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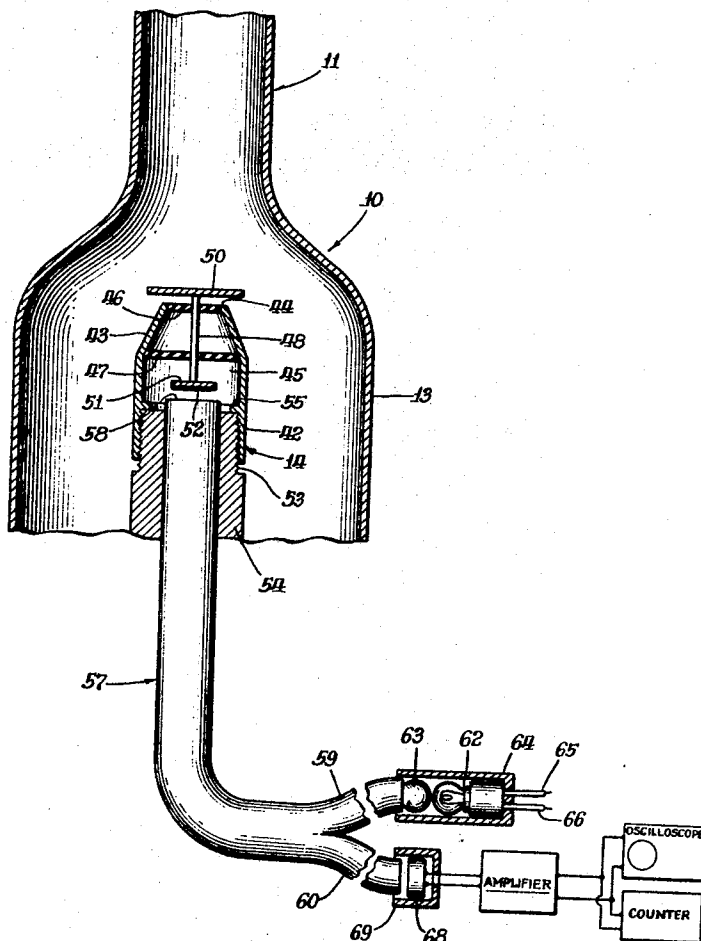
[54] DEVICE FOR COUNTING PARTICLES IN A FLOWING FLUID 15 Claims, 6 Drawing Figs.

[52] U.S. Cl..... **250/218,**
250/231; 73/28
[51] Int. Cl..... **G01n 21/26,**
G01b 15/00
[50] Field of Search..... 250/218,
222 (M), 222, 231, 227; 356/37, 38, 102; 235/92,
30; 73/28

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ABSTRACT: A fluid having the particles to be detected suspended therein is introduced into a tube. The tube has a capillary section through which the flow is laminar in the absence of a particle and which changes to a turbulent flow as a particle traverses the section. Immediately downstream of the section is a flow characteristic detector to indicate whether the flow is laminar or turbulent. In one embodiment the detector is a vane which is pushed sideways by the laminar flow exiting from the section to open an electrical switch and which returns to switch closed position in the presence of turbulent flow. In a second embodiment the detector is a vane which is moved away from the capillary section by laminar flow but which returns toward the section in the presence of turbulent flow. The position of the latter vane is determined by reflecting light angularly therefrom toward a light receiving position with the light present at the receiving position being measured with the measurement being a function of the vane position.



