Oct. 24, 1967 A. E. MARTENS ETAL 3,349,227

PARTICLE COUNTER

Filed March 30, 1964 2 Sheets-Sheet 1

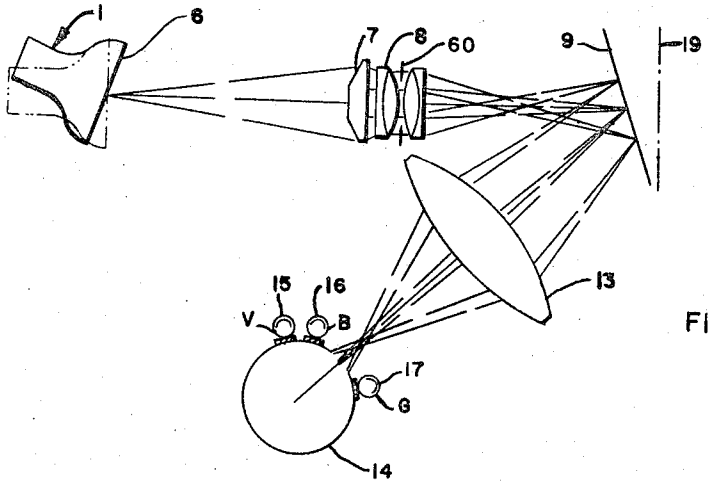


FIG. 1

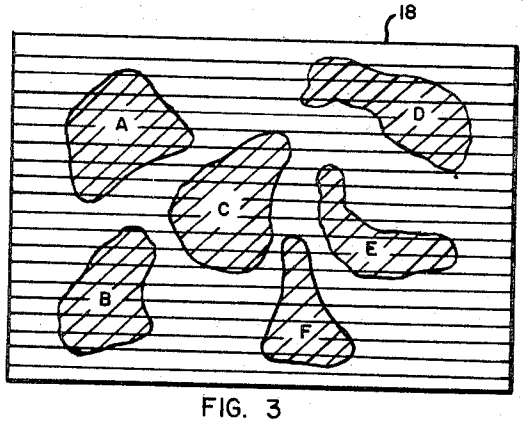


FIG. 3

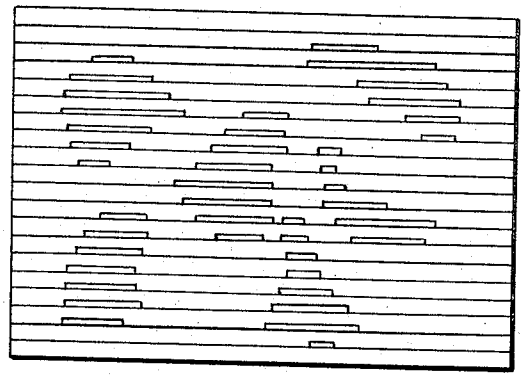


FIG. 4

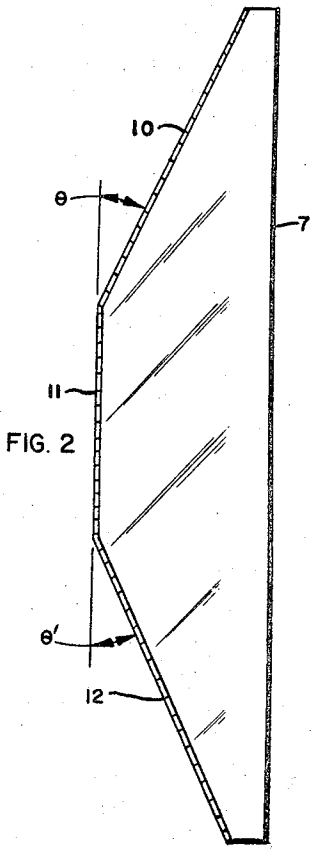


FIG. 2

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PARTICLE COUNTER

Filed March 30, 1964 2 Sheets-Sheet 2

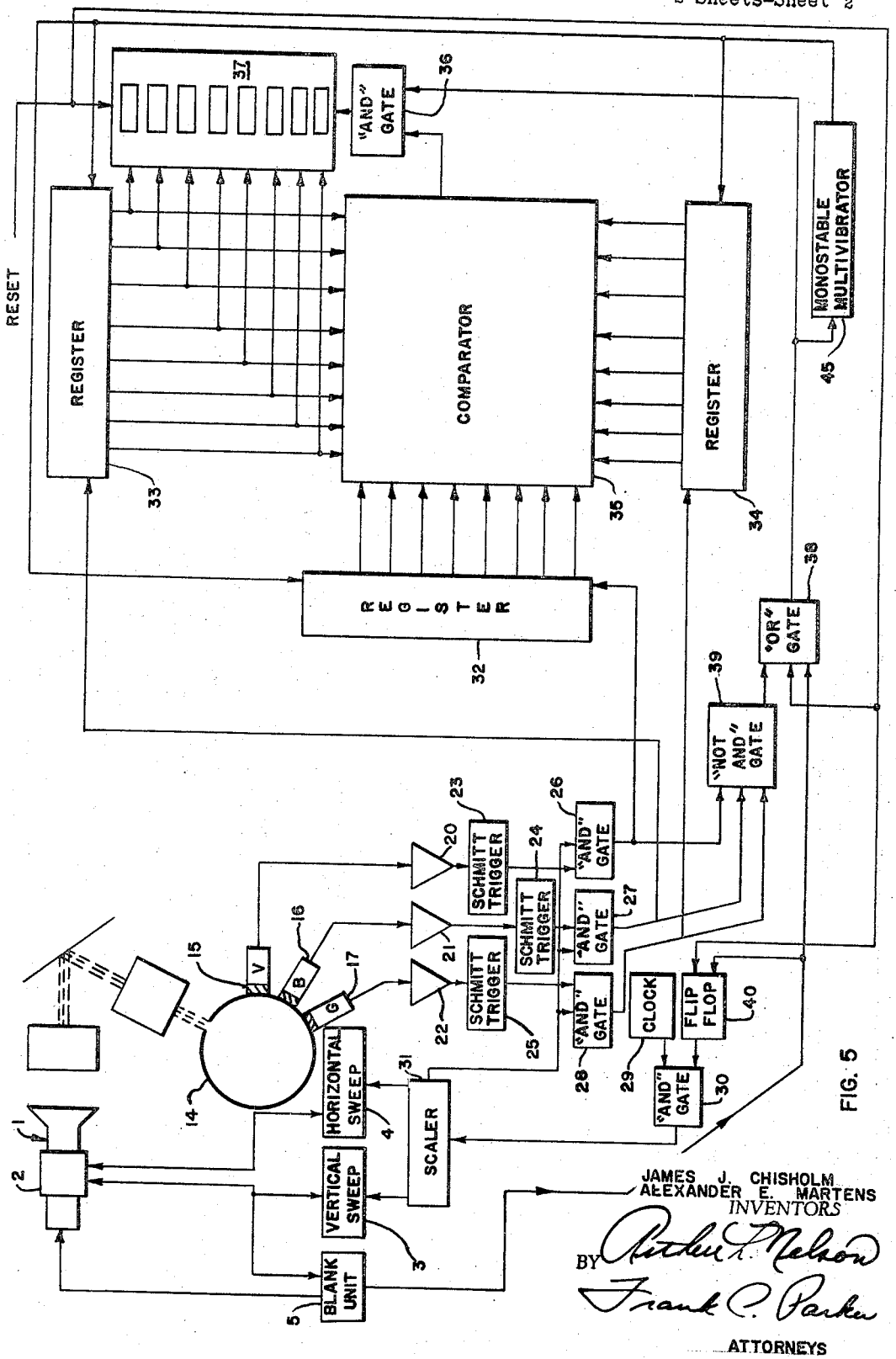


FIG. 5

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PARTICLE COUNTER

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11 Claims. (Cl. 235—92)

This invention relates to a particle counter and more particularly to a particle counter providing classification of size and size distribution of particles.

The problem of particle counting arises in the field of biology and medicine as well as industry. Particle counters are used for blood cell counting, bacterial culture and also dust and smoke particles in the industrial field. Particle counters use various principles and provide a counting means for a fluid, liquids and photographic reproduction, or microscope slides. It is the two latter types of media which adapt themselves well to the counting device covered in this invention.

Various types of manual counting means have been devised whereby a photograph or slide is placed with a grid superimposed on it to divide the field into small squares. The particles in each of the squares are then manually counted and recorded to provide a total count of particles. This invention is directed to an automatic particle counter which provides means for particle or particle image counting and size distribution analysis applied to photographs, microscope slides or collection filters.

