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[54] MICROVOLUME FLOW CELL

[72] Inventors: **Henry J. Emmel,** Irondequoit; **Thomas J. Morgan,** Rochester, both of N.Y.

[73] Assignee: **Bausch & Lomb Incorporated,** Rochester, N.Y.

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[52] **U.S. Cl.** **356/246,** 73/425.6, 250/218

[51] **Int. Cl.** **G01n 1/10**

[58] **Field of Search** 356/102–104, 208, 356/246; 250/218; 73/425.6

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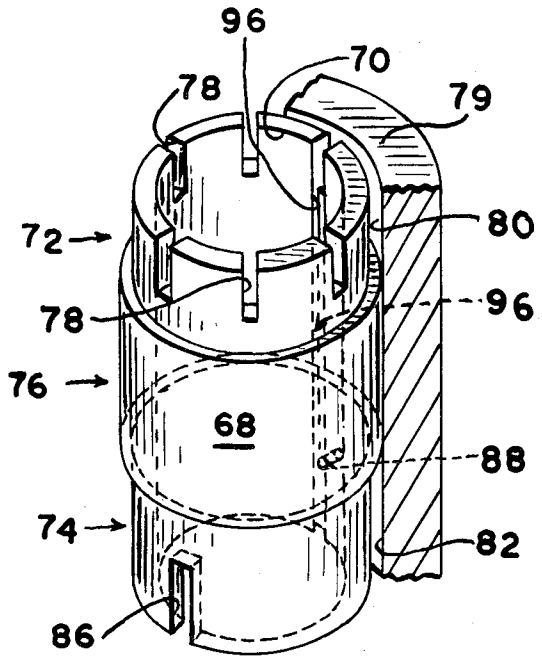
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Primary Examiner—Ronald L. Wibert
Assistant Examiner—Warren A. Sklar
Attorney—Frank C. Parker and Bernard D. Bogdon

[57] **ABSTRACT**

A microvolume flow cell for providing laminar fluid flow comprises an insert having an inlet and an outlet and each defining a plurality of openings channeling to a generally cylindrical fluid chamber formed therein. The openings in the inlet end are elongated and equidistantly disposed about the periphery of the inlet for providing for a laminar fluid flow therethrough into the fluid chamber. The openings in the outlet end comprise two diametrically disposed exit ports of differing size for fluid communication with a waste system. The smaller exit port is disposed with a troughlike drainage slot extending the length of the fluid chamber.