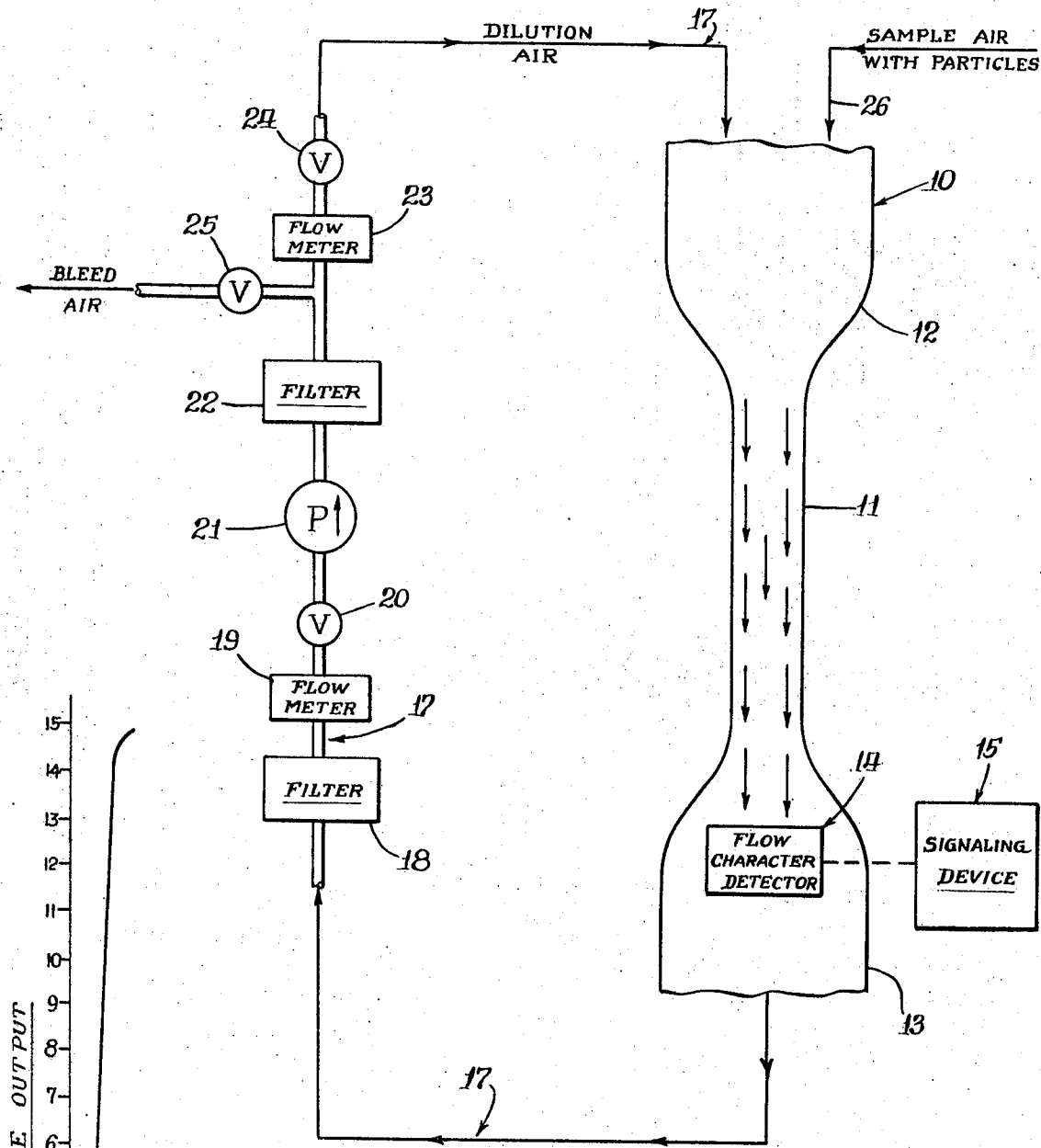


Fig. 1.

