USOORE37353B1

(19) **United States**
(12) **Reissued Patent**
Kreikebaum et al.

(10) **Patent Number: US RE37,353 E**
(45) **Date of Reissued Patent: *Sep. 4, 2001**

(54) **PARTICLE SENSOR WITH VARIABLE-SPEED BLOWER**

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(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **08/917,257**

(22) Filed: **Aug. 25, 1997**

Related U.S. Patent Documents

Reissue of:
(64) Patent No.: **5,600,438**
Issued: **Feb. 4, 1997**
Appl. No.: **08/616,456**
Filed: **Mar. 15, 1996**

U.S. Applications:

(63) Continuation of application No. 08/364,389, filed on Dec. 23, 1994, now Pat. No. 5,515,164, which is a continuation of application No. 08/109,007, filed on Aug. 19, 1993, now abandoned.

(51) **Int. Cl.**^{7} **G01N 21/05**; G01N 21/53
(52) **U.S. Cl.** **356/339**; 356/246; 250/576
(58) **Field of Search** 356/335–343, 356/244, 246, 436, 440, 441, 442; 250/574, 564, 576; 377/10, 11, 53

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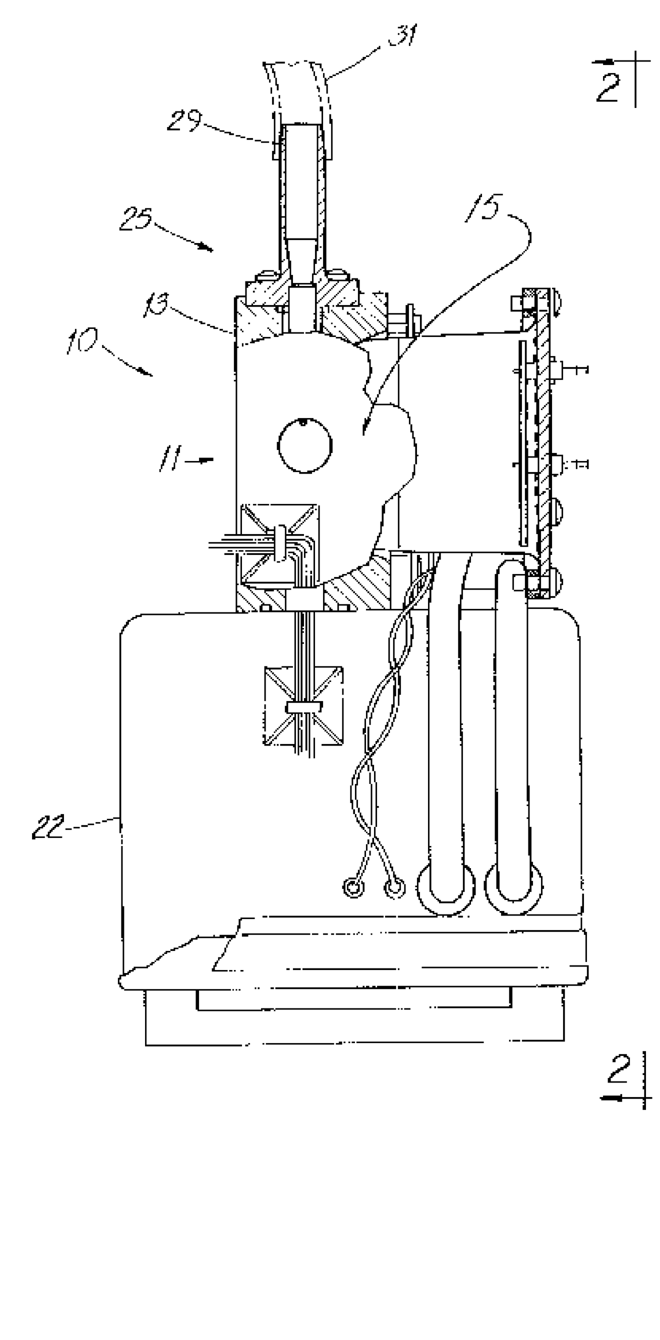
(57) **ABSTRACT**

Disclosed is a particle sensor having a light beam with a beam long axis and an air flow tube with an inlet end and a particle exit mouth. In an aspect of the invention, the cross-sectional area of the flow passage at the inlet end is greater than the cross-sectional area of the exit mouth. This enlarged area dramatically reduces pressure drop along the tube. The exit mouth is in registry with the light beam and is elongate in a direction substantially parallel to the beam long axis. Thus, particles flowing through the mouth pass through the beam. In another aspect, the invention includes a centrifugal blower which is light in weight and which may be battery powered.

