

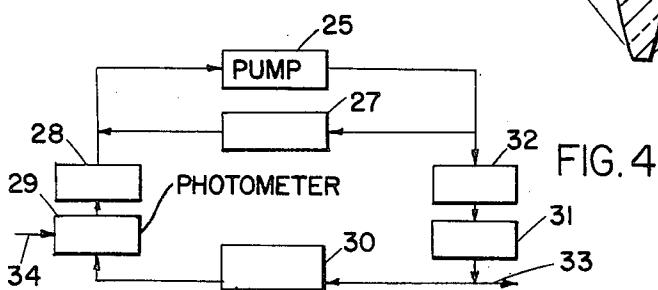
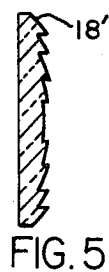
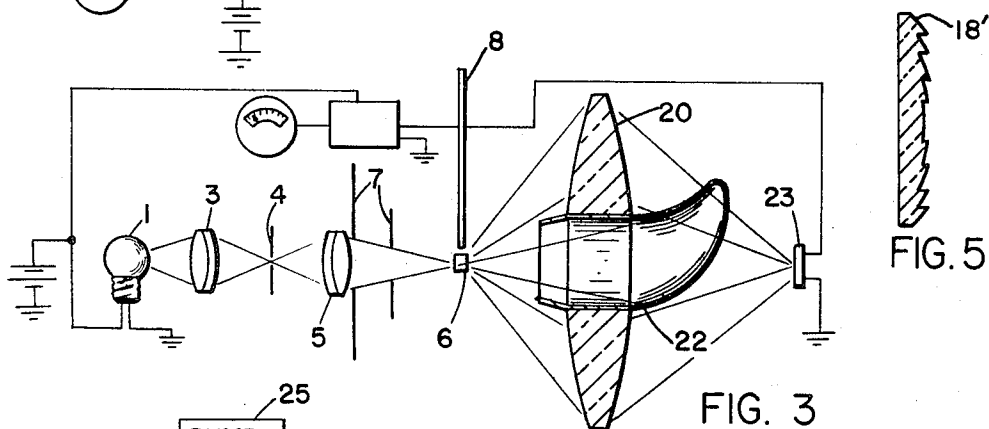
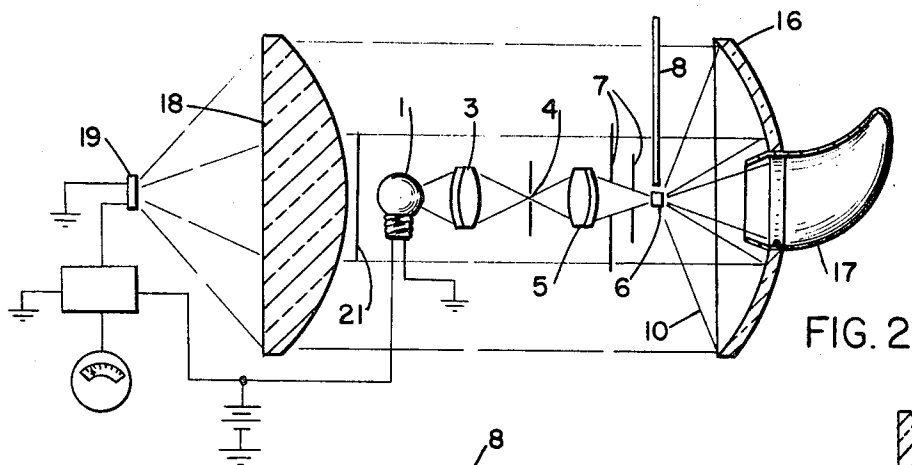
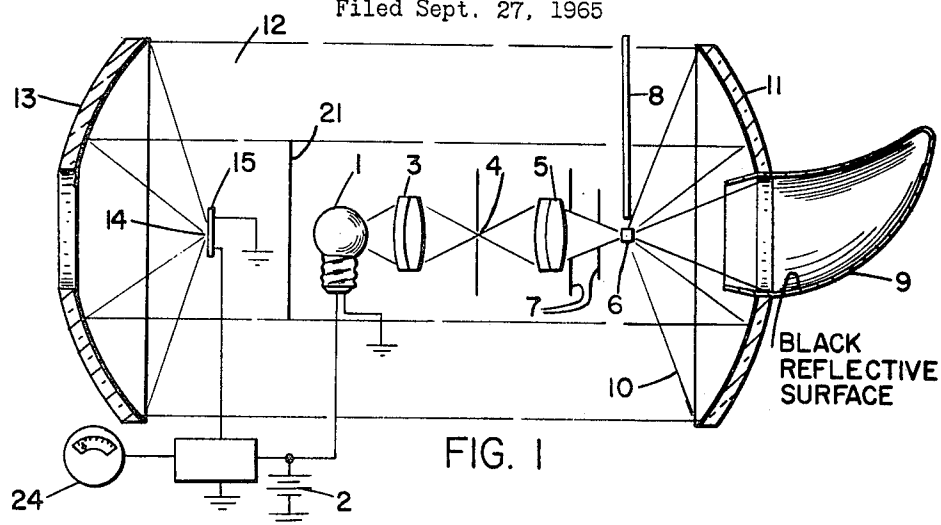
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FORWARD SCATTER PHOTOMETER