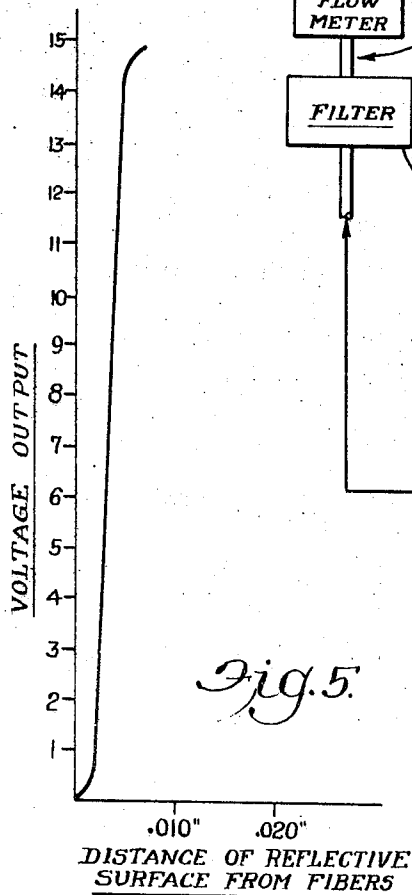
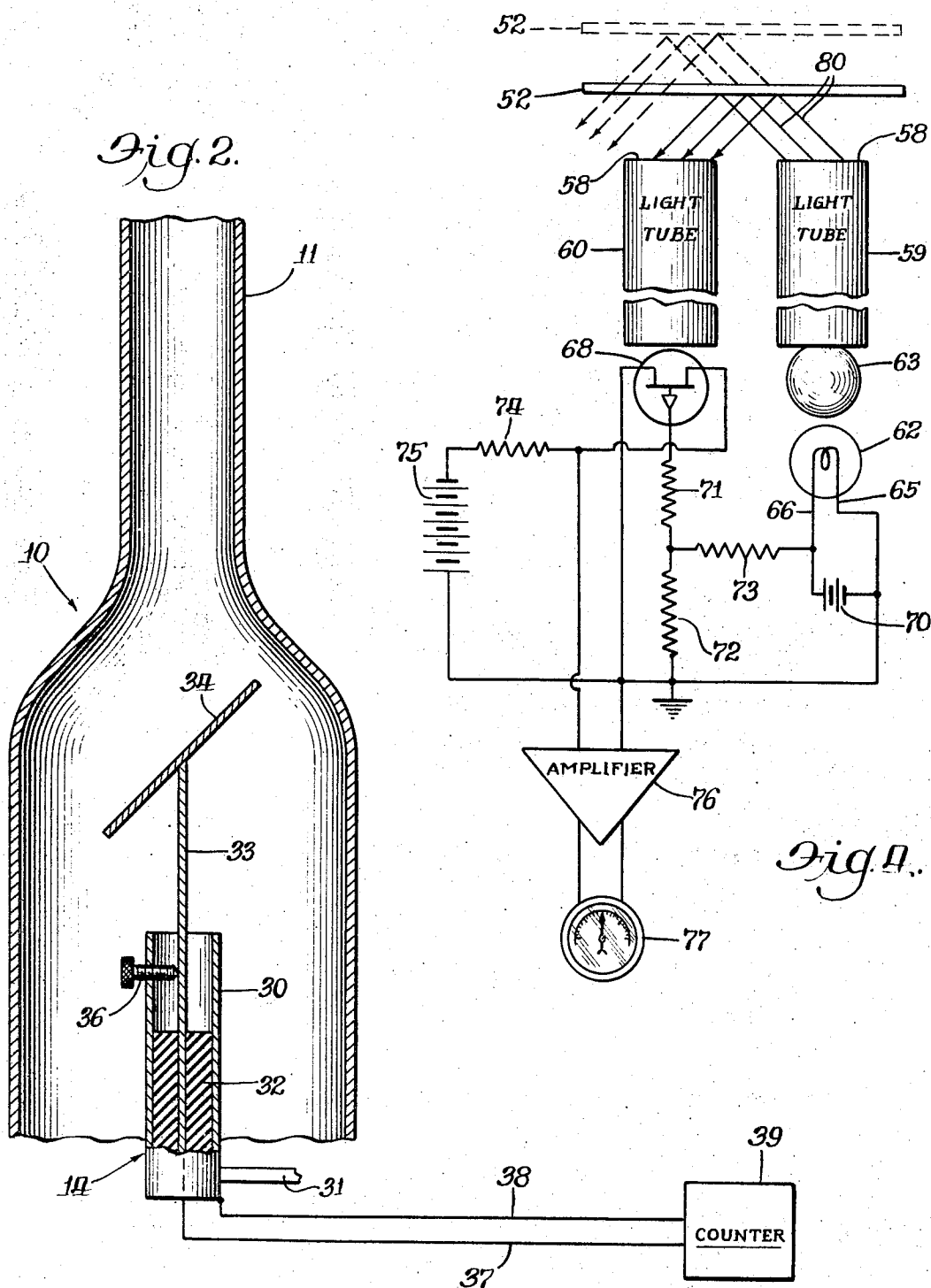
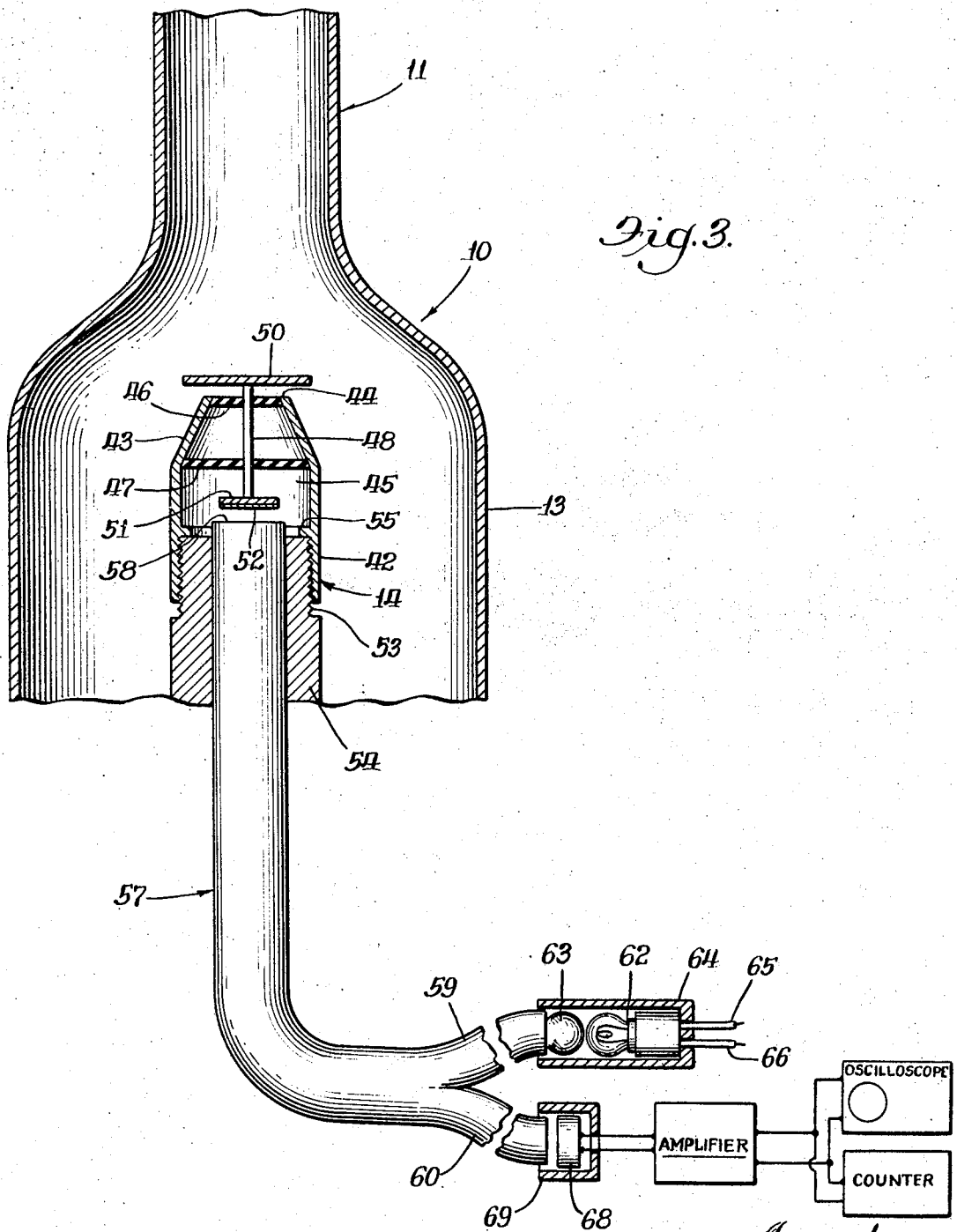


Fig. 5.

