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**Nickles et al.**

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[54] **METHOD AND APPARATUS FOR MEASURING ABSOLUTE DENSITIES**


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[52] **U.S. Cl.** ..... **73/433,** 73/38

[51] **Int. Cl.** ..... **G01n 9/02**

[58] **Field of Search** ..... 73/19, 38, 49.2, 73/49.3, 49.4, 149, 433, 32; 141/83



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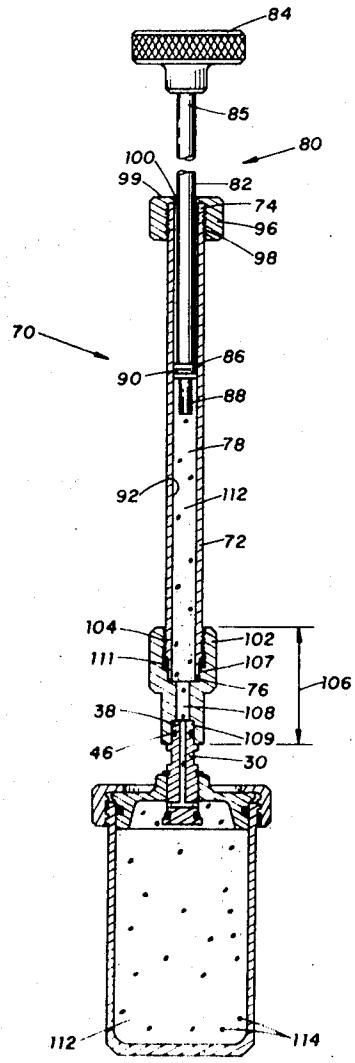
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[57] **ABSTRACT**

Disclosed herein is a method and an apparatus for measuring the absolute densities of fluids. The apparatus includes a sample cup and a sealing cap with a valve therein through which the cup can be charged with fluid to be measured. A pressure pump and weighing device are also disclosed with which the cup is charged and weighed.


**6 Claims, 6 Drawing Figures**



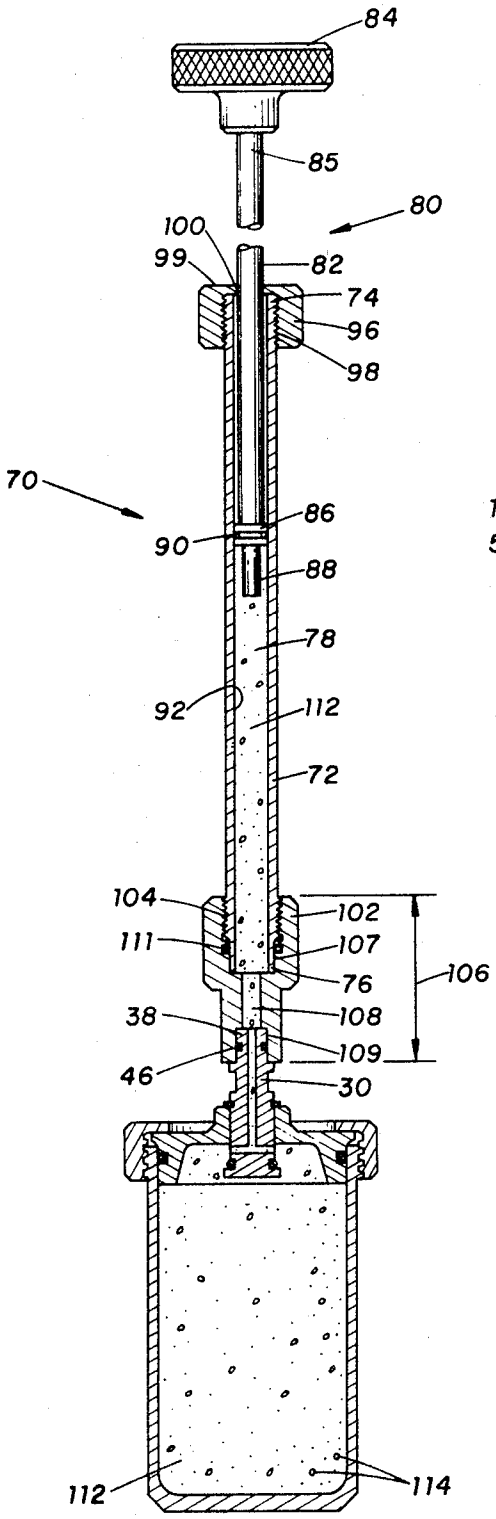



FIGURE 2.