7 Claims, 8 Drawing Sheets



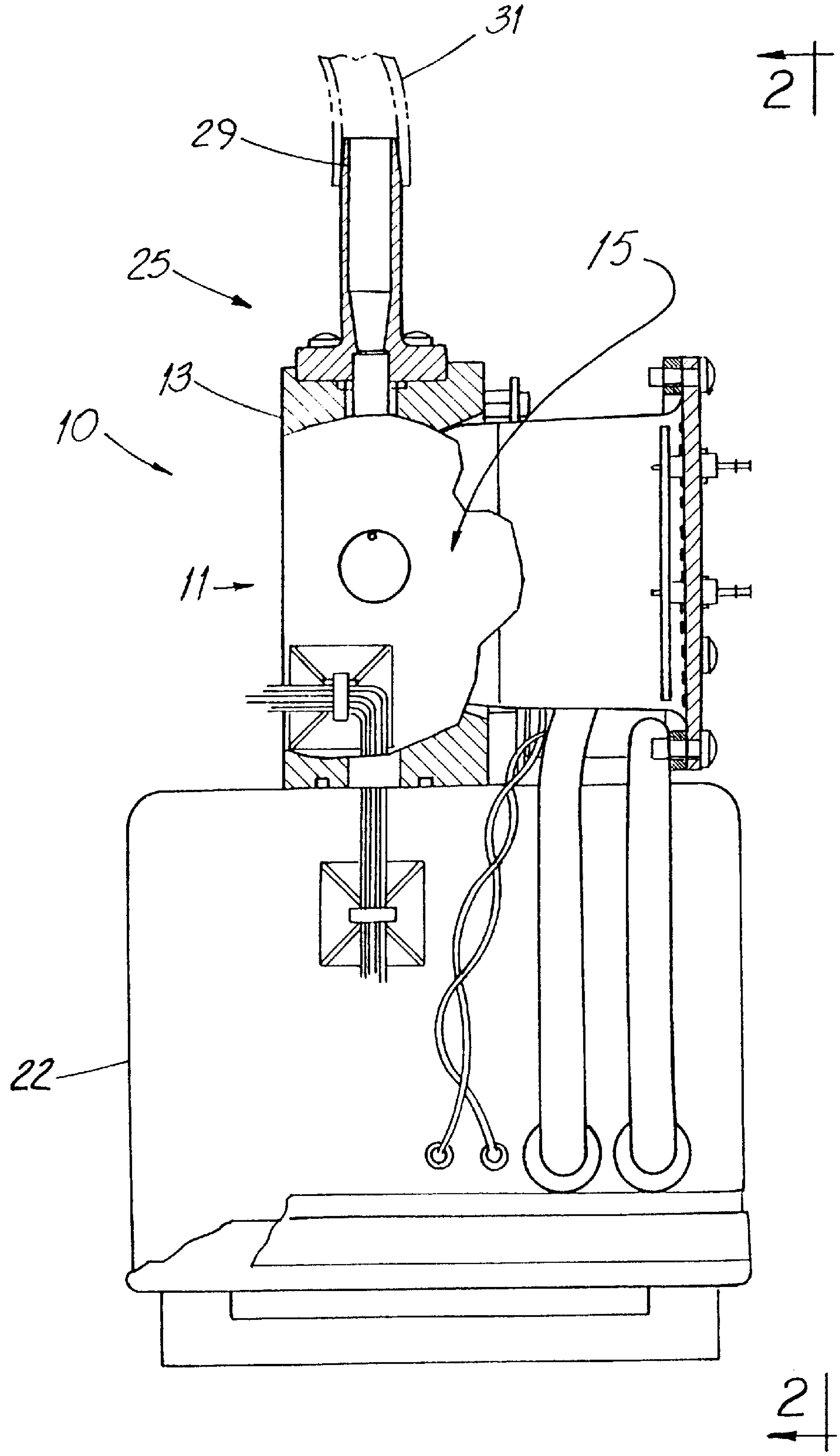


FIG. 1

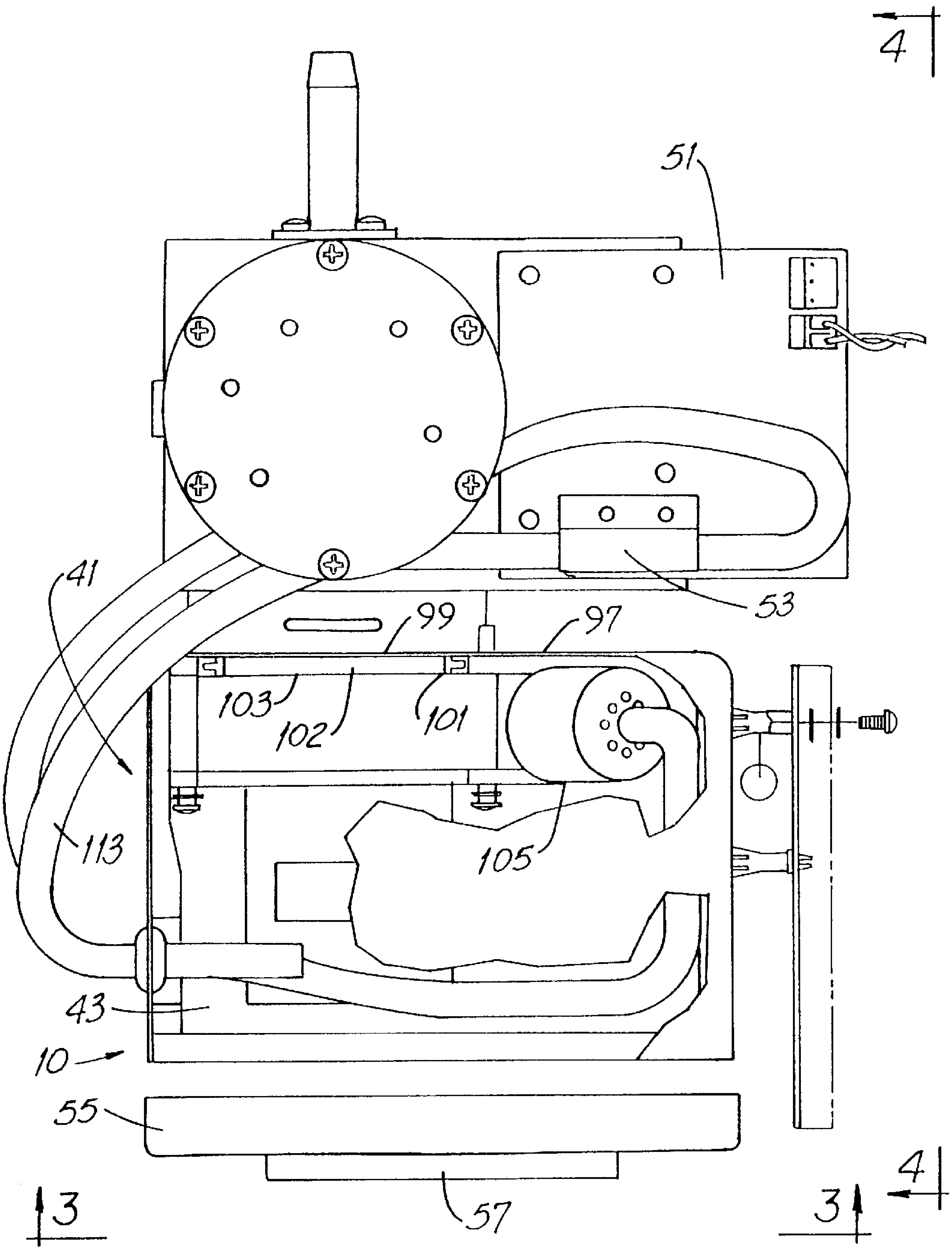


FIG. 2

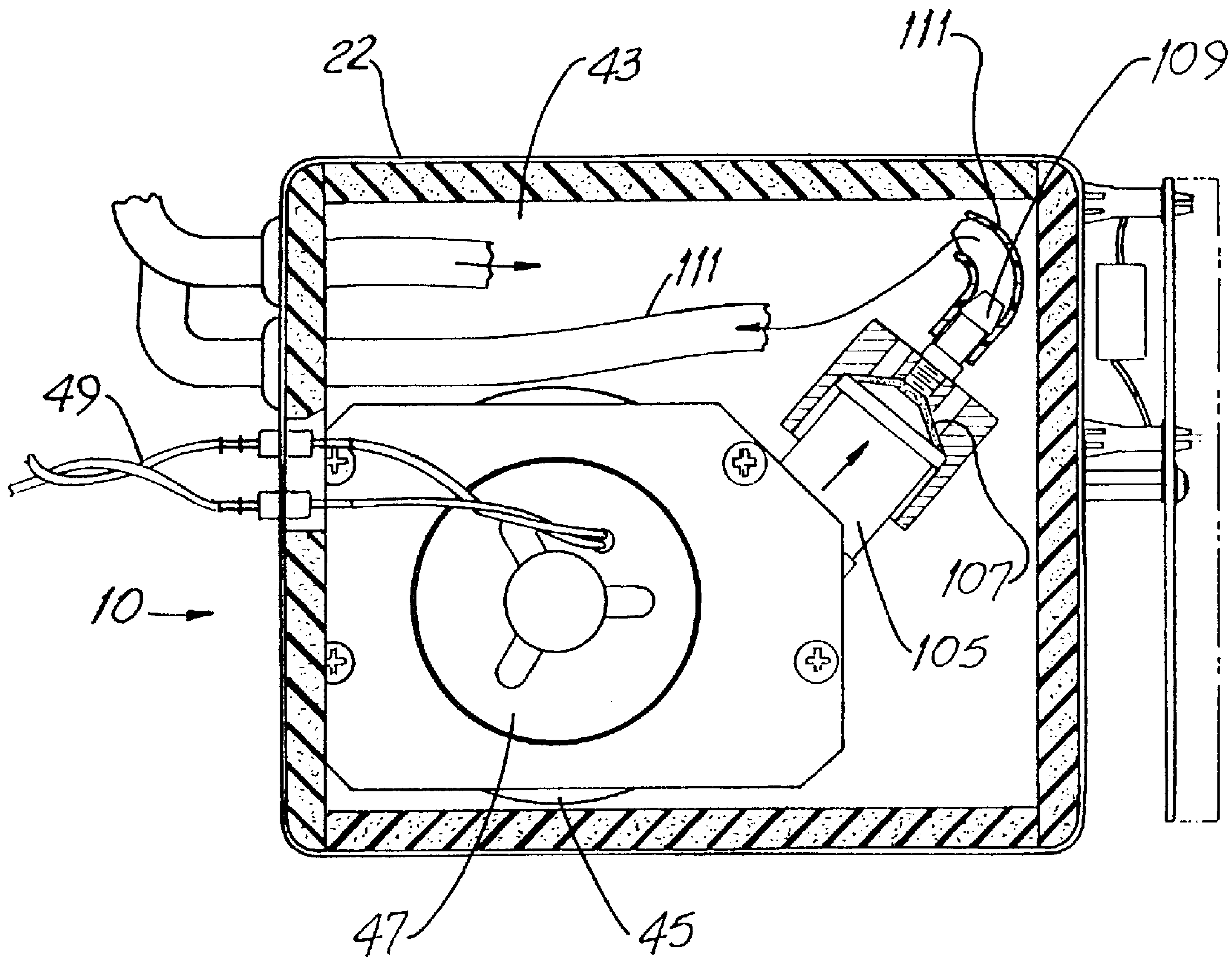


FIG. 3

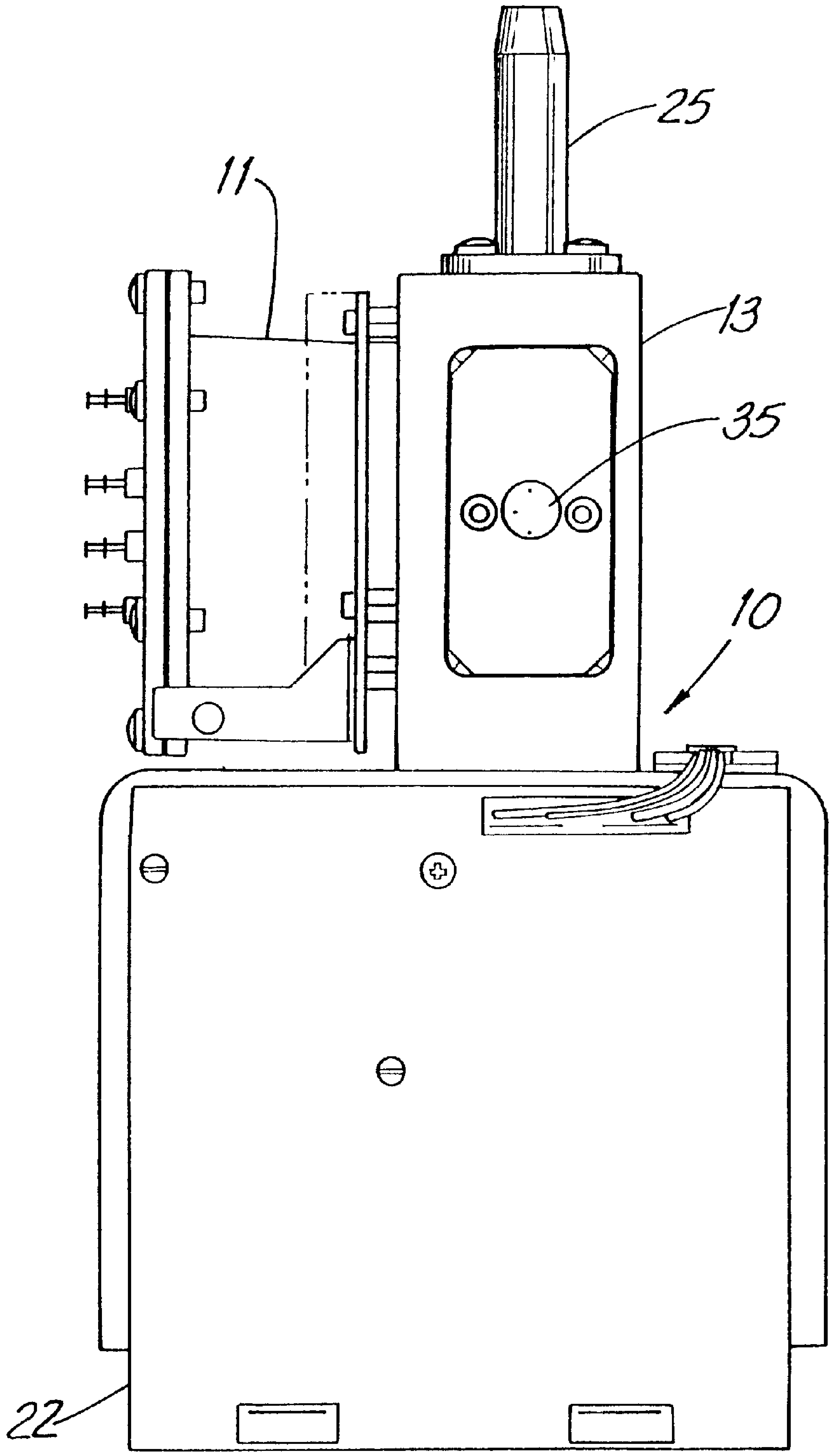


FIG. 4

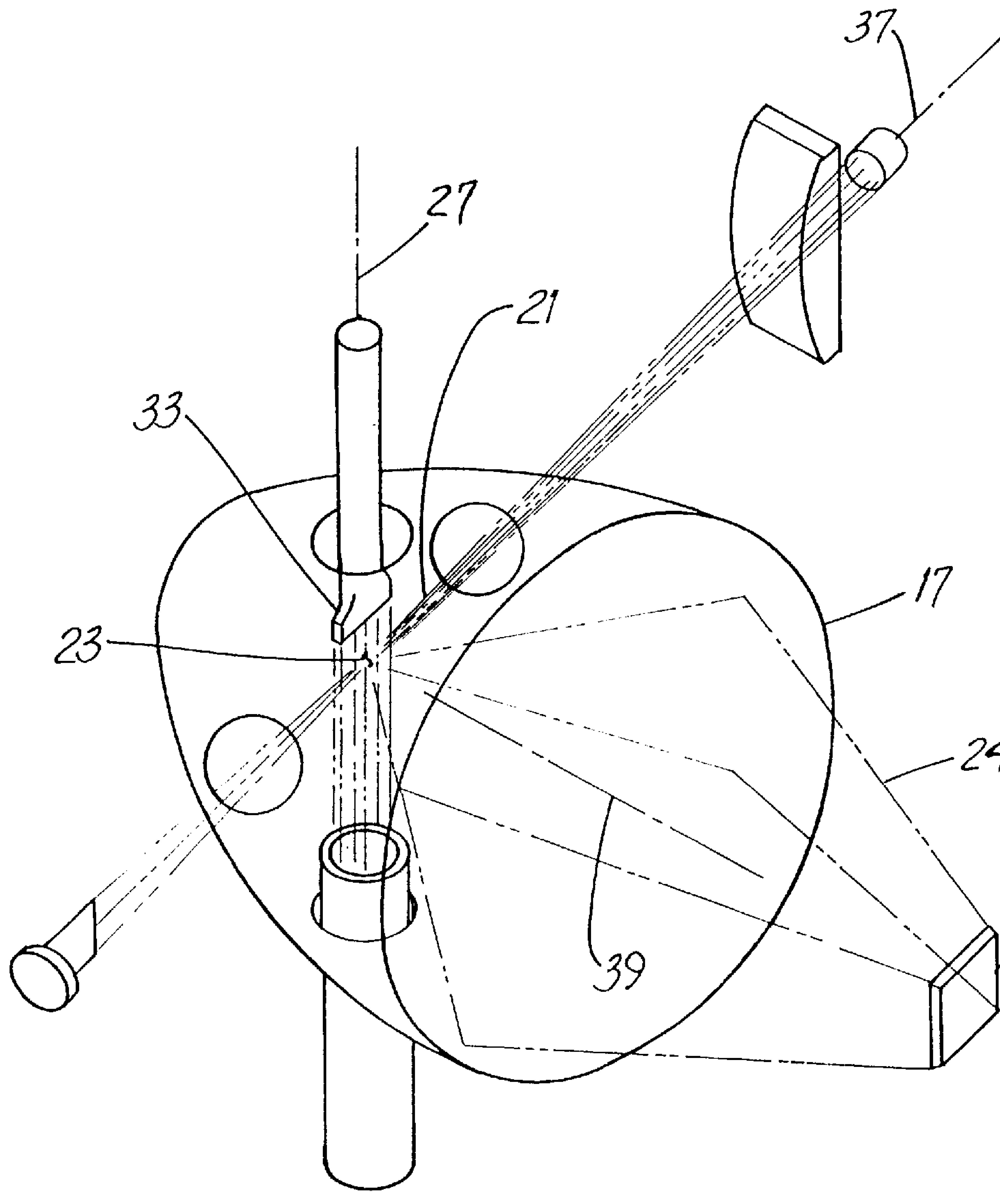


FIG. 5

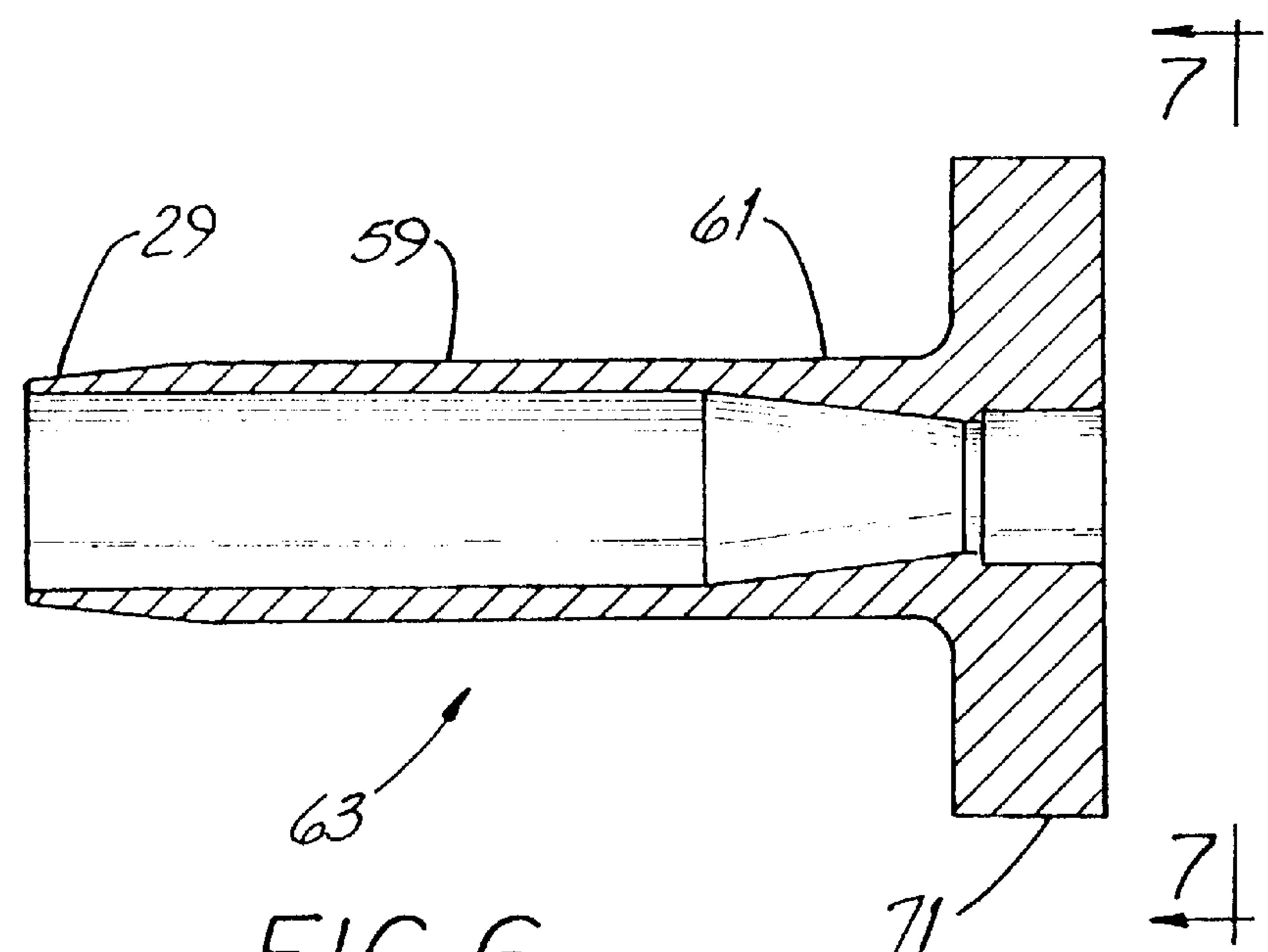


FIG. 6

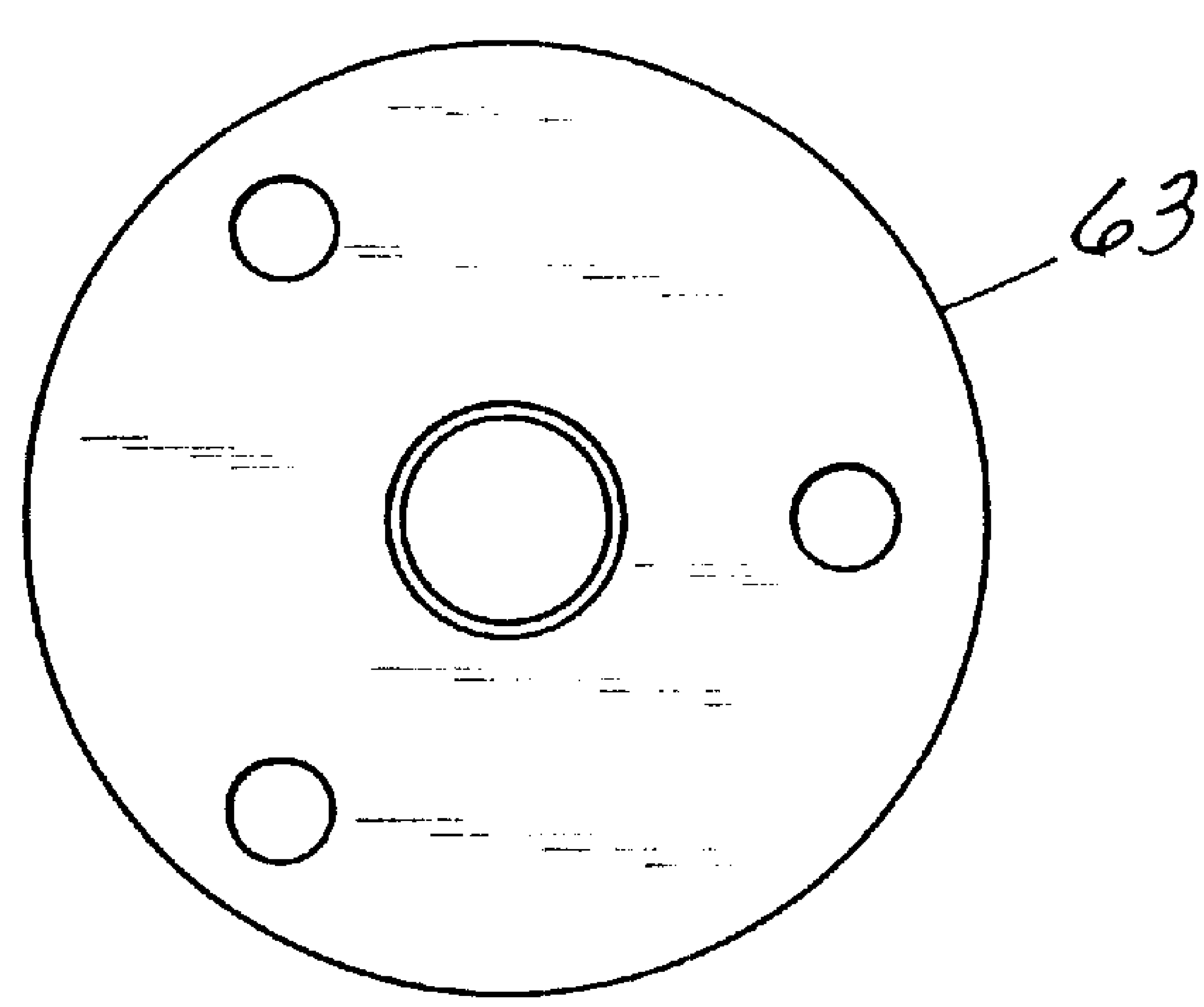


FIG. 7

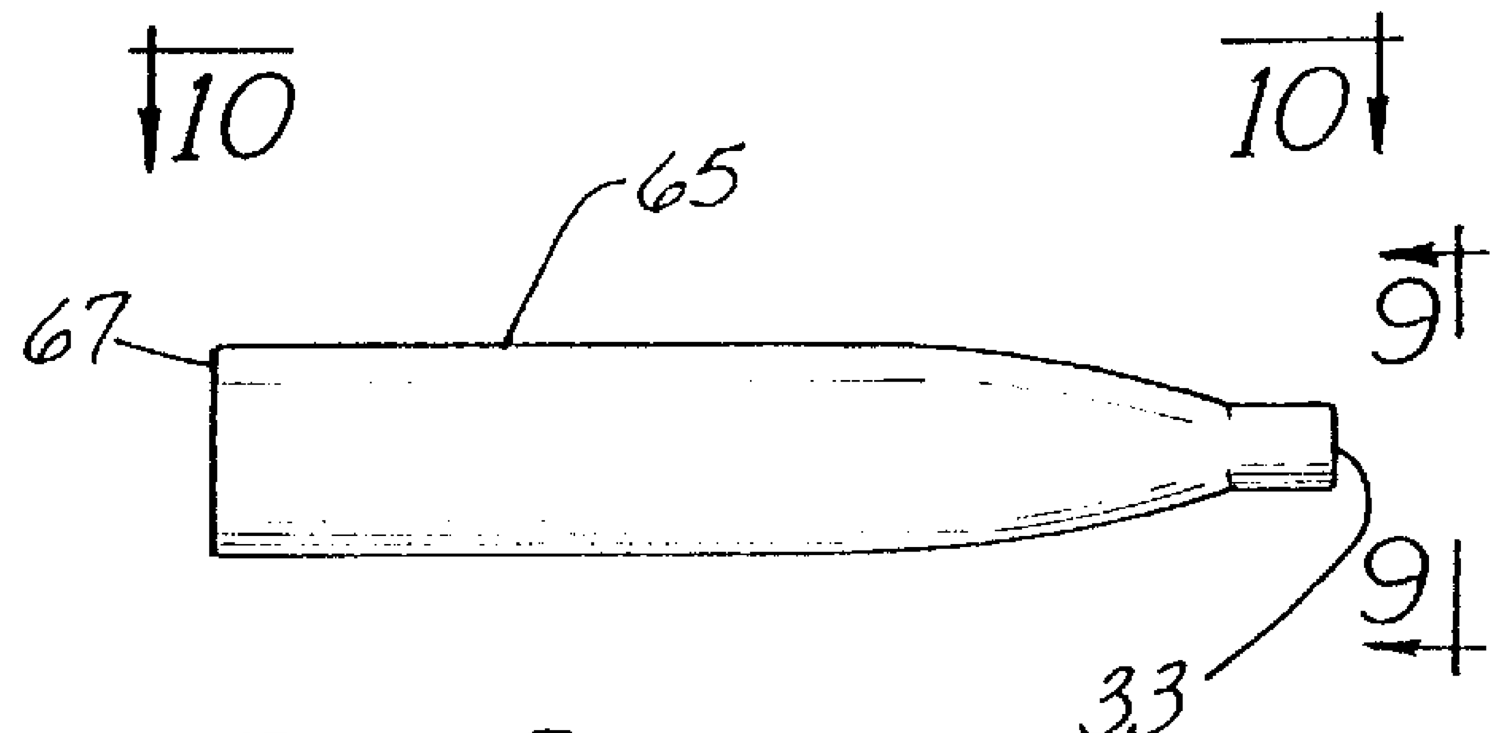


FIG. 8

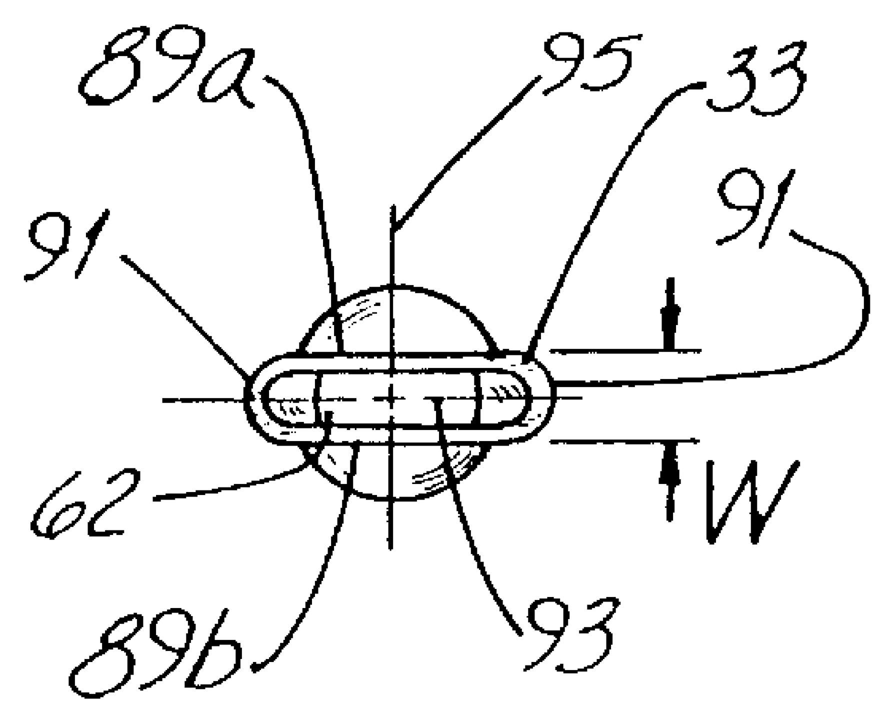


FIG. 9

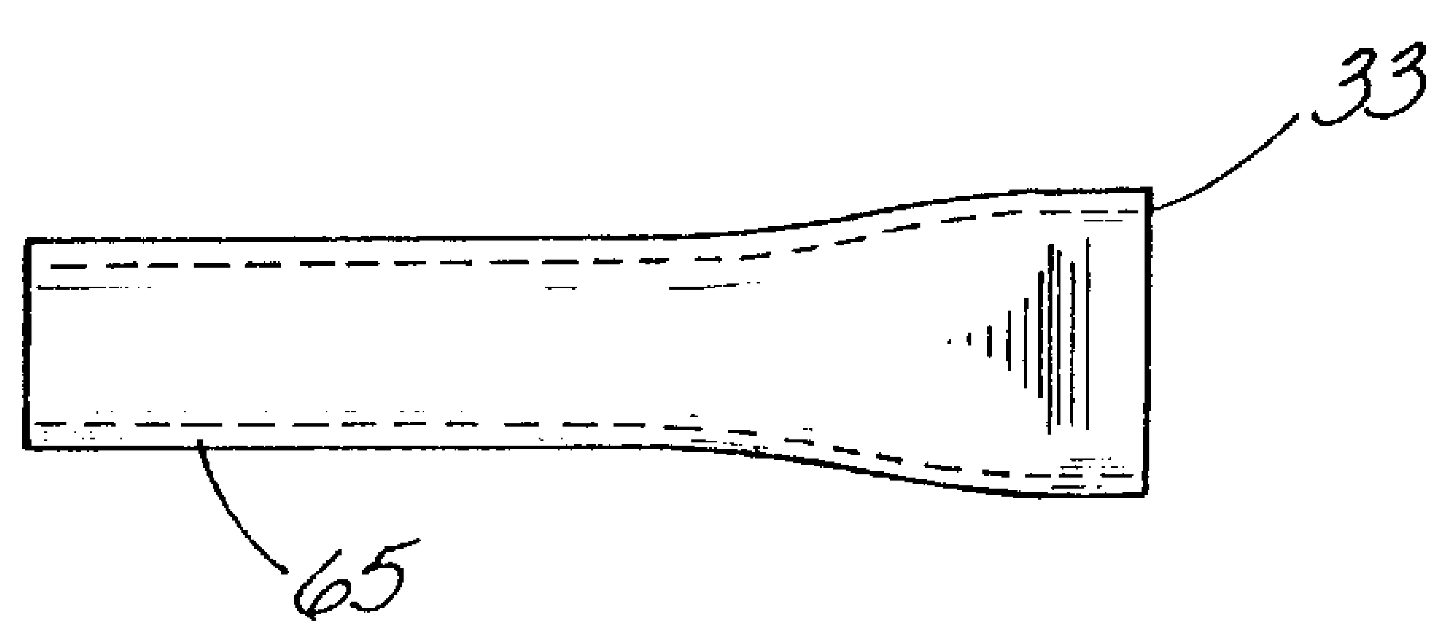


FIG. 10

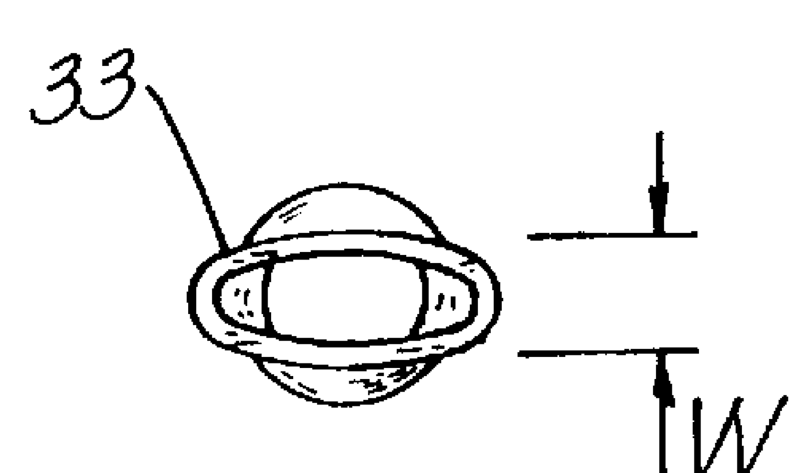


FIG. 15

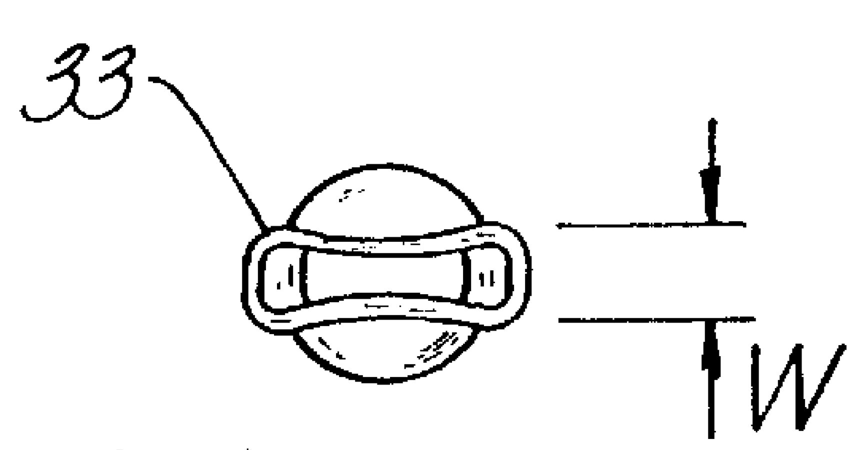


FIG. 16

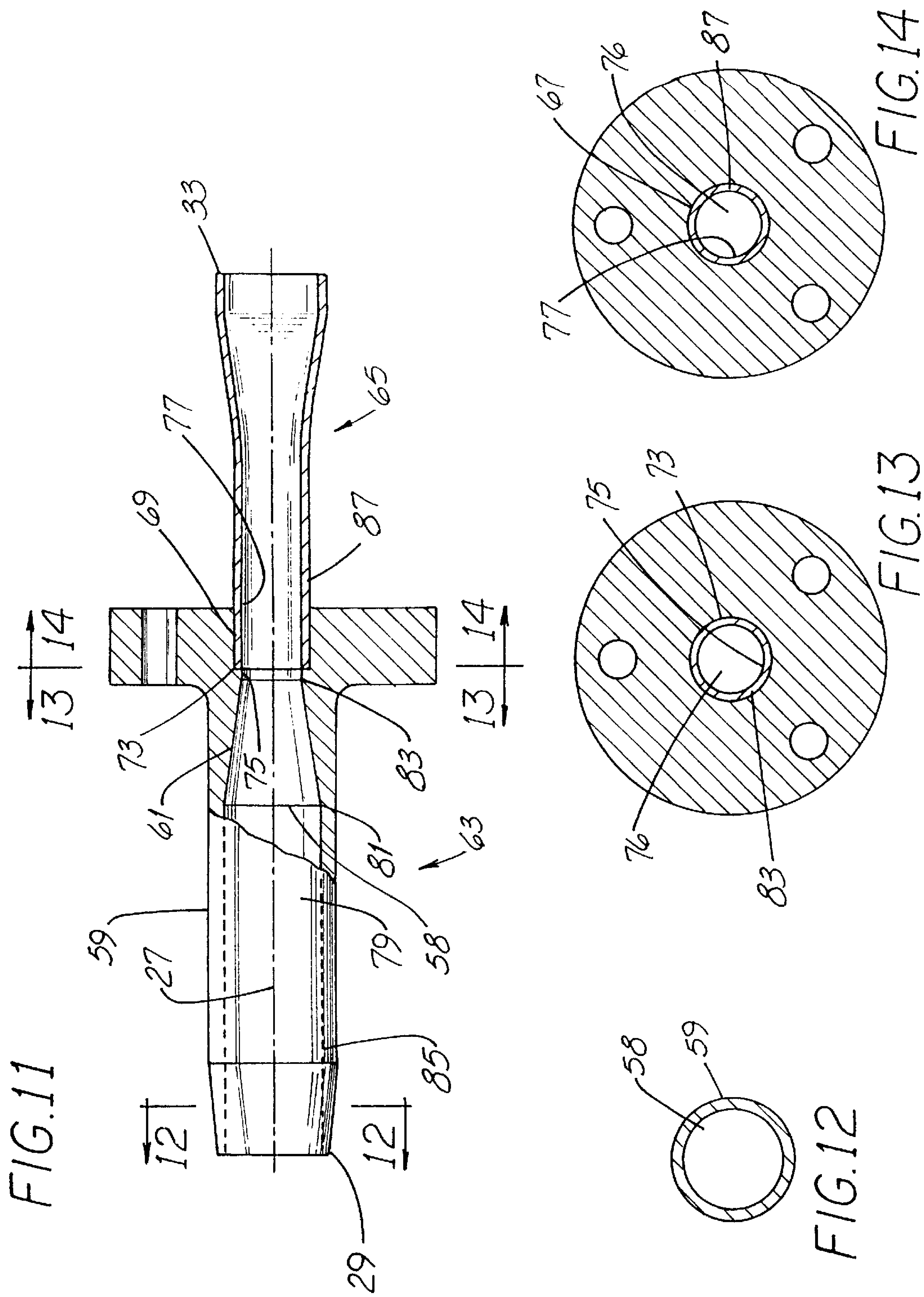


FIG.11

FIG.12

FIG.13

FIG.14

PARTICLE SENSOR WITH VARIABLE-SPEED BLOWER

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

RELATED APPLICATION

This application is a continuation of application Ser. No. 08/364,389 filed on Dec. 23, 1994, now U.S. Pat. No. 5,515,164 which, in turn, is a continuation of application Ser. No. 08/109,007 filed on Aug. 19, 1993, and now abandoned.

FIELD OF THE INVENTION

This invention relates generally to air quality and, more particularly, to instruments for assaying airborne particulates.

BACKGROUND OF THE INVENTION

Particle counters and sensors are used to detect light scattered by particles entrained in a stream of fluid, e.g., in an air stream. Such counters and sensors draw air (with entrained particles) from a room, for example, and flow such air along a tube and through an illuminated sensor "view volume" to obtain information about the number and size of such particles. Such information results from an analysis of the very small amounts of light reflectively "scattered" by the particle as it moves through the view volume.