It is an object of this invention to provide a particle counter having a three beam scanner and a three channel sensor unit which counts and classifies particle sizes and number.

It is another object of this invention to provide a particle counter utilizing a plural light beam scanning and a maximum particle dimension sensor operating in conjunction with a particle size and number counter.

It is a further object of this invention to provide a particle size counter for detecting particle size and number through a reflectance or transmittance method to provide a discreet pattern classification of size and size distribution.

The objects of this invention are accomplished by scanning a print, transparency, and microscope slide or filter with three dissimilar light beams separated by a predetermined distance which rapidly scans the surface of the medium. A three channel sensor unit generates three signals which are digitized and compared as to the maximum intercept dimension of the light scan. The maximum dimension is sensed when the middle scan is greater than the first and last which causes a logic circuit to send a command to the counter or display unit. The system provides a count of all particles which are classified as to size and indicated on the display unit.

The proposed system will allow the classification and counting of particles represented by images on a photographic print, microscope slides or collection filters. Such classification and counting will be fully automatic requiring the operator only to insert and remove the particle medium, to start the operation of the device and to read the results from a multi-channel display. The proposed system will automatically size the particle images by measuring the length of the greatest intercept in the direction of the scan (x-axis). Each particle will be counted only once within the limits of the systems as follows: The print is scanned by three equally and closely spaced spots of light in the horizontal direction, starting at the top left corner.

During the first scan the upper-most spot (violet) scans line 1, the middle one (blue) scans line 2, and the lower one (green) scans line 3. During the first scan

for the particle image A only the green spot produces an intercept, as seen in FIGS. 4 and 5. The length of this intercept is recorded in the corresponding part of the electronic memory and compared to the intercepts of the blue and violet beams for the same location, which in this case are zero. The particle is therefore not counted, and the memory is cleared.

The next scan brings the green spot into line 4, the blue into 3 and the violet into 2. Now both green and blue will show intercepts for particle A. The results are again compared and scan progresses without recording particle A. This process repeats until violet spot is scanning line 5, the blue line 6, and the green line 7. All three spots will intercept particle A, with the blue spot having the greatest length of intercept. This means that the middle beam crossed the particle at the point of its greatest dimension in the direction of the scan. The fact that the intercept length of the blue spot is greater than either the violet or the green is recognized in the logic and a command is given to a counter, which counts all particles of a given size, to record particle A. In the subsequent scans, the blue intercepts are shorter than those of the violet spot, hence the particle A is disregarded for the remainder of the scans. When all three beams leave the particle image in the horizontal direction a command is generated which clears the temporary storage facilities (registers) making the device ready to evaluate the next intercept (for instance, during the first scan, lines 1, 2, 3 particles A and D will be intercepted).

The method works well theoretically on all particles except the so-called "double-entry" particles which may be C or S shaped, causing multiple intercepts. Fortunately, however, such particle shapes are infrequent. The second source of errors are the particles located too closely together. If the interval is smaller than the resolution of the system such particles will produce a single count.

The resolution of the system is adjusted according to the size of the smallest particle to be counted. The spot of light is generated by a flying-spot scanner CRT. Electronic scanning affords much greater scanning speed and design flexibility.

The beam of light is converted into three separate beams of different colors. The optical system required for such conversion is described later. The separate colors for each beam provide means for a photoelectric identification of each beam. This is done by means of color-filter equipped photosensors. The length of each intercept is electronically converted (digitized) into a number of equally spaced pulses of short duration, such that the number of pulses in a given pulse-train corresponds to the length of the intercept.

When the information is handled electronically in digital form greater accuracy, speed, and reliability can be usually achieved. The second reason for this analog-to-digital conversion is that many parts of proposed logic are commercially available as standard units. Hence the design and manufacturing costs can be drastically reduced.

The preferred embodiment of the invention is described in the subsequent description and illustrated in the attached drawings.

FIG. 1 illustrates the optical system which provides the triple light beam for scanning.

FIG. 2 illustrates the prism encoder which forms multicolor coded images from a single object.

FIG. 3 illustrates a film with the particles enlarged to illustrate operation.

FIG. 4 illustrates pulse generation in proportion to the length of intercept of the particles shown in FIG. 3.

FIG. 5 illustrates a schematic diagram of the overall system.