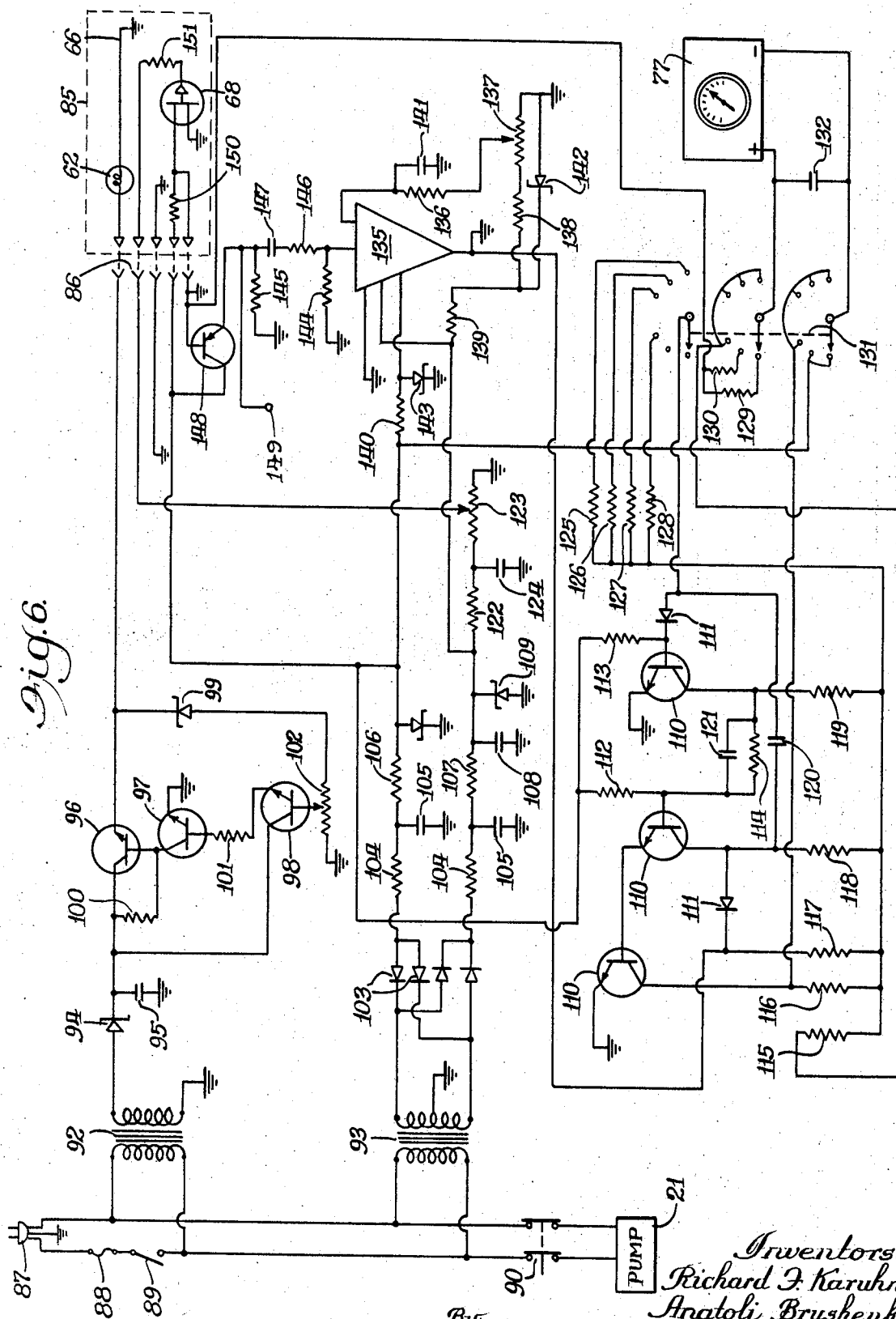
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DEVICE FOR COUNTING PARTICLES IN A FLOWING FLUID

BACKGROUND OF THE INVENTION

In many fields it is desired to know the number of particles present in a given volume of fluid and, additionally, in some instances, the relative size of the particles. For example, in air pollution detection or monitoring of stack emissions, particle concentrations are measured in the number of particles per cubic foot of air or the like. Another example can be found in businesses that check for the presence of particulate materials in air, e.g. flour. One of the pieces of apparatus commonly used for particle detection is a light scattering photometer. These are expensive and complicated pieces of equipment.

A number of researchers have experimented with a capillary tube through which air is drawn. When a particle passes through the tube an audible click occurs, which can be heard upstream, but not downstream, of the capillary section. These researchers have employed microphones positioned upstream to detect the clicks and produce a resulting electrical signal. Typical of the work in this respect is that reported in the Journal of Colloid Science, Volume 20, No. 6, Aug. 1965, commencing at page 602. So far as is known, the work in this respect has not been sufficiently satisfactory to result in commercial utilization of apparatus of this type.

The present invention similarly employs a capillary tube through which the fluid is passed. It differs from the prior art, however, in that a flow characteristic detector is placed adjacent the downstream end of the capillary tube. This detector distinguishes between the type of fluid flow through the tube when no particle is present and the type of flow through the tube when a particle is present. While this flow characteristic detector could take a number of forms, in the disclosed embodiments it is in the form of a vane which assumes different positions depending upon the characteristic of the flow through the tube. The position of the vane can be determined photoelectrically or by a switch which is open or closed by the position of the vane. As compared to the microphone type detectors, this apparatus has the advantage that there is not a substantial time delay between the time it is actuated by the passing of one particle and before it is ready to detect the passage of another particle. In most microphone type detectors there is a decay time involved which limits the rapidity with which successive particles may be individually detected and discriminated between.

The photoelectric detector produces an electrical response which is substantially linear over a given range of movement of the detection vane. The tests to date also indicate that the movement of the detection vane is a function of the size of the particle passing through the capillary section. Thus, to a significant extent the electrical output will reflect the size of the particle. By distinguishing electrically between the output signals and counting the signals falling into different categories, it is thus possible to obtain information as to the particle size distribution in a sample of particles.

This photoelectric detector can be employed in other applications, e.g. distance measuring instruments generally, to obtain an electrical signal that is a function of a distance to be measured. For example, the vane of the disclosed detector could be coupled to a micrometer so as to give an electrical readout of the micrometer measurement.

Further objects and advantages will become apparent from the following description taken in conjunction with the drawings

SUMMARY OF THE INVENTION

The present invention relates to a comparatively simple and inexpensive method and apparatus for detecting particles present in a fluid and, if desired, obtaining information as to their relative size and to a photoelectric distance measuring instrument used as a component thereof.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a drawing illustrating schematically the general arrangement of the test method and apparatus;

FIG. 2 is a cross-sectional view, partially schematic, of a flow character detector usable in the system illustrated in FIG. 1;

FIG. 3 is a sectional view, partially schematic, of an alternative form of flow character detector usable in the system of FIG. 1;

FIG. 4 is a schematic drawing illustrating the principle of operation and basic electrical wiring employed in the embodiment of FIG. 3;

FIG. 5 illustrates a typical electrical response as a function of movement of the relative surface; and

FIG. 6 is a schematic diagram of a complete electrical system.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Although the following disclosure offered for public dissemination is detailed to ensure adequacy and aid understanding, this is not intended to prejudice that purpose of a patent which is to cover each new inventive concept therein no matter how others may later disguise it by variations in form or additions or further improvements. The claims at the end hereof are intended as the chief aid toward this purpose; as it is these that meet the requirement of pointing out the parts, the improvements, or combinations in which the inventive concepts are found.