Some types of sensors flow such air along an enclosed transparent tube; others "project" the air and accompanying particles at a particular flow rate (often measured in cubic feet per minute) from one tube across an open space to another tube. In sensors of the latter type, there is no tube wall (however transparent such wall may be) to impair light scattering and collecting. In other words, the particle is briefly illuminated by a very-small-diameter light beam is it "flies" through an open space.

Among other uses, particle counters incorporating particle sensors are used to obtain a measure of air quality by providing information as to the number and size of particles present in some specified volume of air, e.g., a cubic meter of air. Even work environments which appear to human observation to be clean—business offices, manufacturing facilities and the like—are likely to have substantial numbers of microscopic airborne particles. While such particles are not usually troublesome to the human occupants, they can create substantial problems in certain types of manufacturing operations.

For example, semiconductors and integrated chips are made in what are known as "clean rooms," the air in which is very well filtered. In fact, clean rooms are usually very slightly pressurized using extremely clean air so that particle-bearing air from the surrounding environs does not seep in. And the trend in the semiconductor and integrated chip manufacturing industry is toward progressively smaller products.

A small foreign particle which migrates into such a product during manufacture can cause premature failure or outright product rejection even before it is shipped to a customer. This continuing "miniaturization" requires corresponding improvements in clean-room environments (and in the related measuring instruments) to help assure that the number and size of airborne particles are reduced below previously-acceptable levels. While known particle counters and sensors have been generally acceptable for their intended purpose, certain disadvantages exist.

