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(54) **Title:** FLUIDIC DENSITY MEASUREMENTS BASED ON BETA PARTICLES DETECTION

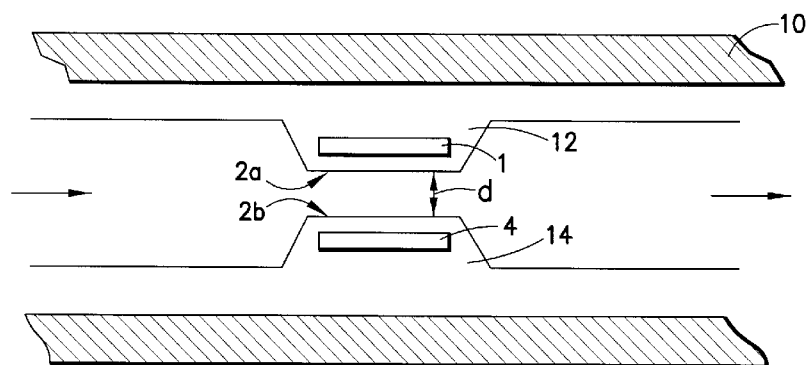


FIG.3A

(57) **Abstract:** Devices, methods and related systems are described for measuring a property of a fluid including density in a subterranean environment. A device includes a pressure housing having one or more window formed in the pressure housing, and a flow device arranged in the pressure housing for the fluid to flow through the flow device. Further, a radiation source mounted within the pressure housing approximate a first source window configured to generate particles into the fluid. A detector supported by the pressure housing and positioned approximate a first detector window of the one or more window, the first detector window located between the detector and the flow device. The detector can be a solid state beta particle detector with a wide band gap such as the diamond detector, and the radiation source can be a beta particle source such as a strontium 90 source.





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FLUIDIC DENSITY MEASUREMENTS BASED ON BETA PARTICLES DETECTION

BACKGROUND

1. Field

[0001] This patent relates generally to devices and methods for measuring fluid properties for oilfield and other industrial applications. In particular, the patent relates to measuring one or more fluid properties such as density.

2. Background

[0002] Ability to measure fluid density and other fluid properties downhole is paramount to petroleum exploration as it enables one to differentiate between oil, gas and water [W. D. McCain, Jr., *The Properties of Petroleum Fluids*, 2nd ed. (1990)]. The relative amounts of oil and gas produced have a direct impact on reservoir development cost. Furthermore, it allows one to locate the oil-water contact line and hence the thickness of the pay zone of a formation. The ability hinges upon availability of an accurate and robust sensor that works reliably in the harsh environment found in an oilwell. Oilfield pressures downhole may be as high as 25,000 psi with temperatures up to 175°C or higher. There are wells with even more extreme conditions, especially offshore. A further challenge in downhole fluid analysis is that acquiring large quantities of representative downhole fluids is difficult due to the ever-present contamination, such as drilling mud or formation water [O.C. Mullins, M. Hashem, H. Elshahawi, G. Fujisawa, C. Dong, S. Betancourt, T. Terabayashi, *Petrophysics* 46, 302 (2005)].

[0003] Fluid density provides a means of fluid typing. Water has a density of 1.0

g/cm³. Densities of liquid-rich hydrocarbons vary between 0.5 to 0.9 g/cm³, and dry gas or condensate formations have a significantly lower density. The above values are understood to vary with reservoir pressure and temperature. Further, an understanding of the heterogeneity of the reservoir may require that densities be measured at several depths so that the compositional variation can be fully deduced. Such information can aid in identifying zones with the highest economic value; for example a dry gas may be preferred if the well is drilled in a gas field with existing infrastructure to handle gas transport through pipelines. Furthermore, for a given gas composition, the amount of standard cubic feet (SCF's) of gas producible is directly proportional to the density. Knowledge of the fluid density is essential for avoiding costly economic errors in applications, by non-limiting example, oilfield applications.

[0004] It is straight-forward to measure a liquid density at ambient pressure and temperature in a laboratory setting. Typically a flask of well-defined volume (volumetric flask) is filled with the fluid of interest and it is weighed on a scale. The density is obtained by dividing the fluidic mass by the known volume. Measurements at elevated pressure and temperature, however, require more sophisticated techniques. Gaseous fluids and heterogeneous liquids further complicate the measurement task. There are some known measurement methods employed for pressure/temperature density measurements, but they have limitations for downhole implementation.

[0005] For example, a known method includes a resonating sensor such as resonating tube densitometer and Coriolis flow meter, however, this method is not well-suited for subterranean applications. Firstly, the sizes of such flow meters in many cases are too large to fit in downhole tools, by non-limiting example, oilfield applications.

Secondly, mud can be omnipresent at the beginning of a job (i.e., an oilfield application job), and it is unclear that mud can be completely cleaned from the two flow lines of the sensor. Thirdly, the method operates at pressures in the order of 1,000 psi, which makes such method unusable at pressures much higher than 1,000 psi.

[0006] Furthermore, there are special fluid conditions that can present problems for resonating sensors to measure fluid properties, such as density. For example, some of the problems for resonating sensors include inaccurate measurements of the fluid properties such as density due to special fluid conditions, i.e., gaseous fluids, emulsions, non-Newtonian fluids, supercritical fluids or multiphase Fluids.

[0007] Therefore, there is a need for a device, method and system that can measure the fluid properties such as density for oilfield applications and other industries that can overcome the above noted problems either above ground or in a subterranean environment.

SUMMARY

[0008] According to some embodiments of the disclosed subject matter, a device for measuring one or more property of a fluid including density. The device comprising: a pressure housing having one or more window formed in the pressure housing. The device includes a flow device arranged in the pressure housing for the fluid to flow through the flow device, and one or more radiation source mounted within the pressure housing approximate a first source window of the one or more window that is configured to generate particles into the fluid. Finally, the device has one or more detectors supported by the pressure housing and positioned approximate a first detector window of the one or more window, the first detector window located between the one or more detector and the

flow device. It is noted that the one or more detector can be from a group consisting of one of a solid state detector, radiation detector, a scintillator detector or a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or an another radiation detecting device.

[0009] According to some aspects of the disclosed subject matter, the fluid can be from the group consisting of at least one liquid, at least one solid mixed with the at least one liquid, at least one gas or some combination thereof. Measurements can be made while the fluid temperature is one of at least -150 Celsius or greater, at least -50 Celsius or greater, at least 50 Celsius, at least 100 Celsius or at least 175 Celsius. The fluid can be one of flowing or not flowing through the flow device while measuring the one or more property of the fluid which includes density. Further, the fluid may be a supercritical fluid such as carbon dioxide (CO₂) that is in a supercritical condition which is approximate to a downhole application. The fluid can be one of an emulsified fluid, a drilling fluid or a multiphase fluid.

[0010] According to some other aspects of the disclosed subject matter, the one or more radiation source may be from the group consisting of a beta particle source, a strontium source, a strontium 90 source or a positron source. The one or more radiation source can produce beta particles within a energy range of 2MeV to 3MeV. The generated beta particles of the one or more radiation source can be emitted through the first source window, into the flow device containing the fluid, out of the flow device and through the first detector window to be detected by the one or more detector, so at least one electronic device such as a processor is in communication with the one or more

detector for receiving a pulsed signal from the one or more detector in one of a downhole environment, a reservoir, a borehole, inside a surface metering device or testing device. The one or more detector may be from the group consisting of one of a solid state detector, a radiation detector, a scintillator detector, a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or an another radiation detecting device.

[0011] According to some other aspects of the disclosed subject matter, a wide band gap solid state detector may include one of a band gap of approximately 5.45 eV, a approximate density of 3.51 g/cm³ or a approximate dimension of a 5mm length by a 5mm width by a 0.5mm height. The wide band gap solid state detector may operate in a routine environment of temperatures approximately equal to and above one of 150 Celsius or 200 Celsius or more. The wide band gap detector is compatible for applications in one of a microelectromechanical system (MEMS), a nanoelectromechanical system (NEMS), a micromachine related device, a nano-tips based detector or a Field-emitting array based gas detector.

[0012] According to some other aspects of the disclosed subject matter, a nano-tips based gas radiation detector, or field-emission gas tube may also operate in a routine environment of temperatures stated above or more. With a dimension of a few mm length by a few mm width and by a 0.5mm height it can be also compatible for applications in one of a microelectromechanical system (MEMS), a nanoelectromechanical system (NEMS), or a micromachine related device. Comparing with a solid-state detector, the nano-tips based gas detector, due to the induced avalanches from the ionization, may have advantages of outputting read-out pulses with

large amplitudes and detecting lower energy betas passing through the fluidic device.

[0013] According to some other aspects of the disclosed subject matter, the at least one electronic device such as a processor can be in communication with the one or more detector for receiving a pulsed signal from the one or more detector, the at least one electronic device processes the received pulsed signals to provide the capability to determine the one or more property including density of the fluid. The determined density measurement of the fluid may be from the group consisting of one of a gaseous fluid density measurement, an emulsion fluid density measurement, a non-Newtonian fluid density measurement, a supercritical fluid density measurement or a multiphase fluid density measurement. The device is in communication with a processor and a mass density measuring device that measures a mass density of the fluid, the processor is capable of determining a fluidic hydrogen index from data received from the device and the mass density measuring device. The device can be in communication with a processor and a fluidic hydrogen index measuring device that measures a fluidic hydrogen index, the processor is capable of determining a fluidic mass density from data received from the device and the fluidic hydrogen index measuring device.

[0014] According to some other aspects of the disclosed subject matter, the pressure housing can be of a material from the group consisting of a stainless steel or one or more other materials and stainless steel. The pressure housing may include a source space with a source retainer that is in communication with the first source window to secure the one or more radiation source. The pressure housing may include a detector space, detector shield and a detector cap that is in communication with the first detector window to secure the one or more detector. The detector space may further include an elastomeric

device. It is possible the one or more detector is structured and arranged to be integral with the pressure housing. The pressure housing may be capable of withstanding pressures up to 30,000 psi or more and temperatures to 200 Celsius or more. The device can be designed to operate at pressures of one of 10k psi or more, 15k psi or more or 20k psi or more. Further, the device may be designed to operate at temperatures of one of more than -150 Celsius, more than -50 Celsius, at least 50 Celsius, at least 100 Celsius or at least 150 Celsius. It is noted the device can be designed to operate at pressures within the flow device of one of at least 5 kpsi, at least 10k psi or at least 20kpsi.

[0015] According to some other aspects of the disclosed subject matter, the device may further comprise deploying the pressure housing, the radiation, the detector and the first source window and first detector window downhole and wherein the fluid measurements are made downhole. Further, the one or more window and flow device are made of a material having an approximate density of at least one combination of a glass and a peek material or a combination of the glass, the peek material and another material. It is noted that a thickness of the first source window, a wall of the flow device and the first detector window can be approximately equal. It is possible that a thickness of the first source window, a wall of the flow device approximate the first source window, the first detector window and a wall of the flow device approximate the first detector window may also be approximately equal. Further, a first distance from the first source window to the wall of the flow device approximate the first source window can be approximately equal to a second distance from the first detector window to the wall of the flow device approximate the first detector window. Further still, the first source window and the first detector window of the one or more window can have a thickness capable of allowing

transmission of particles from the one or more particle source within the pressure housing to the one or more detector, to allow for the particles to be detected by the one or more detector. It is possible the one or more detector is from the group consisting of one of a solid state detector, a radiation detector, a scintillator detector, a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or an another radiation detecting device.

[0016] According to some other aspects of the disclosed subject matter, the flow device can be from the group consisting of a tube, a flowline, a channel, a pipe and a microfluidic channel that is integral with the pressure housing. Further, the flow device can have one of a thickness or a diameter ranging from approximately equal to or less than 0.5 mm to approximately. It is noted the flow device can have one of two or more thicknesses such as a first and a second thickness or two or more diameters such as a first and a second diameter. Further still, the one or more beta sources can have two or more beta sources and the one or more beta detector has two or more beta detectors. It is possible a first beta source and a first beta detector can be arranged to measure the mixed fluid and a second beta source and a second beta detector are arranged to measure a gas. It is noted the device may further comprise of: (a) a first beta source of the two or beta sources is located approximate the first diameter of the flow device and the first source window, and a first beta detector of the two or more beta detectors is located approximate the first diameter of the flow device and the first detector window; and (b) a second beta source of the two or beta sources is located approximate the second diameter of the flow device and a second source window, and a second beta detector of the two or more beta detectors is located approximate the second diameter of the flow

device and a second detector window. Further, the at least one electronic device can be in communication with the first detector and the second detector for receiving a first pulsed signal from the first detector and a second pulsed signal from the second detector, so that the at least one electronic device processes the received first and second pulsed signals to provide the capability to determine the one or more property including density of the fluid. Further still, the device can be deployed downhole and the one or more radiation source mounted within the pressure housing generates particles into the fluid within one of a downhole environment, a reservoir or in a borehole.

[0017] According to another embodiment of the disclosed subject matter, an apparatus for measuring one or more property of a fluid including density in a subterranean environment. The apparatus comprises: a pressure housing to be deployed within the subterranean formation having one or more window formed in the pressure housing capable of operating in routine pressures of at least 15kpsi; a flow channel arranged in the pressure housing for the fluid to flow through the flow channel; one or more particle source mounted within the pressure housing approximate a first source window of the one or more window is configured to generate particles into the fluid within an energy range up to 3 MeV; and one or more detector mounted within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more detector and the flow channel.

