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Boll

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[54] **RADIATION SENSITIVE FLUID ANALYZER**

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[52] **U.S. Cl.** **250/575**, 250/565, 356/207

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

[58] **Field of Search** 250/564, 565, 216, 573, 250/574, 575, 578; 356/205–208, 103, 104

[56] **References Cited**

UNITED STATES PATENTS

3,617,756	11/1971	Sick	250/574
3,652,850	3/1972	Briggs	250/573
3,659,946	5/1972	Kozawa et al.	356/208 X
3,677,652	7/1972	Little	356/206 X
3,809,912	5/1974	Henning et al.	250/574

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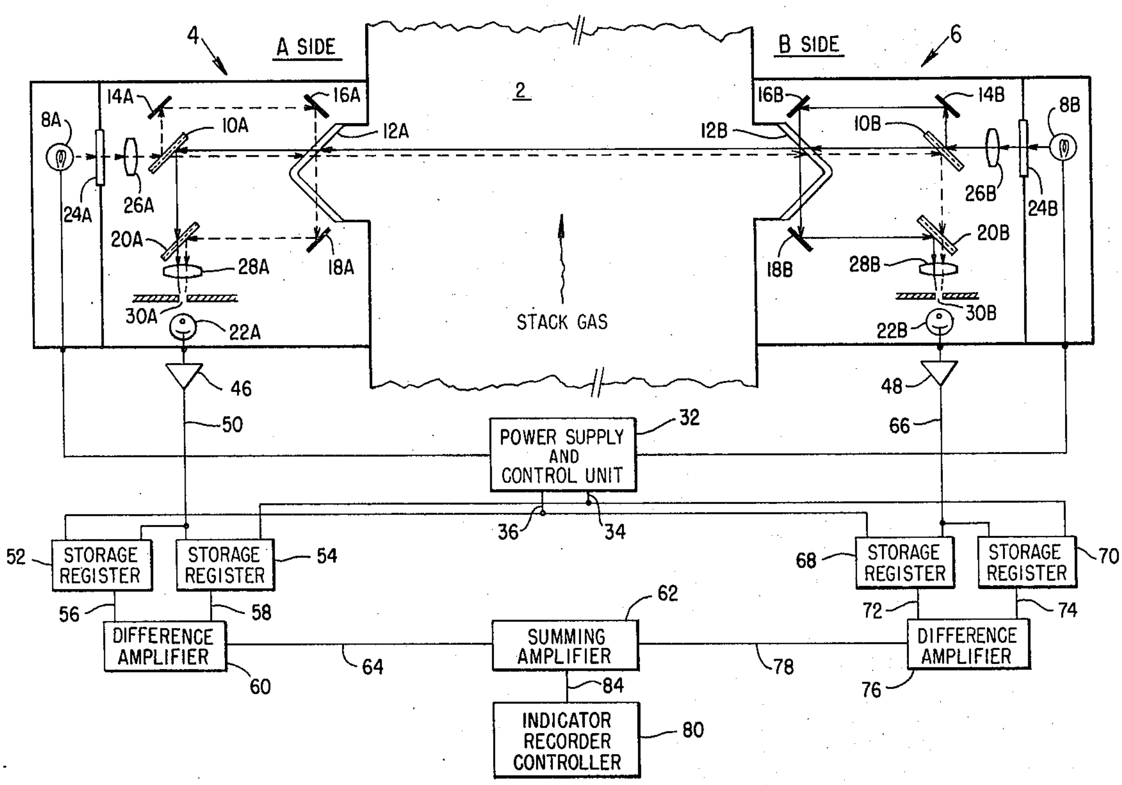
[57] **ABSTRACT**

An analyzer for determining the characteristic of a fluid such as, but not limited to, opacity, turbidity, the concentration of particulate matter in the fluid, the concentration of a constituent gas or liquid in a mixture of gases or liquids; comprising a pair of symetrical transmitter-receiver units each including a radiation source, and isolating window through which radiation from the source is transmitted through the fluid and the isolating window in the other of the units, each having a phototransducer adapted to receive radiation from the other unit when operating as a receiver and to receive radiation from the source in the unit after passing through the isolating window but without passing through the fluid, means for alternately and cyclically energizing the radiation source in each of the units, whereby the characteristic of the fluid computed from the output signals of the phototransducers is completely compensated for variations in the outputs of the radiation sources, input-output characteristics of the phototransducers and changes in the transparency of the isolating windows or, more specifically, for radiation source and phototransducer ageing and window fouling.

