United States Patent [19]

Hogg

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[45] **July 17, 1973**

[54] **APERTURE TUBE ASSEMBLY FOR A PARTICLE STUDY APPARATUS**

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[73] Assignee: **Coulter Electronics, Inc.**, Hialeah, Fla.

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[52] **U.S. Cl.** ..... **324/71 CP**

[51] **Int. Cl.** **G01n 27/00**

[58] **Field of Search** ..... 324/71 R, 71 CP; 23/252 R, 259; 73/425.6, 425.4

[56] **References Cited**

UNITED STATES PATENTS

3,444,464	5/1969	Coulter et al.	324/71 CP
1,969,081	8/1934	Vogel-Jorgensen	73/425.6

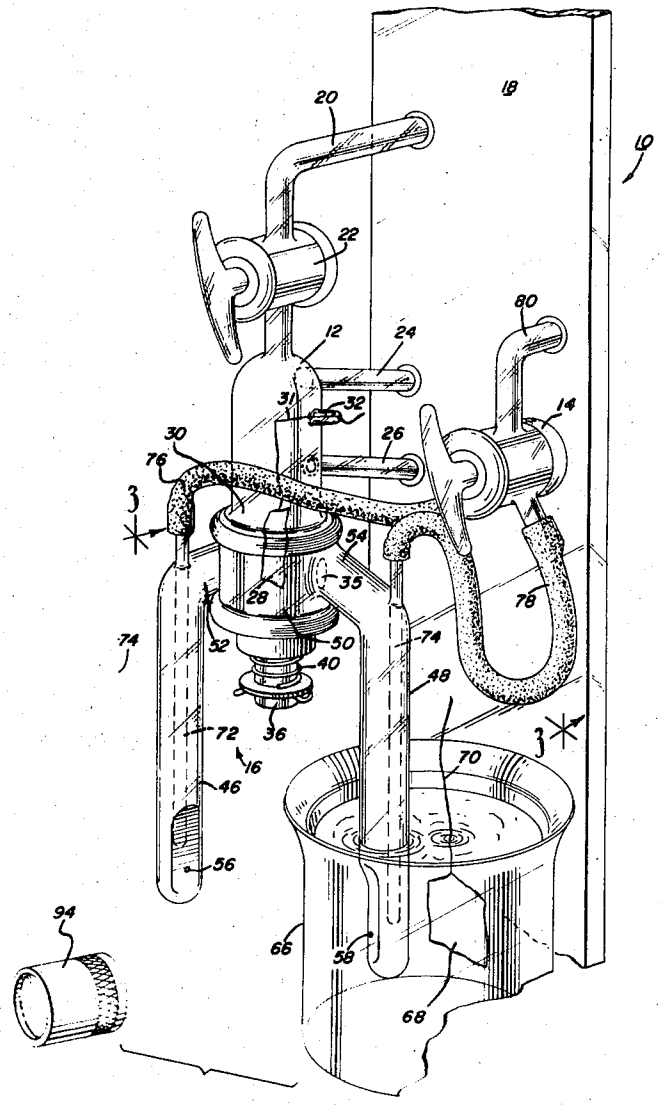
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[57] **ABSTRACT**

An assembly which includes a plurality of particle counting and sizing aperture tubes for use with a particle analyzer of the Coulter type. The assembly includes a rotatable, turret-like fitting having coupled thereto at their open-top end a plurality of the aperture tubes, preferrably having different aperture sizes. The fitting has passageways providing fluid and electric current communication between the interior of each aperture tube and a port in a housing part of the assembly. The housing is in a fixed position, opens into and can form a part of the fluid control piece of a typical Coulter type analyzer. The housing and fitting have fluid tight mating surfaces such that selective rotation of the fitting causes the port in the housing to be aligned with one of the passageways leading into any desired one of the aperture tubes, while the remaining aperture tubes are blocked off by the imperforate portion of the housing which seals the remaining passageways of the fitting.