Referring to the drawings the system includes the optical portion which includes the scanning device and photo-

sensor elements. The necessary prism, lenses etc. provide the proper optical means for the triple scan of the slide or photographic reproduction.

The electrical means includes the necessary amplification gating components and comparator elements which provide a display of size and size distribution of particles on the slide or photographic reproduction.

FIG. 1 illustrates a cathode ray tube **1**. A cathode ray tube **1** as illustrated in FIG. 5 is provided with a yoke **2** connected to the vertical sweep generator **3** and the horizontal sweep generator **4**. A blanking unit **5** is connected to the cathode ray tube **1** for blanking the sweep on its return movement.

A cathode ray tube provides a scanning of a light beam on the face of the tube. The flying spot produced on the face **6** of the tube **1** is imaged by the prism encoder **7** and the lens system **8** on the print **9** for scanning slides or transparencies. The optical system would be correspondingly adapted, as obvious to those skilled in the art. The prism encoder **7** as shown in FIG. 2 is a six sided prism which splits the source point into three virtual source points. The prism shown is merely for illustration and any number of virtual source points may be produced depending on the requirement of the system. A multiple of colored films is formed integral with the prism encoder **7**. The film includes a green transmitting interference coating **10**, a blue transmitting interference coating **11**, and a violet transmitting coating **12** and any other combination of colors or other means for beam identification could be used. Such other means may be accomplished by polarization, or modulation of light intensity. The portion of light received from the cathode ray tube **1** is projected in its various color components through the lens system **8** causing three separate light beams and a triple scan on the face of the print **9**. In actual practice the separation of these beams will be quite small which is dependent on the angle θ and θ' as shown in FIG. 2.

FIG. 1 is used to measure specular reflection of a print. The image on the face of the print **9** is reflected through the lens **13** to the integrating sphere **14**. For measurement of diffused light the lens **13** may be removed from the system and the integrating sphere would be suitably located relative to the print. A plurality of photosensors **15, 16** and **17** are attached to the integrating sphere and receive light through filters which selectively transmit the desired color signal, violet, blue and green respectively. The term photosensor is used but is intended to be illustrative and not limitative as photocells, photomultipliers, etc. may be used. The photosensors are connected to an electrical circuit and generate electrical signals in response to their respective wavelength sensitivity.

FIG. 3 illustrates a print, slide or transparency **18**. The print would be used in the illustration of FIG. 1. A transparency or slide **19** could be positioned at the phantom line **19** and the cathode ray tube **1** could be placed horizontally to direct the light through the transparency **19** to the lens system optically aligned behind the transparency **19**. The integrating sphere **14** and photosensors **15, 16** and **17** would also receive light and be positioned aligned behind the field lens **13**. Either system for use of a print or transparency works equally as well.

FIG. 4 is an illustration of the pulse generated due to the intercept of a single beam of light scanning the print **18**. The dark particles A, B etc. cause an electrical pulse of the length of the inercept of the scan on the particular particle counted.

The optical portion of the counter feeds into a plurality of amplifiers **20, 21** and **22**. These amplifiers generate a pulse signal of the length proportional to the linear intercept of the light scan for the particular particle scanned by each light beam. The amplifier feeds into Schmitt trigger circuits **23, 24** and **25**. The Schmitt trigger circuits provide a gating voltage to "AND" gates **26, 27** and **28**. The pulse signals are digitized at this point. The clock **29** generates timing pulses at a rate desired for the scan speed, and resolution. The blanking unit **5** is connected to the flip flop. The timing pulses pass through "AND" gate **30** when the flip flop generates a gating voltage which is applied to the "AND" gate **30**. The scaler **31** feeds the timing pulses to the "AND" gates **26, 27** and **28**. The digitized signals passing through the "AND" gates **26, 27** and **28** are registered on the registers **32, 33** and **34**. The digitized signals registered on the registers are then compared to the comparator **35**. The register **33** sequentially activates the decades on the display **37** in accordance to the number of pulses in the digitized signal. When the particle intercept, or the digital signal to the registers **33** is greater than the signals received on the registers **32** and **34** a command signal is sent to the "AND" gate **36** and the particle is counted according to the active index decade. For the "AND" gate to operate it is necessary that a signal be received from the "OR gate **38**. This pulse signal is received from the "NOT AND" gate **39**, and is generated when the digitized signals from the "AND" gates **26, 27** and **28** are absent.