9 Claims, 6 Drawing Figures



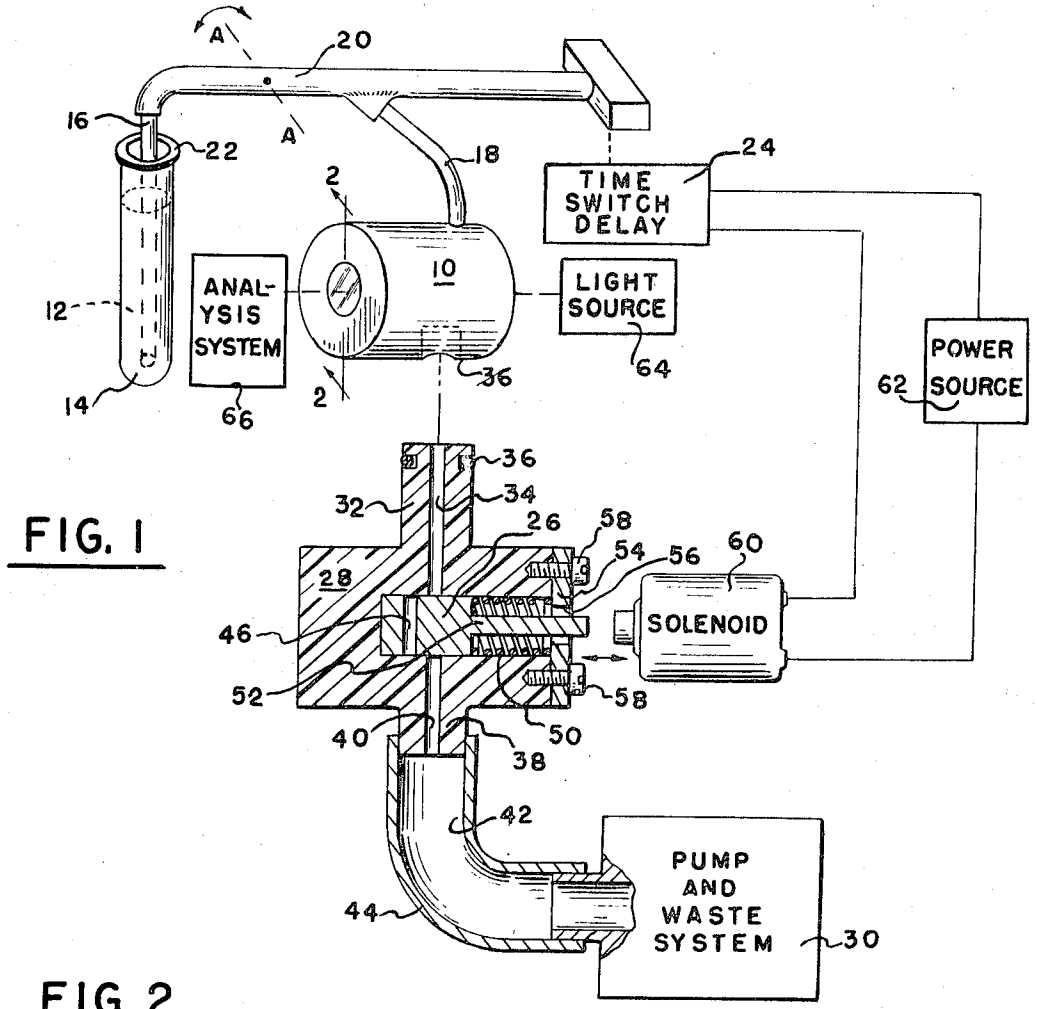
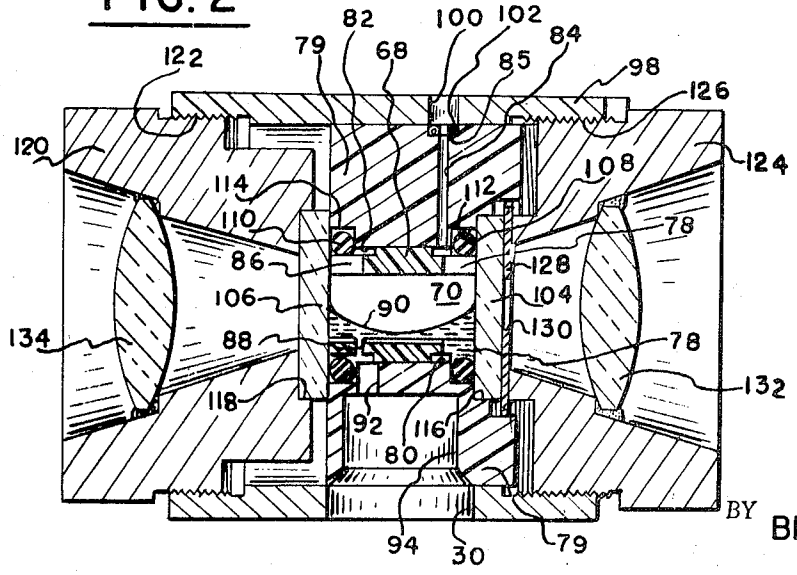


