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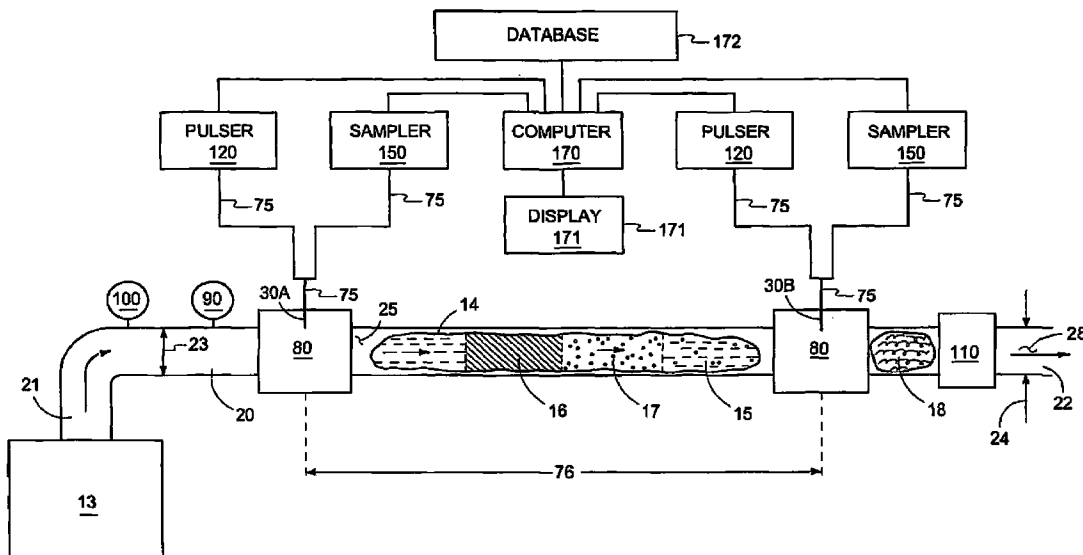
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(54) Title: METHOD FOR IDENTIFYING AND MEASURING VOLUME FRACTION CONSTITUENTS OF A FLUID



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A method for identifying and measuring volume fraction constituents of a fluid using time domain analysis and frequency domain analysis to identify individual volume fraction constituents within a pipe on a real time basis and to measure the volume of the individual volume fraction constituents flowing through the pipe on a real time basis.

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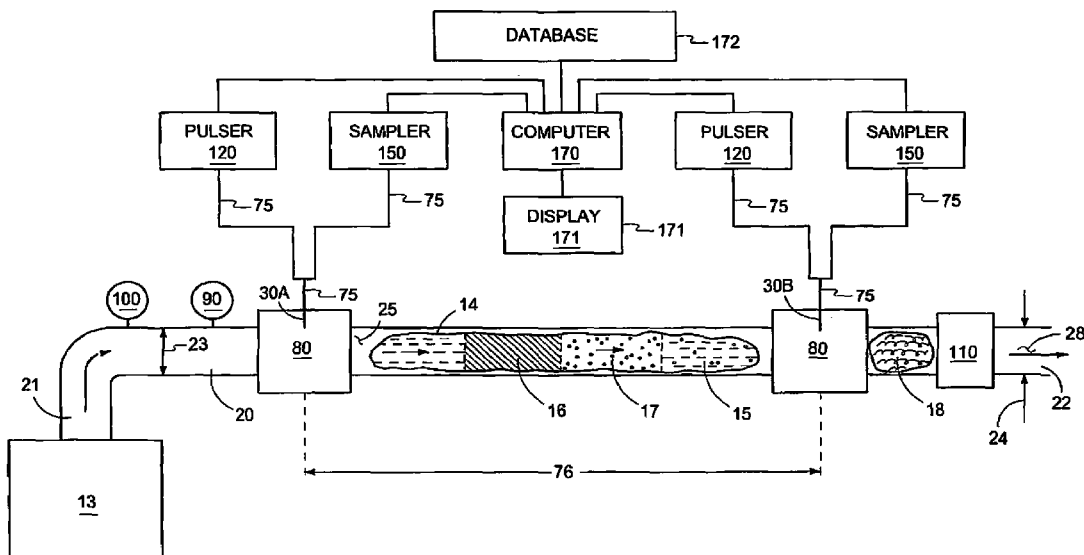


FIG. 1

(57) Abstract: A method for identifying and measuring volume fraction constituents of a fluid using time domain analysis and frequency domain analysis to identify individual volume fraction constituents within a pipe on a real time basis and to measure the volume of the individual volume fraction constituents flowing through the pipe on a real time basis.



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DESCRIPTION

METHOD FOR IDENTIFYING AND MEASURING VOLUME FRACTION CONSTITUENTS OF A FLUID

5 **TECHNICAL FIELD**

This invention relates to a method for identifying and determining relative proportions of intermixed volume fraction constituents of a fluid using reflected electrical signals and resonance points.

10 **BACKGROUND OF THE INVENTION**

The current practice in the oil and gas and petroleum chemical/fuel industry for identifying measuring quantities of oil, water, natural gas and other components being produced by a given well, or group of wells, is to separate the produced components in a separator and to identify and measure the produced components individually. The separators are typically large, expensive, maintenance intensive and typically provide production information only after long intervals during which the components separate under the influence of gravity.

Similarly, when a well is being drilled, drilling fluids ("drilling mud"), which one typically complex mixtures of synthetic and organic compounds which are expensive and proprietary in nature, are regurgitated from the wellbore being drilled. The drilling mud is used to lubricate the cutter head, and also to evacuate "cuttings" and rock chips and the like from the wellbore. Further, the drilling mud seals and stabilizes the circumferential walls of the wellbore to prevent leakage, collapse and the like. The fluids which are regurgitated from the wellbore are typically transferred to a settling pond for the solids to "settle out" and thereafter the fluids are transferred

to a separator to identify and measure the individual components which may thereafter be reused in the drilling process.

To address the drawbacks of separators, composition meters have been developed to continuously measure volume fractions of natural gas, water and oil being produced. When such a composition meter is combined with a flow meter, production rates for the various components may also be calculated. Known composition meters use measurement of dielectric constant, in combination with a density measurement, to determine the volume fractions.

For known composition meters to be consistently accurate, all the dielectric constants and all the densities of the individual produced fluid components must be known for every measurement condition (temperature and pressure). Unfortunately, this is nearly impossible to accomplish because all the conditions are continually varying and changing as the well is drilled and as the oil well, or group of oil wells, produce. Accuracy of the measurements is further complicated by several of the lower density hydrocarbon components (for example but not limited to, ethane, propane, butane and pentane) existing in either a liquid state or a gaseous state at pressures between approximately 20 and 250 atmospheres. Further, the produced components are typically at very high temperatures and as a result, produced water boils off into steam within the pipes causing identification and measurements of gaseous components to be particularly difficult because the dielectric constant of steam is very close to the dielectric constants of the lower density hydrocarbon components.

Prior art publications claim it is "impossible" to accurately identify and measure the volume fractions of oil, water, and natural gas without knowing how much of each hydrocarbon constituent is in the liquid or gaseous phase at any given time.

Another important measurement problem in the oil and hydrocarbon production industry is the accurate measurement of water content. Water content directly affects the price paid for the product. Various devices are available to continuously measure water content, and most such devices are capacitance meters which measure the dielectric constant of the oil/water mixture to determine the water content. Unfortunately, such devices, which are known in the industry as "water cut meters" are not continuously accurate because the temperature, density and dielectric constant of the oil/water mixture all change as measurement conditions change, which results in measurement errors.

A further complicating factor in measuring volume fraction constituents of mixtures of produced oil and water and natural gas is the salt content of the mixture. The salt also affects the dielectric constant of the fluid components. Similarly, lubricants within the drilling mud and proprietary lubricating drilling fluids may further affect the dielectric constants of the components which may make accurate identification and measurements difficult.

Our method for identifying and measuring volume fraction constituents of a fluid overcomes various of the drawbacks of known volume fraction constituent identifying and measuring apparatus.

SUMMARY OF THE INVENTION

A first aspect of the present invention is a method for identifying and measuring volume fraction constituents of a fluid, comprising a source of fluid with a known temperature, and having a volume fraction constituent, and wherein the volume fraction constituent has a previously calculated and known dielectric constant and a previously calculated and known resonance points, and wherein information about the previously calculated, and known dielectric constant and resonance points is stored in and is accessible from a database; a probe exposed, at least in part, to the fluid, and wherein the probe has a known length; an electrical pulse emitter which electronically generates an electrical pulse which is delivered to the probe, and which travels the known length of the probe and which generates an electrical pulse reflection; an electrical pulse sampler which electronically communicates with the probe and which further receives and senses the electrical pulse reflection generated by electrical pulse within the probe; a computer electronically coupled with the probe, the electrical pulse emitter, the electrical pulse sampler, and the database, and wherein the computer determines a time period between the electrical pulse emission into the probe and the receipt of the sensed electrical pulse reflection, and wherein the resonance points of the volume fraction constituent is calculated by the computer from the time period which is determined, and wherein the computer further correlates the determined time period to the previously calculated, and known dielectric constant and previously calculated and known resonance points of the volume fraction constituent as provided in the database so as to identify the volume fraction constituent in the fluid and determine a volume of

the volume fraction constituent in the fluid; and a user interface electronically coupled with the computer, and which further generates a user perceivable output which identifies the volume fraction constituent of the volume of the volume fraction constituent.

5 A second aspect of the present invention is wherein the volume fraction constituent is selected from the group consisting of petroleum, water, natural gas and drilling fluid.

A third aspect of the present invention is wherein the volume fraction constituent is a multiplicity of volume fraction constituents.

10 A fourth aspect of the present invention is wherein the multiplicity of volume fraction constituents includes a fluid and a gas.