The pulse from the "OR" gate **38** is delayed in the monostable multivibrator **45** and is used to clear and reset the registers **32, 33** and **34**. This delay permits information in the register **33** to be received by the display **37** before the information is cleared.

The counter operates in the following described manner. The optical portion includes a prism encoder which creates three virtual images of any single point on the surface of the scanner tube; one violet, one blue and one green image. The separation of virtual images is controlled by the wedge angles θ and θ' of the prisms. Separation can also be varied continuously by displacing the prism encoder along the optical axis between the scanner tube and the relay lens. The relay lens then images the violet, blue and green virtual images onto the photographic print. The print **9** can be either manually or automatically introduced into the scan field in the position shown and is scanned by the three beams simultaneously from the top left corner to the bottom right corner. The light is reflected from the print and imaged by the field lens **13**, into the integrating sphere **14**. The field lens which must of necessity be large, if the print is large picks up the specularly reflected light from the print and images the aperture stop **60** in the relay lens onto the entrance port of the integrating sphere. The integrating sphere combines the three beams and has three exit ports, one port has a violet filter which passes violet light but not blue and green light and the other exit ports have blue and green filters in front of their photosensors to sense independently the amounts of blue and green reflected from the print. Specific colors are used to illustrate the principle involved, however, the device will work equally as well in the non-visible portion of the spectrum.

The intensity of the light in the beam changes whenever the beam is intersecting the image of a particle. For the sake of discussion it has been assumed the top beam is violet, the center beam is blue, and the lower beam is green though other arrangements could be used. The selection of colors or more specifically wavelength is dictated by the filters and the overall wavelength range is dictated by the phosphor emission spectrum available from the cathode ray tube **1**. The photosensors receive light from the integrating sphere **14**. The photosensors **15, 16** and **17** will respond respectively to violet, blue and green light and generate electrical signals which are applied to the electrical circuits.

Electrical pulses are generated in the respective photosensors **15, 16** and **17** whenever one of the beams intercepts a particle image on the print **9**. The pulses are fed into the buffer amplifiers **20, 21** and **22** and the Schmitt trigger **23, 24** and **25** respectively. The pulse width corresponds with the length of the particle intercept. The Schmitt triggers will generate pulses of afixed amplitude and width equal to that of the input pulse. The Schmitt

triggers serve as pulse height discriminators rejecting spurious pulses or those to partial occlusion of the beam.

The clock **29** generates timing pulses at a rate determined by the desired scan speed, and resolution. The width of the timing pulses is smaller than that of an intercept pulse due to the smallest particle image to be recognized. The timing pulses are passed through the "AND" gate **30** and the scaler **31** to the three "AND" gates **26, 27** and **28**. The gates **26, 27** and **28** are enabled by the output from the buffer amplifiers and Schmitt triggers **23, 24** and **25** respectively. The signal from each of these gates **26, 27** and **28** are passed to each of the registers **32, 33** and **34**. The number of timing pulses passed by the gates **26, 27** and **28** dependent upon the length of the particle intercept. The registers **32, 33** and **34** operate from the gates generated initially by the violet, blue and green beams in that order. These registers are equipped with decade counting devices (for example, Beam-X tubes) connected in series. The number of decade units depends upon the desired number of resolution increments. For instance five units will provide means for fifty channel particle size display. The first pulse after a register has been cleared and set, turns on the first position of the first decade unit, the second unit transfers the index to the next higher position etc. After the first decade is occupied the index is transferred to the next decade etc. The scan count comparator **35** compares continuously the index values (positions) of the registers **32, 33** and **34**. At the completion of an intercept by all three beams of a given particle image the comparator **35** generates an enabling pulse to the "AND" gate **36** if, and only if, the index of the register **33** is higher by at least one position than separate indices have both registers **32** and **34**. The number of discreet counters in the size distribution display **37** corresponds to the number of positions in the register **33**. Only eight positions are indicated in FIG. 5 for the sake of simplicity. Each counter can be set separate or the whole display cleared.

