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[54] **DETECTOR FOR PARTICULATE MATTER IN FLOWING GAS STREAMS**

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[52] **U.S. Cl.**.....**250/575,** 340/237, 356/207

[51] **Int. Cl.**..... **G01n 21/26**

[58] **Field of Search**..... 356/206, 207, 208; 250/218, 227; 340/237

[56] **References Cited**

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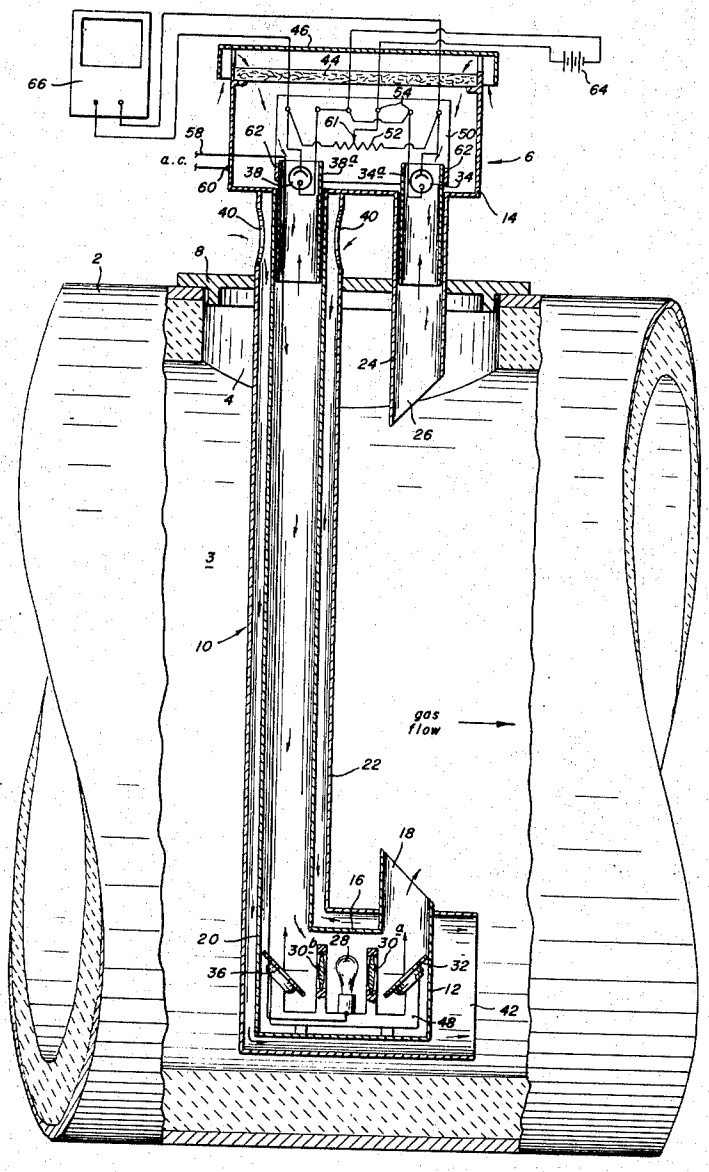
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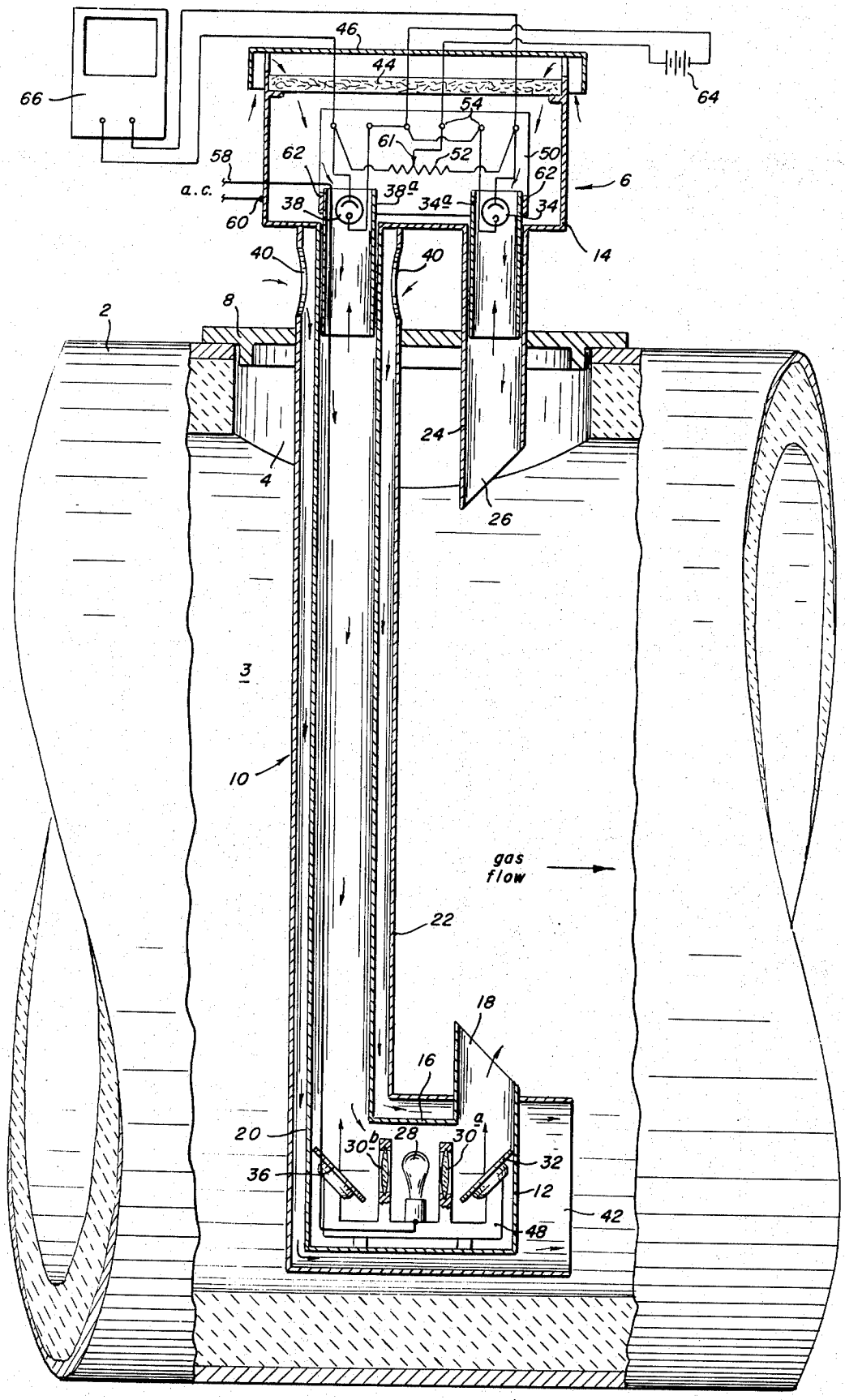
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[57] **ABSTRACT**