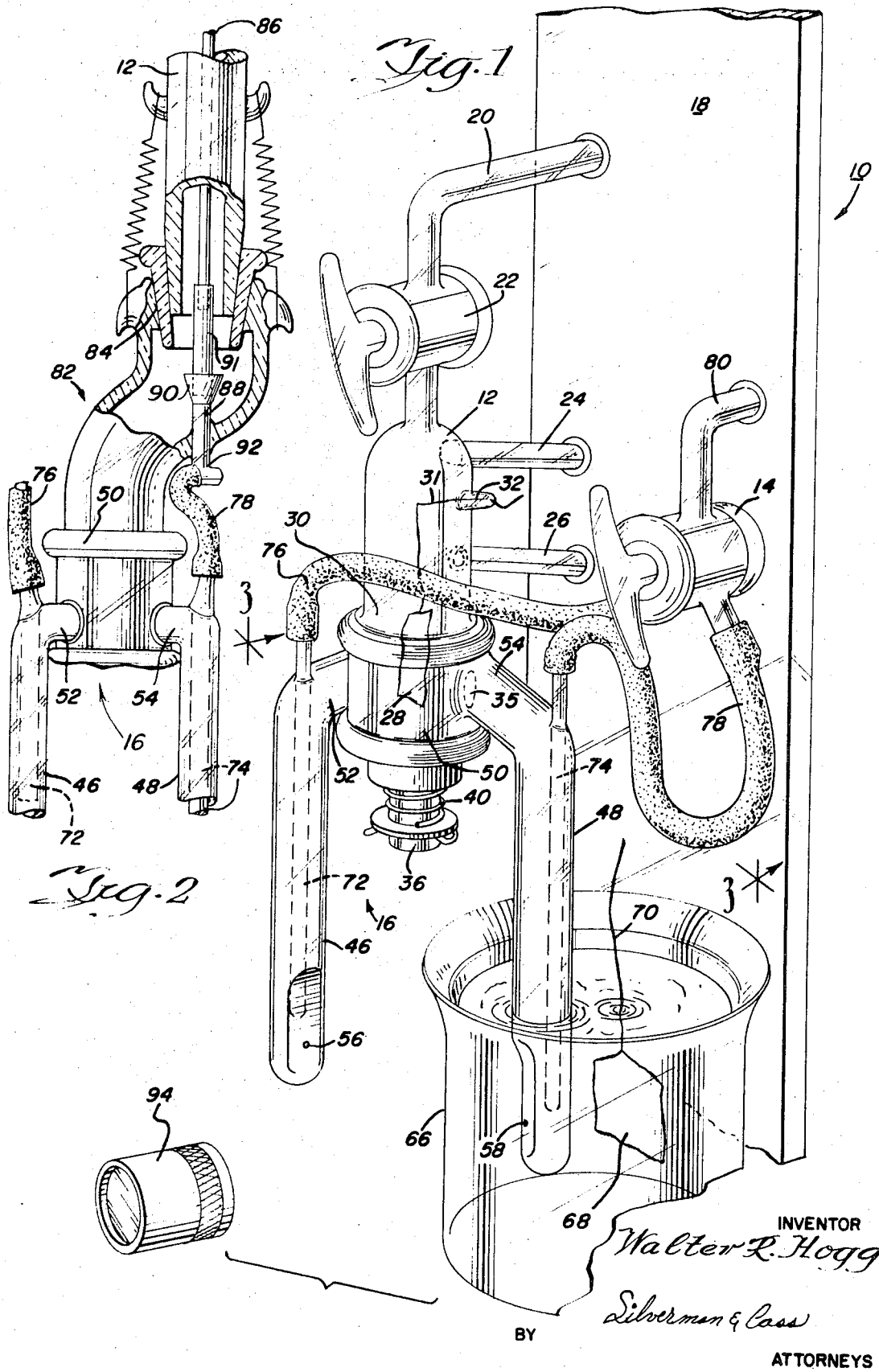
31 Claims, 5 Drawing Figures



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