FIG. 1

FIG. 2



HENRY J. EMMEL
THOMAS J. MORGAN
INVENTORS

BY BERNARD D. BOGDON
ATTORNEY

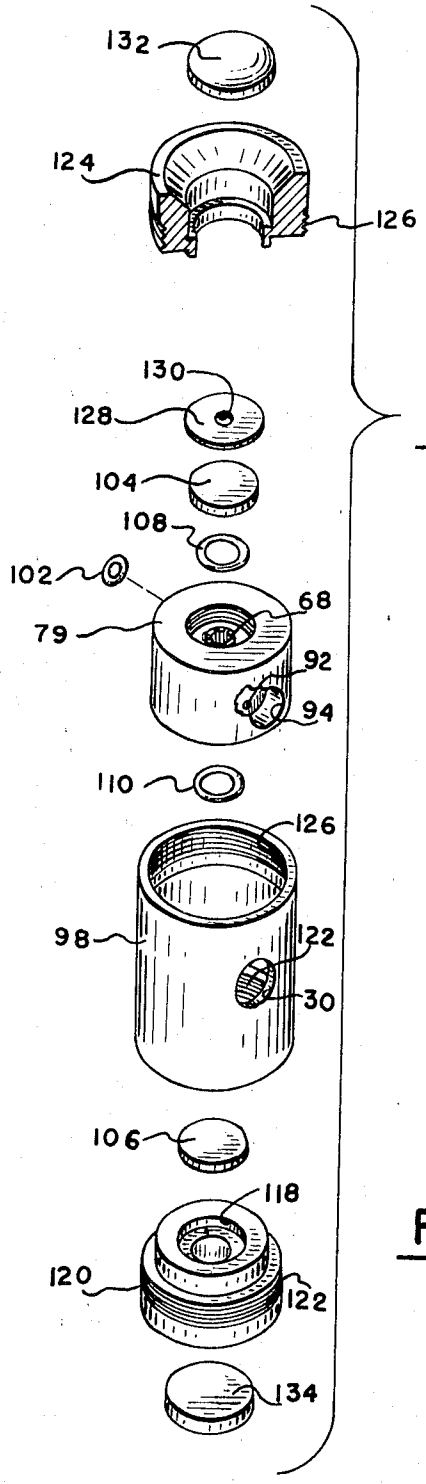


FIG. 3

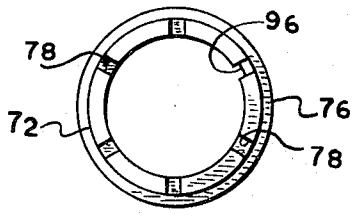


FIG. 5

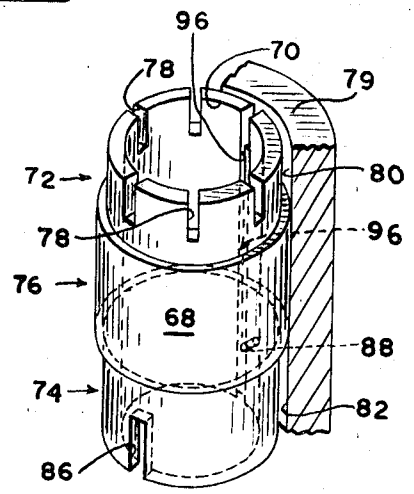


FIG. 4

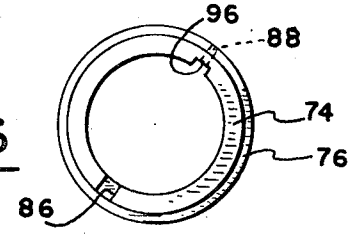


FIG. 6

HENRY J. EMMEL
THOMAS J. MORGAN
INVENTORS

BY BERNARD D. BOGDON
ATTORNEY

MICROVOLUME FLOW CELL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a flow-through cell and more particularly to a microvolume fluid cell for providing laminar flow.

2. Description of the Prior Art

Since the advent of fluid cells of micro and semimicrovolume capacities, the problems of providing for laminar fluid flow therein have often been formidable. For example, it will be appreciated by those skilled in the art that the smaller the fluid chamber of a flow cell the more difficult it is to obtain laminar flow of fluids passing therethrough and likewise, it is as equally well appreciated that the smaller the volume of a flow cell chamber, the more difficult it is to purge the fluid contents of the cell without leaving behind a quantity of meniscus forming fluid from a first sample for substantially contaminating a subsequently introduced second sample.

Flow cells are often used in equipments designed to analyze great numbers of small quantity samples in relatively short periods of time. As a result, fluid samples are introduced into the small volume cells at relatively high velocity and conditions are prime for great turbulence and forming bubbles. The smaller the examining chamber of each cell the more likely it is that the formed bubbles will constitute a part of the examining path through which, for example, an examining light beam will pass and the more likely it is that the analytical results obtained by the equipment will be deleteriously affected.

Contemplation of the problems has resulted in many varied designs as presented in the microvolume flow cells of today. Those cells which have been designed to reduce fluid velocity differentials at various locations within the cell to preclude bubble formation and collection, have generally been complex and costly to manufacture.