Apparatus is an air-cooled and air-cleaned photoelectric smoke or particulate matter detector that can be installed into a gas flue or other gas passageway using only one entry into the flue through a single aperture.

4 Claims, 1 Drawing Figure




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30b
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30a
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DETECTOR FOR PARTICULATE MATTER IN FLOWING GAS STREAMS

The present invention relates generally to detector devices and more particularly to a detector device especially suitable for detecting smoke or particulate matter in a gas stream flowing through a gas passageway.

The present invention contemplates the detection of particulate matter that is borne in gas streams, for example, smoke in flue gases, vapor in discharge from spray booths or cooling towers, dust in discharges from air cleaning equipment, etc.

A well-known method for accomplishing such detection has been through the use of a source of light and a photocell. In the practice of this method, the light source is located on one side of a gas stream and the photocell is located diametrally opposite the light on the other side of the gas stream. More or less light is obscured as more or less particulate matter passes in the gas stream through the beam between the light source and the photocell.

Prior to my invention, serious disadvantages were encountered in using the above-described photoelectric method in that apertures had to be made in each of two opposite walls of the passageway through which the gas stream flowed. In many instances, it is impractical or impossible to make the two apertures; the walls of the passageway may be excessively thick masonry as, for example, the smoke stack of a coke oven battery; or only one side of the passageway may be accessible as in an underground flue where the entry may be made practically only from the top surface. The installation of much combustion equipment is made with underground flues and is supplied usually with occasional manholes for inspection and cleaning purposes. These manholes provide convenient access to the flue.

My invention comprises a photoelectric smoke or particulate matter detector that accomplishes its purpose using only one entry into a gas passageway through a single aperture. This makes it applicable to many installations where, prior to my invention, it was impossible to utilize a photoelectric smoke or particulate matter detection system.

It is, accordingly, the primary object of my invention to provide an improved photoelectric smoke or particulate matter detecting apparatus which can be installed and operated through a single aperture in a gas passageway.

It is a more specific object of my invention to provide an improved photoelectric system as set forth in the above statement of object which includes a unitary housing containing a pair of photoelectric cells; a light source for the photoelectric cells; means sealing the beam from the light source to one of the photoelectric cells and exposing the beam from the light source to the other photoelectric cell through the gas stream traveling through a passageway in which the housing is installed; and means connected with the photoelectric cells for indicating differences in intensities of the light traveling from the light source to the two photoelectric cells so that the density of or the amount of particulate matter in the gas stream traveling through the passageway can be determined.

It is another object of my invention to provide an improved photoelectric detecting apparatus as set forth by the object immediately above which includes means

for circulating ambient air through the housing for cooling and cleaning purposes.

The above and other objects will become more apparent after referring to the following specification and drawing in which the single FIGURE is a longitudinal sectional view showing the apparatus of the invention installed in a gas passageway.

Referring now more particularly to the drawing, reference numeral **2** designates generally the wall of a flue **3** having an aperture or opening **4** therethrough. The apparatus of the invention, designated generally by reference numeral **6**, is shown inserted into the flue through the aperture **4**. The aperture is sealed by a cover plate **8** which surrounds the apparatus of the invention and is shaped to receive the apparatus. The apparatus **6** includes an elongated housing **10** having a first compartment **12** formed on the end thereof adapted to be inserted into the flue and a second compartment **14** formed on the end thereof which projects outwardly of the flue when the apparatus **6** is inserted therein.

The housing **10** is provided with a substantially L-shape duct **16** connecting the compartments **12** and **14**. Duct **16** is provided with an open-end short leg portion **18** which extends ouwardly of the compartment **12** substantially parallel with the long leg portion **20** of the duct **16**. A second substantially L-shape duct **22** surrounds duct **16**. Duct **16** is sealed from duct **22** and is located therewithin in a concentric manner.

A third duct **24** having an open end **26** extends from the compartment **14** through the cover plate **8** and the flue wall **2**. The open end **26** of the duct **24** is spaced from and in alignment with the open end of the end portion **18** of duct **16**.

Light from a light source in the form of a lamp **28** disposed in the compartment **12** is collimated by two lenses **30***a* and **30***b* which are disposed one on opposite sides of the lamp **28** in the compartment **12**. The lenses collimate the light from the lamp **28** so that one beam of light proceeds through lens **30***a* to a plane mirror **32** and thence upward through the short end portion **18** of duct **16**. The beam of light which is directed by the lens **30***a* to the mirror **32** eventually falls upon a photoresistive light detector or electrophotocell **34** mounted in the compartment **14** located outside of the flue wall **2**. Another beam of light passes through lens **30***b*, strikes plane mirror **36** and is directed upwardly through the long leg portion **20** of duct **16** until it strikes another electroresistive light detector or photoelectric cell **38** which is also mounted in the compartment **14** outside of the flue wall **2**.