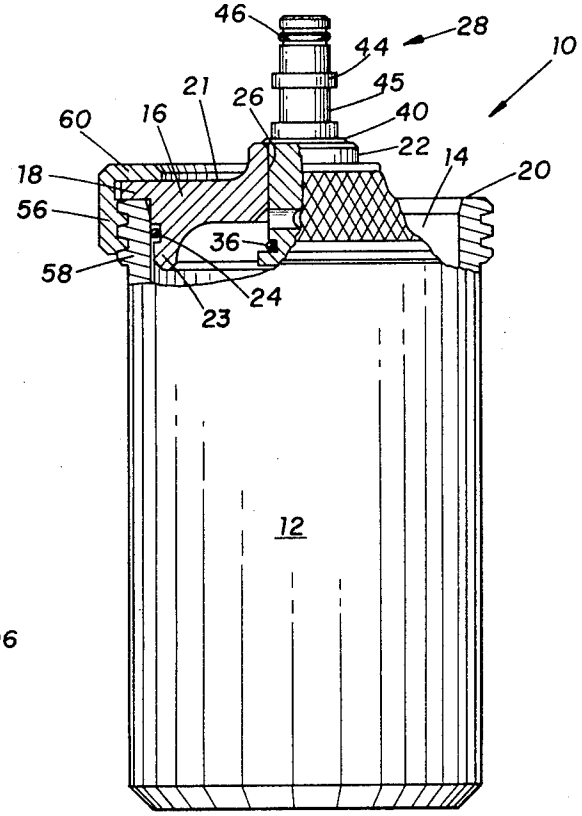



FIGURE 1.

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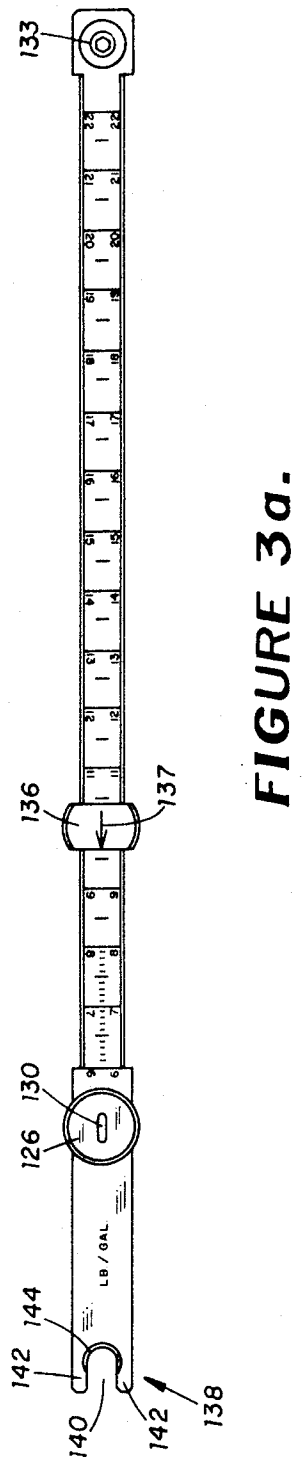



FIGURE 3a.