A fifth aspect of the present invention includes a pipe having a known interior diameter communicating with the source of the fluid so that a volume of the fluid moves through the pipe at a velocity; a second probe exposed at least in part to the fluid moving through the pipe a known distance downstream from the first probe; a first output generated by the first probe when a volume fraction constituent is sensed by the first probe and a second output generated by the second probe when the same volume fraction constituent is subsequently sensed by the second probe, and wherein the first and second probe outputs are communicated to the computer; and
15
20 the computer uses a time difference between the first probe output and the second probe output to determine the velocity of the fluid moving through the pipe and by correlating the determined velocity with a known volume of fluid moving through the pipe a volume of the volume fraction constituent is determined by the computer and

by correlating the resonance points of the volume fraction constituent to the resonance points for various constituents of volume fraction constituents in the fluid, the volume of the volume fraction constituent is determined .

5 A sixth aspect of the present invention includes a backpressure regulator communicating with the pipe to maintain fluid pressure within the pipe and about the probes at a pressure at least equal to the pressure of the source of the fluid to prevent boiling within the pipe.

10 A seventh aspect of the present invention is a method for identifying and measuring a volume fraction constituent of a fluid, the method comprising providing a source of fluid, the fluid having a volume fraction constituent, and wherein the volume fraction constituent has a previously calculated and known dielectric constant, and previously calculated and known resonance points; providing a database having accessible stored information about the previously calculated and known dielectric constant of the volume fraction constituent and having accessible
15 and stored information about the previously calculated and known resonance points of the volume fraction constituent; providing a probe exposed, at least in part, to the fluid, and wherein the probe has a known length; providing an electrical pulse emitter which electronically generates an electrical pulse which is delivered to the probe, and which further travels the known length of the probe and which generates an
20 electrical pulse reflection; providing an electrical pulse sampler electronically coupled with the probe and which further receives and senses the electrical pulse reflection generated by electrical pulse within the probe; providing a computer electronically coupled with the probe, the electrical pulse emitter, the electrical pulse

sampler and the database, and wherein the computer determines a time period between the electrical pulse emission into the probe, and the receipt of the sensed electrical pulse reflection, and wherein the resonance points of the volume fraction constituent are calculated by the computer from the determined time period, and
5 wherein the computer further correlates the determined time period to the previously calculated and known dielectric constant and the previously calculated and known resonance points of the volume fraction as provided in the database to identify the volume fraction constituent in the fluid; and providing a user interface electronically coupled with the computer, and which further generates a user perceivable output
10 which identifies the volume fraction constituent in the fluid.

An eighth aspect of the present invention includes applying a Fast Fourier Transform (FFT) to the determined time period to determine the resonance points which may be resonance frequencies of the volume fraction constituent.

A ninth aspect of the present invention is wherein the volume fraction constituent
15 is selected from the group consisting of petroleum, water, petroleum, gas and drilling fluids.

A tenth aspect of the present invention is wherein the volume fraction constituent is a multiplicity of volume fraction constituents.

An eleventh aspect of the present invention is wherein the multiplicity of volume
20 fraction constituents includes a liquid and a gas.

A twelfth aspect of the present invention includes providing a pipe having a known interior diameter communicating with the source of a volume of the fluid so that the fluid moves through the pipe at a velocity; providing a second probe

5 exposed at least in part to the fluid moving through the pipe a known distance downstream from the first probe; generating a first output by the first probe when a volume fraction constituent is sensed by the first probe and generating a second output by the second probe when the same volume fraction constituent is subsequently sensed by the second probe, and communicating the first and second probe outputs to the computer; and determining a velocity of each volume fraction constituent moving through the pipe by calculating a time difference between the first probe output and the second probe output and determining the volume of each volume fraction constituent moving through the pipe.

10 A thirteenth aspect of the present invention includes maintaining fluid pressure about the probes at a pressure at least equal to the pressure of the source of the fluid to prevent boiling within the pipe.

A fourteenth aspect of the present invention includes providing a back pressure regulator communicating with the pipe downstream of the probe.

15 A fifteenth aspect of the present invention is a method for identifying and measuring a volume fraction constituent of a fluid comprising determining a dielectric constant of a volume fraction constituent by determining a time delay between an electrical pulse emission into a probe exposed, at least in part, to the fluid and a reflection of the electrical pulse from the probe; correlating the determined time delay to a database of known dielectric constants of known volume fraction constituents which generate similar time delays to identify the volume fraction constituent; applying a Fast Fourier Transform to the determined time delay to
20 generate a sine wave frequency of the volume fraction constituent; calculating a

power spectral density calculation to determine the power and resonance points of the sine wave frequency; correlating the generated resonance points of the volume fraction constituent to a database of known resonance points of known concentration of volume fraction constituents to identify the volume fraction constituent; and
5 providing a user interface which generates a user perceivable output of the identified and measured volume fraction constituents in the fluid in a user perceivable form.

A sixteenth aspect of the present invention includes providing a pipe having a known interior diameter communicating with the source of the fluid so that a volume of the fluid moves through the pipe at a velocity; providing a second probe exposed
10 at least in part to the fluid moving through the pipe a known distance downstream from the first probe; generating a first output by the first probe when a volume fraction constituent is sensed by the first probe, and generating a second output by the second probe when the same volume fraction constituent is subsequently sensed by the second probe, and communicating the first and second probe outputs
15 to the computer; and determining a velocity of the volume fraction constituent moving through the pipe by calculating a time difference between the first probe output and the second probe output with the known interior diameter of the pipe and known volume of fluid moving through the pipe; and correlating the resonance points of the volume fraction constituent to the resonance points for various concentrations
20 of volume fraction constituents in the fluid the volume of the volume fraction constituent is determined.

A seventeenth aspect of the present invention is a probe formed of Inconel® Alloy having a chrome alumina oxide coating extending entirely thereabout and having an electrical impedance of approximately 90 ohms in air.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a generalized block diagram of our apparatus showing arrangement of the various components and fluid flow therethrough.

Figure 2 is an orthographic front view of the two representative spaced apart grayloc supports and an electronics box mounted on a moveable support skid.

10 Figure 3 is an exploded isometric front, side and top view of a grayloc support showing arrangement of the components and the probe.

Figure 4 is an orthographic side view of the assembled grayloc support of Figure 3, less the sealed hubs.

15 Figure 5 is an orthographic cross section view of the assembled grayloc support of Figure 4 taken on line 5-5 from Figure 4.

Figure 6 is an isometric front, side and top view of a first configuration of a probe and support block.

Figure 6A is an enlarged isometric view of the probe and support block showing details of the coaxial cable connection.

20 Figure 7 is an exploded isometric front, side and top view of the probe of Figure 6.

Figure 8 is an orthographic front view of the probe of Figure 6 less the support block.

Figure 9 is an isometric front, side and top view of a second configuration of probe having offset ground plates.

Figure 10 is an orthographic side view of the second configuration of blade probe of Figure 9, showing the open structure formed by offsets of the ground plates relative to the center conductor.

Figure 11 is a time domain reflectance trace of an electrical pulse through the probe in air showing the start point and the end point.

Figure 12 is a time domain reflectance trace of an electrical pulse through the probe in water showing of the start point and the end point.

Figure 13 is a time domain reflectance trace of an electrical pulse through the probe in mineral oil showing the start point and the end point.

Figure 14 is a time domain reflectance trace of an electrical pulse through the probe in peanut oil showing the start point and the end point.

Figure 15 is a comparison time domain reflectance trace of an electrical pulse through the probe in peanut oil, mineral oil and gear oil showing the start point and the endpoint and showing the similarity in the traces amongst the different types of oils.

Figure 16 is a time domain reflectance trace of an electrical pulse through the probe in a mixture of air, mineral oil, peanut oil and water showing the differences in the traces which allows identification of the components.

Figure 17 is a power spectral domain (frequency domain evaluation) graph of the TDR traces of Figure 16 after applying the FFT and PSD showing the resonance points of the components.

Figure 18 is a power spectral domain (frequency domain evaluation) graph of the TDR trace of Figure 11 showing the resonance points in air.

Figure 19 is a power spectral domain (frequency domain evaluation) graph of the TDR trace of Figure 12 showing the resonance points in water.

5 Figure 20 is a reduced scale power spectral domain (frequency domain evaluation) of the probe in water, similar to that of Figure 19 showing the resonance points.

Figure 21 is a power spectral domain (frequency domain evaluation) graph of the TDR trace of Figure 13 showing the resonance points in mineral oil.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A method for identifying and measuring volume fraction constituents of a fluid generally comprises a source of fluid **13**, a pipe **20**, a probe **30**, a grayloc support **80**, a pulse emitter **120**, a pulse sampler **150**, a computer **170**, and a support frame **200**.

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The source of fluid **13** is typically an oil well, or grouping of oil wells producing a fluid **14** that contains a mixture of various volume fractions including, but not limited to, oil **15**, water **16** and natural gas **17**. The source of fluid **13** may also be a stream of fluid **14** or a settling pond or similar volume of fluid **14** used in the drilling of a well (not shown) and including without limitation, drilling fluid or "drilling mud". (not shown). It is also contemplated the source of fluid **13** may be a volume of stored fluid **14** such as a volume of fuel within a storage tank (not shown). When produced from the source of fluid **13**, the fluid **14** is at pressure and is typically at a temperature that may exceed ambient temperature by hundreds of degrees, although the temperature

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and pressure vary over time and conditions. It is further contemplated and anticipated the fluid **14** volume fraction constituents **15**, **16**, **17** may be produced, and flow through the pipe **20**, in segregated fashion, and at other times it is anticipated the volume fraction constituents **15**, **16**, **17** will be a mixture or emulsions
5 **18** of fluid **14** that may or may not be homogeneously distributed within the pipe **20**.

Oil **15**, water **16** and natural gas **17** are different molecular compounds, and have different, well recognized dielectric constants and resonance points depending upon the concentration. The dielectric constant of water **16** ranges from approximately 80 for cold water down to approximately 25 for very hot water. The dielectric constant of
10 steam is approximately 1.01 increasing to approximately 1.15 as temperature increases. The dielectric constant of oil **15** is approximately 2.0 to 2.5 depending upon the density of the oil **15**. The dielectric constant of natural gas **17** is approximately 1.2 to approximately 1.6.