Fig. 3

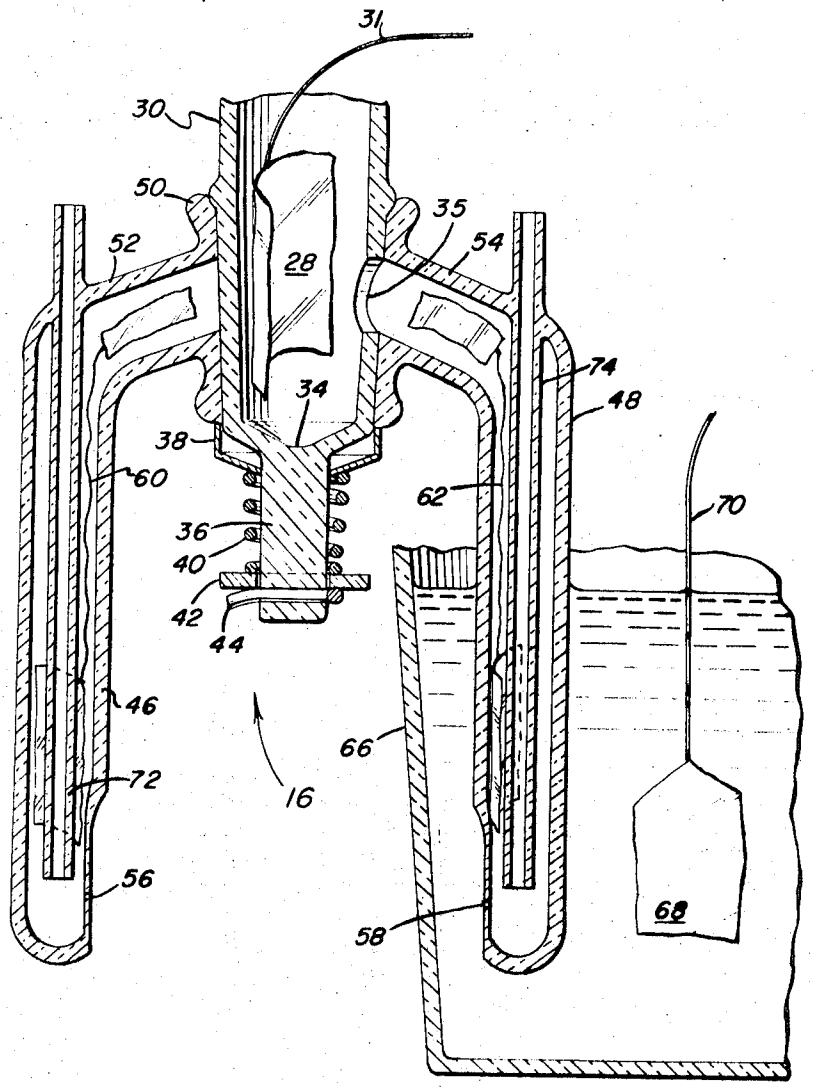
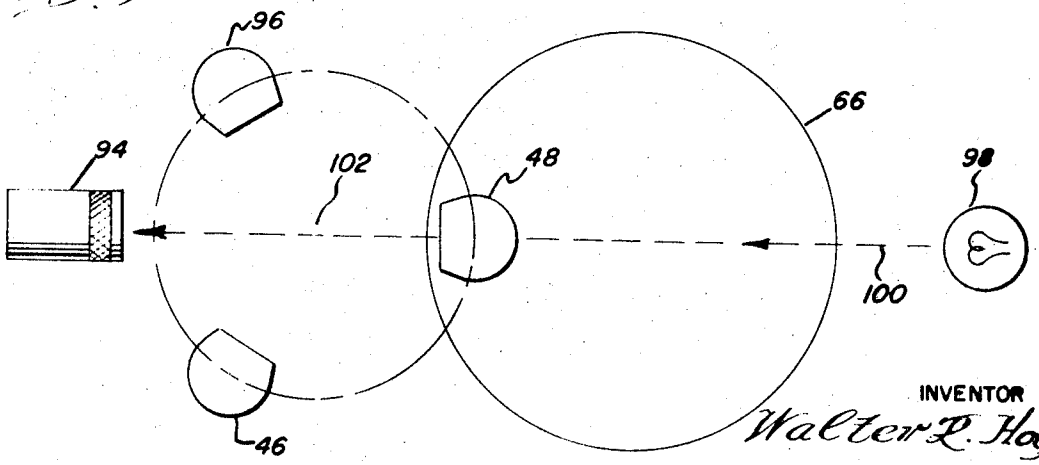