The problem of sufficient removal of a first sample in order not to substantially contaminate a subsequently introduced sample has generally been tackled by purging with a first portion of the subsequent sample or purging with sufficient flushing fluid such as air or neutral solution. If the subsequent sample is used to flush, frequently insufficient sample remains for analysis and if other flushing fluid is used, then more complex equipment is needed and additional time is wasted in preparation for sample taking. Solution to the purging problem lies in removing the first sample in sufficient quantity by a single step operation generally not involving the use of subsequent sample or other flushing fluid.

SUMMARY OF THE INVENTION

The present invention overcomes the hereinbefore mentioned difficulties and provides for laminar flow in fluid cells of micro or semimicrovolume capacities. This invention provides for laminar flow in relatively small volume chambers through the use of a plurality of openings substantially uniformly or symmetrically disposed about the walls of a chamber at its inlet end and for removing nearly all, if not all, fluid before introducing a following sample by providing a plurality of exit ports preferably comprising two of differing size diametrically disposed. The smaller port is disposed at the bottom of the chamber and is in communication with a drainage slot at the bottom for immediately carrying away fluid sample which normally forms a meniscus about the lower portion of the fluid chamber during the entire drainage process.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a fluid flow cell according to the principles of the present invention incorporated into a typical system for analytically analyzing fluids;

FIG. 2 is a longitudinal cross-sectional view of the fluid cell of FIG. 1 along the plane of line 2—2 of FIG. 1;

FIG. 3 is a fragmentary perspective exploded view of the fluid flow cell of FIG. 1;

FIG. 4 is an enlarged perspective view of an insert of the fluid flow cell of FIG. 3 according to the principles of the present invention juxtaposed to a fragment of a surrounding sleeve;

FIG. 5 is an end view of the fluid flow cell insert of FIG. 4 at the inlet end; and

FIG. 6 is an end view of the fluid flow cell insert of FIG. 4 at the outlet end.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A typical fluid sample and photometric analysis system incorporating a microvolume flow cell **10**, according to the principles of the present invention, is illustrated in FIG. **1**. As will be appreciated a fluid sample **12** carried within, for example, a test tube **14** is introduced through, for example, an extensible suction probe **16** registering with the flow cell **10** by means of fluid conduit **18** extending through an actuating arm **20**. The probe **16** is preferably formed of a nonwetting material, such as Teflon, to eliminate liquid carryover to preclude sample contamination. The arm **20** is pivotable, for example, by a lifting motion at the underside of the arm **20** by a lip **22** of the test tube **14** or by means of a finger from a human hand. Pivotal action of the arm **20** causes the contacts of a time delay switch **24** to close to complete an electrical circuit for mobilizing a piston valve **26** of a fluid gate assembly **28** to a flow-through position to pass suction from a generating pump and waste system **30** in registration therewith to cause the fluid sample **12** to flow from the test tube **14** into the flow cell **10**.

The fluid flow cell **10** registers with the fluid gate assembly **28** at cell exit port **30**. As will be appreciated, the fluid gate **28** provides passageway for the sample fluid **12** from the flow cell **10** therethrough to a pump and waste system **30**. The fluid gate **28** has at its inlet end a cylindrical extension **32** defining a fluid passageway **34** for registration with the fluid chamber of the flow cell **10**. The cylindrical extension **32** is sealed to the flow cell **10** by means of, for example, an O-ring **36** disposed in an annular recess in the cylindrical extension **32**. The outlet end of the fluid gate **28** comprises, for example, a cylindrical extension **38** defining a fluid passageway **40** in fluid communication with the fluid and waste system **30** by means of a passageway **42** defined by a conduit **44** connecting the gate **28** and the pump and waste system **30**.

The pump and waste system **30** provides a vacuum for suctioning the fluid sample **12** through the various conduits and passageways into and through the fluid chamber of the flow cell **10** at such time when the fluid passageway **34** and **40** of the fluid gate **28** are in registration with each other. This registration is accomplished when a fluid passageway **46** defined by and transversely passing through the piston valve **26** is in registration with each other. This registration is accomplished when a fluid passageway **46** defined by and transversely passing through the piston valve **26** is in registration with both passageways **34** and **40**. The valve **26** is carried by the fluid gate **28** and is formed of material having favorable magnetic properties and is normally biased to the closed position, illustrated in FIG. **1**, by a generally helical spring **50** engaging a cylindrical surface of the piston and encircling an integrally formed cylindrical arm **52** of the piston **26**. The spring **50** is carried within the piston chamber and is held therein by means of a cover plate **54** defining a generally central opening **56** through which the piston arm **52** extends, the plate **54** being affixed to the fluid gate **28** by means of, for example, machine screws **58**.