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FORWARD SCATTER PHOTOMETER

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ABSTRACT OF THE DISCLOSURE

A beam of radiation is directed through a fluid containing particles and then subsequently into radiation trap. Forward scattered radiation is collected and reflected back in a direction opposite the direction of the beam. The reflected scattered radiation is focused and directed to a photosensor.

This invention relates to a photometer and more particularly to an aerosol particle counter.

The air in the atmosphere contains particulate matter and thus may be considered an aerosol. The size of these particles in the air range from very large particles when the air is in vigorous motion, down to very small particles which remain suspended in the air even though the air is at rest. The concentration of large particles is extremely low in relation to the concentration of the small particles. The number of particles per unit volume increases rapidly, almost exponentially, as the particles size decreases.

Various photometers have been constructed to measure the concentration of particulate matter in the air. The impurities may range from the very small particle sizes such as smoke to larger particle sizes. The operation of many photometers depend primarily on measuring the change in light level of light passes through a sample of the atmosphere and falling on a photosensor.

As an illustration of the physical principles involved as practiced by the invention consider a beam of light passing through a dimly lit room while your back is toward the light source. Viewing the beam of light with the back to the source a scattering of light from the particles is visible, and the visibility of the beam of light is in direct proportion to the amount of scattering or in other words the number and size of particles suspended in the air. Scattering, as the term is used here, combines the net effect of reflection, diffraction and refraction. Forward scattering will be considered light scattered forward of a line normal to the light beam and rearward scattering will be considered as light scattered rearward of such line. If the beam of light is viewed from the forward position the forward scattered light produces a greater intensity than the back scattered light. Accordingly a greater amount of light is scattered in the forward direction than the rearward direction from the particles suspended in the air.

It would seem that the best position for a photosensor would be to intercept the forward scattered light by positioning the photosensor somewhere in a cone off-axis from the irradiating beam of light and forward of the point of scattering from the particles. It is also desirable to detect light against a dark background which is difficult if the photosensor is positioned in direct line with the forward scattered light.

Accordingly this invention provides a photometer which

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senses forward scattered light but is positioned rearwardly of the point at which the beam intercepts the particles. This is provided through a series of reflectors, lenses and baffles to eliminate stray light and position the photosensor to sense the light impulses against a dark background. This invention collects scattered light from the individual particles passing through the sample volume in such a manner that the individual particles sequentially produce light pulses which are registered and counted by the photosensor by means of an electrical circuit. The concentration of particles greater in size than a chosen size is a measure of the particles in the air. The electrical pulses from the photosensor are applied to a discriminator which detects only particles that are larger than a predetermined size. The size limit is controlled through a control in the electrical circuit.

A novel circuit provides a means of averaging the pulse frequency whereby meter movement is proportional to the pulse frequency and therefore averages the particles concentration which may be read on the calibrated meter scale.

It is an object of this invention to provide an aerosol particle counter.

It is another object of this invention to provide a photometer for counting particle concentration in a unit volume.

It is a further object of this invention to provide a photometer for individual particle counting in forward scattered light from a light beam by means of a photosensor registering light impulses against a dark background.

The objects of this invention are accomplished by providing an illuminating means which is imaged on a view volume in the flow path of an aerosol. The view volume is of such a small magnitude that the individual particles passing through the aerosol flow path individually produce a light impulse which is collected and focused on a photosensor. The photosensor senses the light impulse against a dark background. The source of illumination radiates a light beam into the light trap, which attenuates the portion of the light beam which does not intercept any particles in the view volume. A series of baffles help in eliminating any stray light and thereby produce a dark background for the photosensor as it senses the light impulses. The embodiments of this invention are illustrated in the attached drawings and described in the subsequent paragraphs.

