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[54] **LIGHT SCATTERING PARTICLE ANALYZER**

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[51] **Int. Cl.** **G01n 21/00**, G01j 3/46

[58] **Field of Search** ..... 356/39–42, 102, 356/103, 104, 207, 208, 181; 250/218 X

[56] **References Cited**

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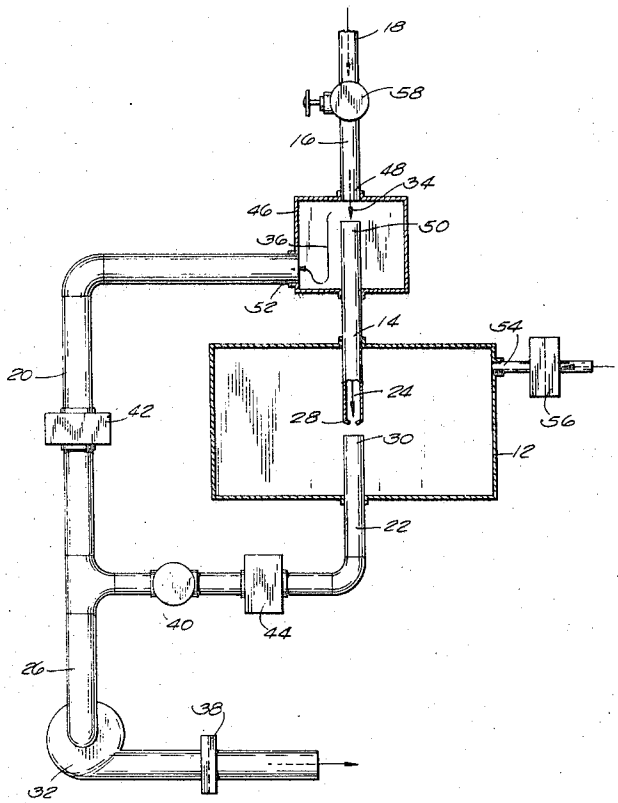
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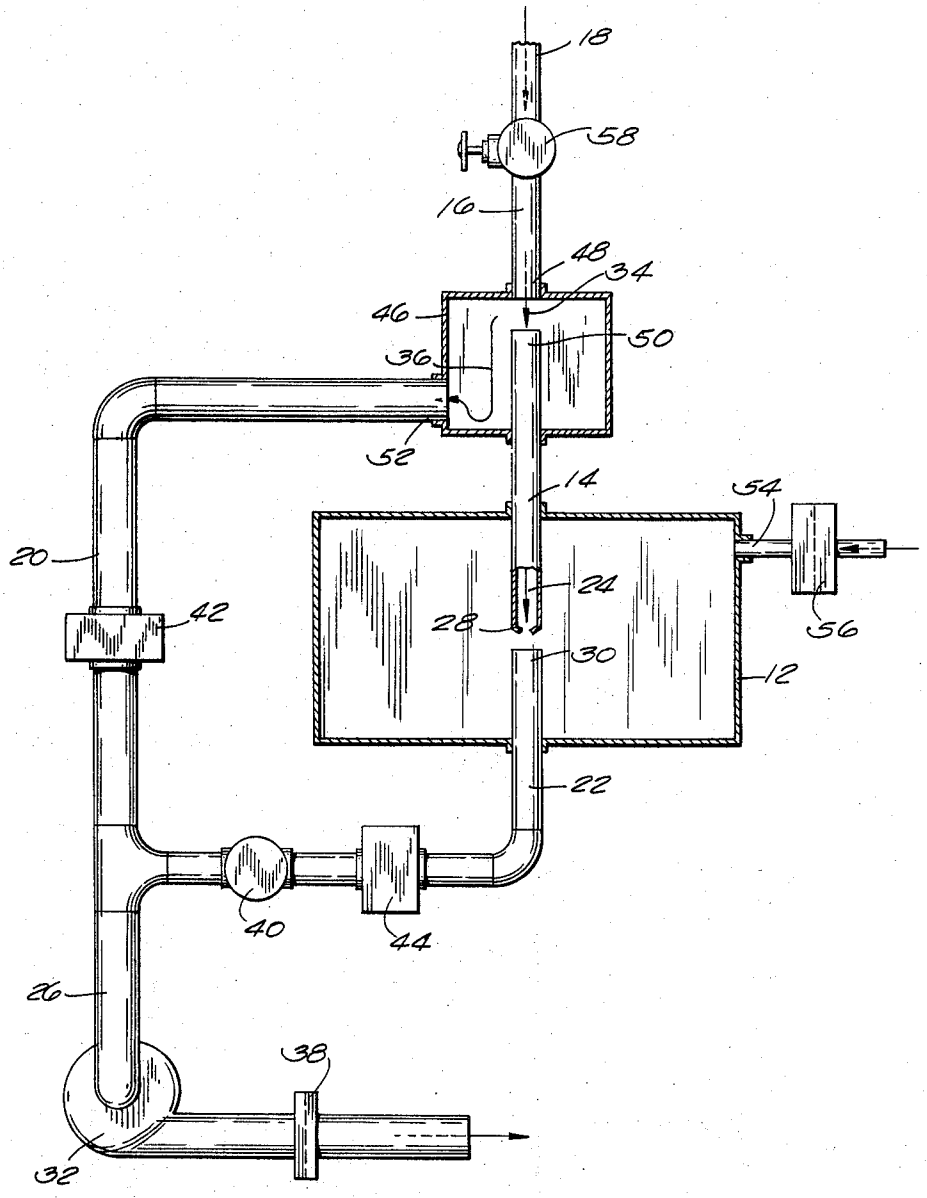
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[57] **ABSTRACT**