9 Claims, 2 Drawing Figures



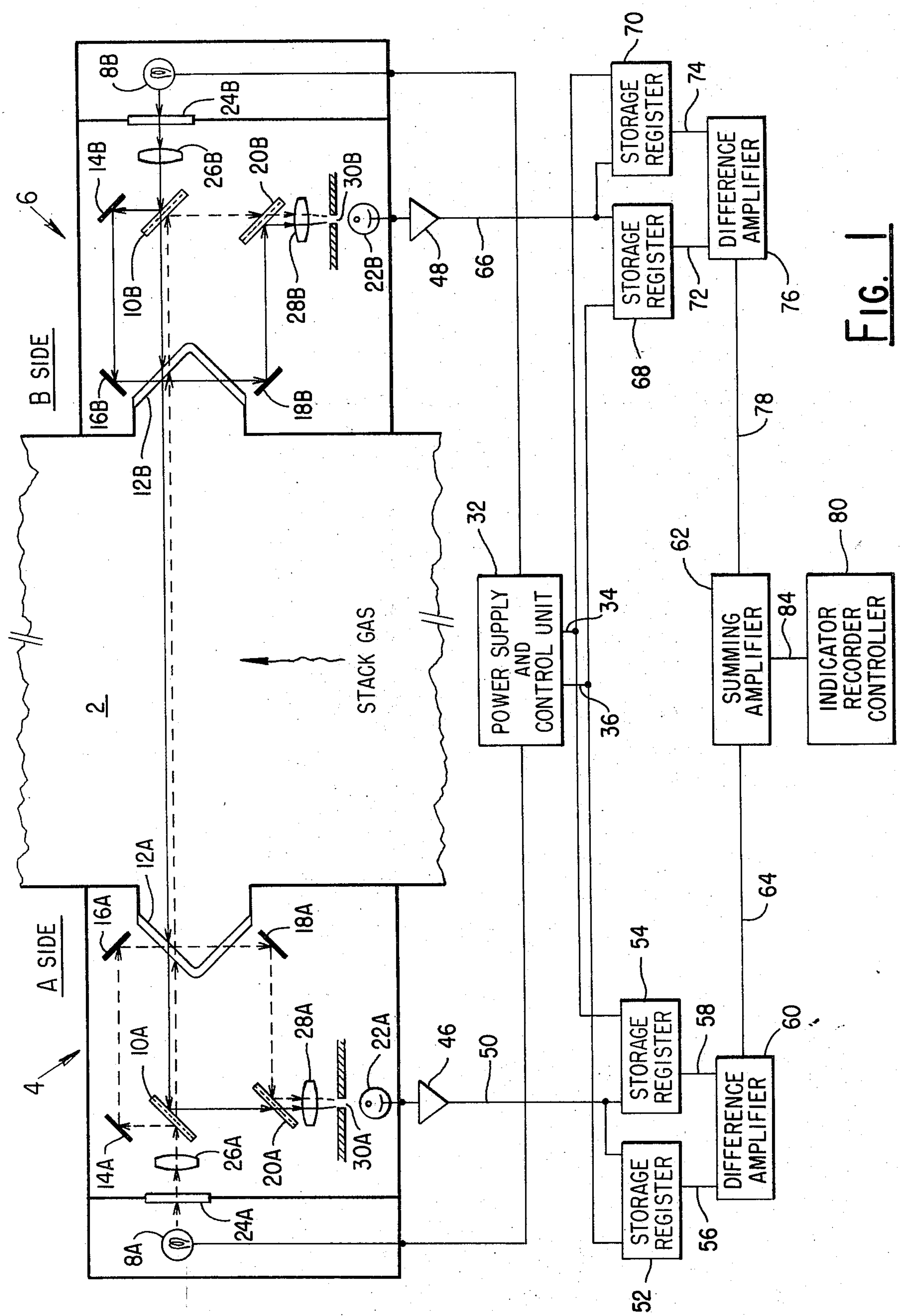

B SIDE
A SIDE
STACK GAS
2
4
6
8A
8B
10A
10B
12A
12B
14A
14B
16A
16B
18A
18B
20A
20B
22A
22B
24A
24B
26A
26B
28A
28B
30A
30B
POWER SUPPLY AND CONTROL UNIT
32
34
36
46
48
50
66
STORAGE REGISTER
52
STORAGE REGISTER
54
56
58
DIFFERENCE AMPLIFIER
60
64
SUMMING AMPLIFIER
62
STORAGE REGISTER
68
STORAGE REGISTER
70
72
74
DIFFERENCE AMPLIFIER
76
78
INDICATOR RECORDER CONTROLLER
80
84