The compartment **12** is disposed in the end of the duct **16** between the long leg portion **20** and the short leg portion **18**.

Duct **22** is provided with apertures **40** at the end outside the flue walls **2** to permit free flow of ambient air into the duct **22**, down around duct **16** and the compartment **12**, and eventually out into the gas stream flowing through the gas flue **3** via an opening **42** adjacent the end of the duct **22** which surrounds the compartment **12**.

Compartment **14** is open at its outer end, but the opening is fitted with a fiber glass filter **44** similar in construction to furnace filter, stock number 8314 supplied by Sears, Roebuck and Company. The compartment **14** and its filter **44** are covered by a loosely fitting cover **46** in such a manner that air may flow freely be-

tween the cover and the compartment **14**, passing through the filter **44** on the way. The compartment **14** and ducts **16** and **22** are contiguous and, as indicated by arrows, there is free passage of ambient air from the compartment **14** through ducts **16** and **24** into the flue **3** whose smoke or particulate matter content is being measured. Cooling ambient air flows into the openings **40** of duct **22**, through the duct and then outwardly into the gas stream in the flue through opening **42**.

The lamp **28** may be a General Electric No. 1156 bulb, and lenses **30***a* and **30***b* are simple double convex or asymmetric collimating lenses of diameter and focal length suited to the dimensions of a particular size detector. Mirrors **32** and **36** are simple, plane glass, silvered mirrors mounted on a support **48** that holds them at the requisite angle to direct the collimated light from lamp **28** upwardly through the long leg portion **20** of duct **16** on the one side and the short leg portion **18** of duct **16** and duct **24** on the other side.

Photoelectric cells **34** and **38** are photoresistive cells, which, for example, may be RCA Model No. 7163, and are mounted on a circuit board **50**. The circuit board also contains a potentiometer **52** and terminals **54** for connection to a recorder readout device as will be described hereinafter. A source of power for the circuit board may be a 12–volt battery **64** or other suitable dc or ac power supply. The lamp **28** is connected to a source of ac voltage **58**, one side of which is grounded to the housing **10** as at **60**. The other side of the ac voltage source **58** leads to a contact at the base of the bulb **28**.

The electrical system of the detector of the invention is basically a simple Wheatstone bridge using photoelectric cells **34** and **38** as two arms of the bridge and potentiometer **52** as the other two arms of the bridge disposed on either side of its sliding contact **61**. These components are mounted on or attached to the circuit board **50**.

Photoelectric cells **34** and **38** are set into the top of open-ended collimating tubes **34***a* and **38***a*, respectively. The collimating tubes **34***a* and **38***a* keep stray illumination from affecting the photoelectric cells and restrict their view entirely to the collimated beams coming up from the mirrors **32** and **36**. Collimating tubes **34***a* and **38***a* may be attached to the circuit board **50** by mounting straps **62** and held at a spacing which corresponds to the center line spacing of the long leg portion **20** of duct **16** on one side and the center line of the aligned short leg portion **18** of duct **16** and duct **24** on the other side.

A recorder readout device **66** which may be, for example, a potentiometer recorder, Speedomax H, Model R manufactured by Leeds & Northrup Company, is connected with terminals **54**. The entire device is powered by either the battery **64** or other power supply which, for example, could be Model No. LCS–3–02 manufactured by the Lambda Corporation. The recorder readout device **66** is attached to the terminals **54**, and power supply **64** is connected to the Wheatstone bridge as shown.