A disadvantage of known particle sensors involves the air passage, usually circular, along which air and entrained particles flow. In particular, such passage has a very small cross-sectional area. As a result, the pressure differential between the ends of the passage (sometimes referred to as the "pressure drop" across the passage) is quite high. It is not unusual to encounter a pressure drop in the range of 25–70 inches of water at a flow rate of about one cubic foot per minute (CFM). In the field of particle sensors, a pressure drop of 25–70 inches of water at that air flow rate is typical.

(Parenthetically, measuring pressure in inches of water is common. An analogy is found in older style blood pressure measuring devices which include a column of mercury contained in and visible through a graduated glass tube. Blood pressure is measured in "millimeters of mercury" and in such older style devices, blood pressure was equal to the column height. Blood pressure is still measured in millimeters of mercury but a different type of gauge is used to make the measurement.)

Because of the typical pressure drop along the very-small-area air flow passage, known sensors require a motor-driven positive displacement vacuum pump, usually of the diaphragm or vane type, to create enough vacuum to overcome such pressure drop. The necessary electric drive motor and vacuum pump are likely to be relatively heavy. And the motor requires outlet-sourced power; battery power is not practical because of the relatively large amount of power consumed. And because such a sensor requires an electrical cord and plug, it is not so readily moved from site to site, especially remote sites.