FIG. 1

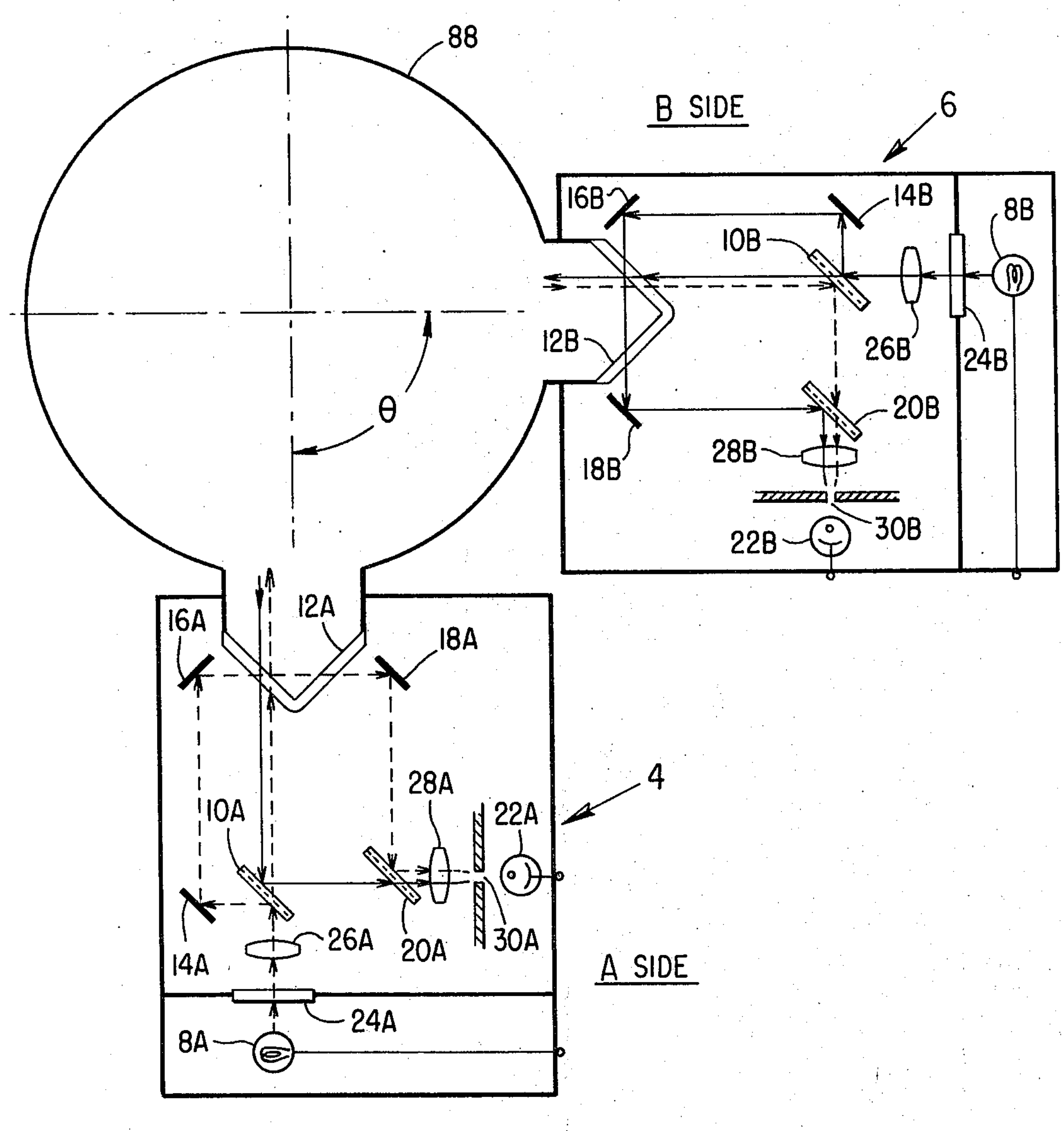

88
B SIDE
6
16B
14B
8B
10B
12B
26B
24B
20B
28B
18B
30B
22B
12A
16A
18A
4
28A
22A
10A
26A
20A
30A
14A
A SIDE
24A
8A
θ

FIG. 2

RADIATION SENSITIVE FLUID ANALYZER

This invention relates to fluid analyzers of the type wherein a characteristic of the fluid is determined from the absorption of radiation transmitted from a source through the fluid to a phototransducer. The transmitting and receiving units of such devices are usually isolated from the fluid by means of isolating windows through which the radiation is transmitted and received. As is well known, such devices are subject to error due primarily to deterioration of the radiation source and phototransducer and fouling of the isolating window. Various means have been employed for compensating for such errors, such as, providing a compensating phototransducer adjacent to the radiation source and continuously or intermittently washing the faces of the isolating windows exposed to the fluid. Such expediences do not provide complete compensation for the errors as the compensating phototransducer compensates only for degradation of the radiation source and not for changes in the input-output characteristics of the phototransducers. The expediencies employed for washing the isolating windows require various forms of gadgetry such as maintaining a steady flow of air or liquid over the exposed faces of the isolating windows. Because of the insufficiencies of the compensating means presently available, analyzers of the type hereunder discussion require frequent adjustment and calibration materially limiting their application, particularly for continuous use in industrial applications.

With the foregoing in mind it is one primary objective of this invention to provide an analyzer completely self compensating for such factors as deterioration in the radiation source and phototransducer and isolating window fouling.