FIG. 1 illustrates a photometer using a double reflector system for collecting the scattered light and focusing this light on the photosensor.

FIG. 2 illustrates a modification of the photometer utilizing a lens for focusing light on the photosensor.

FIG. 3 illustrates a lens operating as a collector and focusing means for the detector.

FIG. 4 illustrates a vacuum system for drawing a continuous air sample through the view volume and provide a supply of clean filtered air within the photometer body.

FIG. 5 illustrates a modification of the light focusing means for the photosensor.

Referring to FIG. 1 a source of illumination 1 is energized by a source of electrical energy 2 and radiates a beam of light through the condenser lens 3 which is imaged on the slit 4. The slit 4 defines the maximum height of the beam at this point. The slit is a narrow slit and its width is limited to a dimension relatively close to the slit height. The relay lens 5 images the slit 4 on the

view volume 6. The baffles 7 absorb stray light from the optical system. The height of the view volume 6 may be considered to be defined by the height of the image of the slit 4 which is imaged at the view volume. The view volume may also be considered to be defined by the area of the aerosol flow passing through the flow tube 8. Accordingly the view volume may be considered as a cylindrical volume of aerosol equal to the inner diameter of the tube 8 as it flows through the light beam and a segment of this imaginary cylinder of no greater height than the image of the slit 4.

If no impurities were present in the flow of the medium passing through the flow tube 8 the light beam would be directed into the light trap 9. The light trap 9 defines a horn having a black reflecting inner surface which produces continuous reflection and absorption to attenuate the light beam and prevent any light escaping from the light trap.

Considering that the photometer is intended to measure an aerosol flowing through the tube 8 the particles in the air flow path produce forward scattering of light which defines a hollow cone 10 which is reflected by the mirror 11. The mirror 11 shown in this modification is considered to be a parabolic mirror with the focal point being the view volume and therefore the light is collimated as it is reflected from the mirror 11. The collimated light 12 is reflected by a second parabolic mirror 13 to the focal point 14 at which is positioned the photosensor 15. The photosensor 15 does not see any stray light from the source of illumination 1. The only light the photosensor 15 sees are the light impulses from the forward scattered light from the view volume 6 against the dark background from the mirror 13. It is understood that the mirrors 11 and 13 need not be parabolic and might be elliptical or similar shape to provide the reflecting and collimating function as defined.

Referring to FIG. 2 a modification is illustrated utilizing a reflecting mirror 16 and a similar light trap 17. The forward scattered light is reflected by the mirror 16 and then focused by the lens 18 onto the photosensor 19. A shield 21 prevents direct radiation from falling on the photosensor 19. The lens 18 provides more control over aberration in the image at the photosensor 19 and also permits the sealing of the detector assembly from the clean air port of the system.

FIG. 5 shows a Fresnel lens 18' for use in place of lens 18 in a modification.

Referring to FIG. 3 a modification is illustrated whereby a collector lens 20 receives the forward scattered light from the view volume 6. The rays in the beam of light which do not intercept particles are trapped in the light trap 22. The scattered light is then focused on the photosensor 23 and the signals are read by the meter 24.

The electrical circuit receives the light impulses which are sensed by the photosensor and produce electrical signals. The electrical signal is applied to a pulse amplitude discriminator which detects only signals generated by particles having predetermined size. The signal is a series of pulses of a given magnitude which are separated in time in accordance with the number of particles passing through the view volume. All the pulses exceeding a predetermined magnitude are shaped and formed to generate a pulse of constant amplitude by the electrical circuit. The pulses applied to the meter are of equal amplitude and equal width and thus the meter responds to the time average of the pulse repetition and accordingly all of the particles greater in size than a chosen size is measured and this provides a measure of the particles in the air.

Referring to FIG. 4 a vacuum system is illustrated whereby a pump 25 is driven by a motor. A bypassing valve 27 is connected to the inlet and the outlet of the pump 25. A vacuum is created by the pump which draws a vacuum through the muffler 28 and the vacuum is created in the photometer 29. The photometer 29 includes the main body of the photometer and produces clean air

throughout the body of the photometer. A particle filter 30 and 31 and the muffler 32 are connected between the photometer and the pump to provide purified air as it is fed into the body of the photometer. An exhaust port 33 is connected between the particle filters 30 and 31. An intake tube 34 provides an intake for aerosol flow which passes through the tube 8 and through the view volume. The intake tube is of small diameter and the flow of the aerosol is caused by a reduced pressure inside the photometer.