While the pressure drop along the air flow passage can be reduced by increasing the passage cross-sectional area, there is another design constraint which militates against that approach. To help assure accuracy in particle sensing and counting, all (or substantially all) of the air-entrained particles flowing along the passage must pass through the beam of light. Usually, the "flight path" of particles is perpendicular to such beam. However, the light beam is preferably sharply focused and its diameter is very small, e.g., less than about 0.1 inch. Therefore, the diameter of the air flow passage cannot be appreciably larger than that of the light beam and still assure that most or all of the particles will pass through the light beam and be detected.

The invention addresses these seemingly intractable difficulties and inconsistent design parameters in a unique and imaginative way.

OBJECTS OF THE INVENTION

It is an object of the invention to provide an improved particle sensor overcoming some of the problems and shortcomings of the prior art.

Another object of the invention is to provide an improved particle sensor in which the air flow passage exhibits exceptionally low pressure drop at a flow rate of about one CFM.

Another object of the invention is to provide an improved particle sensor in which substantially all of the particles are directed through the light beam.

Yet another object of the invention is to provide an improved particle sensor which is lighter in weight than comparable conventional sensors.

Still another object of the invention is to provide an improved particle sensor which is battery powered and highly portable, even to remote sites. How these and other objects are accomplished will become more apparent from the following descriptions and from the drawing.

The invention is an improvement in a particle sensor of the type having a light beam with a beam long axis and also having an air flow tube with (a) an inlet end, and (b) a particle exit mouth. In the improvement, the cross-sectional area of the flow passage at the inlet end is quite large and is greater than the cross-sectional area of the exit mouth. And the exit mouth is elongate in a direction substantially parallel to the beam long axis and, preferably, is "race-track" shaped and has first and second side edges which are generally parallel to one another.

The flow passage (of relatively large area) dramatically reduces the pressure drop along the tube. And the long, relatively narrow exit mouth (about as wide as the width of the light beam) helps assure that particles flowing through the mouth pass through the beam.

More specifically, the air flow tube has an inlet portion and a nozzle portion. The latter has a first inlet section which has a minimum cross-sectional area, i.e., an area less than that of any section along the length of the inlet portion. Further, the nozzle portion has a first nozzle section which has a maximum cross-sectional area, i.e., an area greater than that of any section along the nozzle portion.

In a highly preferred embodiment, the cross-sectional area of the first inlet section is no less than the cross-sectional area of the first nozzle section. Additionally, the inlet portion has an enlarged second inlet section having a cross-sectional area greater than that of the first inlet section. The first inlet section and the first nozzle section have substantially the same shape, e.g., circular.