Further objects of the invention will be apparent from the following detailed description taken in connection with the drawings in which:

IN THE DRAWINGS

FIG. 1 is a schematic illustration of an analyzer embodying the principles of my invention showing a typical in-situ application and in block diagram a typical computing circuit which may be used therewith.

FIG. 2 is a schematic illustration showing a typical application of the analyzer as a turbidimeter.

DETAILED DESCRIPTION

For purposes of description I have chosen to illustrate and describe the invention in FIG. 1 as applied to the in-situ determination of the opacity of waste gases flowing through a duct or stack such as caused by particulate matter carried in suspension, water vapor and the like commonly collectively referred to as smoke. It will be recognized that the invention has a wide variety of other applications and is not limited to the in-situ analysis of waste gases; but may be used, for example, to determine a particular characteristic of a fluid whether liquid or gas and regardless of whether or not the analysis is made in-situ. Further it will be apparent that the invention may be used to determine a particular characteristic of fluids produced for use in industrial processes to aid in maximizing the efficiency of production or to aid in maintaining the characteristic at, or below, or above some predetermined value.

Referring to FIG. 1 there is shown a duct or stack **2** through which waste gases flow in the direction of the arrow, having sides, identified for convenience as the A side and the B side. Mounted on the A side is a transmitter-receiver unit generally indicated at **4** and a symetrical transmitter-receiver unit generally indicated at **6** mounted on the B side.

In the following description components incorporated in the transmitter-receiver unit **4** are identified by a numeral followed by a letter A, whereas similar components in the transmitter-receiver unit **6** are identified by the same numeral followed by the letter B.