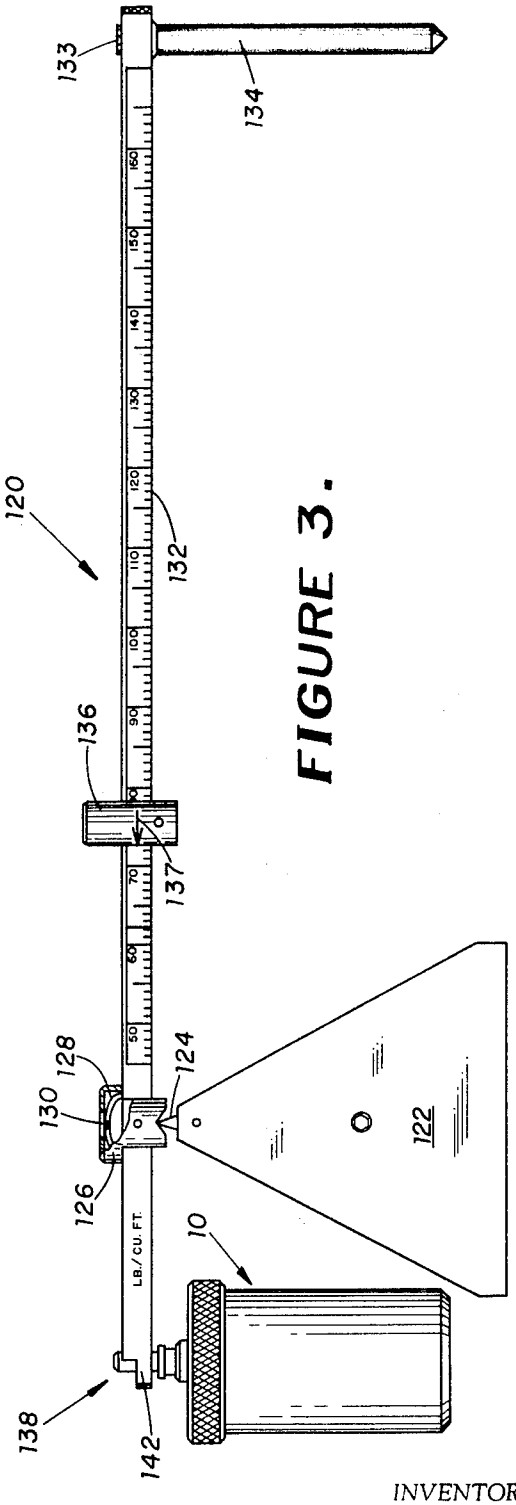



FIGURE 3.

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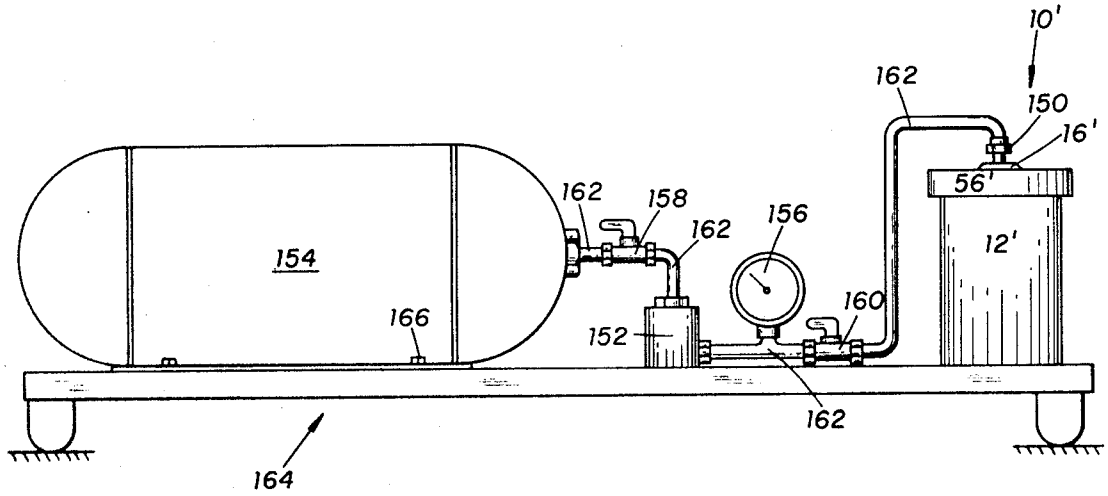



FIGURE 4.