[0018] According to some other aspects of the disclosed subject matter, the fluid may be from the group consisting of a liquid, a liquid mixed with a solid, a gas or some combination thereof, and the fluid is one of flowing or not flowing through the flow channel while determining the one or more property of the fluid that includes density.

The one or more particle source can be from the group consisting of a beta particle source, a strontium source such as a strontium 90 source or a positron source. The one or more detector may be from, but not limited to, the group consisting of one of a solid state detector, a radiation detector, a scintillator detector, a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or another radiation detecting device. Further, at least one electronic device such as a processor can be in communication with the one or more detector for receiving a pulsed signal from the one or more detector, the at least one electronic device processes the received pulsed signals to provide the capability to determine the one or more property including density of the fluid. Further still, the flow channel can have one of a thickness or a diameter ranging from approximately equal to or less than 0.5 mm to approximately. It is possible the first source window and the first detector window of the one or more window can have a thickness capable of allowing transmission of particles from the one or more particle source within the pressure housing to the one or more detector, to allow for the particles to be detected by the one or more detector. It is note that a portion of the pressure housing approximate the first detector window can have a thickness sufficient to substantially attenuate the transmission of particles so that a linear resolution of the one or more particle detector is increased.

[0019] According to some embodiments, a system for measuring one or more property of a fluid including density in a reservoir environment. The system comprising: a pressure housing to be deployed within the reservoir formation has one or more window formed in the pressure housing; a flow channel arranged in the pressure housing for the fluid to flow through the flow channel; one or more beta particle source mounted

within the pressure housing approximate a first source window of the one or more window is configured to generate beta particles up to a energy of 3MeV into the fluid; and one or more detector mounted within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more detector and the flow channel.

[0020] According to some other aspects of the disclosed subject matter, the one or more beta particle source can be a strontium source such as a strontium 90 source.

[0021] According to some embodiments, a method for measuring one or more property of a fluid including density in a subterranean environment. The method comprising: deploying a pressure housing within the subterranean formation configured to operate at temperatures of at least 150 Celsius, the pressure housing includes one or more window formed in the pressure housing; arranging a flow channel in the pressure housing for the fluid to flow through the flow channel; mounting one or more beta particle source within the pressure housing approximate a first source window of the one or more window configured to generate particles into the fluid; and mounting one or more wide band gap solid state detector such as a diamond detector within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more radiation detector and the flow channel.

[0022] According to some other aspects of the disclosed subject matter, the wide band gap solid state detector can include one of a band gap of approximately 5.45 eV, a approximate density of 3.51 g/cm³ or a approximate dimension of 5mm height by 5mm length by .5mm width or some combination thereof.

[0023] According to some embodiments, a method for measuring one or more property of a fluid including density in a downhole environment. The method comprising: deploying a pressure housing within the subterranean formation having routine environment temperature of equal to or more than 140 Celsius, the pressure housing includes one or more window and a flow channel formed in the pressure housing, wherein the fluid channel is arranged for the fluid to flow through the flow channel; mounting one or more beta particle source within the pressure housing approximate a first source window of the one or more window that is configured to generate beta particles into the fluid; and mounting one or more solid state charged beta particle detector within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more solid state charged beta particle detector and the flow channel.

[0024] According to some other aspects of the disclosed subject matter, the one or more solid state charged beta particle detector can be one of a beta particle ionization detector or a wide band gap solid state detector such as a diamond detector. Further, the wide band gap solid state detector can include one of a band gap of approximately 5.45 eV, a approximate density of 3.51 g/cm³ or a approximate dimension of 5mm height by 5mm length by .5mm width.

[0025] According to some other aspects of the disclosed subject matter, the fluidic channel or flowline can be geometrically wide or flat [the flow channel cross-section for example can be a few cm x a few mm] so that the flowing volume can be maintained high while the beta particle pass length is kept around a few mm. In such a geometrical arrangement, multiple Sr90 sources and multiple detectors can be implemented across the

“flat” flowing channel, resulting a high counting or measurement speed.

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[0026] Further features and advantages will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The present disclosure is further described in the detailed description which follows, in reference to the noted plurality of drawings by way of non-limiting examples of exemplary embodiments, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:

[0028] FIG. 1 illustrates the principle of flowline densitometer which consists of a beta emitter, a flowline having a first wall and a second wall, fluid flowing through the flow line and a beta particle detector. The beta particle flux as illustrated by the array of arrows is attenuated by the flowline walls and by the fluid passing through the flowline, wherein the fluid density can be deduced from the beta particle flux changes, i.e., the counting rate changes in the detector, according to some embodiments;

[0029] FIG. 2 illustrates a beta particle penetration distance as a function of its energy, according to some embodiments;

[0030] FIG. 3A illustrates a pressure housing that includes a flow device, beta source and beta detector having a single pressure compensate set of chambers with one distance between the beta source and the beta detector, according to some embodiments;

[0031] FIG. 3B illustrates a pressure housing that includes a flow device, having two

beta sources and beta detectors, wherein each has a single pressure compensate set of chambers with a distance between the beta source and the beta detector, according to some embodiments;

[0032] FIG. 4A illustrates the principle of the detection of charged particles using a diamond detector, according to some embodiments;

[0033] FIG. 4B illustrates the spectra of counting rate vs. MCA channel for two different preamp cable lengths, where the location of the noise threshold is graphically shown and the channel number or energy corresponding to these points is what is referred to as the noise threshold, according to some embodiments;

[0034] FIG. 5 is a plot illustrating beta particle counts in the detector as a function of the fluid density, wherein the trend-line is a polynomial fit of all data except the crude samples, according to some embodiments;

[0035] FIG. 6 is the same as in FIG. 5, but only data in the density region from 0.6 to 1.0 g/cc, according to some embodiments;

[0036] FIG. 7 illustrates a plot of the measured density vs the true density, wherein the line is a fit, according to some embodiments;

[0037] FIG. 8 illustrates a plot of the discrepancy between the measured and true density as a function of the true density, wherein the line is a fit, according to some embodiments;

[0038] FIG. 9 illustrates a plot of the Z/A ratios of fluidic samples used in the measurements, wherein the Z/A ratio is defined by the atomic number “Z” and the atomic mass “A” for all the elements. The samples include alkanes, crude oils, and water/isopropanol mixtures that form a main trend line, while the other samples, those of

acetone, benzene, toluene and their mixtures (benzene/hexadecane or toluene/hexane) form another branch, according to some embodiments;

[0039] FIGS. 10 is a plot showing the counting rates as a function of the product of the Z/A ratios and densities, according to some embodiments;

[0040] FIG. 11 is a plot showing the discrepancy between true and measured $Z/A \cdot \text{Density}$ as a function of the true $Z/A \cdot \text{Density}$, which is often defined as the “electron density”, according to some embodiments;

[0041] FIG. 12 illustrates pressurized nitrogen gas data plotted with previously taken liquid data vs. density normalized to an empty channel, according to some embodiments;

[0042] FIG. 13 illustrates normalized pressurized nitrogen gas data plotted with previously taken liquid data vs. $Z/A \cdot \text{Density}$ to negate the effects of varying hydrogen indices of the materials, according to some embodiments; and

[0043] FIG. 14 illustrates density Discrepancy for the second order fit as a function of density for repeated pressure cycles during the nitrogen gas measurements, according to some embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0044] The following description provides exemplary embodiments only, and is not intended to limit the scope, applicability, or configuration of the disclosure. Rather, the following description of the exemplary embodiments will provide those skilled in the art with an enabling description for implementing one or more exemplary embodiments. It is understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the subject matter disclosed in the application as set forth in the appended claims.

[0045] Specific details are given in the following description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, systems, processes, and other elements in the subject matter disclosed in the application may be shown as components in block diagram form in order not to obscure the embodiments in unnecessary detail. In other instances, well-known processes, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments. Further, like reference numbers and designations in the various drawings indicated like elements.

[0046] Also, it is noted that individual embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process may be terminated when its operations are completed, but could have additional steps not discussed or included in a figure. Furthermore, not all operations in any particularly described process may occur in all embodiments. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or the main function.

[0047] Furthermore, embodiments of the subject matter disclosed in the application may be implemented, at least in part, either manually or automatically. Manual or automatic implementations may be executed, or at least assisted, through the use of

machines, hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program code or code segments to perform the necessary tasks may be stored in a machine readable medium. A processor(s) may perform the necessary tasks.

[0048] According to an embodiment, a device for measuring one or more property of a fluid including density. The device comprising: a pressure housing having one or more window formed in the pressure housing. The device includes a flow device arranged in the pressure housing for the fluid to flow through the flow device, and one or more radiation source mounted within the pressure housing approximate a first source window of the one or more window that is configured to generate particles into the fluid. Finally, the device has one or more detector supported by the pressure housing and positioned approximate a first detector window of the one or more window, the first detector window located between the one or more detector and the flow device. It is possible the one or more detector can be from the group consisting of one of a solid state detector, a radiation detector, a scintillator detector, a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or an another radiation detecting device.

[0049] Further, according to some embodiments, the devices, methods and related systems described for measuring one or more property of a fluid including density, includes a pressure housing having one or more window formed in the pressure housing, and a flow device arranged in the pressure housing for the fluid to flow through the flow device. Further, a radiation source mounted within the pressure housing approximate a

first source window of the one or more window and configured to generate particles into the fluid. Also, a detector supported by the pressure housing and positioned approximate a first detector window of the one or more window, the first detector window located between the detector and the flow device. The detector can be a solid state charged beta particle detector such as a diamond detector, and the radiation source can be a beta particle source such as a strontium 90 source.

[0050] The subject matter of the application includes, by non-limiting example, the technique for downhole fluid density measurement that involves no direct contact of the sensor with the fluid to be measured. In particular, using a detector to measure the density-dependent attenuation of beta particles. The density measured is a volumetric average of the fluid density situated between a source and the detector and as such is less dependent upon surface contamination (i.e. scale buildup or the like), a common problem for density measurements in the challenging subterranean environment, i.e., downhole.

[0051] It is contemplated that at least two implementations for such a measurement may include a macroscopic implementation and a microscopic implementation. The macroscopic implementation may have applications in conventional oilfield application tools where the beta path length through a flowline is about approximately a few millimetres. An example of microscopic implementation is a density measurement downstream of a microfluidic separator through a microfluidic channel of a diameter of approximately 0.5 mm or less.

[0052] FIG. 1 is a sketch that illustrates the principle of the flowline densitometer which consists of a beta emitter 1, a flowline having a first wall 2a and a second wall 2b, fluid 3 flowing through the flowline and a beta particle detector 4. The beta particle flux

is illustrated by the array of arrows attenuated by the flowline walls 2a and 2b and by the fluid 3 passing through the flowline. The fluid density can be deduced from the beta particle flux changes, i.e., the counting rate changes in the detector 4. The interactions of fast electrons or beta particles with materials are discussed in the Knoll reference (see Glenn F. Knoll, Radiation Detection and Measurement, Third Edition, Chapt. 2, John Wiley & Sons Inc., 2000). When beta particles passing through materials, they lose energy due to ionization, excitation and bremsstrahlung. The first two, often referred as “collisional losses”, are dominate for betas with energy less than a few MeV. The “rate” of such energy loss or specific energy loss $-dE/dx$ along a beta particle track can be factorized by the classical expression, which is known as the Bethe formula:

$$-\frac{dE}{dx} = \frac{2\pi e^4}{mv^2} * NZ * B \quad \text{Eq. 1}$$

Where m is the electron mass, e the electron charge, and v the electron velocity. N and Z are the number density and atomic number of the absorbing material atoms. B represents the Bethe formula for the collisional losses of fast electrons, and is related to electron velocity or energy and the averaging excitation and ionization potential of the absorber, which is rather a constant for many common elements, compounds and different materials for fast electrons. Thus, for electrons with a given energy (mono-energetic) they can travel a certain distance in a given absorbing material. This distance is called the electron “range” and is reversely correlated to the electron number density in the material as shown by the NZ product in Eq. 1. The attenuation of beta particles emitted by a radioisotope source, because of the continuous distribution in their energy, differs significantly from the simple picture for mono-energetic electrons. The low energy betas are rapidly absorbed by a small thickness of the absorber material, so that the initial slope

on the attenuation curve is greater. For the majority of beta spectra, the curve will have a near-exponential shape and is therefore nearly linear on the semilog plot. An “absorption co-efficient” μ is sometimes defined by:

$$\frac{I}{I_0} = e^{-\mu t} \quad \text{Eq. 2}$$

where I_0 is the counting rate without absorber, I counting rate with absorber, and t absorber thickness. The co-efficient μ is directly proportional to the beta energy losses in the absorber material and convoluted by the continuous energy distribution of the beta particles emitted from a source with fixed-endpoint energy. Hence the coefficient μ is directly related to the material density of the absorber. And the attenuation measurements can be used to extract the material density of the absorber.