Incorporated in the transmitter-receiver **4** is a radiation source, such as a lamp **8A**, radiation from which during the half cycle of operation, when the unit is operating as a transmitter, (as indicated by the dashed line directional) passes through a beamsplitter **10A**, through a V-shaped window **12A**, the stack gases present in duct **2**, V-shaped window **12B** and is reflected by beamsplitter **10B** onto a phototransducer **22B**. Also during this half cycle of operation radiation from lamp **8A** is diverted by beamsplitter **10A**, to a mirror **14A**, thence to a mirror **16A**, through window **12A** to a mirror **18A**, thence to a beamsplitter **20A** and thence to a phototransducer **22A**.

During the half cycle of operation when the unit **6** is operating as a transmitter the operation is reversed. As shown by the solid directional line, radiation from source **8B**, passes through beamsplitter **10B**, through V-shaped window **12B**, the stack gases present in duct **2**, V-shaped window **12A** and is reflected by beamsplitter **10A** onto phototransducer **22A**. Radiation from source **8B** is diverted by beamsplitter **10B** to a mirror **14B**, thence to a mirror **16B**, through window **12B** to a mirror **18B**, thence to a beamsplitter **20B** and thence to phototransducer **22B**.

As is evident from the following equations (1) through (9), from the output signals of phototransducers **22A** and **22B** during one complete cycle of operation the turbidity, or smoke concentration, in the stack gases may be computed:

When a side transmitter-receiver unit **4** is a transmitter

$$S_{10} = AM_A\ W_A^2 I_{10} \tag{1}$$

$$S_1 = BM_A^1\ W_A W_B I_{10}\, e^{-\gamma L} \tag{2}$$

Where:

S_{10} = output signal from phototransducer **22A**
A = sensitivity factor of phototransducer **22A**
M_A = mirror transmission factor including the characteristics of mirrors **14A**, **16A** and **18A** as well as beamsplitters **10A** and **20A**
W_A = transmission factor of window **12A**
I_{10} = radiation intensity of source **8A**
S_1 = output signal of phototransducer **22B**
B = sensitivity factor of phototransducer **22B**
M_A' = mirror transmission factor which includes the characteristics of beamsplitters **10A**, **10B** and **20B**
W_B = transmission factor of window **12B**
γ = specific turbidity of the flue gases
L = length of the radiation path through duct 2

When B side transmitter-receiver unit **6** is a transmitter

$$S_2 = AM_B'\ W_A W_B I_{20}\, e^{\gamma L} \tag{3}$$

$$S_{20} = BM_B W_B^2 I_{20} \tag{4}$$

Where:

S_2 = output signal from phototransducer 22A

M_B' = mirror transmission factor including the characteristics of beamsplitters 10B, 10A and 20A

I_{20} = radiation intensity of source 8B

S_{20} = output signal of phototransducer 22B

M_B = mirror transmission factor including characteristics of mirrors 14B, 16B and 18B as well as beamsplitters 10B and 20B

Dividing equations (1) and (2) and (3) and (4):

$$S_1/S_{10} = (B/A)\ (M_A'/M_B)\ (W_B/W_A)\ e^{-\gamma L} \tag{5}$$

$$S_2/S_{20} = (A/B)\ (M_B'/M_B)\ (W_A/W_B)\ e^{-\gamma L} \tag{6}$$

and multiplying equations (5) and (6):

$$(S_1/S_{10})\ (S_2/S_{20}) = (M_A'/M_A)\ (M_B'/M_B)\ e^{-2\gamma L} \tag{7}$$

Taking natural logarithms of both sides of equation (7)

$$\ln (S_1/S_{10}) + \ln (S_2/S_{20}) = -2\gamma L + \ln [(M_A'/M_A) \cdot (M_B'/M_B)] \tag{8}$$

and rearranging:

$$\gamma L = (\ln S_{10} - \ln S_2) + (\ln S_{20} - \ln S_1) + \ln [(M_A'/M_A) \cdot (M_B'/M_B)] \tag{9}$$

thus the turbidity is obtained completely independent of the window transmission factors, W_A and W_B, independent of the phototransducer sensitivities, A and B and independent of the lamp intensities, I_{10} and I_{20}. Moreover the third term on the right hand side of equation (9) is a constant whose value will remain fixed over long periods of time inasmuch as the transmitter-receiver units may readily be constructed so as to substantially hermetically seal the interior of the units from ambient conditions.