FIG. 1 illustrates the general overall system of the method and apparatus of the present invention. A detector tube method and generally 10 has a section or portion 11 in the form of a capillary tube. The overall tube 10 is of glass and, as illustrated, the transition from the large end portions 12 and 13 of the tube into the capillary portion 11 are smooth curves. The detector tube might be of plastic, or metal. It is important that the interior of the approach to and the exit from, as well as the capillary section itself, be very smooth. When a fluid such as air is passed through tube 10, the flow through capillary portion 11 has one state if no particle is present and a second state should a particle be present passing through the capillary portion 11. As best can be determined, the flow, which is laminar in the absence of a particle, becomes a turbulent flow in the presence of a particle therein. When it is in the first state, there is a strong jet of air at the downstream end of the capillary section 11, which strong jet disappears, to a greater or less extent, with the presence of a particle in the capillary section 11. The extent to which it disappears seems to be a function of the size of the particle for a given size of capillary tube. A flow characteristic detector generally 14 is positioned at the downstream end of the capillary section 11 to determine which type of flow is present in the tube at any given instant. This detector is connected to a signaling device generally 14 15, which will give a sensible indication of the type of flow as determined by detector 14.

It is important to note that the foregoing principle of operation is not that of putting a cork in a bottle or an apparent obstruction in a tube. The particle passing through the capillary section 11 will change the character of the fluid flow therein despite the fact that the maximum particle size in many, many times smaller than the internal diameter of the capillary section. The reason for this is not fully understood. The best present evaluation is that there is a fluid flow about the particle which causes tub turbulence about the particle and this minor amount of tub turbulence is sufficient to trigger the whole flow (or a substantial segment thereof) through the capillary tube into changing from a laminar flow to a turbulent flow.

At the same time there is a correlation between the internal diameter of the capillary section 11, the amount of air flow, and the minimum particle size that will change the flow in the capillary section from one state to another. For detecting granular particles, dust and the like, a capillary tube having an

internal diameter of between about 0.5 and 3 millimeters is eminently satisfactory.

Within limits, the length of the capillary tube is not particularly critical, but its length for any given installation will be tailored to the type of detector employed, tube diameter, frequency of particle flow, etc. In general, the greater the length of the tube, the greater is the flow characteristic change at the downstream end of the capillary tube. With the shorter tubes, there may be a necessity for relatively high sensitivity in the flow characteristic detector to obtain equivalent information. If a relatively long capillary section is employed, there is a greater possibility of two particles being in the section at the same time, while producing but a single output indication. Additional dilution of the input sample may be required to guard against such a false indication. Shorter capillary sections often will be used to avoid the necessity for large dilution of the sample (fluid plus particles) being tested.

The length of the approach tube should be such that there is laminar flow, with no turbulence in the area of the capillary tube entrance. In an embodiment having a flow rate of 0.78 c.f.m., wherein the internal diameter of the capillary section is 2 mm., an approach tube having an internal diameter of 15 mm. and a length of 24 cm. is eminently satisfactory. Should the air flow be turbulent rather than laminar at the time it enters the capillary section the detector will "think" it is sensing particles. Established procedures for obtaining laminar flow in tubes and orifices can be followed in designing a flow tube for use with the present invention. For example, if it is otherwise not possible to have a sufficiently long approach time tube, or turbulence is otherwise present, straightening vanes may be used.

Conduit means generally 17 is connected to tube 10. In the loop formed by the conduit means 17 is a filter 18, a flow meter 19, a valve 20, a vacuum pump 21, a filter 22, a flow meter 23, and a valve 24. Connected between filter 22 and flow meter 23 is a valve 25 through which all or a portion of the air may be bled off or discharged. In this arrangement the vacuum pump 21 pulls a vacuum at the low pressure end section 13 of tube 10. As indicated by line 26, the sample air in which the particles to be detected are suspended are introduced into the high pressure end section 12 of tube 10. After the particles have passed through the tube 10, they are filtered out through filters 18 and 22. Flow meter 19 indicates the volume of air passing through tube 10, which volume can be controlled by valve 20. In some instances valve 24 will be closed and valve 25 wide open so that the only air passing through tube 10 is the sample air with the particle suspended therein. However, in some instances, particularly when the particle content of the sample air is higher than can reasonably be monitored accurately, the sample air is diluted with clean air so as to reduce the particle content per unit of volume of air. This is done by partially closing valve 25 and/or partially opening valve 24 so that clean air from the conduit means 17 is introduced into the end 12 of tube 10 along with the sample air. The amount of dilution is determined by the reading of flow meter 23 in relation to the reading obtained from flow meter 19. In some embodiments, pressure gauges could be substituted for the flow meters to obtain the required information as to volume of flow.

FIG. 2 illustrates a specific embodiment of the flow character detector 14. In this embodiment there is a casing 30 which is rigidly mounted as by means of arm 31. Held within casing 30 by means of electrical insulation 32 is an electrically conductive reed 33. On the end of reed 33 adjacent the downstream end of capillary section 11 is a vane 34. As illustrated, the vane 34 is positioned at an angle to, and intersecting the longitudinal axis of capillary section 11 extended. In the illustrated embodiment this angle is about 45°. The reed 33 is of resilient material and is self-urging to a neutral position. In the neutral position (as illustrated) the reed is against an adjustable electrical contact formed by screw 36. The strong flow of air existing from capillary section 11, in the absence of a particle, pushes vane 34 and reed 33 away from

contact 36 breaking the electrical connection between the reed and contact 36. However, the disruption is caused by the presence of a particle traversing capillary tube 11, permits reed 33 to return to its neutral position at which it is against contact 36.