[0053] Still referring to FIG. 1, the beta emitter may be considered from the group consisting of a source, a radiation source, a beta particle source, a strontium source, a strontium 90 source or a positron source. For the purposes of the claimed subject matter of the application, at least one embodiment, contemplates mounting the radiation source within a pressure housing 10 (see FIG. 3) approximate a first source window 11a within the pressure housing 10 that is configured to generate particles into the fluid 3 approximate the first wall 2a of the flowline. Further, the flowline may be considered from the group consisting of a flow device, a tube, a flowline, a channel, a pipe and a microfluidic channel that is integrated with the pressure housing 10. It is contemplated that the flowline may be separated from or integrated with the pressure housing 10 or partially separated and integrated.

[0054] Still referring to FIG. 1, while it is possible that other sources may be used, for the purposes of the claimed subject matter disclosed in the application the source used

may be strontium 90. Strontium 90 provides many advantages, some of the advantages include, by non-limiting example, a high beta particle energy (maximum of 2.3 MeV), with relatively smooth beta energy distribution and its relative long lifetime of 29 years.

FIG. 2 illustrates a beta particle penetration distance as a function of its energy compiled with a computation program from NIST (see M.J. Berger, J.S. Coursey, M.A. Zucker and J. Chang, Stopping-Power and Range Tables for Electrons, Protons, and Helium Ions, NIST, Physics Laboratory, Ionizing Radiation Division, the databases and the computational programs: *estar*, *pstar*, and *astar* (<http://www.nist.gov/phylab/data/star/>)).

[0055] A high energy allows the beta particles to penetrate through 1-10 mm of liquid, for example. As beta particles travel through material they interact with shell electrons of atoms or molecules and produce ionization events, each time losing on the order of tens of electron volts of energy.

[0056] Still referring to FIG. 2, for example, a beta particle of energy 2 MeV can penetrate through one centimeter of 1 g/cm³ liquid before losing its entire energy. Thus, sufficient energy is necessary for the particles to traverse both the flowline walls 2a and 2b and the fluid 3 of FIG. 1 and generate a readable pulse in the detector 4 (see FIG. 1). Therefore, for optimal sensitivity, the flowline diameter should be about a few millimeters for most liquids and the window walls 11a and 11b (or first and second source windows) have to be thin and made of low-density materials such as Peek (1.3 g/cm³). For high-pressure applications, such thin window walls 11a and 11b (or first and second source windows) may require pressure compensation (see FIG. 3). For gaseous fluids (less dense than liquids), the flowline diameter can be enlarged or can be pressurized in a a few mm flowline.

[0057] Still referring to FIG. 2, the penetration depth (or range) of betas as a function of their energies for a few fluids and solid materials are shown. The penetration ranges can be a guide in determining the optimal flow channel dimension for the types of fluids to be measured. Obviously, for less dense gas flows the dimension can be quite large (up to centimeters). However, it is noted that a 2mm flow channel with thin windows 11a and 11b (or first and second source windows) facing both the source 1 and detector 4 will work for most fluids of interest including pressurized gases.

[0058] Referring to FIG. 3A and FIG. 3B, FIG. 3A shows a pressure housing 10 having a source space 12 for the source 1, the flowline having walls 2a and 2b (or first 2a and second 2b source windows) with a distance (d), the diamond detector 4 which is inside a detector space 14. The arrows (not numbered) indicate the direction of flow. It is noted for example, it is possible the flowline may have a 2mm x 10mm in cross-sectional area to fit a main flowline with a 5mm diameter. It is also possible, the pressure housing 10 can be used to high pressure flow line applications that could include a pressurized system.

[0059] FIG. 3B shows a pressure housing 10 having a first source space 12 for the first beta source 1, the flowline having walls 2a and 2b (or first wall 2a and second wall 2b source windows) with a first distance (d_1), the first diamond detector 4 which is inside a first detector space 14. Also, included in FIG. 3B is a second source space 24 for the second beta source 21, the flowline having walls 4a and 4b (or first wall 4a and second wall 4b source windows) with a second distance (d_2), the second diamond detector 8 which is inside a second detector space 18. The arrows (not numbered) indicate the direction of flow. As noted above, for example, it is possible the flowline may have a

2mm x 10mm in cross-sectional area to fit a main flowline with a 5mm diameter. It is also possible the pressure housing may be used to high pressure flow line applications that could include a pressurized system.

[0060] Still referring to FIG.s 3A and 3B, it is noted that low energy beta emitters may be used in a microfluidic version where flowline walls and the flowline are in sub-millimeter range. The energy required for beta particles to penetrate sub-millimeter material is relatively low.

[0061] Still referring to FIG.s 3A and 3B, it is possible that positron emitters such as Na22 could work as well as beta emitters, although it is noted that most of them emit low-energy positrons. Positrons can be similar to betas (electrons) except for their positive charges. For example, other than producing ionization, positrons will also interact with electrons to form positronium states and annihilate into a pair of photons. The thin solid-state detector isn't sensitive to these photons and can still be used to detect penetrating positrons. It is possible one can use a scintillator detector to detect photons from annihilation. Of which, by non-limiting example, those physical processes may lead to different applications. As noted above it is also possible that the one or more detector can be from the group consisting of one of a solid state detector, a radiation detector, a scintillator detector, a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or an another radiation detecting device.

[0062] Still referring to FIG.s 3A and 3B, mono-energetic beta emitters such as Bi207 may also be used. Here one will need to use energy spectroscopy information from the detector and correlate the energy losses to the fluid density. It is note, that this may

put an additional burden on the read-out electronics.

[0063] Still referring to FIG.s 3A and 3B, beta emitters, producing betas with a continuous distribution of energy such as Sr90, are ideal for this application. As shown in Figure 2, betas with different energies penetrate different depths. The counting rate in the detector is directly correlated with the flow density. Therefore, the read-out electronics can be a simple counting circuit with a stable threshold. Energy spectroscopy information from the detector is not required.

[0064] Still referring to FIG.s 3A and 3B, the detector counting rate depends on the strength of the beta emitter and the flowline design. Based on the feasibility studies carried out in the lab, a Sr90 beta emitter with an activity in the range of 10-50 uCi is sufficient to give a precise density measurement in a second or in a few seconds with a 2mm flowline. Certainly, one can change the source strength to adjust the measurement time.

[0065] Still referring to FIG.s 3A and 3B, in oil wells the ambient temperature is often above 130°C. Traditional silicon detector will have difficulty operating in such an extreme temperature environment. However, diamond detectors have shown a remarkable performance even beyond 200°C, thus, is ideal for downhole applications.

[0066] Still referring to FIG.s 3A and 3B, diamond detectors work in the same way as a silicon detector (or more generally a semiconductor) detector. The semiconductor detectors are widely used for radiation detection, especially for charged particle detection. However, the diamond detector has one intrinsic advantage over semiconductor detectors due to its large band-gap, which makes it ideal for high-temperature applications, i.e., downhole applications.

[0067] FIGs. 4A and 4B, 4A is a sketch that shows the principle of the detection of charged particles using a diamond detector. The working principles of a diamond or a semiconductor detector are quite similar. Radiation is measured by means of the number of charge carriers set free by the radiation in the detector volume between two electrodes. Ionizing radiation produces free electrons and holes, namely, a number of electrons are transferred from the valence band to the conduction band, and an equal number of holes are created in the valence band. The number of electron-hole pairs is proportional to the energy deposited by the radiation in the detector volume. Under the influence of an electric field, electrons and holes travel to the electrodes and produce an electrical pulse that is measured with a charge-sensitive amplifier (often called “pre-amplifier”). As the amount of energy required for creating an electron-hole pair is known, and is independent of the energy of the incident radiation, the number of electron-hole pairs produced is proportional to the energy of the incident radiation.

Table 1, band gaps and density properties of several materials.

	Silicon	Silicon-carbide	Diamond
Band gap (eV)	1.11	2.86	5.45
Density (g/cm³)	2.33	3.22	3.51

[0068] Still referring to FIG. 4A, for comparison, the band gaps and densities of a few materials are listed in Table 1 above. The very large band gap of diamond detectors results in a very small leakage current when biased with an electric field, even at more than 200°C. This characteristic makes it ideal for oil-field or any other high-temperature applications.

[0069] FIG. 4B illustrates typical Spectra of beta particles from a Sr90 source as read out from a diamond detector in the present setup for two different preamp cable lengths. The read-outs from amplifiers were analysed by a pulse height analyser [PHA] and plotted as a function of a MCA (multi-channel analyser) channel number.. The location of the noise threshold is graphically shown. The channel number or energy corresponding to these points is what is referred to as the noise threshold. In particular, it was noted that the noise was drastically reduced and maintained more stable by installing an uninterruptable power supply (UPS) in the testing laboratory. The signal going from the detector to the preamp is only a few fC of charge collected in ~10 ns and is very susceptible to interference. Normally preamplifiers are placed very close to the detector to minimize the RF pickup and the capacitance of the cable. However, for an actual implementation of this device in a down-hole application, it may be desirable to have a longer cable between the detector and preamp. The noise picked up by the cable between the detector and preamp is a function of the cable length, so the question exists of how long of a cable can be tolerated. The data show that a reasonable length of cable can be applied without an interference to the measurements in this setup.

[0070] Some additional advantages of the diamond detector, by non-limiting example, include: 1) its small size, for example, a 5x5x0.5 mm detector, which is ideal for applications where there is little space (i.e., in a logging while drilling applications, especially for small borehole sizes), and that it is compatible for applications in microelectromechanical system (MEMS), nanoelectromechanical system (NEMS) and micromachine related devices; 2) the detector is mechanically strong; chemically stable even at high temperatures; resistance to radiation damages; excellent linearity and

provides stability when used as a radiation detector, which makes it ideal for high-radiation and hostile environments applications; 3) the detector is easy to use, it needs approximate 200-500 V/cm bias; has a fast charge collection (~ 10 ns); has a good energy resolution for stopping alphas and betas ($\sim 4\%$); and has a large signal comparable to silicon detectors; along with a very low leakage current ($< \text{pA}$).

[0071] It is noted that one of the alternatives to diamond detectors is to use a Silicon Carbide detector instead of a diamond detector, giving the fact that SiC does have a relative large band gap as shown in Table 1 above.

[0072] Some other additional advantages of diamond detectors relevant to the claimed subject matter of the application include the ability to make accurate measurements under subterranean environment conditions, such as downhole environment conditions. For example, at least one advantage over that of the known resonating sensors is its ability to make accurate measurements of properties of fluid, such as density, when measuring fluids under special fluid conditions. Special fluid conditions, as noted above include gaseous fluids, emulsions, non-Newtonian fluids, supercritical fluids or multiphase Fluids.

[0073] A special fluid condition such as a *gaseous fluid* presents problems for known resonating sensors when trying to measure fluid properties of a fluid, such as density. For example, trying to get an accurate density measurement of any low density fluid such as dry methane or condensates with low carbon number is difficult for any technique, especially for a well-known resonating sensor. After the initial cleaning of a flow line of the resonating sensor, as well as any immersed sensor, it is almost assured that it will be coated with mud. While one can remove particulates and mud with a

miscible fluid; for example, oil directly from the formation, it is difficult to remove such residues with a gas stream. The analogy that is typically made, is that one cannot wash oily hands with just a blast of air. Rather, one needs a fluid that is miscible and can dissolve away the coated particulates and solids. A residual thin layer of mud will dramatically reduce the accuracy of the measurement. On the other hand, the claimed subject matter of the application overcomes the above problems and is able to make accurate measurements of properties of fluid, such as density by making a volumetric measurement through a fluid flow line which results in being less sensitive to such contamination.

[0074] Another example of a special fluid condition such as *emulsions* presents problems for the known resonator sensor when making density measurements. Oil/water emulsions are common in wells throughout the world. They may be resulted from water breakthrough during a sampling job or from the shearing action of drilling when using water-based mud. The measurement of emulsions with a known resonating sensor is particularly challenging due to wetting effects; typically one fluid prefers to wet the sensor tip, providing a biased measurement. On the other hand, the claimed subject matter of the application overcomes the above problems and is able to make accurate measurements of properties of fluid, such as density by making a volumetric measurement that is largely insensitive to wetting.

[0075] Another example of special fluid conditions may include non-Newtonian fluids which also present a significant challenge for resonating sensors. The shear rate of a resonating sensor immersed in fluid is maximum at its surface and decreases with distance, dictating that the shear rate is non-uniform throughout the interrogation

volume. If the shear rate is non-uniform, then for a non-Newtonian fluid the shear stress will be non-uniform as well, producing a viscosity measurement that is certainly not representative of the zero shear rate viscosity. A preponderance of fluids experienced downhole appears to be shear-thinning, and measurements with a resonating sensor typically read low. A low accuracy measurement of the fluid viscosity with a resonating sensor that simultaneously measures fluid density often invalidates the interpretation and leads to incorrect density measurements. Again, a density measurement that did not involve resonance such as described in claimed subject matter of the applicant does not have this problem.

[0076] Another example of special fluid conditions may include supercritical fluids or multiphase fluids which also present significant challenges for resonating sensors. Supercritical fluid can be any substance at a temperature and pressure above its thermodynamic critical point. It can diffuse through solids like a gas, and dissolve materials like a liquid. There is no surface tension in a supercritical fluid as there is no liquid / gas phase boundary. Additionally, all supercritical fluids are completely miscible with each other. In general terms, supercritical fluids have properties between those of a gas and a liquid. However, close to the critical point, small changes in pressure or temperature result in large changes in density and viscosity, allowing many properties to be altered. Thus, this presents enormous challenges for resonating sensors. Further, carbon dioxide is usually in supercritical form under most downhole conditions.

[0077] Since resonating sensors measure fluid properties in a local volume or a small surface area, multiphase fluids such as a liquid with gas bulbs will present another challenge. On the other hand, a nuclear volumetric measurement described here is

insensitive to the apparent forms of fluids regardless whether they are in supercritical forms or multiphase.

[0078] FIG. 5 is a plot illustrating the beta particle counts in the detector as a function of the fluid density, wherein the trend-line is a polynomial fit of all data except the crude samples. Further, the fluidic density measurements were carried out with a test setup in the lab to demonstrate the feasibility. The liquid samples include standard alkanes (C4 to C14); benzene, toluene, and their mixtures, water, isopropanol, and their mixtures, acetone, chloride hydrocarbon fluids, a few crude samples, and a few emulsified fluids were made in the lab with S20 and Hexadecane oils mixed with water. In the following, is shown the results for above mentioned conventional fluids, leaving emulsified and supercritical fluids elsewhere. Note that the measurements were performed with a 1 uCi Sr90 source, and a smaller version of diamond detector which resulted a longer counting time.

[0079] Still referring to FIG. 5, FIG. 5 shows the detector counts vs. densities for most of the samples. Those measurements were accumulated over a couple of months. For each group of samples, repeated measurements were made with the empty flow-channel, or filled with hexane, and occasionally with hexadecane. The data show excellent repeatability, and no normalization was needed. Furthermore, it is noted that a simple 4th order polynomial fits the data very well.

[0080] FIG. 6 is the same as in FIG. 5, but shows only data in the density region from 0.6 to 1.0 g/cc. In particular, FIG. 6 shows a zoom in view of the data in the density range from 0.6 to 1.0 g/cc. The statistical errors become visible in the present setup with a 1 uCi Sr90 source, and a smaller version of diamond detector.

[0081] FIG. 7 illustrates the measured density as a function of the true density. The line is a fit. Also, one can invert the polynomial fit of the beta particle counts as a function of density to obtain the densities from the counts -- the “measured” densities. FIG. 7 shows the results of the measured density as a function of the true density. The straight line fit reveals an excellent 1-to-1 ratio.

[0082] FIG. 8 illustrates the discrepancy between the measured and true density as a function of the true density. The line is a fit. It is noted, the density discrepancy (the difference between the true density and the measured density) is shown in FIG. 8 as a function of density. The distribution is quite flat as a function of density, consistent with the statistical errors. From the data, one can be confident that the measurements achieved with a 0.01g/cc or better accuracy.

[0083] FIG. 9 illustrates a plot of the Z/A ratios of fluidic samples used in the measurements, wherein the Z/A ratio is defined by the atomic number “Z” and the atomic mass number “A”. In order to study the effects of aromatics, one investigated the density dependence of Z/A ratios using acetone, benzene, toluene, and their mixtures. Those fluids normally do not exist down hole or exist only in a very small percentage in crude oils. They have different Z/A ratios comparing with the rest samples. Figure 9 shows the Z/A for all the fluids studied in this invention. The samples of alkanes, crude oils, and water/ isopropanol mixtures form a main trend line, while those of acetone, benzene, toluene and their mixtures (benzene/hexadecane or toluene/hexane) form another branch.

[0084] Still referring to FIG. 9, the Z/A ratios can be computed if the fluids compositions are known. One of the methods determining the Z/A ratios is to determine the fluidic compositions by using optical measurements, as in a down-hole fluidic

analysis device (DFA). Z/A ratios can also be measured by using the hydrogen index obtained from the NMR fluidic analysis. The Hydrogen index (ω_H) is related to the Z/A ratio in a simple way:

$$Z/A = (1 + \omega_H)/2. \quad \text{Eq. 3}$$

[0085] Referring to FIG.s 10 and FIG. 11, FIG. 10 is a plot showing the counting rates as a function of the product of the Z/A ratios and densities. The product of Z/A and Density (often called mass density - ρ_m) can be defined as the electron density (ρ_e), thus:

$$\rho_e = Z \cdot N/N_0 = Z/A \cdot \rho_m \quad \text{Eq. 4}$$

where N/N_0 is the number density of the material with N_0 the Avogadro's number.

[0086] FIG. 11 is a plot showing the discrepancy between true and measured electron density as a function of the electron density.

[0087] Still referring to FIG.s 10 and FIG. 11, the data in FIG. 5 includes only fluids that fall on the main Z/A trend line. For fluids belonging to the branch Z/A line the counting rates will deviate from the main fit line and form similar branches in the counting rates or measured densities plots. A simple way to correct for the deviation is to plot everything as a function of the product of Z/A ratio and density ($Z/A \cdot \text{density}$), i.e., the electron density, instead of mass density. This can be seen in FIG.10, one fit line can describe all the data points for counting rates regardless the fluid types. This demonstrates that the attenuation of beta particle flux in the flowline is through ionization and is directly proportional to the electron density in the flow channel. Using the fit for counting rates, one can obtain "measured" electron densities. The discrepancy between

the true and measured electron density for all the fluid samples are shown in FIG.11. Again, the figure illustrates that it is possible to achieve a precision of 0.01g/cc for fluid density with this technique.

[0088] Still referring to FIG.s 10 and FIG. 11, an important note here: one can apply this downhole real-time measurement in two ways. As mentioned above, the Z/A ratio of flow can be obtained from the down-hole fluidic analysis device (DFA) or NMR measurements. Combining with the method described in this invention, one can have a precise flow density measurement. Or, if one combines this method with another “true” mass density device such as the in situ density device from Schlumberger down-hole fluidic analysis which provides density measurements with a vibrating rod, one can immediately obtain the hydrogen index for the flow [see Equation 4]. Both of these may be advantageous in cases where other measurements are not practical or feasible.

[0089] FIG.s 12 and 13 show the measurements with pressurized Nitrogen gas. FIG. 12 illustrates Nitrogen data plotted with previously taken liquid data vs. density normalized to an empty channel. FIG. 13 illustrates normalized nitrogen data plotted with previously taken liquid data vs. $Z/A \cdot \text{Density}$ to negate the effects of varying hydrogen indices of the materials. The two data sets are normalized to the empty channels filled with air at atmospheric pressure. Every data set has empty channel filled with air at atmospheric pressure to demonstrate repeatability at different times when data were taken. This normalization is necessary because the pressurized device design has approximately a much higher counting rate than the device used for previous liquid measurements due to a stronger Sr90 source and a bigger diamond detector.

[0090] FIG. 14 illustrates density Discrepancy for the second order fit as a function

of density for Nitrogen measurements with repeated pressure cycles. The pressure cycles were found that most of the data falls within ± 0.005 g/cc of the second order trend line.

[0091] As noted above, it is contemplated that at least two implementations for such a measurement may include a macroscopic implementation as discussed above and a microscopic implementation. The microscopic implementation is a density measurement downstream of a microfluidic separator through a microfluidic channel of a diameter of approximately 0.5 mm or less.

[0092] Whereas many alterations and modifications of the present disclosure will no doubt become apparent to a person of ordinary skill in the art after having read the foregoing description, it is to be understood that the particular embodiments shown and described by way of illustration are in no way intended to be considered limiting. Further, the disclosure has been described with reference to particular preferred embodiments, but variations within the spirit and scope of the disclosure will occur to those skilled in the art. It is noted that the foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present disclosure. While the present disclosure has been described with reference to exemplary embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Changes may be made, within the purview of the appended claims, as presently stated and as amended, without departing from the scope and spirit of the present disclosure in its aspects. Although the present disclosure has been described herein with reference to particular means, materials and embodiments, the present disclosure is not intended to be limited to the particulars disclosed herein; rather, the present disclosure extends to all functionally

equivalent structures, methods and uses, such as are within the scope of the appended claims.

What are claimed:

1. A device for measuring one or more property of a fluid including density, the device comprising:
 - a pressure housing having one or more window formed in the pressure housing;
 - a flow device arranged in the pressure housing for the fluid to flow through the flow device;
 - one or more radiation source mounted within the pressure housing approximate a first source window of the one or more window and configured to generate particles into the fluid; and
 - one or more detector supported by the pressure housing and positioned approximate a first detector window of the one or more window, the first detector window located between the one or more detector and the flow device.
2. The device of claim 1, wherein the fluid is from the group consisting of at least one liquid, at least one solid mixed with the at least one liquid, at least one gas or some combination thereof.
3. The device of claim 2, wherein the fluid is one of flowing or non flowing through the flow device while measuring the one or more property of the fluid which includes density.
4. The device of claim 2, wherein the fluid is a supercritical fluid such as carbon dioxide (CO₂) that is in a supercritical condition which is approximate to a downhole application.
5. The device of claim 2, wherein the fluid is one of an emulsified fluid, a drilling fluid or a multiphase fluid.
6. The device of claim 1, wherein the one or more radiation source is from the group consisting of a beta particle source, an electronic source, a strontium source such as a strontium 90 source or a positron source.

7. The device of claim 6, wherein the one or more radiation source produces beta particles within a energy range of one of approximately 1MeV or more, 1MeV to 3MeV or 2MeV to 3MeV.

8. The device of claim 6, wherein the generated beta particles of the one or more radiation source are emitted through the first source window, into the flow device containing the fluid, out of the flow device and through the first detector window to be detected by the one or more detector, so at least one electronic device such as a processor is in communication with the one or more detector for receiving a pulsed signal from the one or more detector in one of a downhole environment, a reservoir, a borehole, inside a surface metering device or testing device.

9. The device of claim 1, wherein the one or more detector is from the group consisting of a charged beta particle detector, a beta particle ionization detector, a diamond detector or a wide band gap detector.

10. The device of claim 9, wherein the wide band gap detector includes one of a band gap of approximately 5.45 eV, a approximate density of 3.51 g/cm³ or a approximate dimension of a 5mm length by a 5mm width by a 0.5mm height.

11. The device of claim 9, wherein the wide band gap detector operates in a routine environment of temperatures approximately equal to and above one of 150 Celsius or 200 Celsius or more.

12. The device of claim 9, wherein the wide band gap detector is compatible for applications in one of a microelectromechanical system (MEMS), a nanoelectromechanical system (NEMS), a micromachine related device, a nano-tips based detector or a Field-emitting array based gas detector.

13. The device of claim 1, wherein at least one electronic device such as a processor is in communication with the one or more detector for receiving a pulsed signal from the

one or more detector, the at least one electronic device processes the received pulsed signals to provide the capability to determine the one or more property including density of the fluid.

14. The device of claim 13, wherein the determined density measurement of the fluid is from the group consisting of one of a gaseous fluid density measurement, a emulsion fluid density measurement, a non-Newtonian fluid density measurement, a supercritical fluid density measurement or a multiphase fluid density measurement.

15. The device of claim 1, wherein the device is in communication with a processor and a mass density measuring device that measures a mass density of the fluid, the processor is capable of determining a fluidic hydrogen index from data received from the device and the mass density measuring device.

16. The device of claim 1, wherein the device is in communication with a processor and a fluidic hydrogen index measuring device that measures a fluidic hydrogen index, the processor is capable of determining a fluidic mass density from data received from the device and the fluidic hydrogen index measuring device.

17. The device of claim 1, wherein the pressure housing is of a material from the group consisting of a stainless steel or one or more other materials and stainless steel.

18. The device of claim 1, wherein the pressure housing includes a source space with a source retainer that is in communication with the first source window to secure the one or more radiation source.

19. The device of claim 1, wherein the pressure housing includes a detector space, detector shield and a detector cap that is in communication with the first detector window to secure the one or more detector.

20. The device of claim 19, wherein the detector space further includes an elastomeric device.

21. The device of claim 1, wherein the one or more detector is structured and arranged to be integral with the pressure housing.
22. The device of claim 1, wherein the pressure housing is capable of withstanding pressures up to 30,000 psi or more and temperatures to 200 Celsius or more.
23. The device of claim 1, wherein the device is designed to operate at pressures of one of 5k psi or more, 10k psi or more, 15k psi or more or 20k psi or more.
24. The device of claim 1, wherein the device is designed to operate at temperatures of one of more than -150 Celsius, more than -50 Celsius, at least 50 Celsius, at least 100 Celsius or at least 150 Celsius.
25. The device of claim 1, wherein the device is designed to operate at pressures within the flow device of one of at least 5 kpsi, at least 10k psi or at least 20kpsi.
26. The device of claim 1, further comprising deploying the pressure housing, the radiation, the detector and the first source window and first detector window downhole and wherein the fluid measurements are made downhole.
27. The device of claim 1, wherein the one or more window and flow device are made of a material having an approximate density of at least one combination of a glass and a peek material or a combination of the glass, the peek material and another material.
28. The device of claim 1, wherein a thickness of the first source window, a wall of the flow device and the first detector window are approximately equal.
29. The device of claim 1, wherein a thickness of the first source window, a wall of the flow device approximate the first source window, the first detector window and a wall of the flow device approximate the first detector window are approximately equal.

30. The device of claim 30, wherein a first distance from the first source window to the wall of the flow device approximate the first source window is approximately equal to a second distance from the first detector window to the wall of the flow device approximate the first detector window.