Shown in FIG. 1 is one form of computing circuit which may be used to automatically compute either the total or specific turbidity (γL) or (γ) from the output signals S_1, S_2, S_{10} and S_{20}.

The radiation sources **8A** and **8B** are connected to a power supply and control unit **32** which during one-half cycle of operation energizes the source **8A** and during the other one-half cycle energizes the source **8B**. During the half-cycle when source **8A** is energized phototransducers **22A** and **22B** generate output signals S_{10} and S_1 respectively. During the alternate half-cycle when source **8B** is energized phototransducers **22A** and **22B** generate output signals S_2 and S_{20} respectively. As the sources **22A** and **22B** are energized control impulses are simultaneously sent along lines **34, 36** from the power supply and control unit **32** indicating the source energized.

The signals generated by phototransducer **22A** input to a logarithmic amplifier **46,** whereas the signals generated by phototransducer **22B** input to a logarithmic amplifier **48.** The output signals from logarithmic amplifier **46** are applied along line **50** to storage registers **52** and **54.** The registers **52** and **54** are connected through lines **56, 58** respectively to a difference amplifier **60** connected to an algebraic summing amplifier **62** by way of line **64.** The output signals from logarithmic amplifier **48** are applied along the line **66** to storage registers **68** and **70.** Registers **68** and **70** are also connected to the power supply and control unit **32** through lines **36** and **34** respectively. The registers **68** and **70** are connected through lines **72** and **74** respectively to a difference amplifier **76,** connected to algebraic summing amplifier **62** by way of line **78.** The output signal from algebraic summing amplifier **62** may be transmitted to an indicating, recording and/or controlling device such as shown at **80.** The algebraic summing amplifier **62** may be provided with a calibration input **82** which may be used to adjust for the third term on the right hand side of equation (9), which heretofor has been related to be a constant whose value will remain fixed over long periods of time.

After one complete cycle of operation the logarithms of the values of unabsorbed radiation from radiation sources **8A** and **8B** are stored in registers **52** and **70,** and the values of the logarithms of absorbed radiation from radiation sources **8A** and **8B** are stored in registers **68** and **54.** The registers **52, 54** provide the inputs to the difference amplifier **60,** while the registers **68, 70** provide the inputs to the difference amplifier **76.** The outputs of the amplifiers **60, 76** provide the inputs to the summing amplifier **62.** The amplifier **62** thus provides an output signal along line **84** that is in functional relationship to the turbidity of the flue gases.

It is apparent that the radiation sources **8A** and **8B** may be selected to emit predominantly radiation having a wave length compatible with the fluid characteristic to be determined. Thus, for example, depending upon the fluid characteristic to be determined the sources could be incandescent, hollow cathode or mercury arc lamps. When used as a smoke detector radiation sources having wave length characteristics close to those of the human eye could be selected so that the analyzer would indicate a smoke opacity approximating that determined by an observer. The transmitted wave length band can be, if desired, further defined by optical filters such as shown at **24A** and **24B.**

Collimating lenses such as shown at **26A, 26B** would normally be employed to produce a radiation beam of substantially parallel rays. Similarly, well known expediencies may be incorporated in the transmitter-receiver units such as the lens-pinhole arrangement comprising lenses **28A, 28B** and pinholes **30A** and **30B** disposed at the focal points of the lenses to limit the viewing angles of the associated phototransducers.