Because the known dielectric constant of steam (approximately 1.01-1.15) is
15 similar to the dielectric constant of natural gas **17** (approximately 1.2-1.6) use of a back pressure regulator **110** communicating with the pipe **20** maintains pressure within the pipe **20** at a pressure at least equal to the pressure of the fluid **14** exiting the source of fluid **13**. With the use of a back pressure regulator **110**, even though the fluid **14** may be at an extremely high temperature, the water **16** within the fluid **14**
20 will not boil, and will remain in a liquid state with the corresponding dielectric constant and resonance points which are measurably different than the dielectric constant of natural gas **17**. Preventing the formation of steam inside the pipe **20**

allows the instant apparatus to distinguish between natural gas **17**, and water **16** using the known dielectric constants and resonance points thereof.

The pipe **20** has an inflow end **21** communicating with the source of fluid **13** and an outflow end **22** communicating with a distribution point (not shown) such as a collection facility (not shown). The pipe **20** has a known interior diameter **23**, an exterior diameter **24**, an exterior surface **25**, defines a medial channel **28** and may contain a plurality of connections **26** where fittings **27** and apparatus and the like may be joined to the pipe **20**, and also where the pipe **20** may connect to other sections of pipe **20** to extend the length thereof. When the invention is used in the drilling of a well to identify and measure components produced in a well drilling operation, the pipe **20** may communicate with a settling pond or similar collection body (not shown) which serves as the source of fluid **13**. Further the pipe may communicate with other pipes (not shown) that carry drilling fluids and the like to and from the well bore, some of which may be under high pressure, such as downstream of a high pressure pump (not shown) and some of which maybe before or after the separation of particulated solids (not shown) from the fluid **14**, such as by a vibrating screen (not shown) or a centrifuge (not shown).

As shown in Figure 1, a temperature sensor **100** and a flow meter may be interconnected with the pipe **20** downstream of the source of fluid **13** and upstream of the grayloc support **80**. The temperature sensor **100** and flow meter **90** are known apparatus and communicate with the medial channel **28** of the pipe **20** to monitor and sense the temperature of and movement of fluid **14** through the pipe **20**.

Information and data sensed by the temperature sensor **100** and the flow meter **90** are communicated to the computer **170**.

In a first embodiment of the invention (Figure 2), there are two spaced apart grayloc supports **80**, **80A**. Each grayloc support **80**, **80A** (Figures 3-5) is a fitting having a "cross" configuration defining an entry port **81**, an exit port **82**, a probe insertion port **83** and a blind port **84**. Each of the ports **81**, **82**, **83**, **84** communicate with a medial chamber **85** therebetween to allow fluid flow therethrough. An exterior circumference of each port **81**, **82**, **83**, **84** defines a radially enlarged sealing flange **86** configured for engagement with a two part sealing clamp **87** to provide a fluid tight seal between the grayloc support **80** and the adjoining pipe **20**, or an adjoining hub **89** to provide fluid containment.

As shown in Figure 2, the second grayloc support **80A** communicates with the pipe **20** a known distance **76** downstream from the first grayloc support **80**. The second grayloc support **80A** has the same components and configuration as the first grayloc support **80** and therefore a detailed description of the second grayloc support **80A** is omitted herein.

In configurations and embodiments where the apparatus is being used to identify and measure volume fraction constituents of a stationary fluid **14**, such as a volume of fluid **14** contained within a storage tank (not shown), only one grayloc support **80** and probe **30** may be employed. If only a single grayloc support **80** is employed, it is necessary to have a flow meter **90** communicating with the pipe **20** if a velocity of the fluid **14** flowing through the pipe **20** is a required measurement.

In the first embodiment there are two spaced apart probes **30A**, **30B**, one probe **30** within each grayloc support **80**, **80A**. The first probe **30A** and the second probe **30B** are identical in configuration and function and therefore only the first probe **30A** will be described in detail. These two spaced apart grayloc supports **80** allows
5 velocity and volume to be calculated without use of a flow meter **90**.

As shown in Figures 3, 4 and 5, the probe **30** is positionally supported within the medial chamber **85** defined by the grayloc support **80** so that at least a portion of the probe **30** is exposed to the fluid **14** flowing through the grayloc support **80** medial chamber **85**.

10 The probe **30** (Figures 6-8) has a body **31** that is generally planar and rectilinear. The body **31** has a first end **32** and an opposing second end **33**, a first surface **34**, and an opposing second surface **35** with a thickness **36** between the first surface **34** and the second surface **35**. The body **31** further has a first edge **37**, and an opposing second edge **38** and defines a dimensionally enlarged shoulder (not
15 shown) in the first edge **37** and the second edge **38** spaced apart from the first end **32**. The body **31** further defines an elongated medial slot **45** between a first ground plate **40** at the first edge **37** and a second ground plate **50** at the second edge **38**. An elongated center conductor **60** is carried within the medial slot **45** and has a root end **61** that is structurally attached to the probe body **31** proximate the second end
20 **33** between the first and second ground plates **40**, **50** respectively, and the center conductor **60** has a free terminal end **62** within the medial slot **45** proximate to the body **31** first end **32**. The free terminal end **62** of the center conductor **60** carries a conductor adaptor link **70** and a conductor weld pad **71** for electronic connection to a

coaxial cable **75**. The length of the center conductor **60** defines the active length of the probe **30**. The first end **32** of the probe body **31** is known as the "active end" of the probe **30**.

5 An elongated gap **66** is defined between each laterally outer edge of the center conductor **60** and a proximate edge of the first ground plate **40** and a proximate edge of the second ground plate **50**. The gap **66** is engineered to provide optimum sensitivity to the detection of charges in volume flow constituents **15**, **16**, **17** by impedance measurements. The gap **66** is uniform along its length and is typically approximately 0.080 inches in width for oil **15**, water **16** and natural gas mixtures. It is expressly contemplated however, other gap **66** widths may be used and/or
10 engineered to match the impedances of other volume fraction constituents **15**, **16**, **17** to be identified and measured in the fluid **14**.

A probe support block **67**, which is generally rectilinear in configuration and formed of silicon carbide defines a generally medial slot (not shown) therein through which the probe body **31** first end **32** extends. The probe support block **67** frictionally
15 engages with the dimensionally enlarged shoulders (not shown) defined in the probe body **31** so as to positionally maintain the probe **30** relative to the probe support block **67**.

A coaxial cable **75** is electronically coupled with the conductor weld pad **71** so that signals may be transmitted to the probe **30** and received from the probe **30**. Best shown in Figure 7, the coaxial cable **75**, and its attachment to the conductor weld pad **71**, is positionally secured to the probe body **31** by an inner slip support **69**, a pack **73** and a ring **74** so that the coaxial cable **75** is securely, and insulatively
20

connected to the center conductor **60**. In the current embodiment the pack **73** and ring **74** are formed of Teflon, but other materials such as PEEK may similarly be used and one contemplated. Plural support straps **72** (Figures 8, 9) spacedly arrayed on the probe body **31** further secure the coaxial cable **75** relative to the probe **30**.

An active end support **77** (Figure 3) frictionally engages the first end **32** of the probe **30** and extends over and about the coaxial cable **75** and an inner slip support **69**. The active end support **77** aligns and positionally maintains the first end **32** of the probe body **31** within the medial chamber **85** of the grayloc support **80**. (See Figure 5). Similarly, a passive end support **78** frictionally engages with the second end **33** of the probe **30** and similarly aligns and positionally maintains the second end **33** of the probe **30** within the medial chamber **85** of the grayloc support **80**. (Figure 5).

As shown in Figure 3, the assembled probe **30** and the active end support **77** are inserted into the grayloc support **80** probe insertion port **83** so that a medial portion of the probe **30** extends across the medial chamber **85** and is oriented so that the first surface **34** and second surface **35** are parallel to the flow of fluid **14** through the grayloc support **80** medial chamber **85**. The probe **30** and end supports **77**, **78** are secured within the grayloc support **80** medial chamber **85** by known means including, but not limited to, a spacer, a retainer plate and alignment pins. Such fastening means secure the first end **32** of the probe **30**, and also secure the second end **33** of the probe **30** so that the probe **30** is supported from both the first end **32** and the second end **33** within the medial chamber **85**. A fluid tight hub **89** is

interconnected with the probe insertion port **83** sealing flange **86**, and also with the blind port **84** sealing flange **86**. Known, two part sealing clamps **87**, and plural threaded fasteners **88** secure the hubs **89** to the sealing flanges **86** to provide a fluid tight seal therebetween. As can be seen in the drawings, the coaxial cable **75** extends through the hub **89** proximate to the first end **32** of the probe **30** by way of a CONAX pressure gland seal **79**. The coaxial cable **75** electronically communicates with the probe **30** center conductor **60** and with the pulse emitter **120** and with the pulse sampler **150**.

The grayloc entry port **81** communicates with the pipe **20** by means of a fluid tight connection **26** therebetween. Similarly, the exit port **82** communicates with a pipe **20** by means of a fluid tight connection **26** therebetween.

The second grayloc support **80A** is also in fluid communication with the pipe **20** a known distance **76** downstream from the first grayloc support **80**. The structure of the second grayloc support **80A**, and the structure of the second probe **30B** carried therein is the same as the aforementioned and described grayloc support **80** and first probe **30A**.

The coaxial cables **75** that electronically communicate with each of the probes **30A**, **30B** are each electronically coupled with a pulse emitter **120** and also with pulse sampler **150**. The pulse emitter **120** and the pulse sampler **150** may also be combined into a single apparatus commonly called a Time Domain Reflectometer (TDR), such as the EFP Signal Processor utilizing the CT100B software developed and manufactured by Mohr Test and Measurement of Richland, Washington, USA. Such TDR EFP Signal Processors are described in U.S. patents US 4,786,857

issued November 22, 1998, and US 5,723,979 issued March 3, 1998, and US 6,144,211 issued November 7, 2000, and US 6,348,803 issued February 19, 2002 and which were all invented by Charles L. Mohr (one of the joint inventors herein). The aforementioned issued US patents and the teachings therein are expressly
5 incorporated herein by this reference.

Time domain reflectometry is an effective means for determining the level of a liquid, such as in a tank. Using time domain reflectometry, electrical pulses are conveyed along a transmission line to an electrically conductive probe **30**. The electrical pulses are partially reflected when there is a change in the electrical
10 impedance of the fluid **14** to which the probe **30** is exposed. The impedance change is associated with a difference in dielectric strength. "Electrical permittivity" is a technical term indicating the dielectric properties of the fluid **14**. The electrical pulses produced by a time domain reflectometry system are affected by the dielectric constant of the surrounding fluid **14** in which the electrical pulse is traveling. The
15 dielectric constant (permittivity) of the fluid **14** directly affects the propagation velocity of an electromagnetic wave as it travels along the probe **30**. In time domain reflectometry systems, an electromagnetic pulse is propagated into and along the probe **30** which has a known length while measuring the time of arrival and the time of reflection from electrical discontinuities at two known, spaced apart, points. The
20 first known point is where a coaxial cable **75** is attached to the probe **30**. The second known spaced apart point, is a distal end of the probe **30**. Since these locations are both known, one can calculate the propagation velocity of the electromagnetic wave and, as a result, calculate the apparent dielectric constant of the material undergoing

tests and to which the probe **30** is exposed. Similarly, changes in the dielectric constant which relate to changes in the fluid **14** adjacent to and surrounding the probe **30** can also be determined. For example, the apparent dielectric constant provides a direct indication of the presence of identifiable types of fluids **14**.

5 The pulse emitter **120** which may be incorporated into a TDR is an electronic apparatus that emits electronic pulses (not shown) which are conveyed to the probe **30** through the coaxial cable **75** at a preferred rate of approximately 500 to 800 samples per second depending upon the speed of computation and generating approximately 500 data points per sample. This means the electronic pulses are at
10 increments of approximately 0.76 picoseconds. When the pulse emitter **120** emits a pulse (not shown) the pulse is conveyed along the coaxial cable **75** and to the probe **30** center conductor **60** through the conductor weld pad **71**. The pulse travels along the center conductor **60** whereupon, depending upon the constituents **15, 16, 17** of the surrounding fluid **14** and the respective impedance (dielectric constants) of the
15 constituents **15, 16, 17** to which the probe **30** is exposed, an electrical pulse reflection (not shown) is created when the pulse experiences a change in velocity due to a change in electrical impedance caused by a change in dielectric constant of the fluid **14** within the probe gaps **66** and surrounding the probe **30** active area. The pulse reflection is received from the probe **30** through the coaxial cable **75** and is
20 communicated to the pulse sampler **150** where the reflection is sensed and recorded.

As the dielectric constant properties of the fluid **14** constituents **15, 16, 17** surrounding the probe **30** and within the probe gaps **66** change due to movement of

the constituents **15, 16, 17** through the pipe **20**, the velocity and distance traveled by the pulse in the increment of time between any two sequential pulses changes the apparent length of the probe **30**. The pulse reflection, which indicates the end of the probe **30** or impedance change (the length of the probe in time), is conveyed along the coaxial cable **75** to the pulse sampler **150**. Known computer logic within the computer **170** which is in electronic communication with the pulse emitter **120** and the pulse sampler **150** calculates the "length of the probe in time." Determination of the "length of the probe in time" is empirically representative of the dielectric constant of the fluid constituent **15, 16, 17**.

The computer **170** has a database **172**, which has stored therein, data and information on predetermined known dielectric constants of fluid constituents **15, 16, 17** and predetermined time delays generated by various dielectric constants. The database **172** also has stored therein predetermined known data and information of resonance points of various known volume fraction constituents **15, 16, 17** and the resonance points of various concentrations of the volume fraction constituents **15, 16, 17**. The database **172** may also be a correlation or an algorithm wherein information may be correlated and/or compared.

The computer **170** determines the time difference between emission of the electrical pulse into the probe **30** by the pulse emitter **120**, and receipt of the pulse reflection from the probe **30**, by the pulse sampler **150**. The determined time is then correlated by the computer **170**, using the database **172** to known predetermined dielectric constants of known volume fraction constituents **15, 16, 17** which would similarly generate the determined time difference. The correlation of the determined

time difference with information contained within the database **172** permits identification of the volume fraction constituent **15, 16, 17** fluid **14** by "matching" the determined time difference, with the predetermined known dielectric constant of various known constituents **15, 16, 17** of the fluid **14** which allows identification of the constituent **15, 16, 17**.

The determined time difference between the electrical pulse emission from the pulse emitter **120** into the probe **30**, and receipt of the electrical pulse reflection from the probe **30** by the pulse sampler **150** provides a "length of the probe" measurement which is shared with a detection algorithm within the computer **170** that compares the known "length of the probe" (which correlates to the impedance of the probe **30**) to known dielectric constants, which may vary with salt content, and temperature as detected by the temperature sensor **100** in order to match the determined parameters with a known baseline to identify the volume fraction constituents **15, 16, 17** within the fluid **14**. This first measure is time domain evaluation. It is the behavior of the electrical pulse within the probe **30**, and the resulting length of the probe **30** which allows a first identification of the fluid constituents **15, 16, 17** passing through the grayloc support **80** medial chamber **85**. As the fluid **14** passes around and about the probe **30** and through the gaps **66** between the center conductor **60** and proximate edges of the ground plates **40, 50**, the pulse reflection, received by the pulse sampler **150** changes as the volume fraction constituents **14, 15, 16** of the fluid **14** change. The change is caused by the changing electrical impedance and changing dielectric constant of the fluid **14** that is in contact with the probe **30** and immediately surrounding the probe **30**. However, it

is known that the dielectric constants of such volume fraction constituents **15, 16, 17** are variable and dependent upon temperature and salt content and therefore using only one measure does not generate consistently reliably accurate results.

A second, frequency domain analysis takes advantage of the resonance of an electrical signal in the fluid **14** and allows measuring of a volume of the volume fraction constituent **15, 16, 17** within the fluid **14**. By performing a Fast Fourier Transform (FFT) of the previously determined time delay of the pulse reflector, a sine wave frequency is determined. The frequency and amplitude of the sine wave signal (Power Spectral Density PSD) as a function of frequency allows different characteristic patterns of the constituents **15, 16, 17** to be identified. By examining the various resonance points as the frequency increases, the distance between the resonance points and the amplitude (strength) of the resonance points provide additional information as to various chemical compounds within the fluid **14** and allows identification and characterization of those various components, such as drilling fluids, drilling mud, oil **15**, water **16**, natural gas **17** and other components which may be newly appearing in the fluid **14** passing by the probes **30A, 30B**. Figure 16 shows the combined signals from a probe **30** in water **16**, mineral oil, peanut oil and air. (Peanut oil and mineral oil were used in testing as representative oils to replicate petroleum). Figure 17 shows the FFT transform of the same signals taken from the probe **30** in the different fluids **14** showing the Power Spectral Density (PSD) as a function of the frequency. As can be seen, the frequency/amplitude points of water **16**, oil **15**, air and peanut oil are distinctly different from one another, and changes in the relative fractions of the composition

(concentrations) of the oil **15** causes a resulting shift in the resonance. The shift in resonance allows a measure of the fraction of each of the volume fraction constituents **15, 16, 17**.

By performing the Fast Fourier Transform (FFT) of the reflected electrical pulse received by the pulse sampler **150**, and by performing a Power Spectral Density (PSD) calculation, the frequency and amplitude of the resonance points can be identified.

The FFT takes a time-based plot (the determined time delay) and converts the time-based plot into a series of sine waves that duplicate the time history of the electric pulse as a series of frequency based sine waves with the maximums and minimums of the sine waves representing amplitude and resonance points of the volume fraction constituents **15, 16, 17** to which the probe **30** is exposed during the pulse and reflection thereof. The PSD calculation determines the average power, amplitude and frequency of the FFT transform. The first resonance point is identifiable because it has a wavelength that is equal to twice the active length of the probe **30**. The relative permittivity of the fluid **14** is calculated by comparing the determined velocity in the fluid constituents **15, 16, 17** to the velocity of light in a vacuum using the following relationship between velocity and dielectric: $\frac{cf}{c} = \sqrt{1/ef}$; where cf is the transmission speed of the pulse in the fluid **14**, c is the speed of light in a vacuum, and ef is the relative permittivity or dielectric constant of the fluid **14**. It is further noted that an inverse of the FFT allows recreation of the time history plot.

Figure 16 shows combined time delay signals from a probe **30** exposed to water **16**, oil **15** and air. The time delay shown in Figure 16 is the transit time for the pulse to reach the end of the probe **30** and reflect therefrom. This time delay is proportional to the dielectric constant of the constituents **15**, **16**, **17** surrounding the probe **30**. Figure 17 shows a graphed Fast Fourier Transform and PSD of the signals shown in Figure 16. Figure 17 also shows the resonant peaks generated by the probe **30** in air, water **16** and oil **15**.

As can be seen in Figure 16, the dielectric constants are all different from one another, and changes in the relative volume fractions **15**, **16**, **17** causes a shift in the resonance peaks.

As shown in Figures 1 and 2, a second grayloc support **80A** is interconnected with the pipe **20** a known distance **76** downstream from the first grayloc support **80**. The second downstream grayloc support **80A** carries a second probe **30B** that is identical in configuration and function to the first probe **30A**. The second probe **30B** is similarly electronically coupled with a pulse emitter **120** and also with a pulse sampler **150**, or a combined TDR. (Not shown). The pulse emitter **120** and pulse sampler **150** perform the same functions as the previously identified pulse emitter **120** and pulse sampler **150** to determine a time delay between the pulse emission into the probe **30B** and receipt of a pulse reflection from the probe **30B** by the pulse sampler **150**. The determined time delay allows determination of the dielectric constants of the constituents **15**, **16**, **17** of the fluid **14** by comparison to the known, pre-determined time delay information stored in the database **172** information that is assessable by the computer **170**. Each probe **30A**, **30B** may be, coupled with, a

separate pulse emitter **120** and a separate pulse sampler **150** which as noted previously may be combined within a single TDR. (Not shown). The computer **170**, and the database **172** accessible thereby, is electronically coupled with both pulse emitters **120** and both pulse samplers **150** (both TDR's) so as to correlate the
5 determined time delays from each probe **30A**, **30B** with the information within the database **172**.

The known distance **76** between the first probe **30A** and the second probe **30B** allows the instant invention to continuously, and in real time, determine the volume of each volume fraction constituent **15**, **16**, **17** moving through the pipe **20**. Because
10 the computer **170** is electronically coupled with the first probe **30A** and with the first pulse emitter **120**, and the first pulse sampler **150**, and also with the second probe **30B** and the second pulse emitter **120**, and the second pulse sampler **150**, the computer **170** is able to determine a time delay between the first probe's **30A** identification of a specific volume constituent **15**, **16**, **17** and the second probe's **30B**
15 identification of the same volume constituent **15**, **16**, **17** subsequent to the first probe **30A** identification. Because the interior diameter **23** of the medial channel **28** is known, the total volume of the fluid **14** moving through the pipe **20** by unit of time may be calculated once the velocity of the fluid **14** in the pipe **20** is determined. The time delay between the first probe **30A** identifying a specific volume constituent **15**,
20 **16**, **17** and the second probe **30B** subsequently identifying the same volume constituent **15**, **16**, **17** is used in conjunction with the known distance **76** and known volumetric formulas to determine the volume of identified volume fraction constituents **15**, **16**, **17** moving through the pipe **20**. The probe's **30A**, **30B** detection

of a change in probe length, as described earlier, is indicative of a different volume fraction constituent **15, 16, 17** being identified by the probe **30A, 30B** and that information, which is communicated to the computer **170** allows identification of the volume constituent **15, 16, 17**, and the volume of the volume of that constituent **15, 16, 17** to be determined.

The time domain evaluation, and the frequency domain evaluation, provide two separate methods to identify volume fraction constituents **15, 16, 17** in the fluid **14** and further allows a determination of a volume of each volume fraction constituent **15, 16, 17** to be determined as the fluid **14** moves through the pipe **20**, on a continuous basis. The frequency domain evaluation further allows the concentration of the various volume fraction constituents **15, 16, 17** in the fluid **14** to be determined by correlating the resonance points of the fluid constituents with known resonance points of known constituent concentration within the database **172**.

Each probe **30A, 30B** has a probe body **31** (Figures 6-10) that is generally rectangular in shape and formed of a metallic alloy and is preferably approximately 0.050 inches thick from the first surface **34** to the second surface **35** and approximately 1.00 inches in width from the first edge **37** to the second edge **38**. The probe body **31** is preferably formed entirely of Inconel® alloy 725 which is highly resistant to the corrosive environment to which the probe body **31** may be exposed during operation. Further, a desirable and durable dielectric oxide coating (not shown) is formed on the probe of body **31** extending entirely thereabout. Inconel® alloy 718 may also be used, but Inconel® alloy 725 is preferred. Inconel® alloy 725

and Inconel® alloy 718 are available from Megamex Specialty Metals of Humble, Texas.

The method of forming the probe **30**, which carries the durable dielectric oxide coating on its outer surfaces **34**, **35**, includes the steps of cutting the desired probe **30** shape from the desired metallic alloy and then oxidizing cleaning the probe body **31** at approximately 1,750° to 2,000° Fahrenheit in air for one to three hours in order to form the highly electrically resistive oxide surface covering the entire body **31** of the probe **30**. The temperatures used in formation of the oxide coating reduce cracking of the oxide coating and prevents embrittlement caused by grain growth. Following the one to three hour heat treatment, the probe body **31** is cooled to less than 1,000° Fahrenheit. Subsequently, the probe body **31** is heated in air to 1,325° Fahrenheit for a period of 8 hours. Thereafter, the probe body **31** is air cooled in an oven to ambient temperature. The heat treatment process forms a chrome alumina oxide coating covering the entire probe body **31** to insulate the probe body **31** in the fluid **14**. The oxide coating is preferably approximately 0.5mm to approximately 3mm thick and is believed to have a chemical composition of approximately CrMoNbTiAl.

It is desirable that the probe body **31**, carrying the chrome alumina oxide coating has an impedance of approximately 90 ohms in air, which allows use of a 90 ohm coaxial cable **75** for interconnection with the pulse emitter **120** and the pulse sampler **150**. The use of a 90 ohm coaxial cable **75** allows the probe **30** to measure 100% water **16**; water **16** containing very little oil **15**; 100% oil **15**; and oil **15** containing very little water **16**. Providing for such a wide range of measurements of water/oil

5 mixtures allows the probe **30** to measure a full range of "water cuts". Further, the ability to operate at 90 ohms allows the probe **30** to identify drilling fluids (not shown) and components thereof and also identify and measure effective water **16** content within drilling fluids. The probe's **30** the ability to measure water content allows the probe **30** to be used in stationary operations, such as to measure the water **16** content of a standing pool of fluid **14**, such as fuel in a fuel tank (not shown) that may be contaminated with an unknown amount of water **16**. The probe's **30** ability to detect and measure drilling fluids/drilling muds (not shown) allows the instant invention and probes **30** to be used in the drilling of hydrocarbon producing wells, as well as the use in hydrocarbon producing wells that are in production.

10 As shown in Figures 9 and 10, a second design of probe **30** is also contemplated herein. This second probe **30** design is intended to reduce potential (clogging) due to particulates and solids within the fluid **14** moving through the medial channel **28** of the pipe **20** and the grayloc supports **80** and is particularly useful for use in drilling operations when drilling mud is a component of the fluid **14**. In the second design (Figures 9, 10) the first ground plate **40** is offset toward the first surface **34** relative to the center conductor **60** defining a gap **66** of approximately 0.080 inches between a proximate edge of the first ground plate **40** and the center conductor **60**. Similarly, the second ground plate **50** is offset toward the second surface **35** by a distance of approximately 0.080 inches to define a gap **66** between the proximate edge of the second ground plate **50** and the center conductor **60**. The offsetting of the first ground plate **40** and the second ground plate **50** relative to the center conductor **60** is facilitated by bends **57** at a bottom portion of the offset portion, and at an upper

portion of the offset portion so that only the active portion of the probe body **31** is laterally offset to allow fluid **14** to flow through the gap **66**. (Figure 10). In other aspects, the second probe design (Figure 10) is the same as that of the first probe design (Figure 6).

5

OPERATION

Having described the method for identifying and measuring volume fraction constituents of a fluid, the operation may be understood.

10

A source of fluid **13** is provided and is interconnected with a pipe **20** defining the medial channel **28** to provide fluid **14** moving therethrough, the fluid **14** having a volume fraction constituent **15, 16, 17** that is desired to be identified and measured, and wherein the volume fraction constituent **15, 16, 17** has previously calculated and known dielectric constant, and a previously calculated and known resonance points, and wherein information about the previously calculated and known dielectric constant and previously calculated and known resonance points of the volume fraction constituent **15, 16, 17** is stored in, and is accessible from a database **172**.

15

A first probe **30A** is exposed at least in part to the fluid **14** moving through the pipe **20**, the first probe **30A** having a known active length, and the first probe **30A** is positionally maintained within a medial chamber **85** defined by a grayloc support **80** communicating with the medial channel **28** of the pipe **20**, so that the fluid **14** flows therethrough and thereabout and therepast the first probe **30A**.

20

A second probe **30B** is also exposed at least in part to the fluid **14** moving through the pipe **20**, a known distance **76** downstream of the first probe **30A**, the second probe **30B** having an known active length, and the second probe **30B** is

positionally maintained within a medial chamber **85** defined by a second grayloc support **80A** that also communicates with the medial channel **28** of the pipe **20**, a known distance **76** downstream of the first grayloc support **80** so that the fluid **14** flows therethrough, and thereabout and therepast the second probe **30B**.

5 A back pressure regulator **110** communicating with the medial channel **28** of the pipe **20** maintains fluid pressure about the probes **30A**, **30B** at a pressure at least equal to the pressure of the source of the fluid **13** to prevent boiling of the fluid **14** within the pipe **20** to prevent formation of steam within the pipe **20**, because steam has a dielectric constant that is similar to the dielectric constant of natural gas **17**
10 which would make it difficult to distinguish between a volume of natural gas **17** and a volume of steam.

The first electrical pulse emitter **120** electronically generates an electrical pulse which is conveyed to the first probe **30A** through the coaxial cable **75**. The electrical pulse then generates an electrical pulse reflection upon interacting with a changed
15 electrical impedance (which is indicated as an end of the first probe **30A**) and which is caused by a change in sensed dielectric constant of the volume fraction constituent **15**, **16**, **17** to which the first probe **30A** is exposed. The first electrical pulse sampler **150** receives and senses of the electrical pulse reflection.

Similarly, the second electrical pulse emitter **120** electronically generates an
20 electrical pulse which is conveyed to the second probe **30B** through the coaxial cable **75**. The electrical pulse similarly generates an electrical pulse reflection upon interacting with the changed electrical impedance (which is indicated as an end of the second probe **30B**) and which is caused by a change in sensed dielectric

constant of the volume fraction constituent **15**, **16**, **17** to which the second probe **30B** is exposed. The second electrical pulse sampler **150** receives and senses of the electrical pulse reflection.

5 The computer **170** is electronically coupled with the first probe **30A**, the first electrical pulse emitter **120**, the first electrical pulse sampler **150** and the database **172**. The computer **170** determines a time delay between the electrical pulse emission into the first probe **30A** and receipt of the sensed electrical pulse reflection from the first probe **30A**.

10 The computer **170** is also electronically coupled with the second probe **30B**, the second electrical pulse emitter **120**, the second electrical pulse sampler **150** and the database **172**. The computer **170** also determines a time delay between the electrical pulse emission into the second probe **30B** and receipt of the sensed electrical pulse reflection from the second probe **30B**.

15 The computer **170** performs the time domain evaluation by correlating and comparing the determined time delay between pulse emission and pulse reflection receipt to the information within the database **172** to match the determined time delay to similar time delays generated by known dielectric constants, and then the computer **170** correlates the identified dielectric constant to known and previously determined volume fraction constituents **15**, **16**, **17** having such dielectric constants.

20 The computer also performs the frequency domain evaluation by determining/calculating the resonance points of the volume fraction constituents **15**, **16**, **17** and concentrations thereof in the fluid **14** by applying a Fast Fourier Transform (FFT) to the previously determined time delay. A Power Spectral Density

(PSD) evaluation is then made of the calculated resonance points by the computer 170 to determine the average power, amplitude and frequency of the volume fraction constituents 15, 16, 17. The computer 170 then correlates the resonance points resulting from the FFT and PSD to the previously calculated and known resonance points as provided in the database 172 as a second measure to identify the volume fraction constituents 15, 16, 17 in the fluid 14 and to measure the volume of the volume fraction constituents 15, 16, 17 in the fluid 14.

A first output (not shown) is generated by the first probe 30A when a volume fraction constituent 15, 16, 17 is sensed by the first probe 30A, and a second output (not shown) is generated by the second probe 30B when the same volume fraction constituent 15, 16, 17 is subsequently sensed by the second probe 30B. The first and second probe outputs (not shown) are communicated to the computer 170 through the coaxial cable 75 wherein the computer 170 uses the time delay between the first probe 30A output and the second probe 30B output to determine the velocity of the volume fraction constituents 15, 16, 17 moving through the pipe 20.

The user interface 210 is electronically coupled with the computer 170 and receives the identification of the volume fraction constituents 15, 16, 17 and the volume fraction 15, 16, 17 volume calculation data from the computer 170 to generate a user perceivable output (not shown) which identifies the volume fraction constituents 15, 16, 17 in the fluid 14 and the volume thereof moving through the pipe 20 continuously and in real time.

The instant invention also provides a method for identifying and measuring the volume fraction constituents 15, 16, 17 of a fluid 14. The method is first initiated by

providing a source of fluid **13** which communicates with the pipe **20** that defines a medial channel **28** for the fluid **14** to move therethrough. The fluid **14** has a volume fraction constituent **15, 16, 17** and each volume fraction constituent **15, 16, 17** has a previously calculated and known dielectric constant and previously calculated and known resonance points.

The database **172**, which is assessable by the computer **170**, has stored assessable information about the previously calculated and known dielectric constant of each volume fraction constituent **15, 16, 17** and stored assessable information about the previously calculated and known resonance points of each volume fraction constituent **15, 16, 17**, and each volume fraction constituent at various concentrations.

The first probe **30A** is positionally maintained within the upstream grayloc support **80**, and the first probe **30A** is exposed, at least in part, to the fluid **14** moving through the medial channel **28** of the pipe **20** and through the upstream grayloc support **80**. The second probe **30B** is similarly positionally maintained within a second grayloc support **80A**, and the second probe **30B** is exposed, at least in part, to the fluid **14** moving through the medial channel **28** of the pipe **20** and through the second grayloc support **80A** downstream a known distance **76** from the first probe **30A**.

The back pressure regulator **110** which communicates with the medial channel **28** of the pipe **20** maintains fluid pressure within the medical channel **28** and about the first and second probes **30A, 30B** respectively, at a pressure at least equal to

the pressure of the source of fluid **13** to prevent boiling of the fluid **14** within the medial channel **28** of the pipe **20**.

The first electrical pulse emitter **120** electronically generates an electrical pulse that is conveyed to the first probe **30A** through the coaxial cable **75**. The electrical pulse is conveyed into the first probe **30A** and generates an electrical pulse reflection when the electrical pulse travels the entire active length of the first probe **30A**, or earlier interacts with a changed electrical impedance or a changed dielectric constant of a volume fraction constituent **15**, **16**, **17** to which the first probe **30A** is at least partially exposed. The pulse reflection is received by the first electrical pulse sampler **150** that is electronically coupled with the first probe **30A** by the coaxial cable **75**.

Similarly, the second electrical pulse emitter **120** electronically generates an electrical pulse that is conveyed to the second probe **30B** through the coaxial cable **75**. The electrical pulse is conveyed into the second probe **30B** and a generates an electrical pulse reflection when the electrical pulse travels the entire active length of the second probe **30B** or earlier interacts with a changed electrical impedance or a changed dielectric constant of a volume fraction constituent **15**, **16**, **17** to which the second probe **30B** is at least partially exposed. The pulse reflection is received by a second electrical pulse sampler **150** that is electronically coupled with the second probe **30B** by the coaxial cable **75**.

The computer **170** is electronically coupled with the probes **30A**, **30B** the electrical pulse emitters **120**, the electrical pulse samplers **150** and the database **172**.

The computer **170** determines a time delay between the electrical pulse emission into each probe **30A**, **30B** and receipt of the electrical pulse reflections from each probe **30A**, **30B**.

5 The computer **170** correlates the determined time delay between the electrical pulse emission into each probe **30A**, **30B**, and receipt of the electrical pulse reflection from the respective probe **30A**, **30B** to the information stored within the database **172** of known time delays generated by known dielectric constants of known volume fraction constituents **15**, **16**, **17** to provide a measure to identify the volume fraction constituents **15**, **16**, **17** within the fluid **14**.

10 The computer **170** also applies a Fast Fourier Transform (FFT) to the determined time delay to generate a sine wave frequency based upon the determined time delay. The computer **170** also calculates the Power Spectral Density (PSD) of the generated sine wave frequency to determine the average power, amplitude and frequency of the sine wave to identify resonance points. The computer **170**
15 correlates the frequency from the Fast Fourier Transform (FFT) and the resonance points of the PSD to the database **172** of known resonance points of known volume fraction constituents **15**, **16**, **17** to provide another measure to identify the volume fraction constituents **15**, **16**, **17** within the fluid **14** and also to measure the volume of the volume fraction constituents **15**, **16**, **17** in the fluid **14**.

20 A first output (not shown) is generated by the first probe **30A** when a volume fraction constituent **15**, **16**, **17** is sensed by the first probe **30A** and identified by the computer **170**, and a second output (not shown) is generated by the second probe

30B when the same volume fraction constituent **15, 16, 17** is subsequently sensed by the second probe **30B** and identified by the computer **170**.

The volume of each volume fraction constituent **15, 16, 17** moving through the pipe **20** is calculated by using the determined time delay between the first probe **30A** output and the second probe **30B** output by calculating the velocity of the sensed volume fraction constituent **15, 16, 17** moving the known distance **76** and using the known interior diameter **23** of the pipe **20**.

The user interface **210** which is electronically coupled with the computer **170** and which receives the identification of the volume fraction constituent **15, 16, 17**, and the first probe **30A** output (not shown) and the second probe **30B** output (not shown) and the correlation of resonance points of the volume fraction constituents **15, 16, 17** generates a user perceivable output (not shown) which identifies each volume fraction constituent **15, 16, 17** in the fluid **14**, and the volume thereof moving through the pipe **20** on a real-time and continuous basis.

15

CLAIMS

1. A method for identifying and measuring volume fraction constituents of a fluid, comprising:
 - providing a source of fluid, the fluid having a volume fraction constituent, and wherein the volume fraction constituent has a previously determined and known dielectric constant, and a previously determined and known resonance point;
 - providing a database having accessible stored information about the previously determined and known dielectric constant of the volume fraction constituent and accessible and stored information about the previously determined and known resonance point of the volume fraction constituent and resonance points of concentrations of the volume fraction constituents;
 - providing a first probe exposed, at least in part, to the fluid, and wherein the first probe has a known length;
 - providing an electrical pulse emitter which electronically generates an electrical pulse which is delivered to the first probe, and which further travels the known length of the first probe and which generates an electrical pulse reflection;
 - providing an electrical pulse sampler electronically coupled with the first probe and which further receives and senses the electrical pulse reflection generated by electrical pulse within the first probe;
 - providing a computer electronically coupled with the first probe, the electrical pulse emitter, the electrical pulse sampler, and the database, and wherein the computer determines a time period between the electrical pulse emission into the first probe, and the receipt of the sensed electrical pulse reflection from the first probe, and wherein a resonance point of the volume fraction constituent is calculated by the computer from the determined time period, and wherein the computer further correlates the determined time period to the previously determined and known dielectric constant and correlates the calculated resonance point to the previously determined and known resonance point of the volume fraction as provided in the database so as to identify the volume fraction constituent in the fluid and the volume of the volume fraction constituent in the fluid;

applying a Fast Fourier Transform to the determined time period to determine a resonant frequency and determine resonance points of the volume fraction constituent; and

providing a user interface electronically coupled with the computer, and which further generates a user perceivable output which identifies the volume fraction constituent of the fluid and the volume of the volume fraction constituent in the fluid.

2. The method of claim 1 further comprising:

applying a Power Spectral Density (PSD) calculation to the Fast Fourier Transform (FFT) frequency to determine amplitude and strength of the resonance point.

3. The method of claim 1 wherein the volume fraction constituent is selected from the group consisting of oil, petroleum, water, natural gas and drilling fluids and drilling muds.

4. The method of claim 1 wherein the volume fraction constituent is a multiplicity of volume fraction constituents; and

the multiplicity of volume fraction constituents includes a liquid and a gas.