A light scattering device for analyzing colloidal particles in a fluid which includes an intake conduit through which a relatively high volume flow of the fluid to be analyzed is drawn by a pump. The intake stream is divided into a sample stream, which comprises a minor fraction of the intake stream and is drawn through an optical sensing chamber via a sample inlet nozzle for analysis, and a by-pass stream, which comprises the remaining portion of the intake stream and is drawn through a conduit by-passing the optical sensing chamber. A trickle flow of purging air is introduced into the sensing chamber through a small filter during normal operation. When flow through the intake conduit is shut off, the pump draws a high volume flow of purging air through the filter to rapidly purge residual particles and other similar contaminants from both the sensing chamber and the sample inlet nozzle.

11 Claims, 1 Drawing Figure




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LIGHT SCATTERING PARTICLE ANALYZER

BACKGROUND OF THE INVENTION

This invention relates to devices for measuring colloidal particles in fluids and, more particularly, to airborne particle analyzers utilizing light scattering particle detection.

Various devices have been employed to measure the size and/or concentration of small colloidal particles, such as smoke, dust, smog, pollen and the like, in air or other fluids. One type of device employs a light scattering technique whereby a sample stream of the fluid is illuminated by a beam of light and light scattered by the particles suspended in the sample stream is detected. These devices are commonly used to monitor the presence of pollution or contamination in the atmosphere of areas where a high degree of cleanliness is required, such as laboratories, hospitals, rooms where dirt-sensitive equipment is operating or being assembled, and the like.

In order to provide precise monitoring, it is essential that the sample stream of fluid be representative of the environment being monitored. Generally, a sample stream flow in the range of about 0.1 to about 1 cubic foot per minute is adequate for most purposes. However, prior art devices capable of analyzing sample streams flows of this magnitude are quite large and expensive. The more practical prior art devices use sampling flows as low as 0.01 cubic foot per minute which is usually far too low to provide a sample which is representative of room-size volumes. Also, larger particles tend to fall out of the sample stream as it flows through the relatively long, small diameter sample inlet tubes or hoses typically used in these low sampling devices, making the sample stream being measured still less representative.

Furthermore, prior devices using low sampling rates have a correspondingly low response time to excursions in size and/or concentration of particles in the atmosphere being monitored. A reasonably rapid response is desirable for many operations. For example, if the device is being used to evaluate the effectiveness of an air filter, location of a particle leak can become a very tedious operation with prior devices having a slow response. In "clean room" operations where a relatively large volume of filtered air is pumped through the room to maintain a substantially particle-free atmosphere, a monitoring device having a rapid response is desired in order to prevent a long lapse of time between the occurrence of a contamination problem and the time the device indicates the problem has occurred.

Another problem with particle analyzing devices of this type is that some of the particles separate from the sample stream in the sensing chamber. These separated particles tend to drift around in the chamber and cause erroneous indications. The error caused by the presence of separated particles in the sensing chamber and/or sample inlet line can be particularly significant when the device is transferred from a heavily contaminated region to a comparatively clean region. Various approaches have been proposed to minimize this problem, such as providing an air sheath to confine the sample flow stream as described in U.S. Pat. Nos. 3,361,030 and 2,732,753. A separate pumping and flow measuring means as well as other additional equipment are usually required for the sheathing air flow.

The additional equipment required substantially increases cost and complexity and, therefore, cannot be practically included in less expensive devices.

It also has been proposed to flow a clean air purge through the sampling system for cleaning. Because of the low flow capacity of the sampling system of prior low cost devices, several minutes are often required for cleaning, particularly when making the transition from ambient air to clean-bench or clean-room air.

SUMMARY OF THE INVENTION

An object of this invention is to provide a simple, inexpensive light scattering device for measuring colloidal particles in a fluid which is capable of providing a highly representative sample for measurement.

Another object of this invention is to provide a light scattering type device for measuring colloidal particles in a fluid which has a relatively rapid response time.

A further object of this invention is to provide such a device wherein the accumulation of separated particles in the sensing chamber is minimized.

A still further object of this invention is to provide such a device which can be cleaned in a minimum time.

Further objects, aspects and advantages of the invention will become apparent from the following detailed description, the drawing, and the appended claims.

In accordance with the invention, a light scattering device for measuring colloidal particles in a fluid is arranged to provide a high transport rate for the sample being drawn into the device from which a low volume sample stream is taken and passed through an optical sensing chamber analysis. The high transport rate of the incoming sample minimizes particle fall out, provides a more representative sample of the atmosphere being analyzed, and facilitates a more rapid response.

More specifically, the device includes an intake conduit means for introducing a stream of the fluid to be analyzed into the device, a sample inlet nozzle communicating with the intake conduit means and extending into an optical sensing chamber for passing a sample stream through the sensing chamber for analysis, by-pass conduit means communicating with the intake conduit means, a sample outlet conduit means communicating with the sensing chamber and through which the sample stream is discharged from the chamber and an exhaust conduit means communicating with the by-pass conduit means and the sample outlet conduit means. A pumping means located in the exhaust conduit means draws a relatively high volume intake stream of the fluid through the intake conduit means, draws a representative sample stream comprising a minor portion of the intake stream through the sample inlet nozzle into the sensing chamber and outwardly from the sensing chamber through the sample outlet conduit means, and draws a by-pass stream comprising the remaining major portion of intake stream through the by-pass conduit means. The outlet of the intake conduit and the inlets of the sample inlet nozzle and the by-pass conduit means are preferably connected to a flow chamber means which is arranged to provide a substantially free jet impingement of the center portion of the inlet stream through the sample inlet nozzle to thereby insure that a representative sample of the intake stream is flowed through the sensing chamber for analysis.

In accordance with another embodiment of the invention, the sensing chamber is provided with a purge

inlet port through which a trickle flow of air is drawn via a filtering means during normal operation to assist in preventing the accumulation of separated particles in the sensing chamber. The sampling portion of the system can be rapidly purged by closing a flow shut off means provided in the intake conduit means so that the pumping means draws a relatively high volume flow of filtered air through the purge air inlet port into the sensing chamber and then through both the sample outlet conduit means and back through the sample inlet nozzle.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a diagrammatic representation of a light scattering device for measuring colloidal particles in a fluid embodied by the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The scattering light device of the invention will be described for use as an airborne particle analyzer for measuring the size and concentration of solid particulates suspended in air. It should be understood that the device is adaptable for many other similar uses for detecting the presence of colloidal particles in other gases and fluids.

Referring to the drawing, the airborne particle analyzer **10** includes an optical sensing chamber **12** into which a sample stream of air being analyzed for the presence of airborne particles is passed through a sample inlet nozzle **14.** Optical sensing chamber **12** is of conventional construction and includes a conventional light generator and transmitter (not shown) for transmitting a focused beam of light along an axial path through the chamber, a conventional reflector means (not shown) for forwardly reflecting light scattered by particles in the sample stream passing through the light beam, and a conventional scattered light detector and measuring means (not shown) for determining the size and/or concentration of air-borne particles in the sample air stream. The optical sensing chamber, the light generator and transmitter means, the reflector means, and the scattered light detection measuring means are all arranged in a conventional manner. Therefore, a detailed description of these components is not necessary to enable those skilled in the art to understand the invention and is purposely omitted for the sake of brevity. For example, U.S. patent (Climet's patent) describes an acceptable arrangement for these components which can be used in the invention, which patent is incorporated herein by reference.

In accordance with the invention, an arrangement is provided whereby a relatively high volume stream of the air to be analyzed is drawn into the device with only a minor representative portion of this stream being passed through the optical sensing chamber **12** as a sample stream for analysis and the remaining major portion of the stream by-passing optical sensing chamber **12.** While various arrangements can be used, in the construction illustrated, such means includes an intake conduit **16** which is open at one end **18** to the atmosphere being analyzed and communicates with sample inlet nozzle **14,** a by-pass conduit **20** communicating with intake conduit **16,** a sample outlet conduit **22** through which the sample air stream (represented by arrow **24**) is discharged from optical sensing chamber **12,** and an exhaust conduit **26** communicating with by-pass conduit **20** and sample outlet conduit **22.**

As in conventional devices, a focused light beam (not shown) having a minimum focus area is provided in optical chamber **12** by the light generating and transmitter means (not shown). The inner end portion **28** of sample inlet nozzle **14** extends through one side of optical sensing chamber **12** along an axis generally perpendicular to the axis of this light beam and in alignment with the central point of the focus area. Inner end portion **28** of sample nozzle tube **14** is located adjacent to one side of the light beam. Sample outlet conduit **22** extends through the opposite side of optical sensing chamber **12** and in coaxial alignment with sample inlet nozzle **14** with the inner end portion **30** located on the opposite side of the focus area.

A pump **32** located in exhaust conduit **26** operates to draw a stream of air from the atmosphere being analyzed (designated by arrow **34**) at a predetermined rate of flow through intake conduit **16.** Sample stream **24,** comprising a minor portion of incoming stream **34,** is drawn through optical sensing chamber **12,** via sample inlet nozzle **14** and sample outlet conduit **22,** by pump **32.** Simultaneously, a by-pass stream (designated by arrow **36**), comprising the remaining major portion of incoming stream **34,** is drawn through by-pass conduit **26** by pump **32.** Sample stream **24** and by-pass stream **36** are combined in exhaust conduit **26** and are discharged therethrough to the atmosphere.

As shown, the discharge of pump **32** can be filtered with a conventional filter **38** to prevent any contamination or recontamination of the area being analyzed and to collect particles for later examination if desired.

Pump **32** can be any conventional motor driven impeller or rotor type pump which is capable of drawing air through intake conduit **16** at the high volume transport rate desired. Generally, an intake flow rate of about 12–18 cubic feet per hour is acceptable for many applications. The velocity of incoming stream **34** in intake conduit **16** is maintained at a level just below where full turbulence occurs. Thus, the maximum flow to keep the particle moving is available without causing significant particle impaction and a consequential disturbance of particle distribution. Sample inlet nozzle **14** and sample outlet conduit **22** are arranged to provide a flow rate for sample stream **24** which is only a fraction flow rate sample stream of intake stream **34,** preferably a flow rate generally corresponding to that used in conventional low cost, low sampling rate devices so that inexpensive sensing equipment can be used. Typically, the flow rate of sample stream **24** is about 1 cubic foot per hour. The flow rate of by-pass stream **36** corresponds to the remaining flow capacity of pump **32,** e.g. 11–17 cubic feet per hour. Thus, pump **32** has a flow capacity substantially greater than that required to draw the sample stream through the sensing chamber.

Preferably, a flow control means, such as valve **40,** is provided in sample outlet conduit **22** so that the flow of sample stream **24** can be adjusted to the level desired. A flow balancing orifice **42** or the like can be provided in by-pass conduit **22** to facilitate balancing of the flows for the various streams. The flow rate of sample stream **24** is measured by a conventional flow meter **44** located in sample outlet conduit **22.** Preferably, a conventional flow meter having an integral flow control valve is used so that both measurement and

control of the sample stream is provided by a single component.

With the above described arrangement, it can be appreciated that advantages associated with using both a high sampling rate and a low sampling rate are obtained. The high transport rate of the intake stream upstream of the sample inlet nozzle minimizes larger particles from falling out, provides a more representative sample of the atmosphere being analyzed, and permits a more rapid response. On the other hand, the low flow rate of the sampling stream permits the use of smaller, less expensive sensing equipment. Hence, the device can be constructed as a compact, portable unit and at a relatively low cost.