Referring to FIG. 2 the operation of the device will be described. FIG. 1 and FIG. 3 operate basically the same as FIG. 2 and so a description of the operation of FIG. 2 will adequately describe the operation of the modifications.

The vacuum system illustrated in FIG. 4 operates to evacuate the photometer body illustrated in FIG. 2. The vacuum system produces a quantity of clean air in the body of the photometer and also creates a condition of reduced pressure within the body of the photometer which induces a flow of aerosol through the tube 8. The aerosol flow path flows through the view volume 6. The source of illumination 1 radiates a luminous flux which is focused by the condenser lens 3 on the slit 4. The height of the slit 4 is adjustably controlled to a predetermined height and the width of the slit is also reduced to a predetermined maximum to reduce stray light in the system.

The image of the slit in the view volume 6 controls the height of the view volume. The baffles 7 reduce stray light from the relay lens 5. The view volume is also defined by the inner diameter of the flow tube 8 which defines the flow path of the aerosol as it passes through the beam of light. Although it is not necessary that the view volume be defined by these limits these limits will be used to illustrate the dimensions of the view volume. Theoretically the size of the image of the slit in the image plane define the area through which the light passes and intercepts the particles in the aerosol path.

The light which does not intercept the particle passes directly into the light trap 17 and is continually reflected and absorbed by the black reflecting surface of the internal portion of the light trap. The light trap may be formed of a glass having a black reflecting surface which continually reflects and absorbs the light to eventually attenuate the light trapped in the light trap. The particles passing through the view volume will scatter light forwardly and backwardly around the optical axis of the system. The major portion of the light will be directed forwardly and scattered in a hollow cone defined by the limits of the cone 10. The scattered light is collimated by the reflector 16 and then focused by the lens 18 onto the photocell 19. The photocell 19 does not see any direct light from the source of illumination 1 or any stray light as this is eliminated by the shield 21 and series of baffles such as the baffles 7. Effectively the photosensor 19 sees only the light rays produced by forward scattered light collimated by the reflector 16 and focused by the lens 18. This produces a series of light impulses at a frequency of the passage of particles having a predetermined size in the aerosol flowing through the view volume. These light impulses provides a series of electrical pulses of varying size in response to the magnitude of the particles. The electrical circuit reduces these impulses to a standard size electrical DC pulse which is fed through a circuit. These pulses are of equal width and equal amplitude, and for each pulse an equal charge flows into a capacitor through the meter. Thus the meter response is the time average of pulse repetition. This application is not particularly concerned with the electrical circuit, however, the optical system is designed to measure light impulses which are sensed by the photosensor and in turn generate electrical DC pulses which are measured in the meter circuit.

The reference to the source of illumination and the beam of light has been described in the specification in terms of light. It is understood that the inventor does not wish to limit this invention to the use of the visible spectrum and the term light is illustrative only. Radiation in

the invisible spectrum such as ultraviolet and infrared will work equally as satisfactorily and therefore is considered to be within the scope of this invention.

The preferred embodiments of this invention have been illustrated and described. It is understood that other modifications may be devised which would fall within the scope of this invention which is defined by the attached claims.

I claim:

1. A forward scatter photometer comprising means defining a view volume for receiving a fluid and detecting particles therein, means for directing a beam of light through said view volume in a first direction along an optical axis extending through said view volume, a light trap positioned beyond the view volume on the optical axis for receiving and attenuating the direct light from said light beam, a collector means concentric with said optical axis for collecting forward scattered light produced by scattering of light at said view volume and reflecting said scattered light along a path substantially parallel to said optical axis in a second direction opposite said first direction, a photosensor, located beyond said means for directing a light beam, a focusing means receiving light from said collector means and converging the collected light on said photosensor for generating electrical impulses in response to scattered light from the particles in said view volume.

2. A forward scatter photometer comprising an illuminating source radiating light, means for producing an aerosol flow through said photometer defining a view volume, a lens means defining an optical axis directing a beam of light from said source along to optical axis in a first direction and focusing said beam of light on particles in said view volume for counting said particles, a light trap concentric with the optical axis receiving direct light in said beam of light and attenuating the direct light through continual absorption and reflection, a collector means concentrically positioned around the optical axis for receiving forward scattered light produced by particles in the view volume of said beam of light and directing said scattered light along a path substantially parallel to said optical axis in a direction opposite said first direction, a focusing means positioned beyond said source receiving light from said collector means and focusing said light at a focal point, a photosensor receiving light from said focusing means and generating electrical impulse responsive to each particle passing through said view volume, and occluder means occluding direct light from said source to said photosensor.