5. The method of claim 1 further comprising:

providing a pipe with a known interior diameter communicating with the source of the fluid so that the fluid moves through the pipe at a velocity;

providing a second probe exposed at least in part to the fluid moving through the pipe a known distance downstream from the first probe;

generating a first output by the first probe when a volume fraction constituent is sensed by the first probe and generating a second output by the second probe when the same volume fraction constituent is subsequently sensed by the second probe, and communicating the first and second probe outputs to the computer; and

determining a volume of the volume fraction constituent moving through the pipe by calculating a time difference between the first probe output and the second probe output to determine the velocity of fluid moving through the pipe.

6. The method of claim 1 further comprising:
 - maintaining fluid pressure about the first probe at a pressure at least equal to the pressure of the source of the fluid to prevent boiling within a pipe.
7. A method for identifying and measuring a volume fraction constituent of a fluid comprising:
 - providing a pipe communicating with a source of fluid, the pipe defining a medial channel with a known interior diameter so that the fluid moves therethrough, the fluid having a volume fraction constituent and wherein the volume fraction constituent has a previously determined and known dielectric constant and previously determined and known resonance points;
 - providing a database having stored accessible information about the previously determined and known dielectric constant of the volume fraction constituent and stored accessible information about the previously determined and known resonance points of the volume fraction constituent and resonance points of concentrations of the volume fraction constituents;
 - providing a first probe exposed, at least in part, to the fluid moving through the pipe, the first probe having a known length;
 - providing a second probe exposed, at least in part, to the fluid moving through the pipe downstream a known distance from the first probe, the second probe having a known length;
 - providing a backpressure regulator to maintain fluid pressure about the first and second probes at a pressure at least equal to the pressure of the source of the fluid to prevent boiling within the pipe;
 - providing an electrical pulse emitter that electronically generates an electrical pulse which is delivered to the first probe and which further travels the length of the first probe and which generates an electrical pulse reflection;
 - providing an electrical pulse sampler electronically coupled with the first probe and which further receives and senses the electrical pulse reflection generated by electrical pulse within the first probe;
 - providing an electrical pulse emitter that electronically generates an electrical pulse which is delivered to the second probe and which further travels the length of the second probe and which generates an electrical pulse reflection;

providing an electrical pulse sampler electronically coupled with the second probe and which further receives and senses the electrical pulse reflection generated by electrical pulse within the second probe;

providing a computer electronically coupled with the first probe, the electrical pulse emitter, the electrical pulse sampler, and the database, and wherein the computer determines a time period between the electrical pulse emission into the first probe, and the receipt of the sensed electrical pulse reflection from the first probe, and wherein a resonance point of the volume fraction constituent is calculated by the computer from the determined time period by applying a Fast Fourier Transform to the determined time period, and wherein the computer further correlates the determined time period to the previously determined and known dielectric constant and to the previously determined and known resonance points of the volume fraction constituent as provided in the database to identify the volume fraction constituent in the fluid;

providing a computer electronically coupled with the second probe, the electrical pulse emitter, the electrical pulse sampler, and the database, and wherein the computer determines a time period between the electrical pulse emission into the second probe, and the receipt of the sensed electrical pulse reflection from the second probe and wherein a resonance point of the volume fraction constituent is calculated by the computer from the determined time period by applying a Fast Fourier Transform to the determined time period, and wherein the computer further correlates the determined time period to the previously determined and known dielectric constant and to the previously determined and known resonance point of the volume fraction constituent as provided in the database so as to identify the volume fraction constituent in the fluid;

generating a first output from the first probe when a volume fraction constituent is sensed by the first probe and generating a second output from the second probe when the same volume fraction constituent is sensed by the second probe, and communicating the first and second probe outputs to the computer;

determining the volume of the volume fraction constituent sensed by the first probe by determining a velocity of the volume fraction constituent moving through the pipe by calculating a time difference between the first probe output

and the second probe output and correlating the calculated time with the known total volume of fluid flowing through the pipe; and

providing a user interface electronically coupled with the computer and which receives the identification of the volume fraction constituent and the first probe output and the second probe output, and which further generates a user perceivable output which identifies the volume fraction constituent in the fluid and the volume thereof moving through the pipe.

8. A method for identifying and measuring a volume fraction constituent of a fluid comprising:

determining a dielectric constant of a volume fraction constituent moving through a pipe by determining a time delay between an electrical pulse emission into a first probe exposed, at least in part, to the fluid and a reflection of the electrical pulse emission from the first probe;

correlating the determined time delay to a database of known dielectric constants of known volume fraction constituents to identify the volume fraction constituent;

applying a Fast Fourier Transform to the determined time delay to generate frequency resonance points of the volume fraction constituent;

correlating the generated resonance points of the volume fraction constituent to a database of known resonance points of known volume fraction constituents and known concentrations of volume fraction constituents to identify the volume fraction constituent; and

providing a user interface which generates a user perceivable output which identifies the volume fraction constituent in the fluid and the volume of the volume fraction constituent in a user perceivable form.

9. The method of claim 8 further comprising:

providing a pipe having a known interior diameter that communicates with a source of the fluid so that a volume of the fluid moves through the pipe at a velocity;

providing a second probe exposed at least in part to the fluid moving through the pipe a known distance downstream from the first probe;

generating a first output by the first probe when a volume fraction constituent is sensed by the first probe and generating a second output by the second probe when the same volume fraction constituent is sensed by the second probe, and communicating the first and second probe outputs to a computer;

determining a volume of the volume fraction constituent moving through the pipe by unit of time by calculating a time difference between the first probe output and the second probe output to determine the velocity of the fluid moving through the pipe; and

correlating the determined resonance points of the volume fraction constituent with the database of known resonance points of concentrations of volume fraction constituents to determine the volume of the volume fraction constituent moving through the pipe.

10. The method of claim 7 and further comprising:
 - applying a Power Spectral Density (PSD) calculation to the Fast Fourier Transform (FFT) frequency to determine amplitude and strength of the resonance point.

11. The method of Claim 8 and further comprising:
 - applying a Power Spectral Density (PSD) calculation to the Fast Fourier Transform (FFT) frequency to determine amplitude and strength of the resonance point.