31. The device of claim 1, wherein the first source window and the first detector window of the one or more window have a thickness capable of allowing transmission of particles from the one or more particle source within the pressure housing to the one or more detector, to allow for the particles to be detected by the one or more detector that is one of a solid state detector or a radiation detector.

32. The device of claim 1, wherein the flow device is from the group consisting of a tube, a flowline, a channel, a pipe and a microfluidic channel that is integral with the pressure housing.

33. The device of claim 1, wherein the flow device has one of a thickness or a diameter ranging from approximately equal to or less than 0.5 mm to approximately 5 cm.

34. The device of claim 1, wherein the flow device has one of two or more thicknesses such as a first and a second thickness or two or more diameters such as a first and a second diameter.

35. The device of claim 34, wherein the one or more beta sources has two or more beta sources and the one or more beta detector has two or more beta detectors.

36. The device of claim 35, wherein a first beta source and a first beta detector are arranged to measure the mixed fluid and a second beta source and a second beta detector are arranged to measure a gas.

37. The device of claim 35, further comprising:

- a) a first beta source of the two or beta sources is located approximate the first diameter of the flow device and the first source window,
and a first beta detector of the two or more beta detectors is located approximate the first diameter of the flow device and the first detector window; and
- b) a second beta source of the two or beta sources is located approximate the second diameter of the flow device and a second source window,
and a second beta detector of the two or more beta detectors is located approximate the second diameter of the flow device and a second detector window.

38. The device of claim 37, wherein the at least one electronic device is in communication with the first detector and the second detector for receiving a first pulsed signal from the first detector and a second pulsed signal from the second detector, so that the at least one electronic device processes the received first and second pulsed signals to provide the capability to determine the one or more property including density of the fluid.

39. The device of claim 37, wherein the device is deployed downhole and the one or more radiation source mounted within the pressure housing generates particles into the fluid within one of a downhole environment, a reservoir or in a borehole.

40. The device of claim 1, wherein the one or more detector is from the group consisting of one of a solid state detector, a radiation detector, a scintillator detector or a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or an another radiation detecting device.

41. An apparatus for measuring one or more property of a fluid including density in a subterranean environment, the device comprising:

a pressure housing to be deployed within the subterranean formation having one or more window formed in the pressure housing capable of operating in routine pressures of at least 15kpsi;

a flow channel arranged in the pressure housing for the fluid to flow through the flow channel;

one or more particle source mounted within the pressure housing approximate a first source window of the one or more window is configured to generate particles into the fluid within an energy range up to 3 MeV; and

one or more detector mounted within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more detector and the flow channel.

42. The apparatus of claim 41, wherein the fluid is from the group consisting of a liquid, a liquid mixed with a solid, a gas or some combination thereof, and the fluid is one of flowing or not flowing through the flow channel while determining the one or more property of the fluid that includes density.

43. The apparatus of claim 41, wherein the one or more particle source is from the group consisting of a beta particle source, a strontium source such as a strontium 90 source or a positron source.

44. The apparatus of claim 41, wherein the one or more detector is from the group consisting of one of a solid state detector, a radiation detector, a scintillator detector or a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, a wide band gap solid state detector such as a diamond detector or an another radiation detecting device.

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45. The apparatus of claim 41, wherein at least one electronic device such as a processor is in communication with the one or more detector for receiving a pulsed signal from the one or more detector, the at least one electronic device processes the received pulsed signals to provide the capability to determine the one or more property including density of the fluid.

46. The apparatus of claim 41, wherein the flow channel has one of a thickness or a diameter ranging from approximately equal to or less than 0.5 mm to approximately 5 cm.

47. The apparatus of claim 41, wherein the first source window and the first detector window of the one or more window have a thickness capable of allowing transmission of particles from the one or more particle source within the pressure housing to the one or more detector, to allow for the particles to be detected by the one or more detector.

48. The apparatus of claim 41, wherein a portion of the pressure housing approximate the first detector window has a thickness sufficient to substantially attenuate the transmission of particles so that a linear resolution of the one or more particle detector is increased.

49. A system for measuring one or more property of a fluid including density in a reservoir environment, the system comprising:

- a pressure housing to be deployed within the reservoir formation has one or more window formed in the pressure housing;

- a flow channel arranged in the pressure housing for the fluid to flow through the flow channel;

- one or more beta particle source mounted within the pressure housing approximate a first source window of the one or more window is configured to generate beta particles up to a energy of 3MeV into the fluid; and

one or more detector mounted within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more detector and the flow channel.

50. The system of claim 49, wherein the one or more detector is from the group consisting of one of a solid state detector, a radiation detector, a scintillator detector or a gas detector, a solid state charged beta particle detector, a beta particle ionization detector, or a wide band gap solid state detector such as a diamond detector.

51. The system of claim 49, wherein the one or more beta particle source is a strontium source such as a strontium 90 source.

52. A method for measuring one or more property of a fluid including density in a subterranean environment, the method comprising:

deploying a pressure housing within the subterranean formation configured to operate at temperatures of at least 150 Celsius, the pressure housing includes one or more window formed in the pressure housing;

arranging a flow channel in the pressure housing for the fluid to flow through the flow channel;

mounting one or more beta particle source within the pressure housing approximate a first source window of the one or more window configured to generate particles into the fluid; and

mounting one or more wide band gap solid state detector such as a diamond detector within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more solid state detector and the flow channel.

53. The device of claim 50, wherein the wide band gap solid state detector includes one of a band gap of approximately 5.45 eV, a approximate density of 3.51 g/cm³ or a approximate dimension of 5mm height by 5mm length by .5mm width or some combination thereof.

54. A method for measuring one or more property of a fluid including density in a downhole environment, the method comprising:

deploying a pressure housing within the subterranean formation having routine environment temperature of equal to or more than 140 Celsius, the pressure housing includes one or more window and a flow channel formed in the pressure housing, wherein the fluid channel is arranged for the fluid to flow through the flow channel;

mounting one or more beta particle source within the pressure housing approximate a first source window of the one or more window that is configured to generate beta particles into the fluid; and

mounting one or more solid state charged beta particle detector within the pressure housing approximate a first detector window of the one or more window, the first detector window located between the one or more solid state charged beta particle detector and the flow channel.

55. The device of claim 54, wherein the one or more solid state charged beta particle detector is one of a beta particle ionization detector or a wide band gap solid state detector such as a diamond detector.

56. The device of claim 53, wherein the wide band gap solid state detector includes one of a band gap of approximately 5.45 eV, a approximate density of 3.51 g/cm³ or a approximate dimension of 5mm height by 5mm length by .5mm width.