When a count pulse is produced by the "AND" gate **36** the counter corresponding to the active index position in the register **33** is advanced by one, thus indicating that a particle falling into a particle size range was counted. The complete size distribution is available after one frame on the cathode ray tube **1**. A separate counter may be connected through an "OR" gate to the output of the comparator **35** to indicate the total number of particles counted. When the intercept of a particle image by all three beams is completed no timing pulses are passed through the "AND" gates **26, 27** and **28** and the "NOT AND" gate **39** generates a pulse. This pulse passes through the "OR" gate **38** to the "AND" gate **36**. If this gate is open (depending upon the state of the comparator **35**) the pulse represents the count command to the display **37**. The same pulse is delayed in the monostable multivibrator **45** and used to clear and reset the three registers **32, 33** and **34**. The delay is necessary to allow the display **37** to receive the information from the register **33** before this information is cleared out.

To scan a print the "Reset" push button is actuated. This clears the display **37**, the register **32, 33** and **34** and sets the flip flop **40** which in turn enables the "AND" gate **30**.

The timing pulses are now passed to the scaler **31** from the clock **29**. The scaler **31** provides the synchronizing pulses to the horizontal sweep generator **4** and the vertical generator **3**. The first pulse initiates the sweep.

At the completion of one frame a signal is passed from the vertical sweep generator **3** to the blanking unit **5**. The blanking unit now generates a bias pulse which turns off the beam in a cathode ray tube **1** during the retrace period. Another pulse from the blanking unit **15** resets the flip flop **40** and through the "OR" gate **38** initiates a clear command for the register **32, 33** and **34**. The "AND" gate **30** is now inhibited by the flip flop **40** and the timing pulses are not allowed to pass to the "AND" gates **26, 27** and **28**. The print can now be removed and a new one inserted.

The speed of counting is determined in the type used in the display unit **37** and by the decade units utilized in the register units **32, 33** and **34** but should not in any case exceed a few seconds per unit. A printer may be easily incorporated into the system to print out the results on tape or cards. A tape can be attached to each print for later evaluation.

The preferred embodiment of this invention is illustrated and described and it is understood that other embodiments might be devised which might fall within the scope of the attached claims which define the scope of the invention.

We claim:

1. A particle counting device comprising a scanning means providing a multiple of scanning beams scanning adjacent lines on a particle carrying medium or image thereof, photosensing means generating multiple signals responsive to particle intercept by said scanning beams, electrical means amplifying and registering the time duration of particle intercept of each of said scanning beams, comparator means receiving the electrical signals from said registers and generating a count pulse in response to a predetermined comparative relationship between said multiple electrical signals, a display counter indicating the total count from said comparator and recording the number of discrete particles scanned by said beams.

2. A particle counting device comprising a scanning means providing multiple dissimilar wavelength scanning beams scanning adjacent lines on a particle carrying medium or image thereof, photosensor means generating multiple electrical signals responsive to particle intercept of said plural beams, electrical means amplifying and digitizing said plural electrical signals, a plurality of registers each receiving one of said electrical signals causing a memory of time duration of each particle intercept by said beams, a comparator receiving signals from said registers and comparing time duration of each of said electrical signals and generating a count pulse in response to a predetermined signal relationship, a counter display receiving and recording the number and magnitude of said electrical signals responsive to particle intercept of said scanning light beams.

3. A particle counting device comprising means providing a scanning beam of light, a relay lens means forming multiple color scanning beams scanning a particle carrying medium or image thereat, photosensing means detecting a plurality of color light signals and generating a plurality of electrical signals responsive thereto, an amplifier means amplifying said electrical signals, a pulse generating clock controlling the rate of scan and the resolution of the scanning means and providing a digitizing signal to said amplifier means, a gating means allowing said digitizing pulse signals to pass through an electrical circuit for a time duration of said electrical signals, register means receiving said digitized pulse signals and providing a memory therein in response to the number of digitized pulses received in said register, a comparative circuit comparing the number of digitized pulses of each particle intercept and generating a count signal in response to a predetermined relationship of signals in said registers, a counter display receiving said count signals and providing a plurality of discreet pattern classification as to size and number of particles scanned by said scanning means.