It will be appreciated that when the piston valve **26** is made to travel a certain distance to the right, in the direction of the illustrated double ended arrow in FIG. **1**, that the passageway **46** will register with the passageways **34** and **40** and that the suction from the pump and waste system **30** will cause general unrestricted fluid flow of the sample **12** from the test tube **14** through the system to the pump and waste system **30**. Alignment of the fluid passageway **46** with the fluid passageway **34**

and 40 is provided when the contacts of the time delay switch 24 are closed to energize a solenoid 60 in electrical circuit with the time delay switch 24 and a power source 62. The core of the energized solenoid 60 attracts the piston valve 26 at the magnetic piston arm 52 and the core is adapted to stop the travel of the piston valve 26 when the passageways 34, 46 and 40 are aligned. The time delay switch 24 is adapted to maintain the electrical circuit in a closed state a predetermined length of time after each actuation to provide for time to suction a sufficient amount of the fluid sample 12 to fill the chamber of the flow cell 10 or if desired, sufficient sample to fill and to purge any previously analyzed sample and accordingly, to eliminate the remaining fluid in at least sufficient volume to preclude significant contamination of the subsequently introduced sample. Purging by drawing through either air or a sufficient amount of the second sample are well known practices and when used with the present embodiment only a minimum of flushing fluid is required.

After introduction of a fluid sample into the chamber of the fluid flow cell 10, analysis is carried out by a light source 64 and a photometric analysis system 66. The photometric analytical elements illustrated in FIG. 1, in operation with the flow cell 10, are formed of suitable materials and are well known in the art.

Having thusly described an application of the preferred embodiment in a useful photometric analytical system, reference is now specifically made to the flow cell 10 as illustrated in FIGS. 2–6. Laminar flow of fluid into the flow cell 10 is provided for by unique configurations in a cell insert 68 defining a fluid chamber 70 and constructed according to the principles of the present invention. The insert 68 is generally cylindrical and comprises an inlet end 72 and an oppositely disposed outlet end 74. A midsection 76 disposed between the inlet and outlet ends 72 and 74, respectively, is cylindrical and of greater circumferential dimension than either the inlet or outlet ends 72 and 74.

Disposed about the insert 68 is a cylindrical sleeve 79 in the form of a tube having a uniformly generated central opening encircling the full length of the insert 68 and engaging its midsection 76. Since the midsection 76 is greater in circumference than the inlet and outlet ends 72 and 74, and since the central opening in the sleeve 79 is generally uniform, there is defined between the sleeve 79 and the outer periphery of the inlet end 72 a cylindrical fluid inlet raceway 80 between the inside wall of the sleeve 79 and the periphery of the inlet end 72 and a cylindrical fluid exit raceway 82 between the inside wall of the sleeve 79 and the periphery of the outlet end 74, as best seen in FIGS. 2 and 4.

To the end of providing for laminar flow fluid into the chamber 70, there is provided, as best seen in FIGS. 4 and 5, at the inlet end 72, a plurality of equidistantly disposed radially extending flow slots 78. There is illustrated six flow slots 78 extending from the edge of the inlet end 72 generally parallel to the axis of the cylindrical insert 68 and ending short of the insert midsection 76. When fluid is introduced at the inlet end 72 laminar fluid flow is provided into the chamber 70 through the flow slots 78. Although slots 78 are illustrated and described, it will be appreciated that other configurations defining, for example, a plurality of differently shaped apertures extending from the periphery of the insert 68 through its walls into the chamber 70 can be provided to provide for laminar flow. The slots 78 are sized so that no one provides a fluid path into the chamber 70 for a significantly disproportionate quantity of the total volume of fluid required to fill the chamber 70.

Fluid is introduced into the fluid inlet raceway 80 through a channel 84 registering with an annular recess 85 formed at the outside of the sleeve 79 for receiving, for example, the fluid conduit 18.

As hereinbefore mentioned after analysis of the fluid sample has been made, it is necessary to purge the flow cell 10 and most desirable to remove virtually all evidence of the analyzed fluid sample in order not to significantly contaminate any subsequently introduced fluid sample. To this end the outlet end 74 uniquely defines a plurality of exit ports as, for example, an elongated slot 86 extending from the edge of the outlet end 74 generally parallel to the axis of the cylindrical insert 68 and ending short of the insert midsection 76. A diagrammatically opposed circular exit aperture 88 extends through the wall of the insert 68 at the outlet end 74.

It is preferred that the in use orientation of the insert 68 be such that its axis be substantially horizontal and that the circular exit aperture 88 communicate with the bottom most portion of the chamber 70, as best seen in FIG. 2. As might be expected, when the orientation of the insert 68 is horizontal, as hereinbefore described, a meniscus 90 is generally formed by a fluid sample at the time of purging, as shown in cross section in FIG. 2, and would remain to significantly contaminate a subsequently introduced fluid sample but for the unique inventive features of the disclosed embodiment.

In operation, at the time of energization of the solenoid 60, the pump and waste system 30 purges the flow cell 10 of the sample fluid 12 and the fluid generally exits from the chamber 70 through the elongated exit slot 86 disposed at the upper most portion of the chamber 70, into the fluid exit raceway 82 in communication with an outlet 92 defined by the sleeve 78 which registers with a cylindrical recess 94 for engaging, for example, the cylindrical extension 32 of the fluid gate 28.

As described, the fluid sample generally exits upward from the fluid chamber 70 through the elongated exit slot 86. The meniscus 90 generally forms at the bottom and the fluid sample remaining there exits through the circular aperture 88 into the fluid exit raceway 82. To facilitate the flowing away of the meniscus forming fluid from both ends of the horizontally disposed fluid chamber 70, there is provided a trough 96 substantially extending the length of the cylindrical chamber at its bottom most portion in communication with the circular aperture 88. The trough 96 readily carries the meniscus forming fluid to the outlet circular aperture 88 to provide a cell chamber 70 ready for introduction of new fluids for photometric analysis.

As hereinbefore mentioned, the elongated exit slot 86 provides a substantially larger cross-sectional area of opening than the circular exit aperture 88 to preclude significant erratic flow of the fluid from the chamber 70 at the time of purging, the greatest quantity of the fluid exiting through the elongated slot 86. The fluid which tends to remain in the chamber 70 due to, for example, surface tension, generally deposits at the bottom of the chamber 70 and is suctioned away through the circular aperture 88 having flowed thereto in the trough 96. To minimize the fluid sample remaining in the chamber 70 due to surface tension, it is suggested that the insert 68 be formed of a nonwetting material, for example, KEL–F a product of E. I. du Pont de Nemours & Co., Inc.

The sectional view and the exploded view of FIGS. 2 and 3, respectively, best show the structural components which comprise the balance of the microvolume flow cell 10. The sleeve 79 is press-fit into a cylindrically formed body 98 defining the aperture 30 and the cylindrical recess 94 of the sleeve 79 is aligned therewith. An opening 100 is provided in the body 98 and is disposed for alignment with the annular recess 85 which communicates with the fluid passageway 84 proximate the periphery of the sleeve 79. An O-ring 102 is disposed at the bottom of the annular recess 85 thereby providing for fluid tight engagement with the fluid conduit 18.

To provide a path for electromagnetic radiation or light through the cell 10 and specifically chamber 70, there are two transparent windows 104 and 106 similarly formed and disposed at opposite ends of the chamber 70. O-rings 108 and 110 are disposed in annular recesses 112 and 114, respectively, and provide for a fluidtight seal between the inlet end 72 and the transparent window 104 and outlet end 74 and the transparent window 106, respectively. For positive location the transparent window 104 is disposed in an annular recess 116 at the inlet end 72 of the insert 68. At the outlet end 74 the transparent window 106 is generally concentrically

located by an annular recess **118** formed in a cylindrically shaped end cap **120** which threadingly engages with the body **98** at threaded surfaces **122**. Similarly, a cylindrical-shaped end cap **124** is threadingly engaged to the body **98** at threaded surfaces **126** to provide for fluidtight engagement between the inner surface of the transparent window **104** and the O-ring **108**.

To preclude or limit the scattering of the electromagnetic radiation passing through the flow cell **10** during sample analysis, there is provided a circular aperture plate **128** sandwiched between the inner surface of the end cap **124** and the outer surface of the transparent window **104**. An aperture **130** concentrically disposed in the plate **128** is sized to keep light from scattering about the walls of the chamber **70** and to limit the possibility of the light path passing through any contaminates or interruptions, i.e., lint and/or bubbles, which might form and generally cling to the sidewalls. It is suggested that the slots **78** and **86** act as a haven for any air bubbles which might possibly form. For photometric efficiency the analyzing light is converged by a convex lens **132** concentrically disposed in the end cap **124**, to pass through the chamber **70** and the fluid sample therein to thereby be generally returned to a parallel path by a convex lens **134** concentrically disposed in the end cap **120**.

Having thusly described our invention in the hereinbefore described embodiment, we claim the following:

1. A fluid cell for carrying fluid to be analyzed by optical analyzing apparatus, comprising:

inner body structure having a fluid inlet end and a fluid outlet end defining therebetween a fluid chamber having a generally cylindrically shaped sidewall, the inner body structure having formed therein at the inlet end a plurality of separate elongated openings in communication with the fluid chamber, said plurality of separate elongated openings extending outwardly from the generally cylindrically shaped sidewall of the chamber for carrying fluid to the chamber for analysis; and

outer body structure disposed about the inner body structure, said outer body structure having optical windows sealed fluidtight at opposite ends of the fluid chamber for permitting the viewing of the fluid by optical analyzing apparatus generally in a direction axial to the generally cylindrically shaped sidewall of the fluid chamber, the outer body structure defining an annularly shaped fluid inlet passageway formed by the inner and outer body structure and said annularly shaped fluid inlet passageway being in fluid communication with the fluid chamber through the plurality of separate elongated openings which extend from the fluid chamber to the annularly shaped fluid inlet passageway, and the outer structure defining at the fluid outlet end a fluid outlet passageway in communication with the fluid chamber.

2. The fluid cell, as defined in claim **1**, wherein each of the plurality of separate elongated openings extends radially from the fluid chamber.

3. The fluid cell, as defined in claim **2**, wherein the inner body structure at the fluid outlet end defines first and second fluid exit ports having openings of differing cross-sectional areas communicating the fluid outlet passageway with the fluid chamber, each fluid exit port substantially diametrically disposed with respect to the other about the fluid chamber.

4. The fluid cell, as defined in claim **2**, wherein the separate elongated openings are formed as elongated slots.

5. The fluid cell, as defined in claim **4**, wherein the slots are elongated in a direction substantially defined by an imaginary line extending between the optical windows at opposite ends of the fluid chamber.

6. The fluid cell, as defined in claim **1**, wherein the separate elongated openings at the inlet end are disposed equidistantly about the fluid chamber of the inner body structure.

7. The fluid cell, as defined in claim **6**, wherein each of the plurality of separate elongated openings is a slot extending radially from the fluid chamber.

8. A fluid cell for carrying fluid to be analyzed by optical analyzing apparatus, comprising:

an inner body member having a fluid inlet end and a fluid outlet end defining therebetween a fluid chamber having a generally cylindrically shaped sidewall, the inner body member having formed therein at the fluid inlet end a plurality of separate elongated fluid inlet openings communicating with the fluid chamber and equidistantly disposed about the generally cylindrically shaped sidewall of the fluid chamber, the inner body member having formed therein at the fluid outlet end first and second fluid exit ports having openings of differing size in communication with the fluid chamber; and

an outer body member disposed about the inner body member, the outer body member having optical windows sealed fluid tight at opposite ends of the fluid chamber for permitting viewing of the fluid by the optical analyzing apparatus, the outer body member defining an annularly shaped fluid inlet passageway formed by the inner and outer body members and the annularly shaped fluid inlet passageway being in fluid communication with the fluid chamber through the plurality of separate elongated fluid inlet openings at the inlet end and the outer body member defining a fluid outlet passageway in communication with the fluid exit ports at the outlet end.

9. The fluid cell, as defined in claim **8**, further comprising a fluid slot defined by the inner body member, the fluid slot being disposed to substantially extend the length of the fluid chamber to communicate with the second fluid exit port.

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