A wire 37 is connected to reed 33 and a wire 38 is connected to casing 30 (and thus screw 36). Wires 37 and 38 go to an electrical counter 39 forming the function of the signaling device 15 of Figure 1. Each time that a particle traverse capillary section 11 reed 33 makes an electrical connection with contact 36, and the number of such electrical contacts are recorded by counter 39.

It will be noted that vane 34 shields the electrical contact areas, as defined by screw 36. Thus, the particles are deflected away so that they do not contaminate the contacts and interfere with operation. It should also be noted that the switch formed by reed 33 and contact 36 is normally open. It is closed only momentarily by the presence of a particle in capillary section 11 and immediately opens as the air jet at the downstream end of the capillary section is restored by the particle getting out of the capillary section. The result is that there is no contact bounce which would give misleading electrical indications at counter 39, such as might be the case were the switch of the normally closed type rather than the normally open switch described.

The embodiment illustrated in FIG. 2 is an eminently satisfactory unit. It has the minor disadvantage, however, that the highly repetitive counting of particles will cause contact wear. This problem can be ameliorated by the use of materials for the contacts which will be particularly resistant to such wear. Because it eliminates this problem and because output information as to particle size is obtainable, the embodiment subsequently described is preferred.

FIG. 3 illustrates an alternative form of flow character detector 14 mounted adjacent the downstream end of the capillary section 11. In this embodiment there is a rod 42 having a truncated conical head 43. The rod is positioned coaxially with the capillary section 11 with the end 44 thereof adjacent the downstream end of the capillary section. Extending across the hollow interior 45 of rod 42 are a pair of resilient diaphragms 46 and 47. These are secured to the rod and to a carrier 48. Diaphragms 46 and 47 are, for example, formed of silicone rubber and normally hold the carrier in one position, while permitting the carrier to be moved to a displaced position. When the carrier is in the displaced position, the diaphragms resiliently urge it to the undisplaced, normal position.

At the upstream end of carrier 48 is a vane 50. At the downstream end of the carrier is a mounting member 51. Affixed to the underside of the mounting member is a reflective surface 52. This reflective surface is, for example, a small portion of reflective tape such as Scotch Brand No. 850. It also could be a polished stainless steel or a polished silver surface.

The interior of rod 42 is threaded to receive the threads 53 of a mounting rod 54. Abutment 55 on the interior of rod 42 provides a stop against which rod 54 may be moved to accurately position the two rods with respect to each other (and thus position surface 52 with respect to ends 58 of the fibers).

A light carrier device, generally 57, extends through mounting rod 54 and is secured thereto. This light carrier comprises a plurality of individual light transmitting fibers, e.g. glass or plastic fibers of light transmitting characteristics. In the main section of the carrier, i.e. that portion adjacent ends 58, the fibers of the two groups are intermingled. This may be a random intermingling or they may be intermingled in a predetermined pattern, such as having fibers of one group positioned on all sides of each fiber of the other group. At the opposite end the fibers are divided into two groups 59 and 60.

Into the group of fibers 59 light is introduced from a light bulb 62. A glass bead is interposed between bulb 62 and the end of the fibers 59, the bead being against the ends of the fibers. The purpose of the bead will be explained in connection with the description of the operation as illustrated in FIG.

4. The light, bead, and the ends of the fibers are enclosed in a light-tight housing 64. The light is energized by means of wires 65 and 66 connected to a suitable source of electrical power.

At the ends of the group of fibers 60 is a photocell 68 mounted in a light-tight housing 69. The photocell is of the type that produces an electrical signal having a magnitude which is a function of the light received. This could be an electric generating cell, e.g. a cadmium sulfide cell, which produces a voltage which is a function of the amount of light received, or it could be of the resistance type wherein the resistance varies as a function of the light received to thereby produce a signal generated by the flow or of current three therethrough.

The FIG. 4 is a diagrammatic illustration of the principle of operation of the detector and shows, in simplified form, the wiring of the photocell and of the light. The light 62 is connected by wires 65 and 66 to a power source as represented by battery 70. In this embodiment the photocell 68 is solid state, a photo FET, as for example Siliconix Type P102. Resistor 71 is a 1 megohm resistor. Resistors 72 and 73 are each 1,000 ohm resistors, and resistor 74 is 10,000 ohms. A 22-volt power source is represented by battery 75. The output is fed through an amplifier 76 to a meter 77.

The light from lamp 62 passes through glass bead lens 63 and into the group of fibers 59. The glass bead 63 causes the light to be introduced into the fibers at an angle. Because of the characteristics of such light transmitting fibers, the light is emitted from the distal end 58 of the fibers at substantially the same angle. It is important that the light be emitted from the ends 58 at an angle. These emitted light rays 80 strike the reflective surface 52 and, shown in the solid line positions, are reflected back to the distal end 58 of the receiving bundle of fibers 60.

As the flow through capillary section 11 changes, as previously described, the fluid pressure on vane 50 changes and the position of the vane, carrier and reflective surface also change. To the extent that the light reflecting surface 52 is moved with respect to the distal ends 58, a greater or lesser amount of light rays 80 will be received by the fibers in the bundle 60. To illustrate this to an exaggerated extent, the light reflective surface 52 is shown in FIG. 4 in dashed lines as moved to a displaced position such that the light rays 80 completely miss the bundle of fibers 60 when they are reflected back.