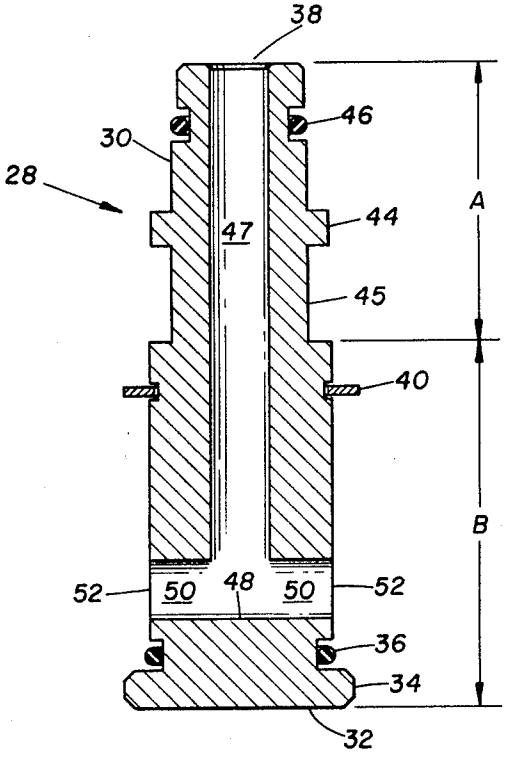



FIGURE 1a.

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# METHOD AND APPARATUS FOR MEASURING ABSOLUTE DENSITIES

## BACKGROUND OF THE INVENTION

In the drilling of oil wells, drilling fluid, called mud, is used to cool and lubricate the drilling bit and to remove rock fragments cut by the bit. It is very important to know at all times the density of the mud being pumped into the well; for example, if the density is too low, and the drill bit hits a high pressure oil and/or gas zone, a blowout may quickly develop, destroying the drilling rig and injuring and/or taking the lives of the drillers. On the other hand, if the mud density is too high and the bit hits a low pressure or "thief" zone, thousands of dollars of expensive drilling mud can be quickly lost to the formation.

Various devices are used in determining densities in the oil fields with the "mud balance" being the most common. The mud balance consists of a base and graduated arm with cup, lid, knife edge, sliding weight, spirit level, and counterweight. The cup, having a constant volume, is affixed to one end of the graduated arm and the counterweight on the opposite end. In operation, the cup is filled with mud, and the density, in pounds per gallon, is measured by sliding the weight along the graduated arm until the arm is equally balanced on both sides of the knife edge.

A major problem which is associated with the density measurements obtained in the manner described above is that often times the fluid being measured contains a considerable amount of entrained air. Thus, the measured density is in error by the amount of air or gas contained in the sample.

The present invention provides an apparatus for measuring absolute density of a fluid which comprises a container having an opening, a cover adapted to close said opening on said container, valve means on said cover for admitting fluid into said container through said cover, and means for securing said cover to said container.

In order to more fully describe the present invention reference is made to the following drawings wherein:

FIG. 1 illustrates a test chamber involving features of the present invention;

FIG. 1*a* is a cross-sectional view of the valve of FIG. 1;

FIG. 2 illustrates the test chamber with a pressuring pump attached;

FIG. 3 illustrates the test chamber attached to a weighing instrument;

FIG. 3*a* is a top view of the weighing instrument of FIG. 3; and

FIG. 4 illustrates a different embodiment of the invention shown in FIG. 1.