Fig. 4



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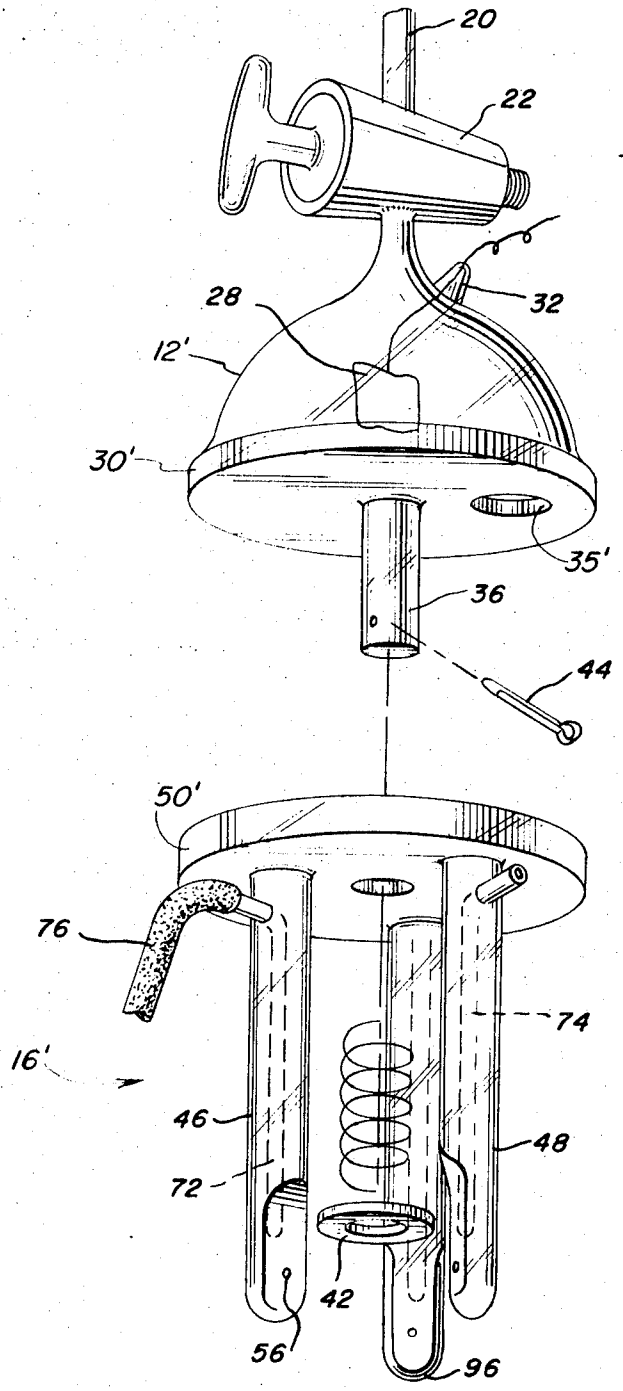


Fig. 5

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APERTURE TUBE ASSEMBLY FOR A PARTICLE STUDY APPARATUS

BACKGROUND OF THE INVENTION

This invention relates generally to the field of particle analysis and more particularly is concerned with the construction of an aperture tube assembly, having a plurality of aperture tubes, which assembly can be used with the Coulter-type particle analyzing apparatus.

In U.S. Pat. No. 2,656,508 there is described a device commonly known as the Coulter apparatus for the counting and sizing of particles in a fluid suspension. The counting of a particular size range of particles is performed optimally with an aperture having a size particularly related to the particle size range.

It has been shown to be desirable to provide a method and apparatus for analyzing suspensions having particles of different size ranges. Several different structures and methods have been devised for this purpose. One approach is to use a single sufficiently large aperture and to discern the different size particles by means of electronic threshold defining and detecting devices. Such arrangement is not highly sensitive to the range of smaller particles, because of the need for a large enough aperture to pass the larger ranges of particles. Such a system is disclosed in U.S. Pat. No. 3,392,331.

Another approach to counting and detecting different size particles is to use a first aperture tube having a particular size aperture, count the particles of a particular size, disassemble the apparatus, replace the first aperture tube with a second aperture tube having a different size aperture and then count the particles which can be detected with the second aperture. This approach requires a great deal of handling and time to set into operation.

Yet another structure for counting different size particles is disclosed in U.S. Pat. No. 3,444,464 wherein an integral unit having essentially separate and independent aperture tubes is disclosed. As is apparent this system would require separate circuitry and a plurality of essentially identical but separate supporting systems.

The above cited patents are representative of Coulter apparatus and have commercial counterparts which are marketed world wide under the trademark Coulter Counter.

SUMMARY OF THE INVENTION

The present invention seeks to overcome some of the limitations of the prior art, avoids duplication of parts, is easy to operate and requires relatively little time to set into operation. Furthermore, it is adaptable to retrofit into existing apparatus.

A primary object of this invention is to provide an aperture tube assembly having a plurality of aperture tubes, each of which may have a different size aperture, wherein an individual aperture tube can be selected for operation.