In actual operation in connection with the particle detector, or as a distance measuring device, the reflective surface would be moved in a range in which some light would always be reflected therefrom to the light receiving bundle 60; however, the amount of light received by the bundle 60 would be a function of the distance between the distal ends 58 and the light reflective surface 52. Also, as previously mentioned, the fibers of the two groups are intermingled at ends 58, rather than being in distinct groups as illustrated in FIG. 4. The amount of reflected light is converted into an electrical signal by phototube 68, which electrical signal is of a magnitude which is a function of the light received. The magnitude of the electrical signal can be read as by means of a meter 77. The readout might be taken on a recording (chart) volt meter or a recording milliammeter depending upon the character of the electrical signal produced by the photocell. Readout also may be made visually on an oscilloscope.

FIG. 5 is an example of the voltage output as compared with the distance of movement of the reflective surface 52 with respect to the distal ends 58 of the fibers. The distal ends 58 are in a plane parallel to the plane of the reflective surface 52. The X-axis of the graph of FIG. 5 represents the distance e between the reflective surface and the distal ends of the fibers. The Y-axis is the voltage output. If the distance between the two is 0.003 of an inch, the voltage output is 4 volts. While, if the distance between the two is increased to 0.004 of an inch, the voltage output is 8 volts. Within predetermined limits, as indicated by the curves at the top and bottom of the graph, the voltage output is a linear function of the distance between the reflective surface and the distal ends of the fibers.

To prevent operation in the curved section of the graph at the bottom end thereof, the top 44 of the rod 42 serves as a stop to prevent further movement of vane 50. When vane 50 is against stop 44, the distance between the reflective surface 52 and the distal ends 58 of the fibers is still sufficiently great so that the operation will not be in the bottom curved portion of the graph. The normal unbiased position of vane 50 is such that the operation will not be in the upper curved portion of the graph. Thus within these limits, the voltage output is a linear function of the distance between the reflective surface 52 and the distal ends 58 of the fibers.

FIG. 6 illustrates a complete schematic of an embodiment such as that illustrated in FIG. 3. In this embodiment of the elements 42—69, previously described, are formed as a unitary package as indicated by dashed lines 85 in FIG. 6. Through a suitable multiple prong plug connection 86, this package is connected to the other electrical components. As represented by plug 87, the apparatus is connected to a suitable source of electricity. In the electric supply line there is a 5 ampere fuse 88 and a main power switch 89. The main power line connects to pump 21 through a double-pole switch 90.

Power transformer 92 is a Triad Type F-14X, while power transformer 93 is a Triad Type F-45X. In the supply line from transformer 92 is a 368A rectifier 94, a 10,000 microfarad capacitor 95, two 2N2405 transistors 96 and 97, a 2N3904 transistor 98, and a 1N4728 diode 99. Resistors 100 and 101 are 30 ohms, while potentiometer 102 is 1,000 ohms. In the power supply leading from transformer 93 are four 1N2071 diodes 103 in a bridge circuit, two 10 ohm resistors 104, two 500 microfarad capacitors 105, a 300 ohm resistor 106, a 100 ohm resistor 107, a 1,000 microfarad capacitor 108, and a 1N4742 diode 109.

Transistors 110 are all 2N2712 type. Diodes 111 are each a 1N456. Resistors 112 and 113 are 150,000 ohms and 10 megohms respectively. Resistor 114 is 47,000 ohms. Resistors 115—119 are respectively 30,000 ohms, 3,300 ohms, 22,000 ohms, 2,200 ohms and 10,000 ohms. Capacitors 120 and 121 are respectively 0.01 microfarads and 320 picofarads. Resistor 122 is 10,000 ohms as is potentiometer 123. Capacitor 124 is 3,000 microfarads.

Range resistors 125—128 are respectively 25,000 ohms, 50,000 ohms, 250,000 ohms and 500,000 ohms (1 percent). Multiple switch 131 is the range switch for meter 77. Capacitor 132 is 50 microfarads.

Number 135 represents a module amplifier such as a Fairchild micro-A-710C. Resistor 136 is 1,000 ohms. Potentiometer 137 is 500 ohms. Resistor 138 is 6,400 ohms. Resistor 139 is 400 ohms. Resistor 140 is 1,300 ohms. Capacitor 141 is 0.01 microfarads. Diode 142 is a 1N4728, while diode 143 is a 1N4735. Resistors 144 and 145 are 1,000 ohms and 10,000 ohms respectively. Resistor 146 is 1,000 ohms. Capacitor 147 is 0.05 microfarads. Transistor 148 is a 2N3906. Resistor 150 is 10,000 ohms, while resistor 151 is 10 megohms. Light 62 is a Chicago Miniature Lamp CM8299. Phototube 68 is a Siliconix Type P102. Meter 77 is a 0—100 microammeter, such as Simpson Type 1327. At 149 is indicated an output connection. Here a signal (with respect to ground) may be obtained to actuate other devices e.g. a numerical counter.

We claim:

1. A particle counter for detecting particles dispersed in a fluid and for use with a device for creating a pressure differential, said counter including:

a fluid flow tube adapted to be connected to said device to result in a fluid flow through said tube from a high pressure end to a low pressure end with said fluid in which particles are dispersed being introduced into the high pressure end for flow to the low pressure end, said tube having a portion intermediate its ends defining a laminar flow passageway means for said fluid which flow changes to turbulent flow when a particle traverses said passageway means; and

flow detector means in said tube adjacent the downstream end of said passageway means, said detector means hav-

ing a first state when the flow is laminar and a second state when the flow is turbulent whereby the presence or absence of a particle moving through said passageway means can be determined.

2. A counter as set forth in claim 1, wherein said detector means includes a movably mounted vane intersecting the longitudinal axis of said passageway means.

3. A counter as set forth in claim 2, wherein said vane is angularly positioned with respect to said axis and said detector means includes a reed fixed at one end and secured to the vane at the other end to serve as the movable mounting for said vane, said reed being positioned generally parallel to said axis.