Also in accordance with the invention, means are provided for assuring that a representative sample is taken from the intake stream and passed through sensing chamber **12** for analysis. While various arrangements can be used, in the preferred construction illustrated, this means comprises a flow dividing chamber **46** located at the junction where intake stream **34** is divided into by-pass stream **36** and sample stream **24.** The outlet end **48** of intake conduit **16** is connected to one side of chamber **46** and the inlet end portion or mouth **50** of sample inlet nozzle **14** extends through the opposite side of chamber **46** in coaxial alignment and concentric relationship with intake conduit outlet **48.** The inlet end **52** of by-pass conduit **20** is connected to one side of chamber **46** along an axis generally perpendicular to the axis of intake conduit outlet **48** and sample inlet nozzle mouth **50.** As shown, sample nozzle mouth **50** extends a substantial distance into chamber **46** and is located upstream of by-pass conduit inlet **52.** The spacing between intake conduit outlet **48** and sample nozzle mouth **50** can be varied, but should be such that substantially all of the vortexing or turbulence occurs below sample nozzle mouth.

Also, chamber **46** is sized that there is a substantially free jet impingement of the center portion incoming stream **34** into sample inlet nozzle **14.** In other words, chamber **46** is large enough so that incoming stream **34** from intake conduit outlet **48** can flow towards sample nozzle mouth **50** without being substantially disturbed by the vortexing effect of the air being diverted into by-pass conduit inlet **52.** Expressed another way, the size of chamber **46** and the size and location of sample nozzle mouth **50** are correlated with the size and location of intake conduit outlet **48** and by-pass conduit intake **52** to obtain the effect of isokinetic sampling, i.e., the velocity of the sample stream entering sample nozzle mouth **50** is the same or substantially the same as that of incoming stream **34.** This arrangement insures that a stable flow of a representative central portion of incoming stream **34** is passed through the sample inlet nozzle and into sensing chamber **12** for analysis.

A trickle flow of filtered air is continuously admitted into sensing chamber **12** through a purge port **54** via filter **56** while pump **32** is operating during normal operation of the device. This flow rate of this filtered air is at a small fraction of the flow of sample stream **24,** e.g., less than 1 percent, so as not to produce a discernible error in the sample stream flow rate being measured by flow meter **44.** Filter **56** and purge port **54** are sized to provide a pressure differential between the internal pressure of sensing chamber **12** and the inlet of filter **16** which produces the desired low flow of filtered air into the chamber. The inlet of filter **56** is preferably open to the atmosphere.

To clean the device, a shutoff valve **58** located in intake conduit **16** is closed. Pump **32** then pulls air through filter **56** into sensing chamber **12** and from the chamber through both sample inlet nozzle **14** and sample outlet conduit **22.** Since the filtered air is being drawn through the system at the full capacity of pump **32,** e.g., 12–18 cubic feet per hour, any residual particles or other contamination in the sensing chamber **12** are quickly purged therefrom. Normally, this cleaning operation can be completed in a few seconds. The high reverse flow through the sample inlet nozzle provides the additional benefit of purging any lint or any other similar contamination from this portion of the system.

Since only a short purging period at high flow is required for cleaning and only a small flow normally passes through filter **56** during normal operation, a small filter element can be used for filtering the purging air. Thus, a compact, low cost integral purging means is provided which permits rapid cleaning of the entire sampling portion of the system.

While the preferred embodiments of the invention has been illustrated and described in detail, it will be apparent to those skilled in the art that various alterations and modifications can be made thereto without departing from the spirit and scope of the invention.

We claim:

1. In a device for measuring colloidal particles in a fluid which includes an optical sensing chamber, means for producing a focused beam of light along an axial path in said sensing chamber and through which a stream of said fluid is passed, and means for detecting and measuring the amount of light scattered by the particles suspended in said fluid stream passing said light beam, the improvement comprising,

an intake conduit means for introducing a stream of said fluid into said device;

a sample inlet nozzle communicating with said inlet conduit means and extending into said sensing chamber for passing a sample stream generally perpendicularly through said light beam;

a by-pass conduit means communicating with said intake conduit means and by passing said sensing chamber;

a sample outlet conduit means communicating with said sensing chamber through which said sample stream is discharged from said sensing chamber;

an exhaust conduit means communicating with said by-pass conduit means and said sample outlet conduit means; and

pump means in said exhaust conduit means for drawing an inlet stream of said fluid through said intake conduit means at a predetermined, relatively high volume flow rate, drawing a by-pass stream comprising a major portion of said inlet stream through said by-pass conduit means, and drawing said sample stream comprising a minor portion of said inlet stream through said sample inlet nozzle into said sensing chamber and outwardly from said sensing chamber through sample outlet conduit means.