This assembly, in a preferred embodiment, comprises a turret-like structure having a cylindrical wall which forms an annular member with a plurality of aperture tubes depending therefrom, with each aperture tube being connected at its open top end to the annular member. Passageways are provided for communication between the interior of each aperture tube and a central bore in the annular member, which is defined by the inside surface of the cylindrical wall. There is also

provided a control piece to which aspirating means are connected and which has a hollow housing at its lower end. The housing has a cylindrical exterior configuration which conforms closely to the central bore and is matingly and rotatably seated therein. A single lateral port in the cylindrical wall of the housing can be brought into alignment with any one of the desired passageways by rotating the housing and turret-like structure with respect to one another. The non-aligned passageways are blocked by the imperforate portion of the cylindrical wall of the housing.

In another embodiment, the turret member has a flat planar surface opening into the top of the aperture tubes, and the hollow housing has a mating, disc-like planar surface with the single port in that surface. The turret is mounted for rotation of its mating surface perpendicular to its axis of rotation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing the turret-like aperture tube assembly mounted to the housing of one form of a control piece and having one of its aperture tubes immersed in vessel for containing a fluid suspension of particles;

FIG. 2 is a fragmentary view partly in section showing an intermediate member for connecting the control piece and aperture tube assembly;

FIG. 3 is a fragmentary sectional view taken along line 3—3 of FIG. 1 showing the aperture tubes, housing and valve arrangement;

FIG. 4 is a diagrammatic top plan view showing one embodiment of the aperture tube assembly aligned with a viewing system; and

FIG. 5 is a perspective view of a second embodiment of the tube assembly, also employing a different form of control piece.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, the front of a Coulter apparatus **10** includes a control piece **12**, a quick-refill stopcock **14** and a turret-like aperture tube assembly **16**. Both the control piece **12** and the stopcock **14** are mounted to a support surface **18**.

The control piece **12** is a hollow structure which is connected to a vacuum source (not shown) through a vacuum line **20** and a stopcock **22**. A manometer or similar device (not shown) is connected to the interior of the control piece **12** through a line **24**. The control piece is mounted so that the lower end thereof is spaced a sufficient distance from the support surface **18** to permit rotative motion of the aperture tube assembly **16**. To add further structural support to the control piece a support post **26** can be mounted to the support **18** and the lower end of the control piece **12**.

The above disclosed orientation of the control piece **12** as illustrated, is slightly different from that found on existing Coulter Counter devices, to the extent that the control piece in existing equipment is positioned too close to the support surface **18** to accommodate the turret assembly **16**. For that reason a retrofit modification, subsequently to be discussed with reference to FIG. **2**, has been designed.

An "interior" electrode **28** is disposed within the control piece and extends into a housing **30** at the lower end of the control piece. The upper end of the electrode is attached to an electric lead **31** which passes through the wall of the control piece and to a

terminal 32 to which particle signal detecting means (not shown) can be coupled.

As shown in FIG. 3, the housing 30 is hollow and has a round cross section, having a closed end 34 and a single lateral port 35 in its side wall. The lower end of the electrode 28 is disposed close to the port 35. At the bottom of the housing is an integral depending post 36 which acts as a mounting device for holding the aperture tube assembly 16 onto the control piece with the cooperation of an annular cap 38, a compression spring 40, a washer 42 and a cotter pin 44. The housing 30 is tapered toward the mounting post 34 to assure accurate engagement between the aperture tube assembly 16 and the housing 30.

The aperture tube assembly 16 includes a pair of depending aperture tubes 46 and 48 which are joined at their open upper ends to a female fitting 50. The inside wall of the fitting 50 defines a central bore which opens into the open upper ends of the aperture tubes and which matingly and rotatively engages the exterior surface of the housing 30 and its port 35. The upper portions 52 and 54 of the aperture tubes slope downwardly away from the fitting 50 to avoid the possibility of air entrapment.

In the lower end of each aperture tube there is provided a scanning aperture 56 and 58 through which a particle containing suspension of electrolyte is drawn for the counting and sizing of the particles. The apertures may be the same or different sizes. To reduce the electrical resistance between the scanning aperture and the electrode 28, electrodes 60 and 62 are provided and extend from adjacent the scanning aperture to an adjacent open upper end of each tube. In a preferred embodiment each electrode includes a length of wire having platinum strips connected to the ends thereof, as shown in FIG. 3.

In FIGS. 1–3, the open upper end 54 of the aperture tube 48 is aligned with the lateral port 35 to provide communication between the interior of the housing 30 and the aperture tube, which will be identified as the active tube.

The active aperture tube 48 is positioned within a beaker 66 for containing the suspension of particles to be analyzed. In this suspension is an "exterior" electrode 68 which by way of an electrical lead 70, would be connected to the particle signal detecting means; thereby, completing an electrical circuit between the exterior electrode 68 and the interior electrode 28.

As appreciated by those familiar with the operation of a "Coulter Counter," it is desirable to have a quick fill and flushing arrangement. Such an arrangement permits the clearing of a blocked scanning aperture and also the quick filling of the aperture tube with clean electrolyte. A quick-fill arrangement, as shown in FIGS. 1 and 3, includes a pair of flushing tubes 72 and 74 each mounted within an aperture tube and having one end exterior of the aperture tube and the other end positioned adjacent the scanning aperture. The exterior end of each flushing tube can be connected by flexible tubing 76 and 78 to the valve assembly 14. The input of the valve assembly 14 is connected to an electrolyte supply through a line 80. The flexible connections permit the rotation of the assembly 16 without disconnecting the flushing arrangement.

The control piece 12 and the housing 30 are shown integral in FIG. 1; however, it may be desired to construct the housing as a separate piece which can be demountably attached to the control piece. Such an arrangement, as shown in FIG. 2, may be necessary in order to adapt or retrofit the aperture tube assembly 16 to various existing instruments of the Coulter type. As illustrated, an S-shaped intermediate member 82, having the control piece 12 at its upper end 84 and the housing 30 at its lower end, is respectively coupled to those two elements by a spring biased, ground-glass joint at its upper end 84 and the previously discussed depending post 36 and fastener means 38-44 at its lower end 30, which is of the same configuration as disclosed with reference to FIGS. 1 and 3.

In order to retrofit the quick fill and flushing structure of existing apparatus, which includes a tube 86 positioned inside the control piece 12 and directly leading into the quick fill valve 14, the intermediate member 82 is provided with a conduit 88 having a flared seat 90 at its top for receiving the bottom end of the tube 86. A flexible tubing 91 can be used for ease of close fitting the tube 86 into the seat 90. The bottom end of the conduit 88 extends externally of the hollow body of the member 82 and terminates at a T-fitting 92, to which can be coupled the flexible tubes 76 and 78, which are to be joined to the flush tubes 72 and 74. In this retrofit form, the valve 14 has an outlet going only to the tube 86 in the control piece and no direct connection with the flexible tubing 76 and 78. To prevent loss of electrolyte through the inactive aperture tube, the associated tubing 76 or 78 can be pinched off with a spring pinchcock.

It is desirable to view the operation of the active scanning aperture to monitor its blockage and other dynamic conditions. A viewing system for this purpose is disclosed in U.S. Pat. No. 3,389,334. Therein a light beam is aligned with the aperture, passes through the suspension in the beaker and the aperture tube, and is collected by an objective lens for viewing. Such an objective lens 94 is shown in FIG. 1. As can now be appreciated, the orientation of the aperture tubes about the female fitting 50 is not positionally or radially restrictive, except for the fact that in any orientation of the turret, the beam of light should pass through only one aperture, that of the active aperture tube.

FIG. 4 depicts a diagrammatic view of one possible arrangement of the aperture tubes with respect to the viewing system. Such arrangement is suitable for a retrofit embodiment. Since the inventive scope of the turret assembly is not limited to two aperture tubes, FIG. 4 illustrates three aperture tubes 46, 48 and 96, with the aperture tube 48 being the active tube and positioned in the beaker 66. A light source 98 projects a beam of light 100 through the aperture of the tube 48 and the objective lens 94. The rotative center of the tubes 102 is the axis of the female fitting 50. It is seen that the tubes 46, 48, and 96 are spaced about 120° apart. By rotating the turret assembly 16 120° in a clockwise direction, the tube 96 can be rendered active, aligned with the lateral port 35, and also aligned with the viewing system, while tubes 46 and 48 are inactive.

The operation of a Coulter type of particle counting device is well known and disclosed in the various aforementioned patents. In the embodiments of this invention, a suspension containing the particles to be counted is prepared and disposed within the beaker 66. The port 35 is aligned with the open and passageway top end of one of the aperture tubes by appropriate ro-

tation of the assembly **16.** The housing **30** and the active aperture tube, such as **48,** are filled with an electrolyte by opening the stopcock **14** until the interior electrode **28** is immersed, so that a complete electric circuit can be established between the interior electrode **28** and the exterior electrode via the aperture **58, 68** through the suspension in the beaker **66** and the electrolyte in the aperture tube **48.** By way of the valve **22** and its vacuum line **20,** the particle containing suspension is then drawn toward the interior of the control piece **12** via the aperture **58.** Appropriate means for determining the volume of the suspension flowing through the aperture are known in the art and are used to provide a basis for determining the concentration of a particular sized particle in the suspension.