4. A counter as set forth in claim 3, wherein said detector means includes a pair of electrical contacts, one of which is attached to said reed and the other is fixedly mounted in juxtaposition to said one, said reed and contacts being downstream of said vane, said contacts being open when the detector means is in said first state and closed when the detector means is in said second state.

5. A counter as set forth in claim 2, wherein said detector means includes a fixed mounting having a part spaced to one side of said axis and downstream of said portion, said vane being movably connected to said part and being resiliently urged in the upstream direction, said vane extending generally transverse to said axis whereby when said flow is laminar said vane will be moved in the downstream direction against said urging to a displaced position and when said flow is turbulent said vane will be upstream of said displaced position, and position detecting means associated with said vane to determine when the vane is in said displaced position and when it is in said upstream position.

6. A counter as set forth in claim 5, wherein said position detecting means includes a light reflective surface on a face of said vane, means at a first point to shine light on said surface at an angle whereby the light reflected to a second point at one side of said first point has one magnitude when said vane is in the displaced position and a second magnitude when the vane is in said upstream position, and means at said second point to detect the magnitude of light at said point light and produce electrical signals indicative thereof.

7. A counter as set forth in claim 6, wherein the light is conducted to and from said points by light conducting fibers.

8. A counter as set forth in claim 7, wherein said fibers have ends adjacent said surface, said ends being approximately parallel to said surface, means at the other end of the fibers of the light shining means to introduce light into those fibers at an angle to the longitudinal axis of the fibers.

9. A counter as set forth in claim 8, wherein the fibers of the light shining means are interspersed with the fibers of the light detection means, said surface being positioned so that it is close to said adjacent ends when said vane is in the displaced position and spaced farther away from said adjacent ends when said vane is in the upstream position, and including means to stop said reflective surface a short distance away from said adjacent ends when said vane is in the displaced position.

10. A counter as set forth in claim 9, wherein said detecting means produces an electrical signal which, within a predetermined range, is of a magnitude that is a function of the distance between said reflective surface and said points and includes indicator means to sensibly indicate the magnitude of

the electrical signal and stop means to limit the minimum distance between said reflective surface and said points.

11. A counter as set forth in claim 10, wherein said position detecting means comprises:

- a hollow rod positioned downstream of the vane, parallel to said axis and with one end of the rod downstream from the downstream face of vane;
- a carrier extending through said end of the rod, said carrier having an end externally of said rod and a second end inside said rod, said external end being affixed to said vane;
- diaphragm means secured to said carrier and said rod, extending transversely to said axis and resiliently supporting said rod with respect to said rod;
- means secured to said second end of said rod and defining said reflective surface; and
- said fibers being attached to said rod and extending therewithin and with said ends of the fibers being adjacent said reflective surface.

12. A counter as set forth in claim 8, wherein said position detecting means comprises:

- a hollow rod positioned downstream of the vane, parallel to said axis and with one end of the rod downstream from the downstream face of vane;
- a carrier extending through said end of the rod, said carrier having an end externally of said rod and a second end inside said rod, said external end being affixed to said vane;
- diaphragm means secured to said carrier and said rod, extending transversely to said axis and resiliently supporting said rod with respect to said rod;
- means secured to said second end of said rod and defining said reflective surface; and
- said fibers being attached to said rod and extending therewithin and with said ends of the fibers being adjacent said reflective surface.

13. A particle counting apparatus including:

- a vacuum pump having an intake and a discharge;
- a tube having two ends with one end connected to said pump intake, said tube having a capillary section intermediate said ends and being otherwise substantially larger in cross section than said capillary section, the other end of the tube defining an air intake, and "whereby the air flow through the capillary section changes from a first character which exists in the absence of a particle therein to a second character which exists in the presence of a particle therein" and

flow character responsive means positioned in said tube immediately downstream of the capillary section to detect the character of the air flow at the downstream end of said section, said responsive means having a first state when the air flow is in the first character and a second state when the air flow is in the second character.

14. An apparatus as set forth in claim 13 and including a recirculation line connecting said two ends and extending through said vacuum pump to return a portion of the air from said one end to the other end, and particle filter means in said recirculation line.

15. An apparatus as set forth in claim 13, wherein said capillary section has an internal diameter of between about 0.5 and 3 millimeters, and the tube, upstream of said section, forms a smooth transition from the cross-sectional size of the capillary section to said larger cross-sectional size of the tube.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,564,264 Dated February 16, 1971

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, line 18, delete "hears".

Col. 2, line 15, "relative" should be - reflective -.

Col. 2, line 33, delete "method and".

Col. 2, line 56, delete "14".

Col. 2, line 62, "in" should be - is -.

Col. 2, line 66, after "causes" delete - tub -

Col. 2, line 67, after "amount" delete - tub -

Col. 3, line 30, delete "time".

Col. 3, line 51, "if" should be - is -.

Col. 3, line 71, "land" should be deleted.

Col. 4, line 2, after "disruption" insert - of the
air jet downstream of the capillary sect
which disruption -.

Col. 4, line 9, "traverse" should be - traverses -.

Col. 4, line 16, after "do" insert - not -.

Col. 5, line 3, "electrical" should be - electric -.

Col. 5, line 6, "Electrical" should be - electric -.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,564,264 Dated February 16, 1971

Inventor(s) R. F. Karuhn and A. Brushenko PAGE - 2

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 5, line 12, delete "or".

Col. 5, line 12, delete "three".

Col. 5, line 32, After "and," insert - as -.

Col. 5, line 32, delete "sod".

Col. 6, line 13, delete "of".

Col. 6, line 21, "double-pale" should be - double-pole -.

Col. 6, line 43, after the sentence ending "(1 percent)"
insert the following sentence: - Resistor
129 is 250 ohms, while resistor 130 is
150,000 ohms -.

Col. 8, line 24, "rid" should be -rod-.

Col. 8, line 41,45, delete quotation marks.

Signed and sealed this 10th day of August 1971.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents