transparency 10 and cause a negative-going signal pulse to appear at the anode of the photosensitive device 40 and at the anode of the diode 49, as explained heretofore. Thus, the light beam passing through the transparency 10 will be caused to scan portions of the contours of the particles upon which it impinges during each horizontal scan. This type of scanning will be referred to hereinafter, and in the appended claims, as "contour scanning."

Referring now to Fig. 3, there are illustrated the paths of a beam of energy during the raster scanning of a particle P. Let it be assumed that the light beam, during its traversal of its first scan line $a-a'$, moving from left to right looking at Fig. 3, does not scan any particle. Under these conditions, substantially the maximum intensity of light is transmitted through the transparency 10 and a negative-going signal will appear at the anode of the photosensitive device 40, and at the anode of the diode 49 (Fig. 2). The diode 49 functions as an open switch to negative-going signals.

During the traversal of the second scan line $b-b'$, the light beam impinges upon the particle P, as at point f on the periphery of the particle P. The intensity of the transmitted light beam will consequently be decreased and will produce a positive-going signal pulse at the anode of the photosensitive device 40. The amplified positive-going signal pulse is now applied to the anode of the diode 49, and will provide a positive going pulse to the current amplifier 38. This set of conditions will cause more current to flow through the vertical deflection coil 34 and will cause the beam of light to be modulated transversely, and to scan the contour of the particle P up to the point f' . At the point f' , the maximum intensity of the light beam will be transmitted through the transparency 10, and the beam will continue to scan horizontally to the end of the line $b-b'$.

While traversing the horizontal scan line $c-c'$, the light beam will travel horizontally until it impinges upon the particle P, as at point g . At the point g , the intensity of the transmitted light beam will diminish and cause the photosensitive device 40 to derive a positive-going signal pulse therefrom. The positive-going signal pulse will pass through the diode 49 and will be applied as a modulating pulse to the vertical deflection coil 34. This will cause the horizontal trace to scan a portion of the contour of the particle P from the point g to

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the point g' , the latter point being a point where the light beam no longer tends to impinge upon the particle P. The horizontal sweep from the point g' to the end of the line $c-c'$ will be a straight line. In a similar manner the scan line $d-d'$ will be a horizontal trace up to a point h on the periphery of the particle P. At the point h , a modulating signal is derived by the photosensitive device 40 and the beam is modulated transversely so as to scan the periphery of the particle P from the point h to the point h' , by contour scanning. From the point h' to the end of the scan line $d-d'$, the trace will be a straight line.

During its traversal of the horizontal scale line $l-l'$, the beam will traverse a horizontal line until it impinges upon the particle P, as at point o . At the point o , the intensity of the transmitted beam will decrease, and a feedback positive modulating pulse, in the manner explained heretofore, will cause the beam to traverse the dotted vertical line $o-o'$, the point o' being at the periphery of the particle P. From the point o' , the beam will contour scan the particle P up to a point that is farthest to the right on the particle P, as at point o'' . When the beam leaves the point o'' , the absence of a feedback modulating pulse will cause the beam to drop suddenly to the point o''' , and from there proceed along the horizontal portion of the line $l-l'$. In a similar manner, the beam, during its scan of the line $m-m'$ will proceed along a horizontal path to the point s on the periphery of the particle P. From the point s , the positive modulating pulse will cause the beam to rise vertically to a point on the periphery of the particle P, as at point s' . From the point s' , the beam will contour scan the particle to the point o'' . The absence of a modulating pulse after the beam passes the point o'' will cause the beam to drop suddenly to a point s'' on the horizontal portion of the line $m-m'$. From the point s'' , the beam will proceed along a horizontal path to the end of the line $m-m'$.

It will be noted, from an examination of Fig. 3, that by the system of contour scanning of a particle, as described, the modulating pulse responsible for the contour scanning of each line increases in amplitude with each successive line that scans the particle. If, for example, only one modulating pulse within a range of critical amplitudes were counted, and the remaining modulating pulses were disregarded, an accurate count of the particles would be had. If small modulating pulses, as for example pulses having an amplitude proportional to a distance less than the distance between two adjacent scan lines, were disregarded and only the modulating pulse having an amplitude proportional to the distance between three successive lines were considered, it will be noted that only one such critical pulse would exist for each particle. In practice, the type of particle scanned as well as the particular application of the equipment will determine the range of amplitudes of critical modulating pulses that are to be counted. Looking at Fig. 3, the critical modulating pulse to be counted may be the modulating pulse necessary to cause the contour scanning of the line $c-c'$, as the contour scanning of the particle from the point g to the point g' .

The modulating pulses may be separated from the scanning means by having the input of a contour sensing amplifier 56 (Fig. 1) connected to the junction of the output of the vertical driver circuit 38 and the vertical deflection coil 34. The output of the contour sensing amplifier 56 is then applied to the input of a non-linear differential amplifier 58 which comprises means to select the modulating pulses within a predetermined range of critical amplitudes applied to it, and to reject the remaining modulating pulses. The output of the non-linear differential amplifier 58 is connected to a counter 60 for counting the pulses of critical amplitude as a measure of the number of particles within the field of view scanned.

Referring now to Fig. 4, there is shown the contour sensing amplifier 56 in detail. The contour sensing am-

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plifier 56 comprises a triode 62 having a control grid connected to the vertical deflection coil 34. The anode of the tube 62 is connected to a source of suitable B+ operating voltage, and the cathode is connected to the cathode of a tube 64. The tubes 62 and 64 may comprise a duotriode sharing a common cathode resistor 66. The anode of the tube 64 is connected to the source of B+ voltage through a load resistor 68. The output of the contour sensing amplifier 56 is also derived from the anode of the tube 64.

The grid of the tube 62 is connected to ground through an RC network comprising a resistor 70 and a capacitor 71 connected in series with each other. This RC network has a relatively long time constant with respect to modulating pulses applied to the grid of the tube 62, but its time constant is relatively short compared to a pulse from the vertical function generator 32. The RC network comprising the resistor 70 and capacitor 71, therefore, comprises means for separating the modulating pulses from the pulse of the vertical function generator 32.

The amplified output of the contour sensing amplifier 56 is applied to the input terminal 72 of the non-linear differential amplifier 58, shown in detail in Fig. 5. The non-linear differential amplifier 58 comprises a pair of triodes 74 and 76, which may comprise a duotriode. The anodes of the tubes 74 and 76 are connected to a source of suitable B+ voltage through load resistors 78 and 80, respectively. The cathodes of the tubes 74 and 76 are connected to each other and to a source of negative potential through common cathode resistor 82. The input terminal 72 is connected to the control grid of the tube 74 through a resistor 84. The control grid of the tube 74 is also connected to ground through a resistor 86. It will now be understood that the resistors 84 and 86 comprise a voltage divider for signals applied to the input terminal 72.

The input terminal 72 of the non-linear differential amplifier 58 is also connected to a source of potential that is negative with respect to ground, through an isolating variable resistor 88, a resistor 90, and a potentiometer 92. The resistor of the potentiometer 92 is connected between ground and a source of negative voltage. The junction of the resistors 88 and 90 is connected to the control grid of the tube 76 through a diode 94. The control grid of the tube 76 is also connected to the movable tap of a potentiometer 96 through a resistor 98. The resistor of the potentiometer 96 is connected between a source of B+ voltage and ground. The anode of the tube 76 is connected to the counter 60.

The movable tap of the potentiometer 92 (Fig. 5) is adjusted so that the point between the resistors 88 and 90 is at a point of a negative voltage, referred to as the voltage existing at the grid of the tube 76, equal in amplitude to the largest amplitude of a range of pulses of critical amplitude to be counted. Therefore, positive pulses, applied to the input terminal 72, that are smaller in amplitude than the negative voltage at the junction between the resistors 88 and 90 will not pass through the diode 94. These positive pulses, however, will be applied to the grid of the amplifier tube 74 and will emerge as positive amplified pulses at the anode of the triode 76. If a positive pulse is greater than a predetermined minimum, for example, greater than a predetermined noise level, the counter 60 will be operated and will count the pulse so applied. Let it now be assumed that a modulating pulse applied to the input terminal 72 of the non-linear differential amplifier 58 is positive and greater in amplitude than a negative voltage at the junction of the resistors 88 and 90. This pulse will pass through the diode 94 and will be applied to the control grid of the tube 76. This will tend to make the output pulse at the anode of the tube 76 negative-going. Though the same positive pulse at the input terminal 72 is applied to the control grid of the tube 74, it will be noted

that this is done through the voltage divider comprising the resistors 84 and 86. Though the reduced positive pulse on the control grid of the tube 74 will tend to drive the anode of the tube 76 positive, the components of the circuit are such that the positive pulse on the grid of the tube 76, applied via the diode 94, prevails and causes the total output at the anode of the tube 76 to be negative-going. Since the counter 60 may be such as to count only positive pulses, in a manner well known in the art, only pulses of a critical amplitude, that is, greater than a predetermined noise level and less than the amplitude between three consecutive scanning lines of the raster scan, can be separated from the modulating signal pulses and counted by the counter 60.

Referring now to Fig. 1a there is shown a modification of means for generating modulation pulses, in connection with the system illustrated in Fig. 1. A television camera 100 is mounted with its viewing lens 102 facing against the eye piece 104 of the microscope 106. The field of view containing particles to be counted is assumed to comprise an unruled counting chamber 10 containing blood cells, for example, arranged on the stage 103 of the microscope 106. Ordinarily, the electron beam in the camera will "raster scan" the field of view presented thereto. As the electron beam of the television camera 100 scans the field of view presented through the microscope optical system, the usual "video" television signals will be generated. These signals will include pulses representative of the particles appearing in the field of the camera. If these video pulses are applied to the input of the feedback amplifier 48, instead of the pulses from the photosensitive device 40 in the system of particle counting described in Fig. 1, and if the output of the vertical driver 38 is applied to the vertical deflection coil within the television camera in the manner described for the cathode ray tube 12, the electron beam of the cathode ray tube of the camera, for example, the "Vidicon" tube, will contour scan the particles in the field of view in the manner described for the light beam. The modulating pulses thus obtained may be detected and counted in the manner described heretofore in connection with the flying spot scanner illustrated in Fig. 1. It is understood, of course, that the storage nature of the mode of operation of the vidicon will determine the maximum speed of scanning. It is also understood that when the television camera and microscope arrangement of Fig. 1a are used, the lens systems 16 and 42 and the photosensitive device 40 of Fig. 1 are not needed.

Thus, there has been shown and described apparatus and a system of counting particles appearing in a field of view against a background contrasting in appearance with the particles. Though the arrangement of apparatus for counting particles as shown in Fig. 1 illustrates the system whereby a light beam is transmitted through a transparency, it will be understood that the light beam could be reflected from a scanned field of view and signal pulses may be derived from the reflected light beam and treated in the manner described. While the apparatus and system described herein in detail illustrates means for contour scanning the upper portion of the particles, because of positive feedback modulating pulses, it is within the contemplation of the present invention to contour scan the lower portions of the particles by utilizing feedback negative modulating pulses. Also, by controlling the amplitude and the polarity of the pulses at the output of the non-linear differential amplifier, as described, and by adjusting the sensitivity of the counter to pulses greater than a predetermined minimum amplitude, the apparatus of the present invention may be used to count modulating pulses within a range of pulse amplitudes, each pulse so counted being representative of a particle of a predetermined size distributed among particles of other sizes.

What is claimed is:

1. Particle counting apparatus comprising means to

scan a field of particles continuously with a beam of energy in a resultant direction that is the vector sum of two directions determined by two sources of simultaneously acting forces respectively, said forces being applied to said beam of energy continuously during the scanning of said field, means to derive a signal pulse from said beam each time a particle is impinged by said beam, means to feedback said signal pulses to one of said two sources to alter one only of said forces and to cause said beam to contour scan said particles, means to sense said signal pulses each time said beam contour scans a particle, and means to count said signal pulses within a range of predetermined amplitudes only.