When it is desired to count particles of a different size range in the same suspension in the beaker **66** or in a different suspension in a different beaker, the beaker **66** is moved from the rotative path of the depending aperture tubes in the assembly **16** which is rotated until the open upper end of the aperture tube **46** is aligned with the port **35** and thus the aperture tube **48** is rendered inactive. The beaker **66** or its counterpart is positioned to retain the aperture tube **46** so that the above discussed fluid transporting and suspension analysis can again take place.

Many valve arrangements can be provided for the selection of the aperture tube to be activated. One alternative to the illustrated rotary turret assembly would be an axially slidable aperture tube assembly in which the female fitting **50** and the housing **30** move axially for the alignment of the open upper ends of the aperture tubes and ports vertically offset in the lateral wall of the housing **30,** as well as radially aligned with the aperture tubes would provide the equivalent of the port **35.** It can be envisioned that connections or joints other than ground glass joints could be used; for example O-rings or other similar devices could be utilized to assure fluid type connection between the housing and aperture tube assemblies, as well as the control piece and the intermediate member in the FIG. **2** embodiment.

Although the diagrammatic view in FIG. **4** shows the objective lens **94** relatively distant from the active positioned aperture tube **48,** it might be found necessary optically to position the lens **94** closer to the beaker **66** and in an orientation that would inhibit the path of movement of the angularly displaced tubes during their positioning into the active position. In such case, their angular spacing would be reduced to approximately 60°.

FIG. **5** illustrates another embodiment of the invention, one in which female-male surface mating relationship between the turret fitting **50** and the housing portion **30** in FIGS. **1–3** are replaced by a flat planar surface to surface mating of their counterpart portions **50'** and **30'.**

As shown, the hollow housing **30'** is disc shaped and carries its port **35'** in its bottom wall, which is a flat surface, for appropriate selective orientation with the open tops of the aperture tubes **46, 56** and **96,** which communicate with the top wall of the disc shaped fitting **50',** which defines its interior surface. The aperture tubes depend from the lower or exterior surface of the fitting **50'.** The control piece **12'** may be of any convenient configuration and may be unitary with the housing **30'.** The spring biased mounting arrangement, including the post **36,** for holding the turret **16'** to the control piece **12'** can be substantially the same as that shown in FIGS. **1** and **3.**

The rotative coaction between the two disc elements **30'** and **50'** by selective rotation of the turret **16'** provides the same desired relationship as described for the earlier described embodiments.

It is believed that the foregoing will enable those skilled in the art to practice the invention and appreciate its scope as defined in the following claims.

What it is desired to be secured by Letters Patent of the United States is:

1. An aperture tube assembly for use with an electronic particle study apparatus of the Coulter type, comprising:

a fitting having interior and exterior surfaces,

a plurality of open-top aperture tubes positioned about said exterior surface of said fitting,

each aperture tube being coupled from its open-top end to said fitting for fluid communication between said interior surface and a scanning aperture disposed in each said aperture tube, and

said assembly being constructed and arranged for mounting to the particle study apparatus and for relative movement of said fitting for aperture tube selecting movement with respect to the apparatus,

said assembly further being constructed and arranged such that at any one time only one of said aperture tubes is in fluid communication with the apparatus by way of said interior surface.

2. An aperture tube assembly according to claim **1** wherein said scanning apertures are of at least two different sizes.

3. An aperture tube assembly according to claim **1** wherein said aperture tubes are positioned relative one another to be other than diametrically opposed.

4. An aperture tube assembly according to claim **1** wherein said aperture tubes are positioned relative to one another such that their apertures are other than axially aligned with one another.

5. An aperture tube assembly according to claim **1** wherein each aperture tube is provided with

an open ended flushing tube partly disposed within the aperture tube,

one of the ends of said flushing tube being inside the aperture tube and proximate the scanning aperture and its other end being external to the aperture tube for connection to an external source of flushing fluid.