Referring to FIG. **2,** there is shown a fluid sampler **88,** which may be a container if a static fluid sample is being analyzed, or a pipe or duct if a flowing fluid is being analyzed in-situ. Secured to the wall of the sampler **88** at an angle θ to each other (usually 90°), are transmitter-receiver units **4** and **6** with the windows **12A** and **12B** exposed to the sampled fluid through suitable openings in sampler **88.** When the unit **4** is operating as a transmitter, the unit **6** receives scattered light from the sampled fluid and vice versa. The turbidity of the fluid and then be determined from the output signals of phototransducers **22A** and **22B.**

When the analyzer is arranged as a scattered light turbidimeter (rather than as a transmitted light opacity meter) equations (2) and (3) do not apply. The factor $e^{-\gamma L}$ would be replaced by a function of turbidity, which may be designated at $f(\gamma)$. In this case, logarithmic processing would produce an output that, in general, is not linear to specific turbidity, but is usually proportional to $\int_n(\gamma)$. Thus, if desirable, the computing circuit described above may be arranged to generate an output signal proportional to $f(\gamma)$ in accordance with the following equation. $f(\gamma) = [M_A\ M_B/M_A'\ M_B']^{1/2}[S_1\ S_2/S_{10}\ S_{20}]^{1/2}$ (10)

From the foregoing description it is apparent, regardless of whether the analyzer is applied as a transmitted light opacity meter or as a scattered light turbidimeter, the advantages of freedom from errors due to window fouling, lamp ageing, or phototransducer ageing are obtained.

While in the foregoing description a specific optical system has been illustrated and described, it is evident that alternate optical systems may be used which have in common the fact that the transmitter-receiver units can function either as a transmitter or receiver, and when functioning as a transmitter, radiation source intensity, changes in window transparency and phototransducer sensitivity are monitored by the phototransducer.

I claim:

1. In an analyzer for determining a characteristic of a fluid, in combination, a pair of symetrical transmitter-receiver units each comprising a housing, a radiation source disposed within said housing, an opening in one wall of said housing, a window closing said opening and forming a cavity having transparent walls through which radiation from the source is transmitted through the fluid to the other of the units, a phototransducer disposed within the housing, means diverting radiation from the source through the window to the phototransducer without passing through the fluid between said units, and means directing radiation received through the fluid from the other of said units through said window to said phototrandsucer, the combination further comprising means for alternately and cyclically energizing the radiation source in each of said units to cause each of said units to cyclically and alternately act as a transmitter and then as a receiver whereby the phototransducer receives radiation from the radiation source in the unit when operating as a transmitter and from the radiation source in the other of said units when operating as a receiver.

2. In an analyzer as set forth in claim **1** further including a computing circuit responsive to the signals generated by said phototransducers generating an output signal corresponding to the characteristic of the fluid.

3. In an analyzer as set forth in claim **1** wherein the means diverting radiation from the source through the window without passing through the fluid between said units comprises a first beamsplitter disposed in the path of the radiation from the source to the window, an optical system directing the diverted radiation through the window onto a second beamsplitter directing the diverted radiation onto the phototransducer.

4. An analyzer as set forth in claim **3** wherein said first beamsplitter also acts as a reflector to direct radiation received from the other of said units onto said phototransducer.

5. An analyzer as set forth in claim **4** further including a lens and pinhole located between the second beamsplitter and phototransducer, said pinhole located at the focal point of said lens.

6. An analyzer as set forth in claim **4** wherein the radiation received from the other of said units after being reflected by said first beamsplitter passes through said second beamsplitter before striking said phototransducer.

7. An analyzer as set forth in claim **2** wherein the computing circuit includes means for algebraically adding the logarithms of the signals generated by said phototransducers to thereby produce an output signal proportional to the opacity of the fluid.

8. An analyzer as set forth in claim **2** wherein said transmitter-receiver units are disposed at substantially right angles whereby each receives scattered light from the other unit when operating as a receiver, and said computing circuit comprises means generating an output signal varying in functional relationship to the signals generated by said phototransducers to thereby produce an output signal proportional to the turbidity of the fluid.

9. A analyzer as set forth in claim **3** wherein said first beamsplitter diverts radiation from the source in a direction at right angles to the radiation from said source, and said optical system comprises a first mirror directing the diverted radiation in a direction parallel to the radiation from said source, a second mirror then directing said diverted radiation in reverse direction but parallel to the radiation diverted by said first beamsplitter through said window onto a third mirror directing the diverted radiation in reverse direction but parallel to the radiation from said source onto said second beamsplitter.

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