## DETAILED DESCRIPTION OF THE EMBODIMENT OF FIG. 1

FIG. 1 illustrates test chamber **10**. Chamber **10** includes cup **12** which holds the sample of fluid to be weighed. An opening **14** in cup **12** is closed by sealing cap **16** whose outward extending flange **18** rests on edge **20** of cup **12**. Surface **21** of cap **16** contains a raised inner platform **22**. Extending downward on cap **16** is skirt **23**. An O-ring **24**, positioned on skirt **23**, provides sealing means between cap **16** and cup **12**. Parenthetically, all O-rings referred to herein, such as ring **24**, are seated in appropriate recesses in accordance with standard practice in connection with such devices.



A centrally positioned passageway **26** extending through inner platform **22** is provided to receive pressuring valve **28** whose function will be discussed later. Referring to FIG. 1*a*, valve **28** consists of an elongated body **30** having on its lower end **32** a flange **34** disposed in a plane perpendicular to the axis of valve **28**. Lower O-ring **36** encircles body **30** directly above flange **34** and provides sealing means between valve **28** and the walls of passageway **26**. The upper end of body **30** is designated at **38**. Positioned between lower end **32** and upper end **38** is outwardly projecting lock ring **40** which prevents valve **28** from falling or from being pushed down through passageway **26** by catching on platform **22** of cap **16**.

The upper half of valve **28**, designated by the letter A, extending from slightly above lock ring **40** to upper end **38**, is of less diameter than the lower half of valve **28**, designated by the letter B, except for a laterally extending ledge **44** located midway between upper end **38** and ring **40**. A recess **45** is defined by ledge **44** and the top of the bottom half of valve body **30**. The function of ledge **44** and recess **45** will be explained below.

An upper O-ring **46** is positioned just below upper end **38**. Its function will be discussed later.

Valve **28** contains central passageway **47** which begins at the face of upper end **38**, extends axially downwardly and terminates within body **30**. At the point of termination, designated at **48**, central passageway **47** divides into two or more lateral passageways collectively number **50**. Passageways **50**, spaced equidistance one from the other, extend outwardly perpendicular to the axis of valve **28**, emerging on the surface of body **30** slightly above O-ring **36**. These places of emergence are collectively numbered **52**.

Returning to FIG. 1, a ferrule **56**, adapted to be attached to cup **12** via companion threads **58**, has an inwardly projecting flange **60**. As shown in FIG. 1, flange **60** bears on cap surface **21** and holds cap flange **18** against cup edge **20** at a fixed point so that the volume of cup **12** is always constant.

Referring now to FIG. 2, test chamber **10** is shown attached to pressuring pump **70**. Pump **70** consists of a housing **72** that has upper end **74**, lower end **76**, and passage **78** extending axially therethrough.

A piston assembly **80** includes a piston rod **82** with a handle **84** at upper end **85** and a piston head **86** adjacent to lower end **88**. Rod **82** and piston head **86** are adapted for reciprocal motion within passage **78** of housing **72**. A fluid sealing element **90** provides a seal between piston head **86** and inner walls **92** of housing **72**.

Rod guide **96**, attached to housing **72** at upper end **74** via companion threads **98**, has an inwardly extending flange **99** which defines a bore **100** whose diameter is slightly larger than the diameter of rod **82** and slightly less than the diameter of piston head **86**. Flange **99** keeps rod **82** axially centered within passage **78** during reciprocal motion, and also prevents withdrawal of piston assembly **80** from housing **72** by retaining piston head **86** within passage **78**.

A valve coupler **102** is attached to the lower end **76** of housing **72** via companion threads **104**. A passageway **106** extends axially through coupler **102**. As shown in FIG. 2, the passageway **106** is formed to have three concentric bores; upper bore **107**, center bore **108**, and lower bore **109**. As explained above, lower end **76** of

housing 72 sits into upper bore 107. O-ring 111, positioned within bore 107 provides a seal between coupler 102 and housing 72. Center bore 108 is adapted to telescopically receive lower end 88 of rod 82. Note that the dimension of bore 108 substantially complements that of lower end 88. Lower bore 109 is adapted to receive the upper end 38 of valve body 30. When so coupled, O-ring 46 positioned on valve 28 establishes a fluid-tight seal between valve 28 and valve coupler 102.