6. An aperture tube assembly according to claim **1** wherein each aperture tube is further provided with

means defining an electrically conductive path,

said path means being disposed entirely within the tube and having one end proximate the scanning aperture and the other end proximate the open top end of the aperture tube, for communicating electrically with said interior surface.

7. An aperture tube assembly according to claim **6** wherein said path means comprises at least one metallic electrode.

8. An aperture tube assembly according to claim **1** which is provided with

means defining an electrically conductive path for each aperture tube,

said path means being disposed primarily within said fitting and proximate said interior surface and thereby proximate the open top end of the aperture tubes.

9. An aperture tube assembly according to claim 8 wherein an electrode defines said path means.

10. An aperture tube assembly according to claim 1 and in combination therewith

means defining an electrically conductive path for each aperture tube,

said path means being disposed external said aperture tubes and proximate said interior surface of said fitting.

11. An aperture tube assembly according to claim 10 wherein an electrode down stream of said fitting defines said path means.

12. An aperture tube assembly according to claim 1 wherein said fitting is in the form of the female part of a concentric joint.

13. An aperture tube assembly according to claim 1 wherein said fitting is annular, with an inner wall of circular cross section which defines said interior surface.

14. An aperture tube assembly according to claim 13 wherein

said aperture tubes are radially positioned about said fitting and

said fitting is constructed and arranged for rotative movement about the axis of its inner wall.

15. An aperture tube assembly according to claim 14 wherein said fitting is in the form of the female part of a concentric joint with its said inner wall telescoping over a male part defined by the particle study apparatus.

16. An aperture tube assembly according to claim 1 wherein said fitting is in the form of a disc with respect to which said interior and exterior surfaces are defined by the opposite faces of said disc.

17. An aperture tube assembly according to claim 16 wherein

said aperture tubes have their open tops radially spaced about and dependent from said exterior surface and

said disc is constructed and arranged for rotative movement about its axis which lies normal to its opposite faces.

18. An aperture tube assembly according to claim 17 wherein said disc is constructed and arranged such that its interior surface is mated with a similar surface of contact defined by the particle study apparatus.

19. An aperture tube assembly according to claim 1 which further comprises

a hollow housing having a wall and at least one port through said wall,

said housing being constructed to mate its said wall with said interior surface of said fitting, such that in any orientation of said fitting a maximum of one of said aperture tubes can be aligned for fluid communication with the interior of said housing by way of the open-top end of that aperture tube and said port.

20. An aperture tube assembly according to claim 19 wherein said wall is constructed to block the open-top end of all of said aperture tubes, except for the one aperture tube in fluid communication with the interior of said housing.

21. An aperture tube assembly according to claim 19 wherein said housing has an axial end which depends from said wall and defines mounting means for joining said housing to said fitting.

22. An aperture tube assembly according to claim 12 wherein

said axial end is closed to enable fluid retention in said housing and

biasing means retains said fitting to said axial end and permits relative movement therebetween.

23. An aperture tube assembly according to claim 19 wherein

said wall defines a side wall of said housing,

said interior surface of said fitting defines a central bore of said fitting, and

said side wall and said central bore are constructed to mate and define a path of relative rotative movement about the axis of said central bore.

24. An aperture tube assembly according to claim 19 wherein

said wall defines the bottom wall of said housing,

said interior surface of said fitting defines the top wall of said fitting, and

said top and bottom walls are constructed to mate and define a path of relative rotative movement about an axis which lies normal to said walls.

25. An aperture assembly according to claim 24 wherein

said top and bottom walls are disc shaped,

an axially positioned member depends from said housing and defines means for mounting said fitting to said housing in fluid tight relationship.

26. An aperture tube assembly according to claim 19 wherein

a fluid conduit is carried by said housing and

one end of said conduit extends external of said housing for connection to a flushing arrangement in said aperture tubes.

27. An aperture tube assembly according to claim 19 wherein the particle study apparatus includes a control piece and said housing is defined by a portion of the control piece.

28. An aperture tube assembly according to claim 27 wherein said housing and the control piece have substantially parallel longitudinal axes which are aligned.

29. An aperture tube assembly according to claim 27 wherein said housing and the control piece have substantially parallel longitudinal axes which are laterally spaced apart.

30. An aperture tube assembly according to claim 19 wherein

the particle study apparatus includes a control piece, and

a member separable from and constructed to be mounted intermediate said fitting and the control piece carries said housing.

31. An aperture tube assembly according to claim 30 wherein said housing and the control piece have substantially parallel longitudinal axes which are laterally spaced apart.

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