2. Particle counting apparatus comprising means to scan a field of particles continuously with a beam of energy in a resultant direction that is the vector sum of two directions determined by two sources of simultaneously acting forces respectively, said forces being applied to said beam of energy continuously during the scanning of said field, means to derive a signal pulse from said beam each time said beam impinges on a particle, means responsive to said signal pulses and connected to one of said two sources of said scanning means to alter one only of said forces and to cause said beam to contour scan said particles, means to separate each of said signal pulses from said scanning means each time said beam contour scans a particle, and means to count only a single pulse within a range of predetermined amplitudes for each particle scanned.

3. Particle counting apparatus for counting particles within a field of view, said apparatus comprising a cathode ray tube for providing a beam of energy and raster scanning means for said beam, said raster scanning means comprising two sources of continuously acting forces on said beam of energy, means to dispose said tube in front of said field and to scan said field continuously with said beam of energy, means to derive a pulse every time said beam of energy impinges upon a particle within said field of view, means to feedback said pulses as modulating pulses to one of said sources to alter one only of said forces of said raster scanning means to cause said beam of energy to contour scan said particles, means to separate said modulating pulses from said raster scanning means, and means to count only selected ones of said modulating pulses within a range of predetermined amplitudes.

4. Particle counting apparatus for counting particles within a field of view, said apparatus comprising a television camera having raster scanning means, means to dispose said camera to view said particles within said field and to raster scan said field continuously with a beam of energy, said raster scanning means comprising two sources of continuously acting forces on said beam of energy, said television camera comprising means to derive a video pulse every time said beam of energy impinges upon a particle within said field of view, means to feedback said video pulses to one of said sources to alter one only of said forces of said raster scanning means of said camera to cause said beam of energy to contour scan said particles, means to separate said pulses from said raster scanning means, and means to count only selected ones of said pulses within a range of predetermined amplitudes.

5. Particle counting apparatus comprising means to raster scan a field of particles continuously with a beam of energy in a resultant direction that is the vector sum of two directions determined by two sources of simultaneously acting forces respectively, said forces being applied to said beam of energy continuously during the scanning of said field, means for detecting energy changes in said beam every time said beam impinges upon a particle within said field, means responsive to said energy changes to feedback pulses to one only of said sources of said scanning means as modulating pulses to change such resultant direction of said beam to contour scan

said particles, means to separate said modulating pulses from said scanning means, counting means for counting pulses greater than a predetermined amplitude, and means connected between said separating means and said counting means to apply to said counting means only said modulating pulses within a predetermined range of amplitudes.

6. Apparatus for counting particles appearing in a field of view against a background contrasting in appearance with said particles, said apparatus comprising means to scan said field continuously with a beam of energy, said scanning means comprising two sources of continuously acting forces on said beam of energy, means for detecting energy changes in said beam after it has impinged on a particle in said field, means responsive to said energy changes and connected to said scanning means to feedback said energy changes as modulating pulses to one of said sources to alter one only of said forces and to modulate said beam transversely whereby to contour scan said particles, means to derive one of said modulating pulses from said scanning means each time said beam contour scans one of said particles, said modulating pulses having amplitudes proportional to the amplitudes of said contour scans of said particles, and means to count only said modulating pulses having amplitudes within a range of predetermined amplitudes.

7. Apparatus for counting particles appearing in a field of view against a background contrasting in appearance with said particles, said apparatus comprising

means to scan said field continuously with a beam of energy in a multiline pattern determined by two sources of simultaneously acting forces, said forces being applied to said beam of energy continuously during the scanning of said field, means to derive a signal pulse from said beam each time said beam impinges upon a particle, means responsive to said signal pulses connected to one only of said two sources of said scanning means to modulate said beam to cause said beam to contour scan each of said particles, means to derive modulating pulses from said scanning means representative of said signal pulses applied thereto, and means to count only said modulating pulses within a predetermined range of amplitudes, said range of amplitudes of modulating pulses comprising a single modulating pulse only for each particle scanned.

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