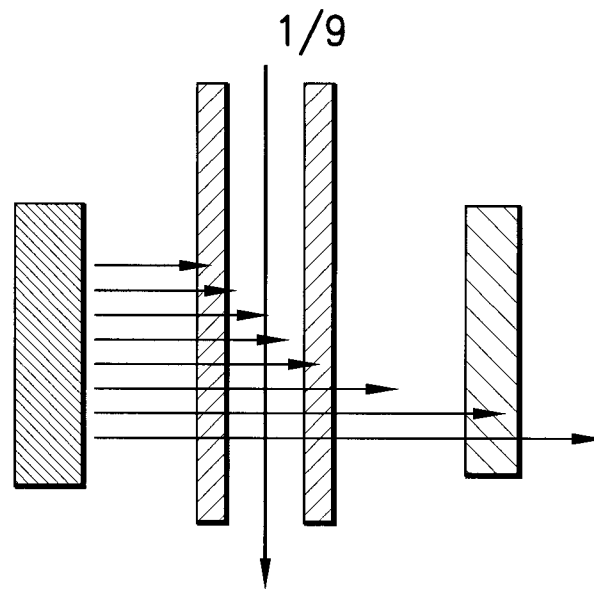


FIG. 1

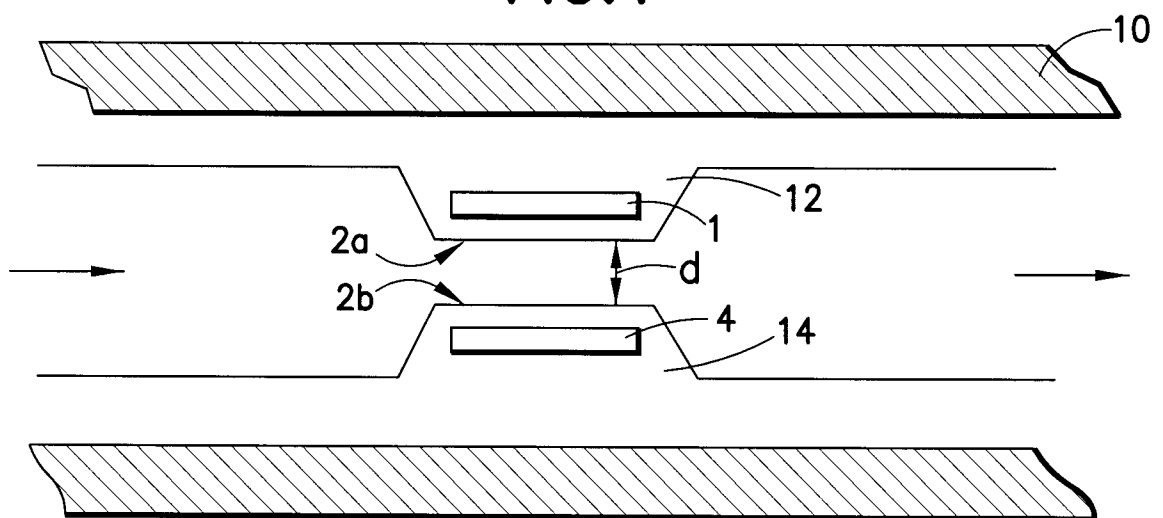


FIG. 3A

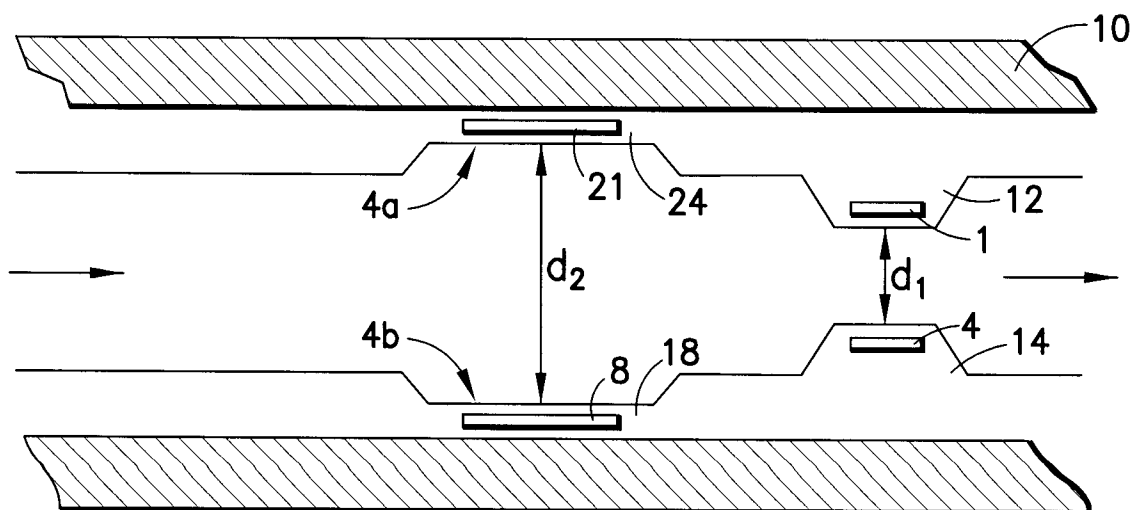


FIG. 3B

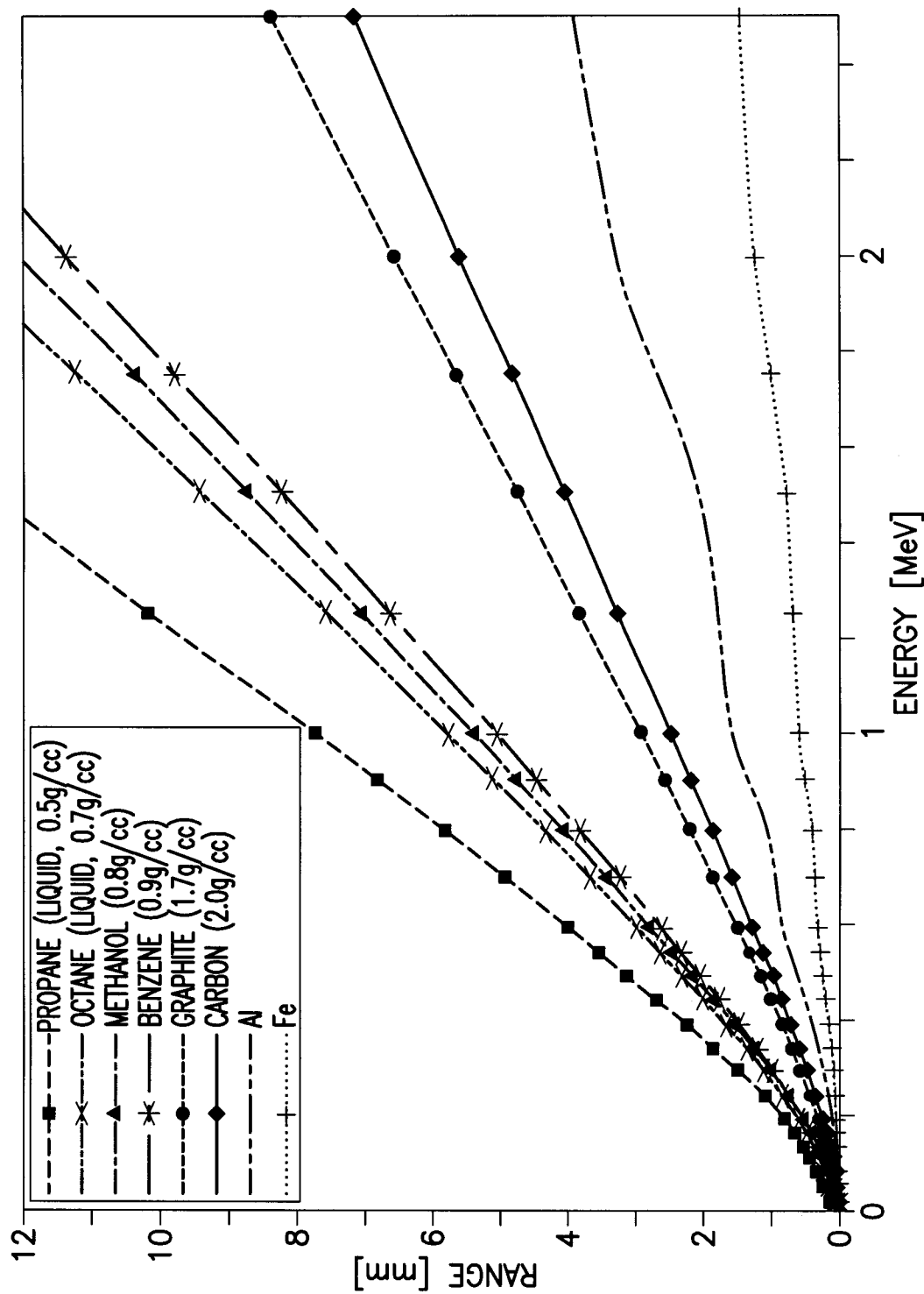


FIG.2

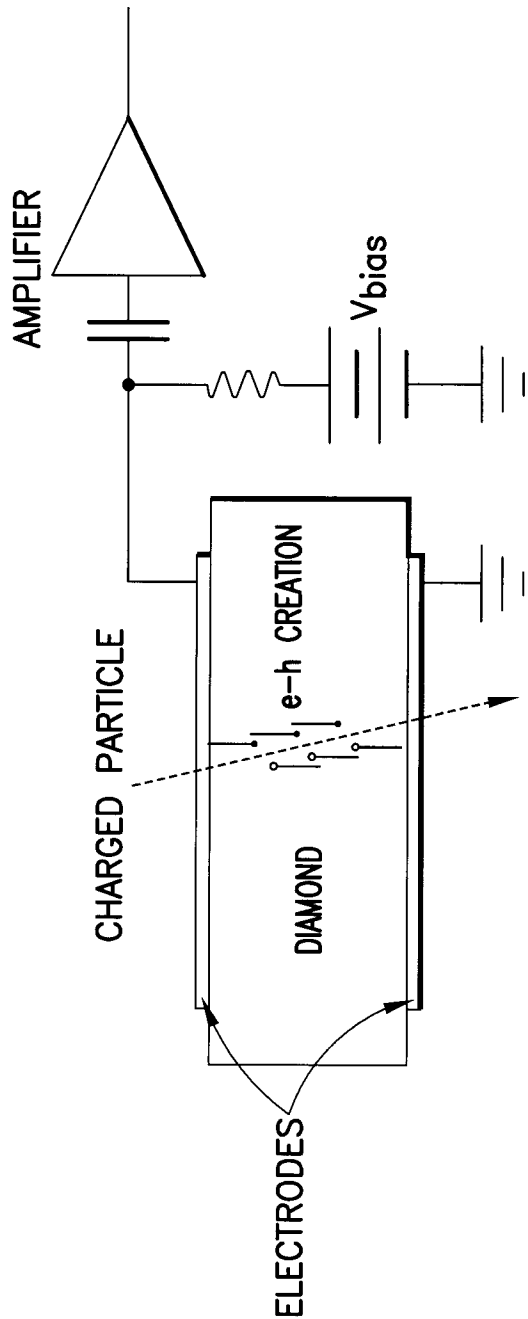
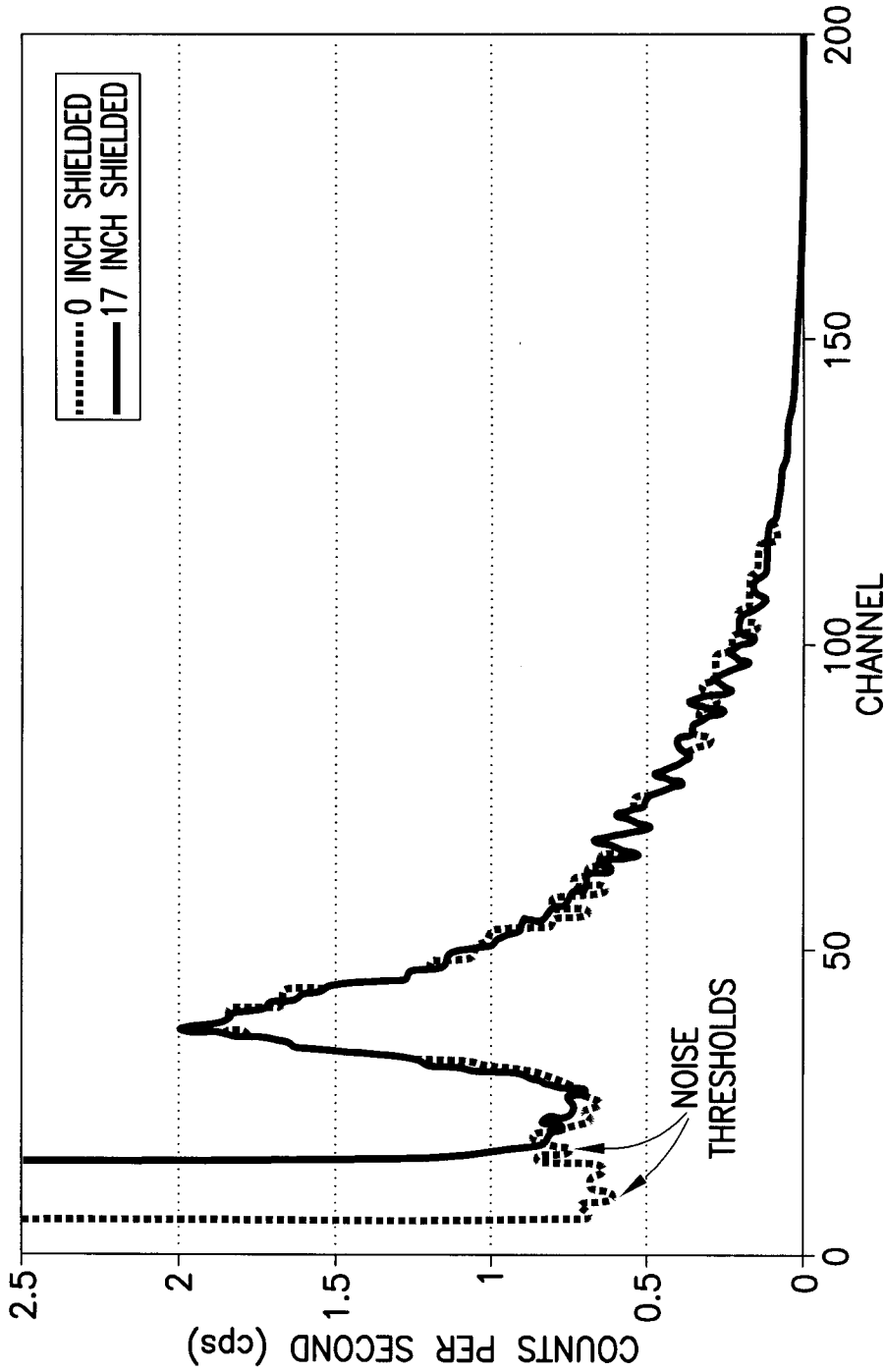