Shown in chamber 10 and pump 70 is fluid 112 whose absolute density is to be measured as will be explained later. Entrained air in fluid 112 is designated at 114.

FIG. 3 illustrates the balancing instrument 120 designed for use with test chamber 10. The instrument 120 includes a mounting base 122 which holds a knife edge 124 on top thereof. Resting on knife edge 124 is pivot 126 which has been partially sectioned to show spirit level 128 positioned within. Window 130 on top of pivot 126 allows visual observation of level 128. A beam 132, graduated for use with chamber 10, passes through and is rigidly attached to pivot 126. At the right end 133 of beam 132 counter-weight 134 is attached. Between pivot 126 and counter-weight 134 and riding on beam 132 is sliding weight 136 which has an arrow 137 inscribed thereon. The purpose of arrow 137 thereon will be explained later.

The left end of beam 132, designated at 138, is adapted to receive chamber 10. The thickness of the beam at left end 138 is reduced to be slightly less than the width of recess 45 on valve 28. A slot 140, which can be seen in FIG. 3*a*, is provided on end 138 which results in the formation of two arms, collectively numbered 142. At the terminal end of slot 140, a semi-circular recess 144 is provided. Test chamber 10 is placed on instrument 120 by placing recess 45 between the two arms 142 and sliding chamber 10 along slot 140 to where it drops down into recess 144.

FIG. 3*a* also shows window 130 on pivot 126, sliding weight 136, and the point of attachement for counter-weight 134. In addition to the parts of instrument 120, FIG. 3 and FIG. 3*a* illustrate the graduated beam 132. Note that one side of beam 132, shown in FIG. 3, is calibrated to measure density in pounds per cubic foot. The top of beam 132, shown in FIG. 3*a*, is calibrated to measure density in pounds per gallon. The opposite side of beam 132 (not shown) is calibrated to measure specific gravity. The operation of instrument 120 will be discussed further below.

## OPERATION OF THE EMBODIMENT OF FIG. 1

When it is desired to determine the density of fluid 112, cup 11 is filled with fluid 112 containing entrained air 114, from some source such as the mud pit; cap 16 is placed on top of cup 12 and ferrule 56 is attached to cup 12, securing cap 16 thereto. Pressuring pump 70, loaded with fluid 112 from the same source, is then coupled to chamber 10 by sliding lower bore 109 of coupler 102 onto the upper half of valve 28 until further movement is arrested by ridge 46 on valve body 30. FIG. 2 illustrates the attachment of pump 70 to chamber 10.

A force is now exerted downwardly by hand both on housing 72 and on piston rod handle 84. The force on housing 72 pushes valve 28 downwardly through cap 16 until lock ring 40 arrests further movement by engaging platform 22 on cap 16. At this point passageways 50 open into cup 12. The force on handle 84 causes piston rod 82 and piston head 86 to move downwardly through passageway 78 pushing fluid 112 into cup 12. This is continued until no more fluid can be forced into cup 12. As the force is released from housing 72 and handle 84, valve 28 is forced upward by the pressure of fluid 112 within cup 12 so that passageways 50 are sealed from the cup by O-ring 36 contacting the walls of passageway 26. At this point all entrained air 114 within cup 12 has been compressed to a negligible volume. Chamber 10, with pump 70 removed from engagement therewith, is placed into recess 144 on left end 138 of beam 132 of instrument 120 for weighting as shown in FIG. 3. Sliding weight 136 is moved left or right until the bubble within spirit level 128 is centered, indicating that test chamber 10 on the left of pivot 126 is precisely balanced by counter-weight 134 and sliding weight 136 on the right of pivot 126. Reading graduated arm 132 immediately to the side of weight 136 to which arrow 137 points, the absolute density of fluid 112 is found.