In operation, the housing **10** is installed by inserting it through the aperture **4** in such a manner that the long leg portion **20** of duct **16** is protected from the smoke or particulate matter in the flue. However, the short leg end portion **18** of duct **16** is open at its end which end is aligned with but spaced from the open end **26** of duct **24** so that particulate matter and smoke will pass between these two open ends and interrupt the light beam that passes through the end portion **18** of the duct **16** and the duct **24**. The lamp **28** directs equivalent beams of light at the two mirrors **32** and **36** and which beams of light impinge upon the photoelectric cells **34** and **38**, respectively. If there is no smoke between the open ends of the ducts **16** and **24**, the paths of light between the mirrors **32** and **36** and the photoelectric cells **34** and **38**, respectively, are equally clear. In this case each photoelectric cell receives the same amount of light and the potentiometer **52** is adjusted so that the bridge is in balance and there is no output on terminals **54**. If smoke or particulate matter enters the space between the end **18** of duct **16** and the end **26** of duct **24**, photoelectric cell **34** will increase in resistance and unbalance the bridge to a degree proportional to its increase in resistance. The unbalance will be sensed as a voltage at terminals **54** and will be displayed on the recorder **66**. Resistance values of photoelectric cells **34** and **38** and potentiometer **52** are chosen to make the recorder **66** go from zero to full scale at an arbitrary range of smoke densities in the space between the duct ends **18** and **26**.

It will be noted that an important advantage of my invention is that a differential clouding of mirrors **32** and **36** as dirt is deposited on them may be compensated for by adjustment of potentiometer **52** when it is known that clean gas is in the space between the duct ends **18** and **26**.

Another important feature of my invention is the arrangement whereby the lamp compartment **12**, the lenses **30** and the mirrors **32** and **36** are kept cool and clean. The temperature within the flue may approach 900° to 1000°F and the pressure in the flue will generally be in the order of one inch water column below the ambient atmospheric pressure outside the duct. The arrangement of my invention is designed so that compartment **12** is cooled by ambient air drawn in through apertures **40** in duct **22** down the annular space between duct **16** and duct **22** around the right angle that surrounds the compartment **12** and out the opening **42** which is adjacent the inner end of the duct **22** within the flue. Thus ambient air is constantly washed down and around duct **16**, compartment **12** and duct **24**. Arrows indicate the flow of ambient cooling air through duct **16**. An additional flow of ambient air is realized through ducts **16** and **24**. Since the short leg end of duct **16** terminates with an open end **18** to the interior of the main flue and the duct **24** also terminates with an opening to the interior of the main flue, through which gas is flowing at a lower than atmospheric pressure, air is drawn out of the open ends **18** and **26** and must necessarily come down ducts **16** and **24**. The air coming down through duct **16** passes through the lamp housing to get to the open end of short portion **18**. This air is drawn in under the loose cover **46** and into the compartment **14** through the filter **44**, then it sweeps down through the long leg **20** of duct **16** across mirrors **32** and **36**, and lamp **28**, and discharges into the flue from the open end of the short leg portion **18** of duct **16**. This flow of air helps to keep photoelectric cell **38**, the mirrors **32** and **36** and lenses **30** *a* and **30***b* clean and cool. An additional flow of air sweeps down through the duct **24** and helps to keep the photoelectric cell **34** clean and cool. The ambient air which passes down through the ducts **16** and **24** is filtered by the filter **44** to keep it clean as possible.

The relatively long straight arrows in the compartment **12** and long leg **20** of duct **16** and in duct **24** indicate the direction of light travel in the device of the invention.

It will be recognized that I have described but one embodiment of my invention. I have, for example, cited a simple Wheatstone bridge that is read out by a potentiometer recorder. The recorder readout device might well be a galvanometer type instrument, such as a simple panel meter, either directly connected to terminals **54** or connected through an operational amplifier that may be used to adjust the impedances in the bridge system. It will be apparent that the power supply **64** can be any source of dc or ac voltage. I have chosen dc in this embodiment to simplify the readout of the bridge. It will also be noted that voltage source **64** and recorder **66** may be located at any distance from the instrument compartment **14** or may be embodied within the compartment **14** itself. The embodiment I have shown has them separated from the compartment **14.** It should also be noted that the voltage source **58** that supplies the lamp **28** may be of any voltage convenient to supply light of sufficient intensity to activate photoelectric cells **34** and **38** through the required range of their readings.

If desired, the duct **22** may be omitted where cooling means are not required or desired, as for example, when the apparatus of the invention is to be used to measure particulate matter in low temperature gas.

It should now be apparent that the apparatus of the invention consists of a device that can be inserted into one opening of a smoke-filled flue and function effectively to detect particulate matter in the gas within the flue. It should also be apparent that the apparatus of the invention provides a smoke detector or particulate matter detector that is integrally cooled and makes use of the pressure differential between the gas flowing through the flue and the ambient air outside the flue to provide a motive force for circulating cooling and cleaning air. The arrangement of the invention also provides a system of filters and ducts that keep clean filtered air passing through the lamp and mirror compartment to cool and clean the same.

If the pressure in the smoke-filled flue is higher than the ambient atmospheric pressure outside the apparatus of the invention, a blower (not shown) may be used to supply motive force to circulate ambient air through ducts **16, 22** and **24.**

While I have shown but one embodiment of my invention, other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. Apparatus for detecting particulate matter in a gas stream flowing through a gas passageway having a lateral opening intermediate its ends which comprises an elongated housing adapted to be disposed transversely in said passageway through said opening with one end thereof projecting from said passageway outwardly of said opening, means surrounding said housing sealing said opening, a first compartment in the end of said housing adapted to be inserted into said passageway, a second compartment at the opposite end of said housing normally disposed outside of said passageway when said housing is inserted therein, a first duct in said housing connected with said compartments, said first duct being substantially L-shape and having an open-end short leg portion extending from said first compartment substantially parallel with the long leg portion of said L-shape first duct, a substantially L-shape sleeve concentrically surrounding said first L-shape duct substantially along its length, a second duct extending from said second compartment toward said open end of said first duct in spaced alignment therewith, a light source in said first compartment, a first photoelectric cell in said second compartment aligned with said first duct, a second photoelectric cell in said second compartment aligned with said second duct and with the open end of said first duct, means in said first compartment directing light from said light source to said first and second photoelectric cells, and means connected with said photoelectric cells adapted to indicate differences in the intensity of light reaching said first and second photoelectric cells from said light source thereby indicating whether particulate matter is present in the gas stream in the passageway between the open ends of said first and second ducts.

2. Apparatus for detecting particulate matter in a gas stream flowing through a gas passageway at a pressure lower than atmospheric pressure having a lateral opening intermediate its ends which comprises an elongated housing adapted to be disposed transversely in said passageway through said opening with one end thereof projecting from said passageway outwardly of said opening, means surrounding said housing sealing said opening, a first compartment in the end of said housing adapted to be inserted into said passageway, a second compartment at the opposite end of said housing normally disposed outside of said passageway when said housing is inserted therein, a first duct in said housing connected with said compartment, said first duct being substantially L-shape and having an open-end short leg portion extending from said first compartment substantially parallel with the long leg portion of said L-shape first duct, a substantially L-shape sleeve concentrically surrounding said first L-shape duct substantially along its length, a second duct substantially surrounding and concentric with said first duct, a third duct having an open end extending from said second compartment into said passageway toward said open end of said first duct in spaced alignment therewith, said second compartment and said second duct having openings for circulation of ambient air through said ducts from the atmosphere outside said passageway into said passageway, a light source in said first compartment, a first photoelectric cell in said second compartment aligned with said first duct, a second photoelectric cell in said second compartment aligned with said third duct and with the open end of said first duct, means in said first compartment directing light from said light source to said first and second photoelectric cells, and means connected with said photoelectric cells adapted to indicate differences in the intensity of light reaching said first and second photoelectric cells from said light source thereby indicating whether particulate matter is present in the gas stream in the passageway between said third duct and said open-end short leg portion of said first duct.

3. Apparatus as defined by claim **2** in which the pressure of said gas stream is above atmospheric pressure, and a air-circulation-inducing means is disposed in said housing.

4. Apparatus as defined by claim **2** in which an air filter is disposed in the path of ambient air flowing through said air openings in said second compartment to said first and third ducts.

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