4. A particle counting device comprising a scanning device producing three color scanning means simultaneously scanning adjacent lines on a particle carrying medium or image thereof, relay lens means directing a plurality of light signals responsive to particle intercept of said scanning beams, an integrating sphere including a plurality of photosensors sensing and generating a plurality of electrical signals responsive to particle intercept of each of said colored beams, an electrical signal amplifying means

amplifying each of said signals generated by said photosensors, a pulse generating clock for controlling the sweep and resolution of the scanning device producing the plurality of light beams and digitizing the signals generated by said photosensors, a plurality of comparators each receiving a signal from a mating scanning light beam and storing a memory of the number of digitized pulses responsive to the duration of particle intercept of each of said beams, a comparator circuit receiving signals from said registers and generating a count command responsive to a predetermined comparator relationship whereby the intermediate scan particle intercept duration is greater than adjacent particle intercepts, a display counter generating a plurality of counts responsive to the magnitude of particle intercept and the number of particle intercept thereby providing a discreet pattern classification as to size and size distribution.

5. A particle counting device comprising a flying spot scanner, prism encoding means having a multiple of color interference films producing a plurality of images scanning a particle carrying medium or image thereof from the flying spot of said flying spot scanner, photosensor means sensing a plurality of color light signals and generating a plurality of electrical signals responsive thereto, electrical means amplifying and registering the time duration of a particle intercept of each of the multiple scanning of said medium, comparator means receiving electrical signals from said registers and generating a count pulse in response to a predetermined comparative relationship between the multiple electrical signals, a count indicator indicating the total count of particles intercepted and recording the number of discreet particles scanned by said beams.

6. A particle counter device comprising a flying spot scanner, a multiple color prism and lens system producing a multiple of scans on a particle carrying medium or image thereof from the spot on said flying spot scanner, a multiple color sensor means sensing a multiple of color signals and producing multiple electrical signals, electrical means amplifying and registering the time duration of particle intercept by each of said plurality of color scanning means, comparator means receiving electrical signals from said registers and generating a count command in response to a predetermined comparative relationship between said registers, a display counter and index decade indicating the discreet particle size and size distribution count scanned by the plurality of multicolored beams.

7. A particle counter device comprising means providing three simultaneous multi-colored scans on a particle carrying medium or image thereof, photosensing means sensing a multiple of signals responsive to particle intercept of the film surface, digitizing means digitizing the signal in said amplified means for a duration equal to the particle intercept of each of said multi-colored scanning beams, comparator means comparing electrical signals from said registers and generating a count command in response to a predetermined comparator relationship between said multiple electrical signals, a counter indicating the number of discreet particle size and size distribution scanned by said multiple colored scanning means.

8. A particle counting device comprising a scanning means providing three scanning beams scanning adjacent lines on a particle carrying medium or image thereof, photosensing means generating three electrical signals responsive to particle intercept of the scanning of said beams, electrical means amplifying and registering the time duration of particle intercept of each of said scanning beams, comparator means receiving electrical signals from said registers generating a count pulse when the intermediate scanning beam has the greater intercept relative to the intercept of the first and third scanning beam, a counter indicator recording the count of particles scanned by said scanning beams.

9. A particle counting device comprising a scanning means providing three colored scanning beams scanning adjacent lines on a particle carrying medium or image thereof, three dissimilar colored photosensing means generating three electrical signals responsive to particle intercept of the scanning of said beams, electrical means amplifying and registering the time duration of particle intercept of each of said dissimilar colored scanning means, comparator means receiving electrical signals from said registers and generating a count pulse responsive to a greater dimensional particle intercept of the intermediate scanning beam relative to the first and third scanning beam, a counter indicating the number of particles scanned by said colored beams.

10. A particle counting device comprising a scanning means providing a multiple of polarized scanning beams scanning adjacent lines on a particle carrying medium or image thereof, photosensing means including a plurality of photosensors each sensitive to a difference of the polarized beams and generating electrical signals responsive thereto, electrical means amplifying and registering the time duration of particle intercept of each of said scanning beams, comparator means receiving the electrical signals from said registers and generating a count pulse in response to a predetermined comparative relationship between said multiple electrical signals, a display counter indicating the total count from said comparator for recording the number of discreet particles scanned by said beams.

11. A particle counting device comprising a scanning means providing a multiple of dissimilar modulated scanning beams scanning adjacent lines on a particle carrying medium or image thereof, photosensing means sensing the plurality of modulated scanning beams and generating electrical signals responsive thereto, electrical means separating and amplifying the electrical signals indicating the time duration of particle intercept of each of said scanning beams, comparator means receiving the electrical signals from said registers and generating a count pulse in response to a predetermined comparative relationship between multiple of electrical signals, a display counter indicating the total count from said comparator and recording the number of particles scanned by said beams.

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