In another aspect of the invention, the sensor air flow tube extends along a flow axis and the sensor has an air blower (preferably a centrifugal blower) rather than the conventional positive-displacement vacuum pump. The blower has an inlet opening which is substantially circular and in concentric registry with the flow axis. In fact, the new sensor has several component parts "stacked" along the flow axis so that particle flow from the inlet portion to the blower is in a straight line.

In another aspect, the new sensor makes unique use of a small centrifugal blower. Such blowers are used in applications other than particle sensors and are employed for their output flow rather than for their ability to "pull a vacuum." In the invention, it is the blower air entry port, not the flow-emanating exhaust port which is of interest. The air entry port is in flow communication with the exit mouth and the blower thereby provides the pressure differential between the inlet end and the exit mouth of the air flow tube.

In fact, substantially all of the air passing through the blower (preferably a centrifugal blower) is drawn from and first through the air flow tube. In that way, the sensor is substantially unaffected by blower-generated contaminants.

The sensor has a sensing cavity and a blower cavity separated from the sensing cavity by a wall. The wall has an aperture through it and the blower is mounted to an annular plate having an opening through it. The aperture and the opening are also in registry with the flow axis.

In yet other aspects of the invention, the air blower is battery powered. While battery-powered air blowers per se are known, earlier designers in the field of particle sensors have never appreciated how to construct an air flow path with sufficiently low pressure drop along its length that a very low power blower could be used and still provide very good air flow rate. A preferred blower is of the adjustable speed type for selecting an air flow rate. Speed adjustment may include closed loop control in connection with a flow meter.

Other detail of the invention are set forth in the following detailed description and in the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a side elevation view of the new sensor. Parts are broken away and other parts are shown in cross-section.

FIG. **2** is an elevation view of the new sensor taken along the viewing plane **2—2** of FIG. **1**. The upper and lower portions and the cover of the sensor are slightly spaced from one another and parts are broken away.

FIG. **3** is a bottom view of the sensor taken along the viewing plane **3—3** of FIG. **2**. Parts are broken away, other parts are shown in cross-section and yet other parts are omitted.

FIG. **4** is an elevation view of the sensor taken along the viewing plane **4—4** of FIG. **2**. The parts shown as slightly spaced in FIG. **2** are fully assembled in FIG. **4**.

FIG. **5** is a spatial perspective view of aspects of the sensor shown in FIGS. **1–4**.

FIG. **6** is a side elevation view in cross-section of the inlet portion of the sensor air flow tube.

FIG. **7** is an end elevation view of the inlet portion shown in FIG. **6** taken along the viewing plane **7—7** thereof.

FIG. **8** is a side elevation view of the nozzle portion of the sensor air flow tube.

FIG. **9** is an end elevation view of the nozzle portion shown in FIG. **8** taken along the viewing plane **9—9** thereof.

FIG. **10** is a top plan view of the nozzle portion shown in FIGS. **8** and **9** taken along the viewing plane **10—10** of FIG. **8**.

FIG. **11** is a side elevation view in cross-section of the inlet portion of FIGS. **6** and **7** and the nozzle portion of FIGS. **8–10** assembled to one another.

FIG. **12** is a cross-section view of the inlet portion of the air flow tube taken along the viewing plane **12—12** of FIG. **11**.

FIG. **13** is a cross-section view of the inlet portion of the air flow tube taken along the viewing plane **13—13** of FIG. **11**.

FIG. **14** is a cross-section view of the nozzle portion of the air flow tube taken along the viewing plane **14—14** of FIG. **11**.

FIG. **15** is an alternate embodiment of the exit mouth of the sensor air flow tube.

FIG. **16** is another alternate embodiment of the exit mouth of the sensor air flow tube.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring first to FIGS. **1** through **5**, the improved sensor **10** includes a sensing portion **11** with a sensor block **13** and a light-scatter sensing cavity **15**. The cavity **15** has a reflecting mirror **17**, e.g., an elliptical mirror, and a detector **19** mounted to receive scattered light **24** scattered by a particle **23** and reflected by the mirror **17**. Referring also to FIGS. **6–11**, an air flow tube **25** is mounted to the block **13**, extends along a flow axis **27** and includes a slightly tapered inlet end **29** for attaching one end of a length of hose **31**. A probe (not shown) is attached to the other end of the hose **31** and air with entrained particles flows through the hose **31** and the flow tube **25** and is expelled at the exit mouth **33**.

The sensing portion **11** also includes a laser diode assembly **35** which provides a very thin, substantially cylindrical beam of light **21** along a beam axis **37**. The axis **39**, the beam long axis **37** and the flow axis **27** are preferably orthogonal; that is, they are mutually perpendicular.

As best seen in FIGS. **2** and **3**, the sensor **10** also has a housing **22** with a blower portion **41** including a blower cavity **43** in which is mounted an air blower **45** with an electric drive motor **47** attached thereto. Such motor may be AC or DC, the latter for easier battery-powered portability. Battery power is provided to the motor **47** through the leads **49**. A printed circuit board **51** provides closed loop feedback control for speed regulation at a set point selected using the flow sensor **53**. Speed control is by pulse width modulation.

The bottom cover **55** of the cavity **43** has an exhaust filter **57** through which must pass all air flowing through the sensor **10**. The filter **57** helps avoid contaminating the environment (which may be a "clean room") with particulates sloughed from the blower **45** itself and/or drawn in through the air flow tube **25**.

Before describing particular details of a preferred air flow tube **25**, an overview comment will be helpful. In general, the air flow tube **25** has a relatively large cross-sectional area **58** at its inlet end **29**. Viewed from left to right in FIG. **11**, such cross-sectional area **58** remains substantially constant along a first segment **59** of the tube **25** and then gradually diminishes at a second segment **61**. Its smallest cross-sectional area is at the exit mouth **33**. The following more detailed description is based upon that general configuration.

Referring particularly now to FIGS. **6–11**, the air flow tube **25** includes an inlet portion **63** (which is generally T-shaped in cross-section) and a nozzle portion **65**, the upstream end **67** of which is snugly fitted into a pocket **69** formed in the downstream end **71** of the portion **63**. Particularly, the upstream end **67** abuts an annular shoulder **73**, the inward edge **75** of which defines an area **76** having substantially the same size and shape as the area **76** defined by the inner surface **77** of the upstream end **67**. Preferably, those areas **76** are circular and of substantially the same diameter.

The area of the passage **79** in the inlet portion **63** gradually increases from the shoulder **73** leftward as viewed in FIG. **11**. The passage **79** attains maximum area **58** at a location **81** between the inlet end **29** and the segment **61**. In a highly preferred arrangement, the segment **61** resembles a truncated cone.

Certain features of the preferred air flow tube **25** will now be described using a few "sections," i.e. profiled like cross-sectional views as aspects of the tube **25** would appear if cut through by an intersecting plane. Referring now to FIGS. **11–14**, the inlet portion **63** has a first inlet section **83** of minimum cross-sectional area **76**. That is, the cross-sectional area **76** of the inlet section **83** is less than the comparable area at any other section along the length of the inlet portion **63**. And the inlet portion **63** has a second inlet section **85** having a cross-sectional area **58** greater than that of the first inlet section **83**. This relationship is apparent from a comparison of FIGS. **12** and **13**.

The nozzle portion **65** has a first nozzle section **87** of maximum cross-sectional area. The area of section **87** is as great or greater than the comparable area of any other section along the length of the nozzle portion **65**. And a visual comparison of FIGS. **13** and **14** demonstrates that the cross-sectional area of the first inlet section **83** is no less than (and is preferable about equal to) the cross-sectional area of the first nozzle section **87**.

In one highly preferred embodiment, the interior passage **79** of the air flow tube **25** is circular in cross-section along most of its length, i.e., up to that part of the nozzle portion **65** at which such portion **65** necks down and fans out to define the exit mouth **33**. As best seen in FIG. **9**, a preferred exit mouth **33** has an area **62** and first and second side edges **89**a and **89**b, respectively, which are generally parallel to one another. The mouth **33** has rounded end edges **91** and the resulting mouth shape resembles that of a face track.

While the exit mouth **33** shown in FIG. **9** is preferred, there are other possibilities. For example, FIG. **15** shows an ovoid mouth **33** and FIG. **16** shows a somewhat bow-shaped mouth **33**. However, it is preferred that the maximum width "W" of any mouth **33** be about equal to or at least not appreciably greater than the diameter of the beam of light **21**. Maintaining that width relationship helps assure that all or substantially all of the air-entrained particles **23** flowing out of the exit mouth **33** pass through the beam of light **21**. On the other hand, an elongate exit mouth **33** helps assure reduced pressure drop as compared to, say, a circular exit mouth having a diameter about equal to the diameter of the light beam **21**.

And there are also other relationships that characterize the preferred embodiment. Referring to FIGS. **5** and **9**, the exit mouth **33** has a major axis **93** and a minor axis **95** generally normal to one another. The mouth **33** is oriented so that the major axis **93** is generally parallel to and spaced slightly from the beam long axis **37**. Considered another way, the exit mouth **33** is elongate in a direction substantially parallel to the beam long axis **37**.