FIG. 4A



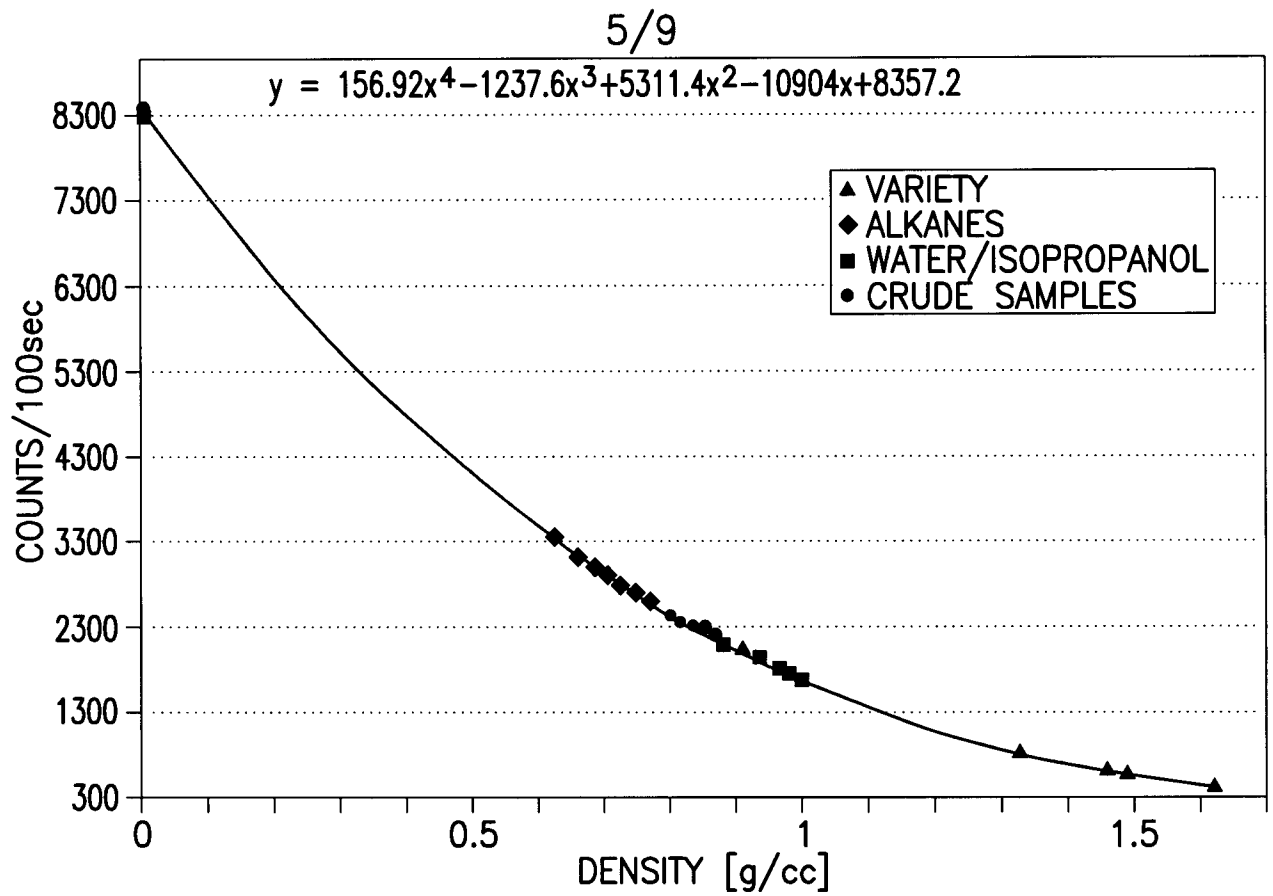


FIG.5

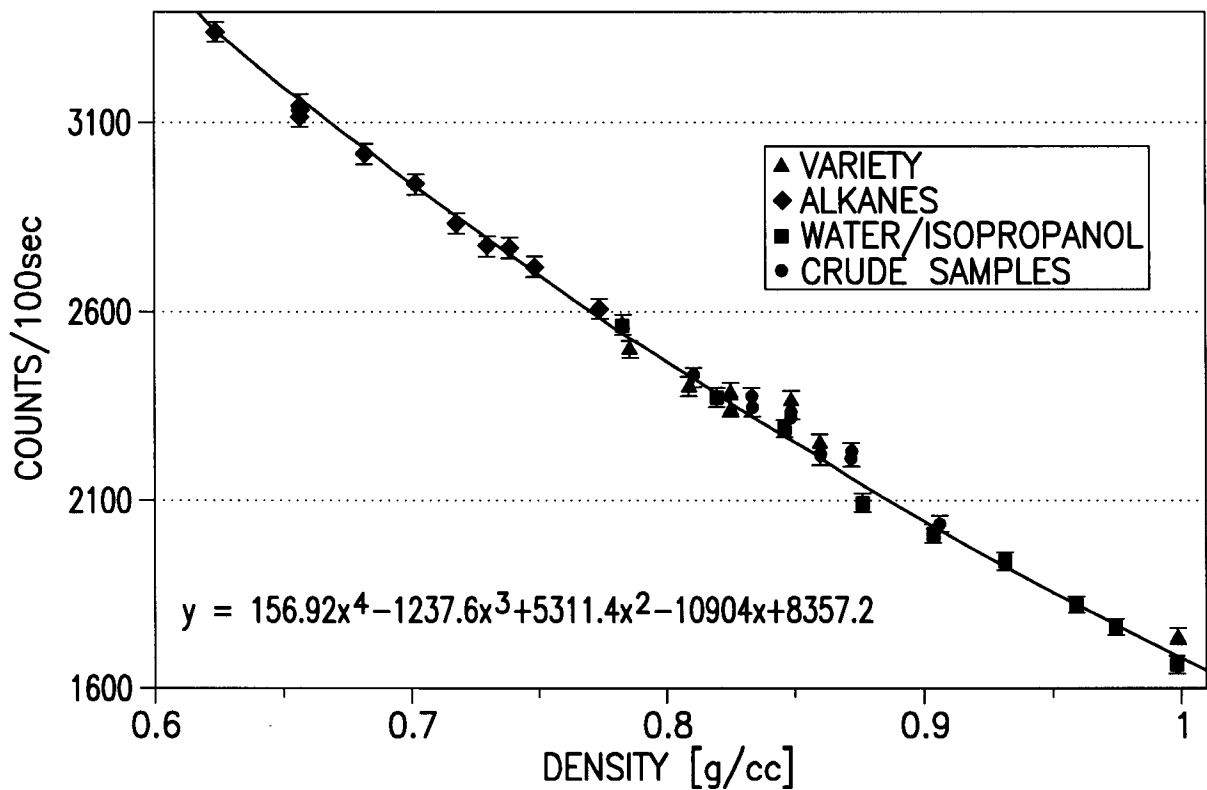


FIG.6

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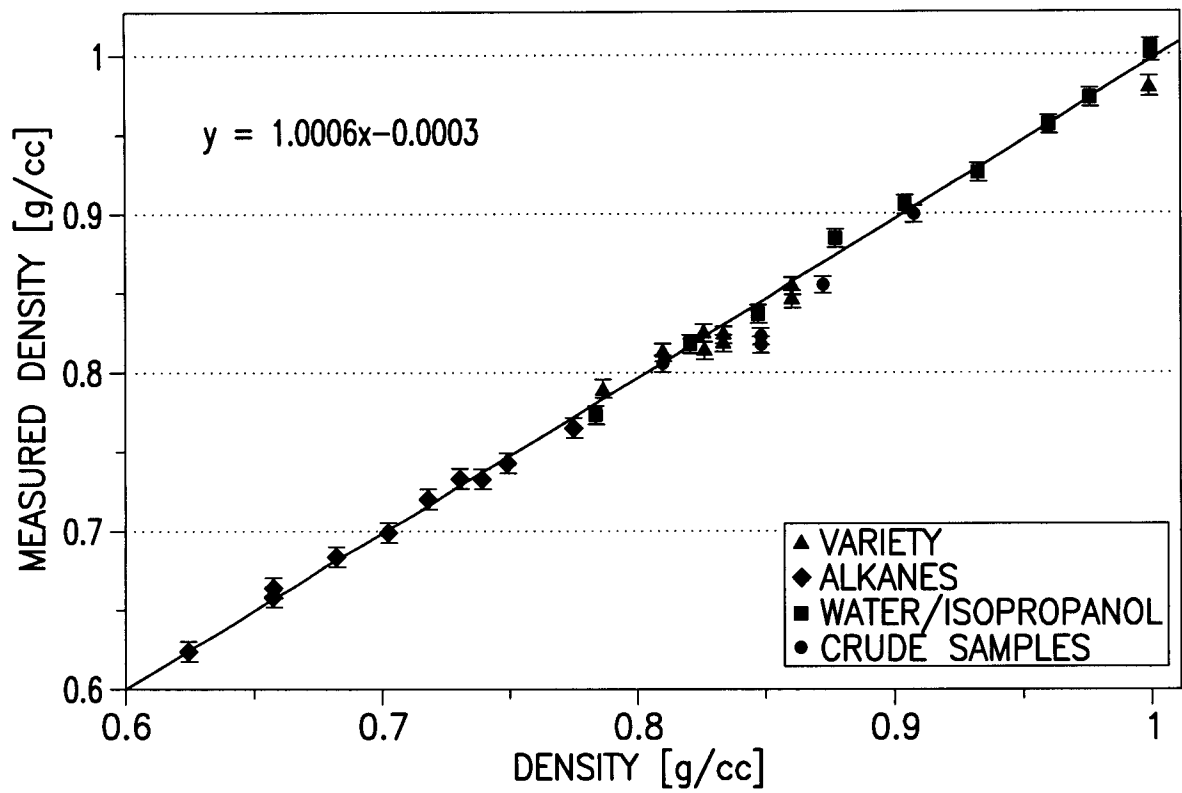