## DESCRIPTION OF THE EMBODIMENT OF FIG. 4

FIG. 4 illustrates a different embodiment of the instant invention. This embodiment permits the measurement of the absolute volume of a fluid or material from which the absolute density may be obtained. Test chamber 10′ is identical to chamber 10 shown in FIGS. 1–3 except that valve 28 has been replaced by a conventional tubing connector 150 attached to sealing cap 16′. Cup 12′ and ferrule 56′ of FIG. 4 are the same as cup 12 and ferrule 56 of FIGS. 1–3.

Instead of a pressure pump 70 (FIG. 2) and a balancing instrument 120 (FIG. 3), the measuring equipment used with chamber 10′ includes a calibrated air fixed volume cell 152, a pressurized air supply tank 154, pressure gauge 156, two valves 158 and 160, and several pieces of tubing, collectively numbered 162, which connect the above pieces of equipment to each other and to chamber 10′ in an arrangement as will now be explained. Cell 152 is connected on one side to tank 154 with valve 158 interposed as shown in FIG. 4. On its other side, cell 152 is connected to chamber 10′, via coupling 150, with valve 160 intervening. Pressure gauge 156 is placed on tubing 162 between cell 152 and valve 160.

Tank 154 may be secured to platform 164 via bolts 166.

## OPERATION OF THE EMBODIMENT OF FIG. 4

Cup 12′ is filled with a sample of any kind of material or fluid (not shown) which may and generally does contain some entrained air. Sealing lid 16′ and ferrule 56′ are fixed to cup 12′. Chamber 10′, its contents being at atmospheric pressure, is attached via coupler 150 to valve 160 which is closed as is valve 158. After making the above connection, valve 158, between cell 152 and tank 154, is opened and cell 152 is charged with air from tank 154 to some desired pressure $P_i$ which is observed on pressure gauge 156. Valve 158 is closed and valve 160 is opened permitting the air in cell 152, which is at a pressure greater than atmospheric, to flow into test chamber 10′. The volume of air from fixed volume cell 152 entering chamber 10′ will be reflected by a reduced pressure reading on gauge 156. Taking this pressure, designated as $P_f$, and the initial

pressure, $P_i$, the absolute volume of the sample can be computed by using the following formula:

$$V_a = V_c + V_p - V_p\,(P_i/P_f)$$

where:

$V_a$ = absolute volume of the sample

$V_c$ = volume of cup **12'**

$V_p$ = volume of cell **152**

$P_i$ = gauge pressure of cell **152** before opening valve **160**

$P_f$ = gauge pressure of cell **152** and chamber **10'** after opening valve **160**

As an example of this operation, assume the volume of cup **12'** to be 20 cubic inches, the volume of cell **152** to be 5 cubic inches and the following pressures observed on gauge **156**:

$P_i$ = 20 pounds per square inch gauge

$P_f$ = 10 pounds per square inch gauge

Using these values in the above equation we obtain:

$$V_a = 20\ \text{in}^3 + 5\ \text{in}^3 - 5\ \text{in}^3\ (20\ \text{psig}/10\ \text{psig})$$

and we find that the absolute volume of the sample is 15 cubic inches. If desired, the absolute density can then be determined by simply weighing the same sample and dividing that weight by the absolute volume.

The above calculations can be avoided by using a pressure gauge **156** whose dial face has been calibrated to read the absolute volume direct after valve **160** has been opened.

Besides determining the absolute density and volume of drilling fluids, the instant invention will find application in many other situations. One application relates to the preparation of a cement slurry used in cementing a string of casing in a well bore. The density of the slurry is increased by adding barite or other similar, expensive material. If the device used in measuring the density does not consider the volume of entrained air, more weighting material will be added than is required. Not only is this an economic waste but the horsepower required to pump the heavier mixture will be unnecessarily increased. For example, a slurry having 10 percent by volume of air entrained will have a density of 19.8 lb/gal if measured by a conventional mud balance and a density of 21.9 lb/gal if measured by the present invention under a pressure of 250 psig. Thus, if the desired slurry density was 19.8 lb/gal an error of 2.1 lb/gal would have been made.