3. A forward scatter photometer comprising means directing a beam of light along a first direction coaxial with an optical axis, means producing a flow of a fluid transverse to said optical axis, a light opening control positioned on the axis of said beam of light, a condenser lens focusing said beam of light on the light opening, a relay lens for imaging the opening on said fluid defining a view volume for detecting particles in said fluid, a light trap having an internally black reflecting surface for receiving direct light of said light beam and continually reflecting and absorbing to attenuate said light beam, a collector means located concentrically with said light trap for collecting forward scattered light, collimating said light and transmitting said scattered light along a path substantially parallel to said optical axis in a second direction opposite said first direction, a photosensor positioned remote from said collector means for generating an electrical signal responsive to light impulses produced by scattered light from particles in the view volume, a focusing means positioned beyond said means directing a beam of light, receiving light impulses from said collector means and focusing said light impulses on said photosensor to provide light impulses on a dark background to said photosensor.

4. A forward scatter photometer comprising a radiation source radiating a beam of light in a first direction

along an optical axis, a slit having a predetermined width and height on said axis, a condenser lens for focusing the light source on said slit, a relay lens for imaging the slit at a point defining a view volume, a light trap coaxially positioned on the optical axis for receiving direct light and attenuating the light beam, means producing an aerosol flow path through said view volume, a collector and collimating means concentrically located with the optical axis for receiving forward scattered light and reflecting said light in a collimated beam substantially parallel to said optical axis and in a second direction opposite to said first direction, a focusing means located beyond the radiation source in said second direction receiving the collimated light and focusing the light at a focal point, a photosensor generating electrical signals responsive to light impulses received from said focusing means in response to light scattered by individual particles passing through said view volume, and occluder means occluding direct light from said radiation source to said photosensor.

5. A forward scatter photometer comprising, means for directing a beam of radiation in a first direction along an optical axis to converge to a focal point and subsequently to diverge, a radiation trap positioned beyond the focal point on the optical axis for receiving and attenuating direct radiation from said radiation beam, means producing a flow of a fluid about said focal point to produce scattered radiation in response to particles in the fluid, a reflecting mirror positioned around the optical axis for receiving forward scattered radiation and reflecting said scattered radiation along a path substantially parallel to said optical axis in a second direction opposite said first direction, a photosensor, a second reflecting mirror positioned beyond said means for directing a beam of radiation receiving radiation from said first reflecting mirror and focusing said radiation on said photosensor for thereby generating an electrical impulse by said photosensor responsive to scattered radiation from the particles.

6. A forward scatter photometer comprising, means for directing a beam of radiation in a first direction along an optical axis to converge to a focal point and subsequently to diverge, a radiation trap concentric with the optical axis receiving direct radiation in said beam and attenuating the radiation by continual absorption and reflection, means producing a flow of a fluid about said focal point to produce scattered radiation in response to particles in the fluid, a reflecting mirror positioned around the optical axis for collecting forward scattered radiation produced by radiation intercepting particles in the fluid and reflecting said scattered radiation along a path substantially parallel to said optical axis in a second direction opposite to said first direction, a photosensor, a focusing lens positioned beyond said means for directing a beam of radiation receiving radiation from said reflecting mirror and focusing the radiation on said photosensor for generating electrical impulses responsive to particles in the fluid.

7. A forward scatter photometer comprising, means for directing a beam of radiation in a first direction along an optical axis to converge to a focal point and subsequently to diverge, a radiation trap positioned beyond the focal point on the optical axis for receiving and attenuating direct radiation from said radiation beam, means producing a flow of a fluid through said focal point to produce scattered radiation in response to particles in the fluid, a reflecting mirror collecting scattered forward radiation from radiation intercepting the particles in the fluid and reflecting said scattered radiation along a path substantially parallel to said optical axis in a second direction opposite to said first direction, a photosensor, a Fresnel lens positioned beyond said means for directing a beam of radiation receiving radiation from said reflecting mirror and focusing said radiation on said photo-

sensor for generating an electrical impulse by said photo-sensor responsive to scattered radiation from the particles.

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