FIG.7

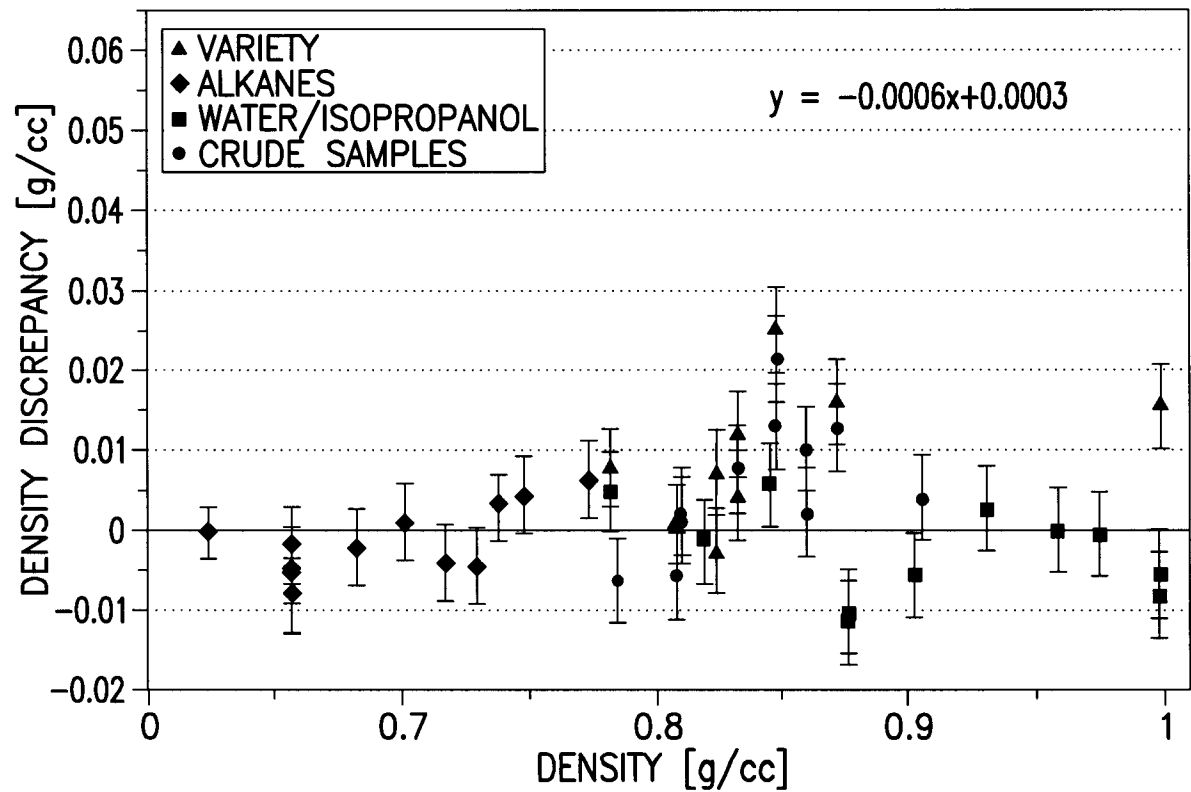


FIG.8

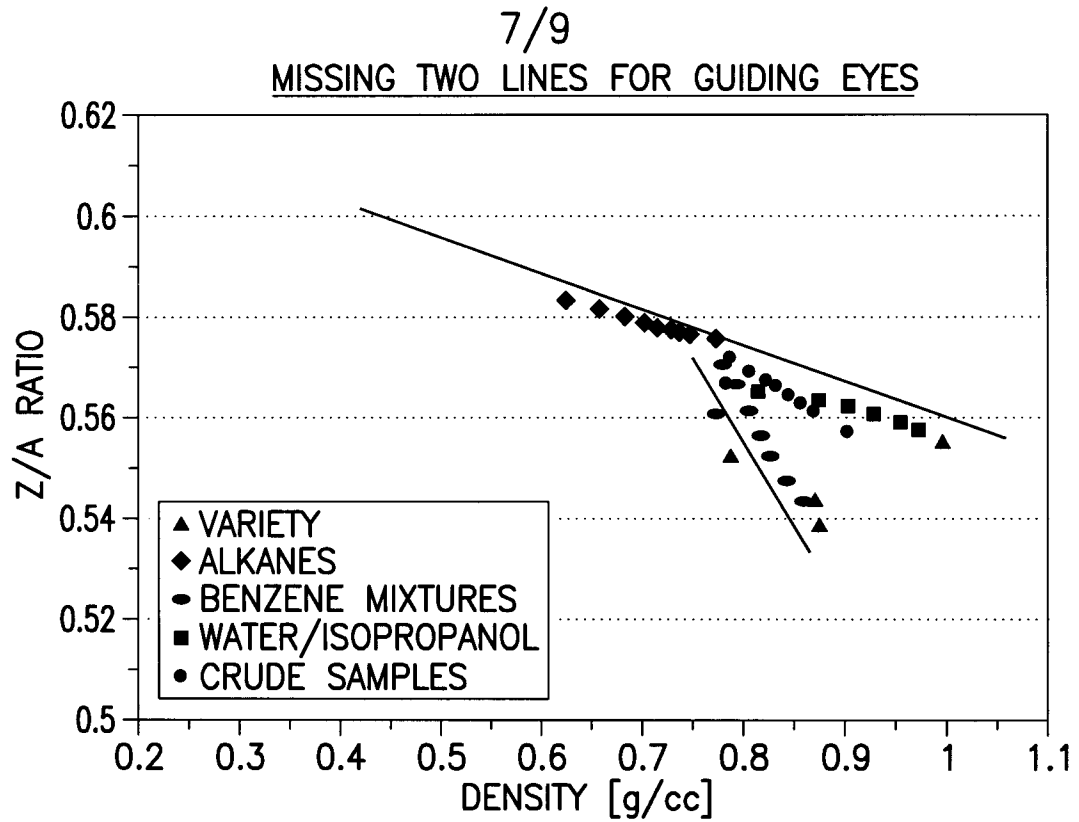


FIG.9

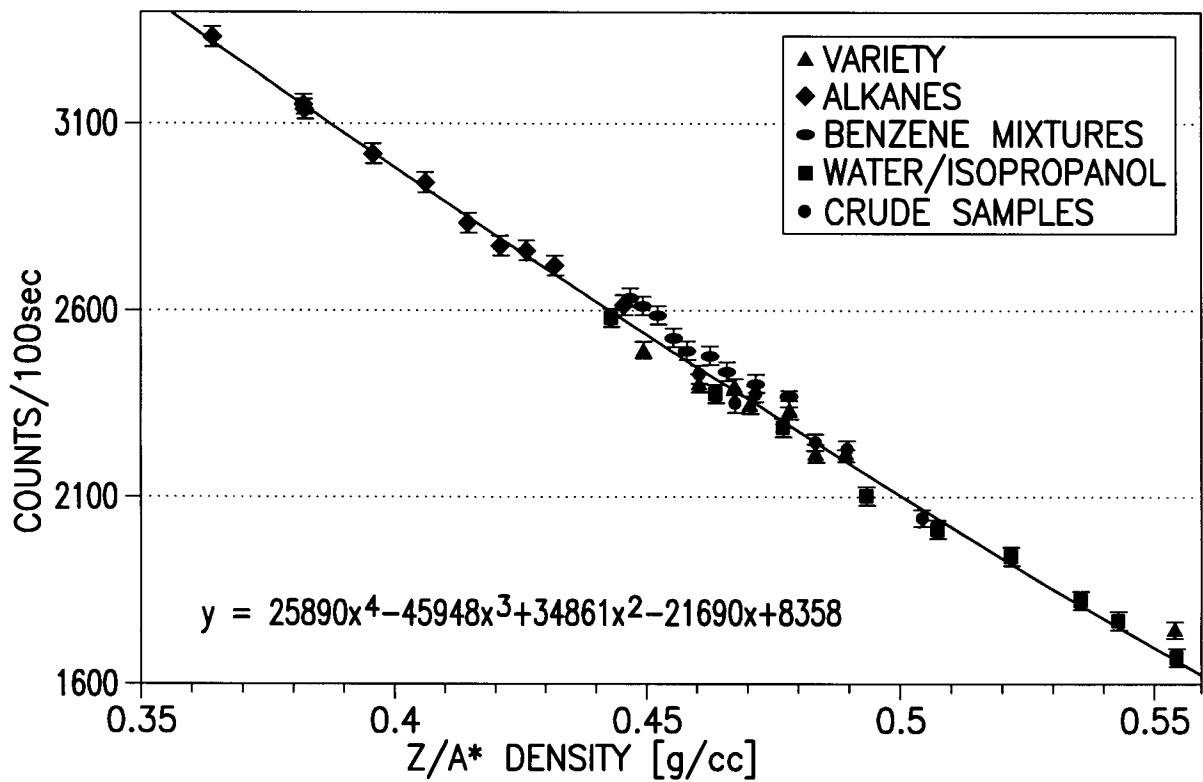


FIG.10

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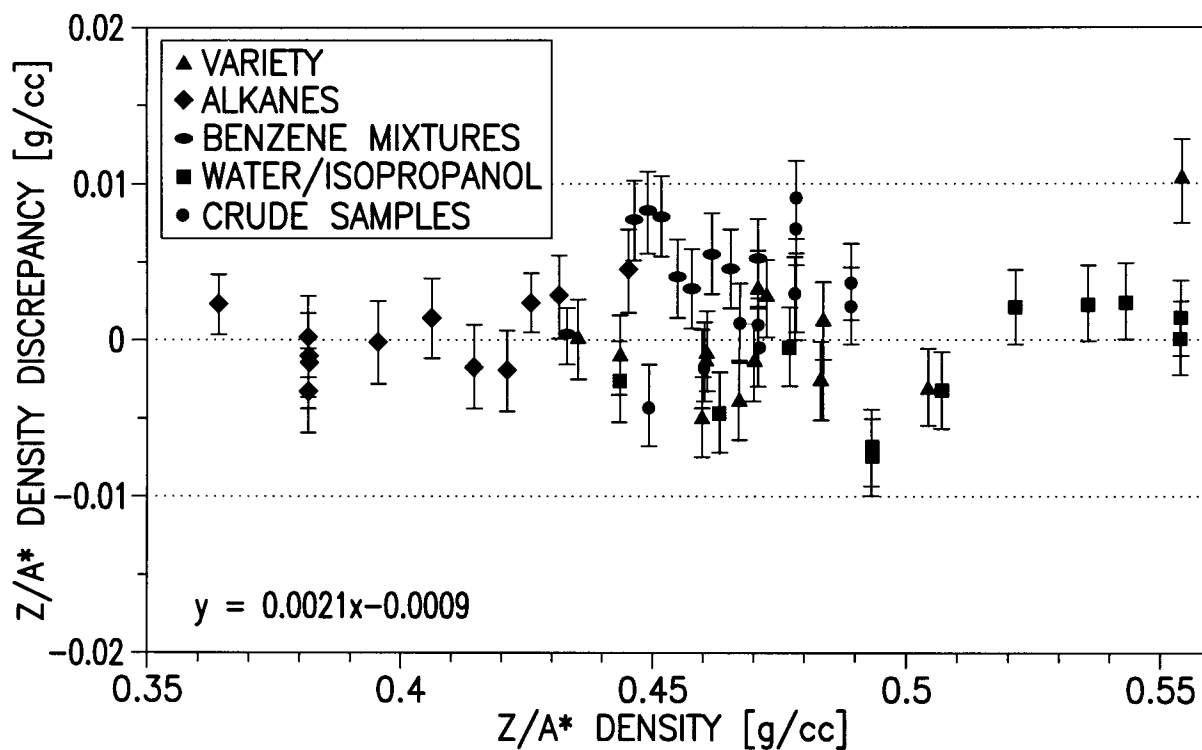


FIG.11

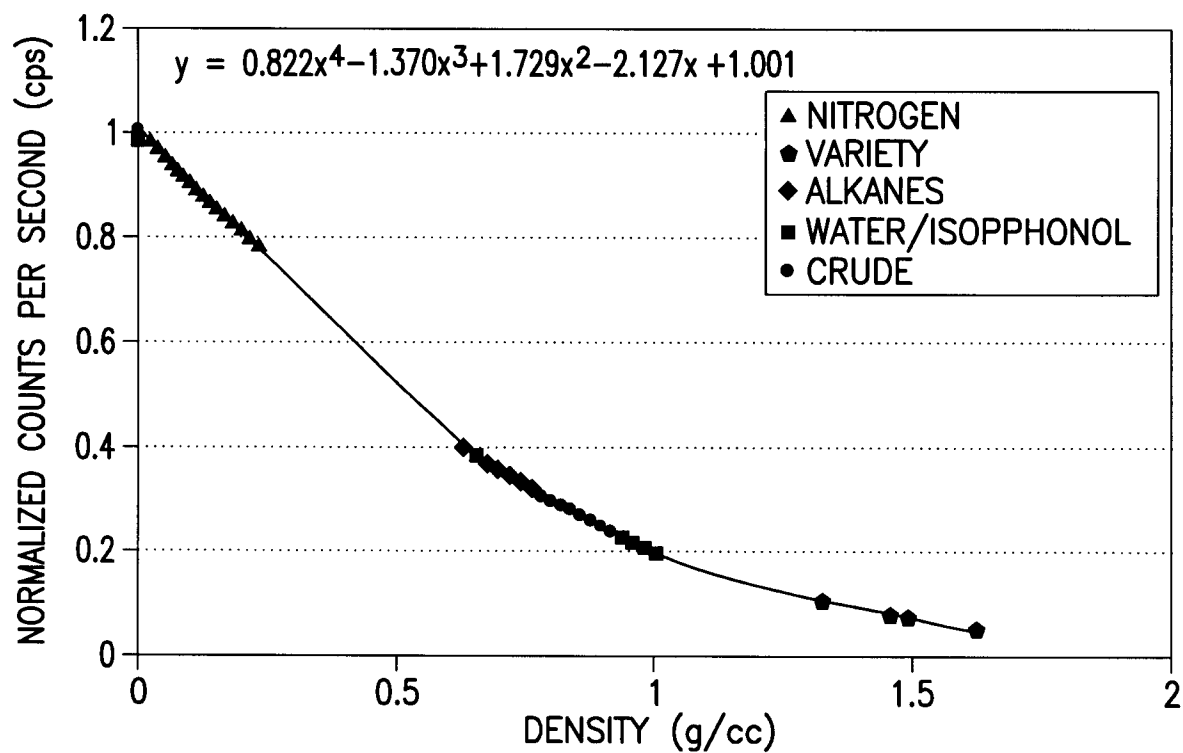


FIG.12

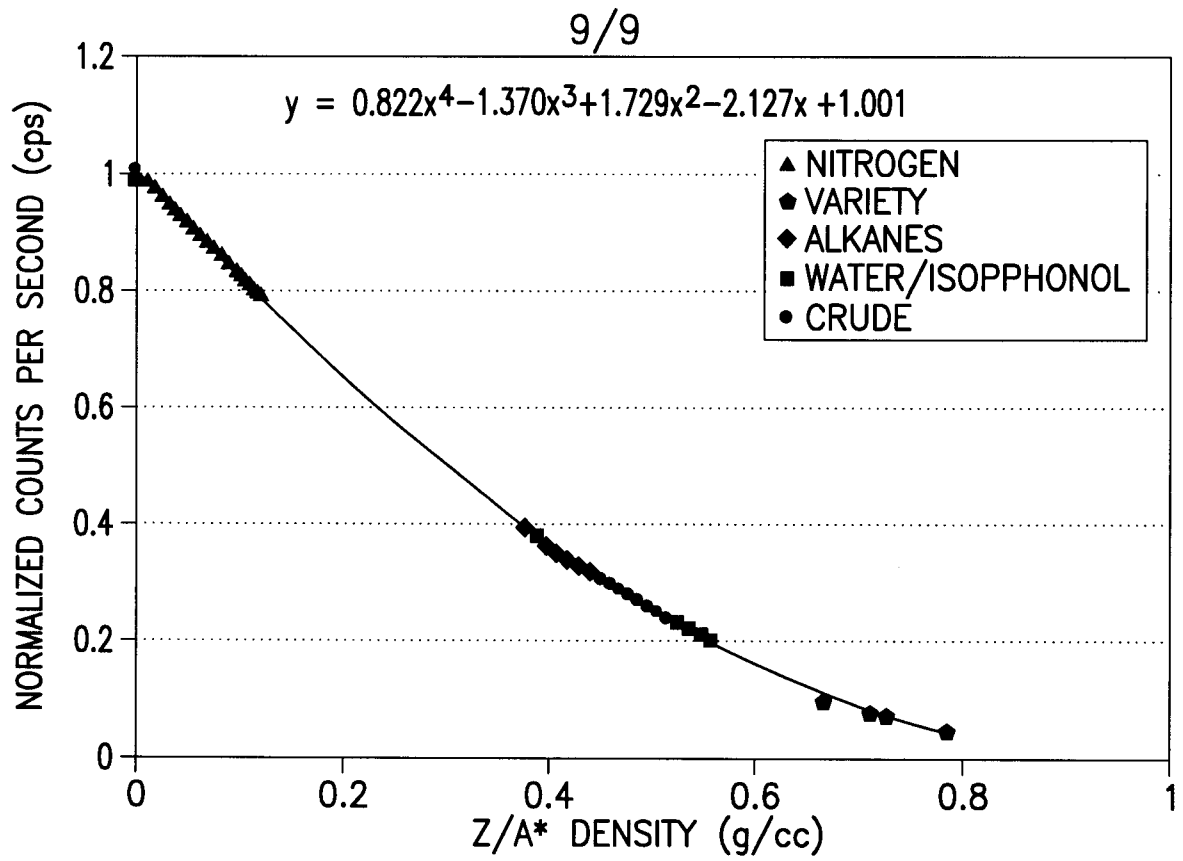


FIG.13

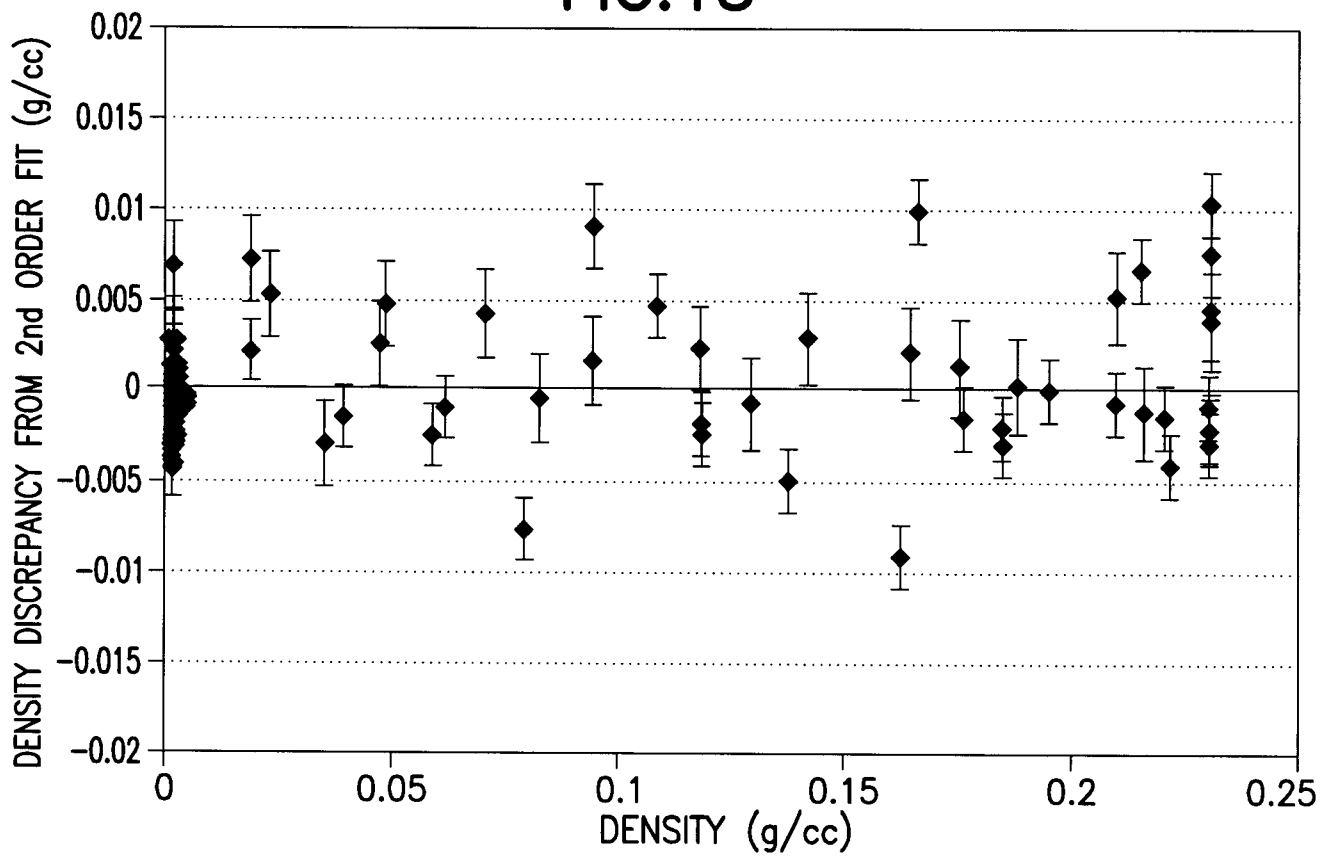


FIG.14