The instant invention can be constructed of various materials such as brass, steel and the like. Two limitations exist; one is that the material must not react chemically with the sample being measured; the second limitation is that the material used must have a high enough yield strength to withstand the pressures imposed on the test chamber. However, the second is not critical. As is well known to those skilled in the art, the higher the pressure used, the closer the value obtained will approach true absolute density. However, the relationship between pressure and absolute density is logarithmic where the true absolute density is approached very rapidly under modest pressures, and additional large increases in pressures result only in very small, almost negligible changes in absolute density values. Thus it follows that the instant invention may be practiced using light weight equipment where approximate absolute densities will suffice.

Two uses have been described herein but many other uses in many industries will be readily apparent to those skilled in the art.

Although the invention has been described with reference to the embodiments illustrated, it will be apparent that many different embodiments may be made without departing from the spirit and scope thereof, and therefore it is not intended to be limited except as indicated in the appended claims.

What is claimed is:

**1.** A method for measuring the absolute density of a fluid, which comprises the steps of:

a. filling a container having a cap with a valve thereon with the fluid to be measured;

b. securing said cap to said container;

c. pumping an additional quantity of said fluid into said container via said valve until air entrained in the fluid in said container is compressed into a negligible volume; and

d. placing said container on an instrument calibrated to measure densities by balancing said container against known weights.

**2.** In weight per unit volume measuring apparatus, a device for providing an accurate volume of fluids and semi-fluid solids having quantities of non-dissolved gas trapped therein, comprising:

a. container means having a closed lower end and a substantially unobstructed upper end;

b. closure means adapted to substantially cover said unobstructed upper end;

c. valve means in said closure means for permitting the flow of fluid therethrough into said container means;

d. means for removably attaching said closure means to said container means;

e. pump means for sealingly engaging said valve means and injecting fluid into said container at a sufficient pressure to compress said entrapped non-dissolved gases to a negligible volume;

f. valve body means slidably located within said valve means and arranged to move downward in response to fluidic pressure applied by said pump means and further adapted to move back upwards upon release of said pumped fluid pressure; and

g. one or more bore passages in said valve body means arranged to provide fluid communication between said pump means and said container means in said downward position of said valve body means, and further arranged in said upward position of said valve body means to prevent fluid communication from said container means back into said pump means.

**3.** The apparatus of claim **2** further comprising means on said apparatus for suspending said apparatus from a weighing scale; and seal means between said closure means and said container means.

**4.** The apparatus of claim **2** wherein said container means comprises a cylindrical cup having an integral closed end at the bottom and a substantially open end at the top; and said closure means comprises a closure cap adapted to fit snugly within said open end of said container, said closure cap having an annular outwardly extending flange adapted to abut the upper edge of said cylindrical cup and platform means having opening means therein for receiving said valve means.

**5.** The apparatus of claim **2** wherein said attaching means comprises an internally threaded ferrule

adapted to enclose said closure cap in abutting relationship with said annular flange thereof and having opening means therethrough for said valve means; and said attaching means further comprises an externally threaded portion on the upper end of said cylindrical cup adapted to matingly receive said threaded portion of said ferrule.

**6.** The apparatus of claim **2** wherein said pump means comprises a tubular housing; lower valve coupler means fixedly attached to the lower end of said housing and arranged to sealingly engage said valve means for fluidic communication therethrough, said coupler means having a fluidic bore passage therethrough communicating with the bore of said tubular housing; piston means sealingly slidable within said tubular body, said piston means having a connecting rod extending out of said tubular housing, and handle means connected to said connecting rod; and piston retaining means fixedly attached to the upper end of said tubular housing, said retaining means adapted to enclose the end of said tubular housing, and said retaining means having an opening therethrough slightly larger than said connecting rod and arranged to have said connecting rod passing therethrough.

* * * * *