Referring again to FIGS. **1**, **2** and **3**, the cavities **15** and **43** are separated by a wall **97** having a wall aperture **99**. The blower **45** is mounted to an annular plate **101** which has an opening **102** through it and the blower **45** itself has a side air entry port **103** through which the blower **45** draws air for expulsion through the exhaust port **105**. In a preferred arrangement, the wall aperture **99**, the plate opening **102** and the air entry port **103** are in registry with the flow axis **27** and, most preferably, are generally concentric with such axis **27**.

From the foregoing, it is to be appreciated that all of the air passing through the blower **45** is drawn from and first through the air flow tube **25**. Blower-generated contaminants, e.g., paint chips, metal "fines" and the like, do not contaminate the air stream and do not enter the sensing cavity **15** where they might impair the accuracy of the sensor **10**. To put it another way, the blower **45** is used "inside out" with respect to its conventional use mode.

The blower air entry port **103** on the intake side of the cage-like rotor is in flow communication with the exit mouth **33**. The blower **45** thereby provides, in the form of a pressure differential between the inlet end **29** and the exit mouth **33** of the air flow tube **25**, the "motive force" moving air through the tube **25**.

Referring again to the FIGURES, in operation, the blower **45** is energized and air (usually with at least some particles **23** entrained therein) is drawn into the inlet end **29** of the air flow tube **25**. The air-propelled particles **23** are expelled from the exit mouth **33** and "fly" through the laser light beam of light **21**. Beam of light **21** reflected by such particles **23** is received by the mirror **17** and reflected to a detector **19** for electronic analysis.

Air and entrained particles **23** continues to flow through the aperture **99**, the opening **102** and the port **103** in the blower **45** and is discharged by the blower **45** through its exhaust port **105**. Such air is urged through a coarse filter disc **107** which helps "smooth" air flow from turbulent to laminar flow. A major portion of the air is then simply exhausted through the openings and "free-flows" through the blower cavity **43** and exhaust filter **57** at the bottom of such cavity.

A relatively small percentage of the air from the blower exhaust port **105** enters a barbed fitting **109** and flows along the tubing **111** and through the flow sensor **53**. From the sensor **53**, such air flows along the tubing **113** and back into the blower cavity **43** from which it, too, free-flows out the exhaust filter **57**.

It has been found that the new sensor **10** exhibits no greater pressure drop than 7–10 inches of water along the air flow tube and, more typically, such pressure drop is about 3 inches of water. This is a startling contrast to the pressure drop of 25–70 inches of water exhibited by prior art sensors.

While the principles of the invention have been described in connection with a few preferred embodiments, it is to be understood clearly that such embodiments are by way of example and are not limiting.

We claim:

1. A particle sensor using scattered light for analyzing airborne particles entrained in air drawn from an environment into the particle sensor, such sensor including:

a variable-speed centrifugal blower having a housing, a motor and an exhaust port;

an opening in the blower housing;

a particle detection system including a sensing portion having a light-scatter sensing cavity;

an air flow tube and a low-pressure-drop nozzle in air flow communication with the sensing cavity and with the opening in the blower housing;

a circuit connected to the motor for providing a speed-controlling variable voltage to the motor;

a flow sensor for providing a speed-affecting signal to the circuit;

an exhaust filter interposed between the exhaust port and the environment;

and wherein:

the particle detection system further includes (a) a light source, (b) a device directing light scattered by a particle entering the cavity through the air flow tube and the nozzle, and (c) a detector for receiving light directed by the device; and

the air flowing in the sensing cavity through the air flow tube is drawn through such sensing cavity by the centrifugal blower, flows at a flow rate dependent upon the speed of the blower motor and is discharged from the particle sensor through the exhaust filter.

2. The particle sensor of claim **1** wherein:

the air flow tube extends along a [linear] flow [axis;] *path;*

the opening in the blower housing is an air inlet port; and

the rate at which air flows along the air flow tube and into the opening in the blower housing is dependent upon the speed of the blower motor.

3. The particle sensor of claim **2** wherein:

the circuit is of the closed loop feedback type;

[air flows along an air] *the* flow path [which] includes [the air flow tube,] the opening of the blower housing and the *blower* exhaust port; and

a sensing device is in communication with the [air] flow path for providing a feedback signal to the circuit.

4. A particle sensor using scattered light for analyzing airborne particles entrained in air drawn from an environment into the particle sensor, such sensor including:

a light source *providing a beam of light* illuminating a particle in the sensor;

a particle detection system having a sensing cavity [with a detector for receiving light scattered by the particle] *and a single air flow tube having an exit mouth flowing air through the beam of light*;

a light-directing device directing light scattered by the particle entering the cavity through the air flow tube and the exit mouth and passing through the beam of light;

a detector for receiving light scattered by the particle and directed to the detector by the light-directing device;

a centrifugal blower powered by a variable-speed *blower* motor [for flowing air through the sensing cavity] *and having an exhaust port*;

[a device connected to the motor for controlling the speed of the motor;

a single air flow tube in air flow communication with the environment, the sensing cavity and the blower;]

the air flow tube is in air flow communication with the environment, the sensing cavity and the blower;

the blower flows air and the particle entrained therein through the exit mouth and the sensing cavity;

a speed control device, independent of the particle detection system, connected to the motor for controlling the speed of the motor and the velocity of the air flowing through the exit mouth and through the beam of light;

and wherein:

the air flow tube has an inlet opening in flow communication with the environment and such opening is the sole inlet for air flowing through the [particle sensor] *beam of light*;

[the] air [flowing] *flows* through the sensing cavity [flows] at a flow rate dependent upon the speed of the blower motor;

all of the air is exhausted through the exhaust port to the environment;

the air flow tube, sensing cavity and centrifugal blower are in series; and

air [flow] *flowing* through the air flow tube and the [sensing cavity] *exit mouth* is moved solely by the centrifugal blower.

5. A particle sensor using scattered light for analyzing airborne particles entrained in air drawn from an environment into the particle sensor, such sensor including:

a variable-speed centrifugal blower driven by a motor and having an exhaust port;

a particle detection system including a sensing portion having a light-scatter sensing cavity;

a laser beam of light extending along a beam axis;

an air flow tube at an angle to the beam axis and having an exit mouth in air flow communication with the sensing cavity and with the blower, the exit mouth being the sole source of airborne particles directed through the beam of light;

an electrical circuit connected to the motor for providing a speed-controlling variable voltage to the motor, thereby controlling the velocity of the air through the exit mouth and the beam of light;

a flow sensor coupled to the circuit for providing a speed-affecting signal thereto;

and wherein:

the circuit is of the closed loop feedback type;

the blower includes a housing;

the blower housing has an exhaust port;

air flows along an air flow path which includes the air flow tube and the exhaust port; and

a sensing device is in communication with the air flow path for providing a feedback signal to the circuit

and wherein:

the particle detection system further includes (a) a device directing light scattered by a particle entering the cavity through the air flow tube and the exit mouth and passing through the beam of light, and (b) a detector for receiving light directed by the device;

the centrifugal blower draws air through the air flow tube at a flow rate dependent upon the speed of the blower motor; and

all of the air passing through the beam of light is exhausted through the exhaust port.

6. The particle sensor of claim 5 wherein:

the exit mouth flows air toward the beam of light;

the blower has a housing including an air inlet port; and

the rate at which air flows along the air flow tube and into the air inlet port is dependent upon the speed of the blower motor.

7. A particle sensor using scattered light for analyzing solid airborne particles entrained an air drawn from an environment into the particle sensor, such sensor including;

a light source emitting a beam of light for illuminating a particle in the sensor;

a particle detection system having a sensing cavity with a detector for receiving light scattered by the particle;

a centrifugal blower powered by a variable-speed motor and flowing air through the sensing cavity;

a device, independent of the particle detection system, connected to the motor for controlling the speed of the motor;

a single air flow tube having an exit mouth for exhausting air through the beam of light, the air having solid airborne particles entrained therein, such air flow tube being in air flow communication with the environment, the sensing cavity and the blower;

and wherein:

the air flow tube has an inlet opening in flow communication with the environment and such opening is the sole inlet for flowing, through the beam of light, the air carrying particles to be analyzed;

the air flowing through the sensing cavity flows at a flow rate dependent upon the speed of the blower motor; and

the air flow tube, sensing cavity and centrifugal blower are in series.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : Re 37,353 E
DATED : September 4, 2001
INVENTOR(S) : Gerhard Kreikebaum and David L. Chandler

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

Column 6,
Line 9, delete "face" and insert -- race --.

Signed and Sealed this

Thirtieth Day of April, 2002

Attest:

JAMES E. ROGAN

Attesting Officer

Director of the United States Patent and Trademark Office