2. A device according to claim **1** including a flow measuring means for measuring the flow rate of said sample stream through said sample outlet conduit means.

3. A device according to claim 1 including flow control means for adjusting the flow rate of said sample stream through said sample outlet conduit means.

4. A device according to claim 1 including a flow dividing means located in the area where said flow inlet nozzle communicates with said intake conduit means and said by-pass conduit means communicates with said intake conduits means for directing a center portion of said inlet stream comprising said sample stream in substantially free jet impingement into said sample inlet nozzle and for directing the remaining portion of said inlet stream into said by-pass conduit means without substantially disturbing the flow of said center portion of said inlet stream.

5. A device according to claim 4 wherein said flow dividing means comprises a flow chamber and wherein said intake conduit means includes an outlet connected to one side of said flOw chamber, said sample inlet nozzle includes an inlet end portion extending through the opposite side of said chamber and disposed in axial alignment and concentrically with said intake conduit means out'et, and said by-pass conduit means includes an inlet communicating with one side of said chamber and disposed below the inlet end of said sample inlet nozzle.

6. A device according to claim 1 including

an inlet port in said sensing chamber for introducing a purging fluid into said sensing chamber and

a filtering means located upstream of said inlet port and through which said purging fluid passes before entering said sensing chamber via said inlet port, the flow of said purging fluid being at a small fraction of the flow of said sample stream during normal operation of said device.

7. A device according to claim 6 including means for shutting off flow through said intake conduit so that, when said pump means is operating thereafter, the flow of said purging fluid into said sensing chamber through said filtering means is increased substantially and separate streams of said purging fluid is drawn from said sensing chamber through said sample outlet conduit and said sample inlet nozzle.

8. A device according to claim 7 wherein said filtering means includes an inlet which is open to the atmosphere.

9. In a device for measuring colloidal particles in a fluid which includes an optical sensing chamber, means for producing a focused beam of light along an axial path in said sensing chamber and through which a stream of said fluid is passed, and means for detecting and measuring the amount of light scattered by the particles suspended in said fluid stream passing said light beam, the improvement comprising,

an intake conduit means for introducing a stream of said fluid into said device;

a sample inlet nozzle communicating with said inlet conduit means and extending into said sensing chamber for passing a sample stream generally perpendicularly through said light beam;

a by-pass conduit means communicating with said intake conduit means and by passing said sensing chamber;

a sample outlet conduit means communicating with said sensing chamber through which said sample stream is discharged from said sensing chamber;

an exhaust conduit means communicating with said by-pass conduit means and said sample outlet conduit means;

pump means in said exhaust conduit means for drawing an inlet stream of said fluid through said intake conduit means at a predetermined, relatively high volume flow rate, drawing a by-pass stream comprising a major portion of said inlet stream through said by-pass conduit means, and drawing said sample stream comprising a minor portion of said inlet stream;

a flow measuring means for measuring the flow rate of said sample stream through said sample outlet conduit means; and

a flow dividing means located in the area where said flow inlet nozzle communicates with said intake conduit means and said by-pass conduit means communicates with said intake conduits means for directing a center portion of said inlet stream comprising said sample stream in substantially free jet impingement into said sample inlet nozzle and for directing the remaining portion of said inlet stream into said by-pass conduit means without substantially disturbing the flow of said center portion of said inlet stream.

10. A device according to claim 9 including

an inlet port in said sensing chamber for introducing a purging fluid into said sensing chamber and

filtering means located upstream of said inlet port and through which said purging fluid passes before entering said sensing chamber via said inlet port, the flow of said purging fluid being at a small fraction of the flow of said sample stream during normal operation of said device.

11. A device according to claim 10 including means for shutting off flow through said intake conduit so that, when said pump means is operating thereafter, the flow of said purging fluid into said sensing chamber through said filtering means is increased substantially and separate streams of said purging fluid is drawn from said sensing chamber through said sample outlet conduit and said sample inlet nozzle.

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