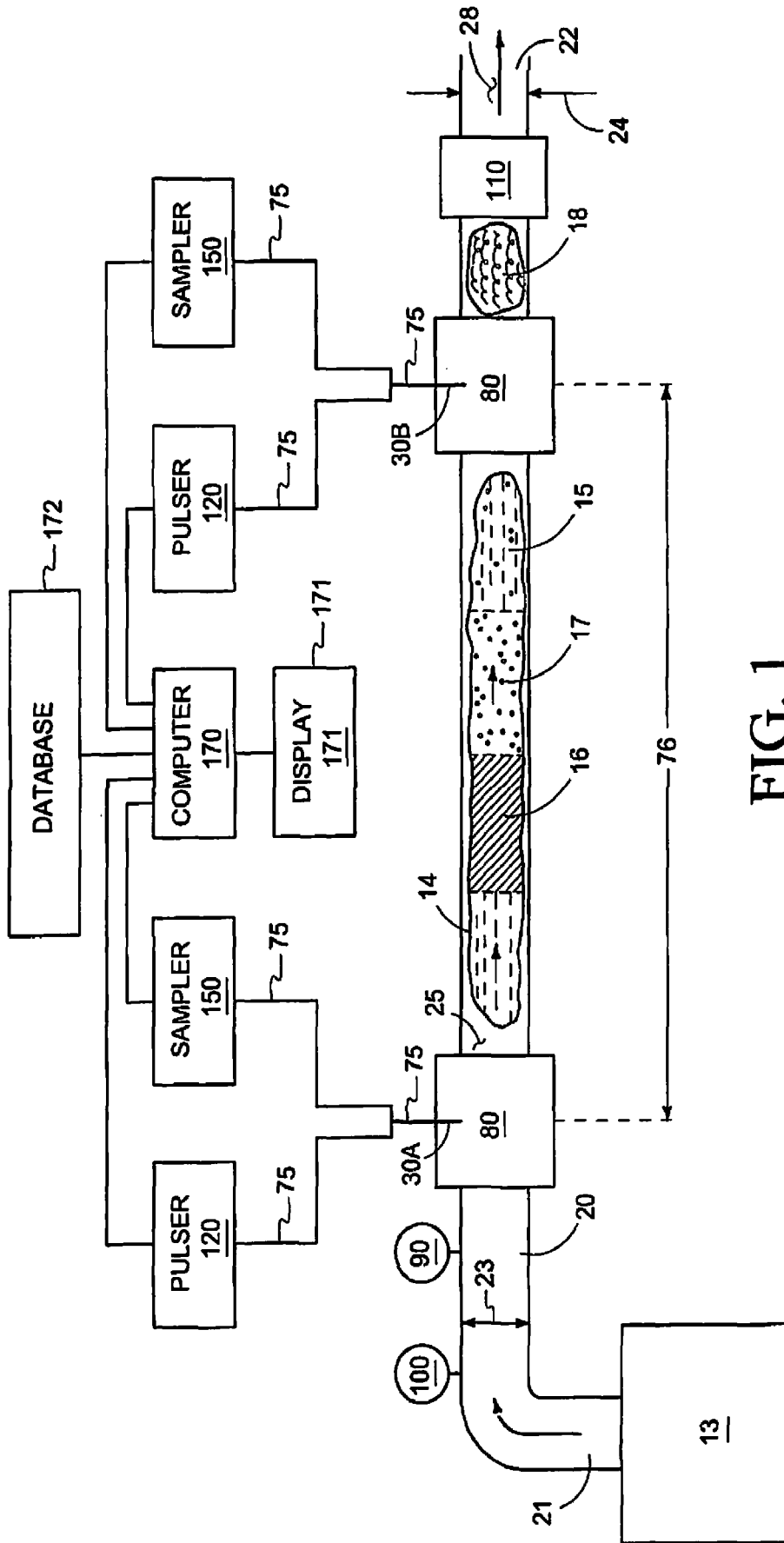


FIG. 1

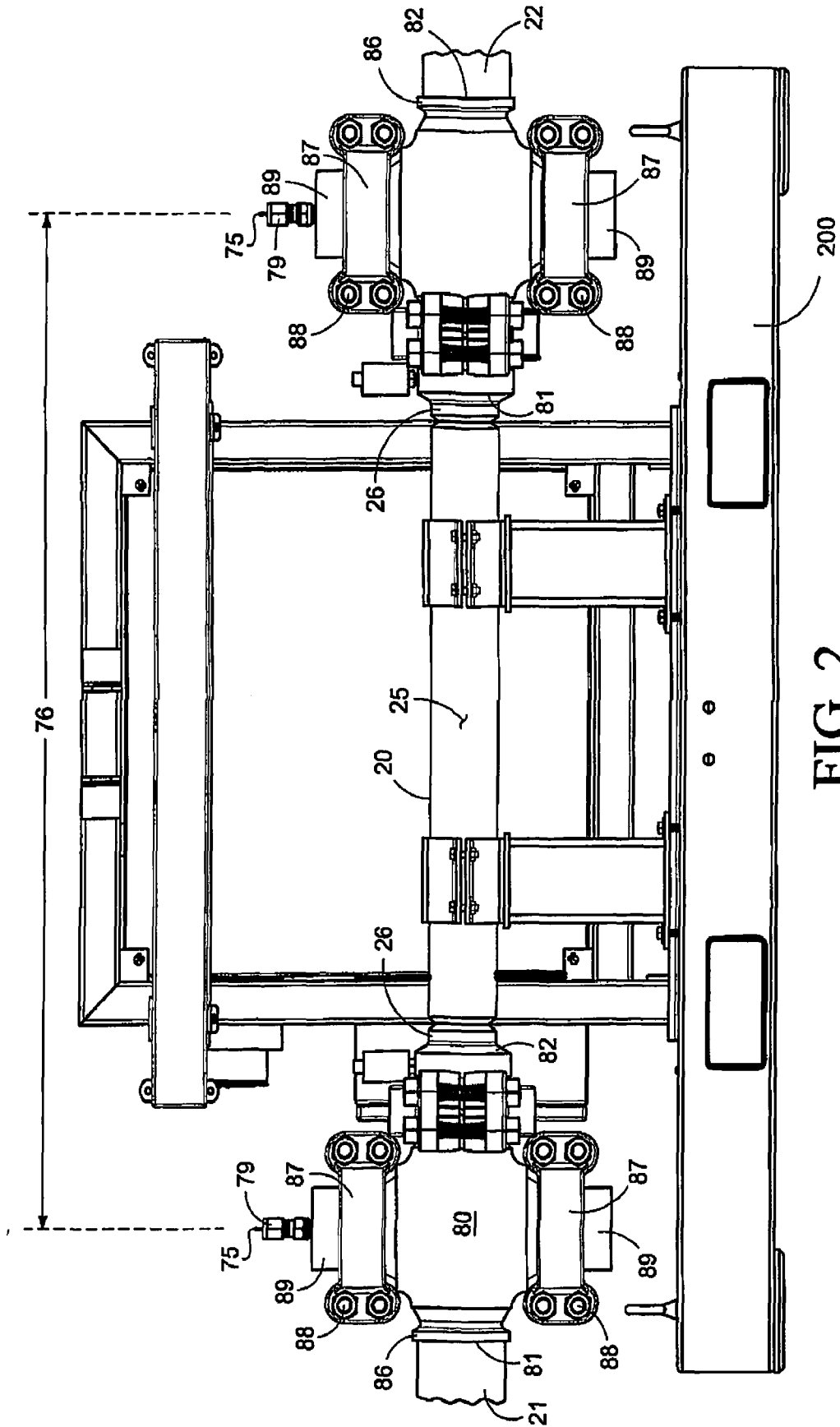


FIG. 2

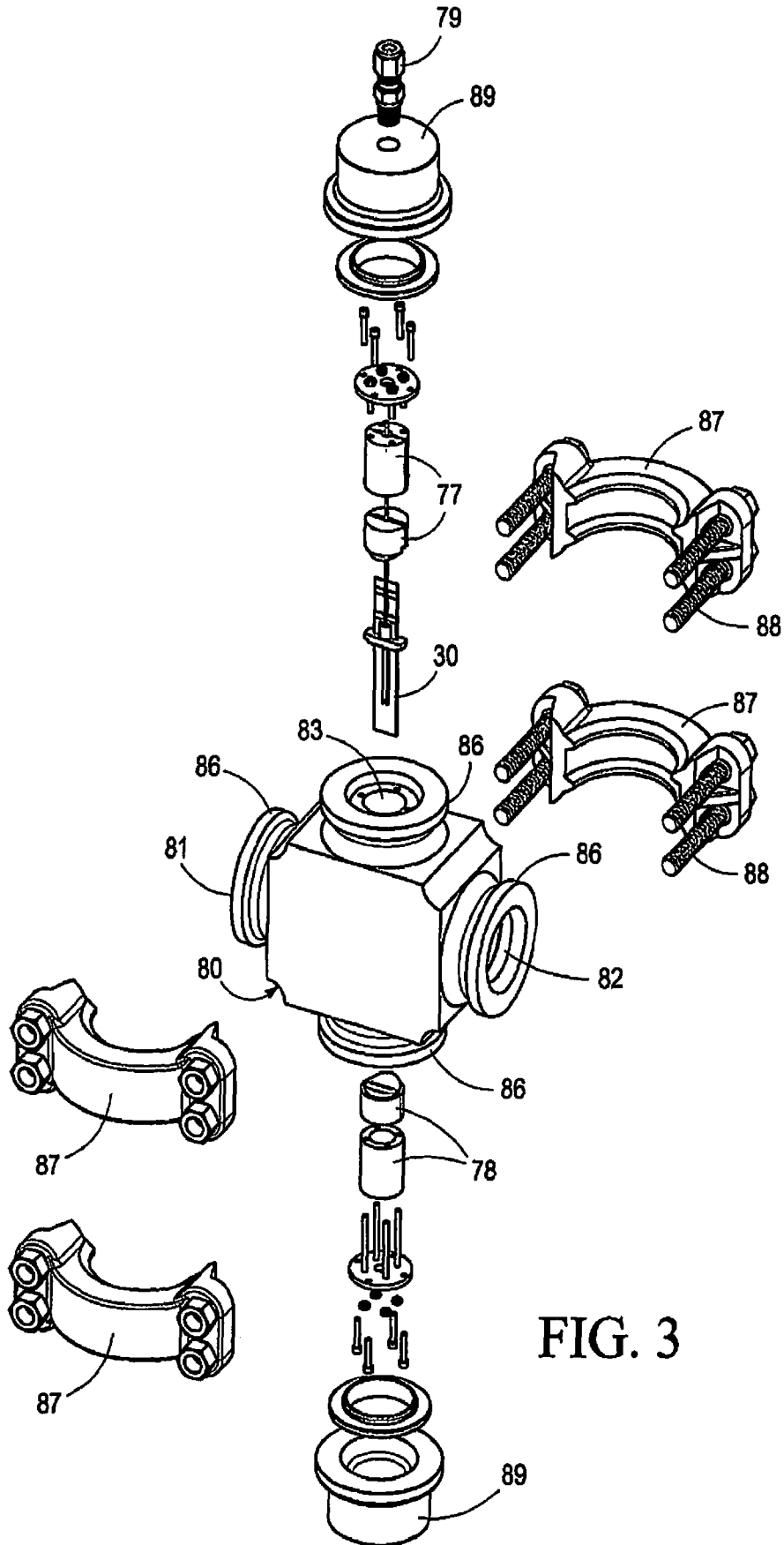


FIG. 3

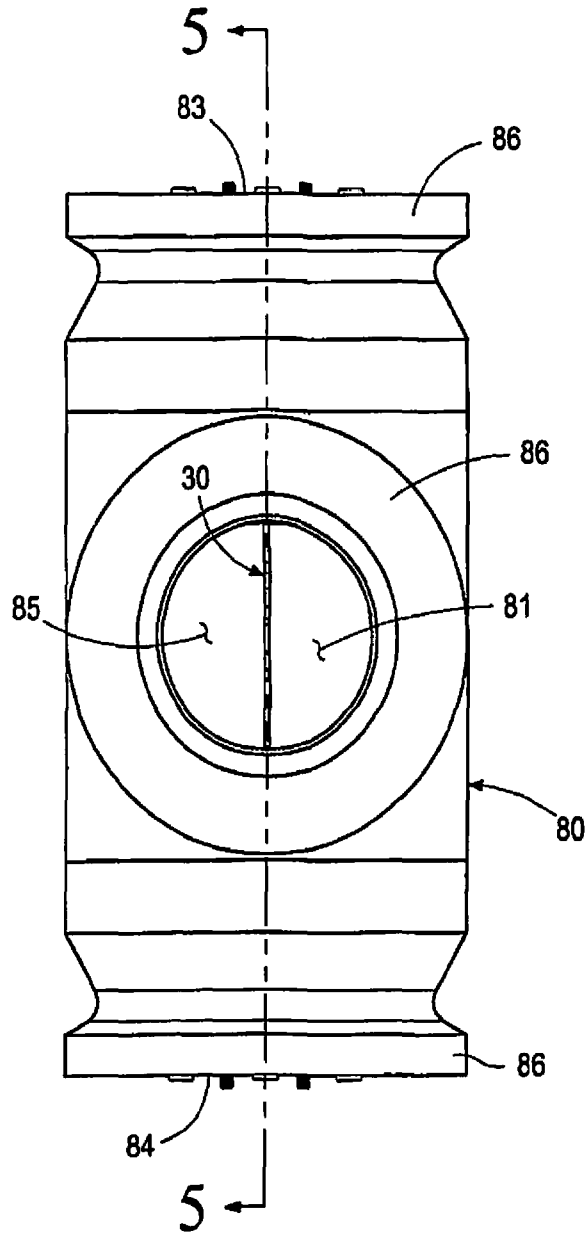


FIG. 4

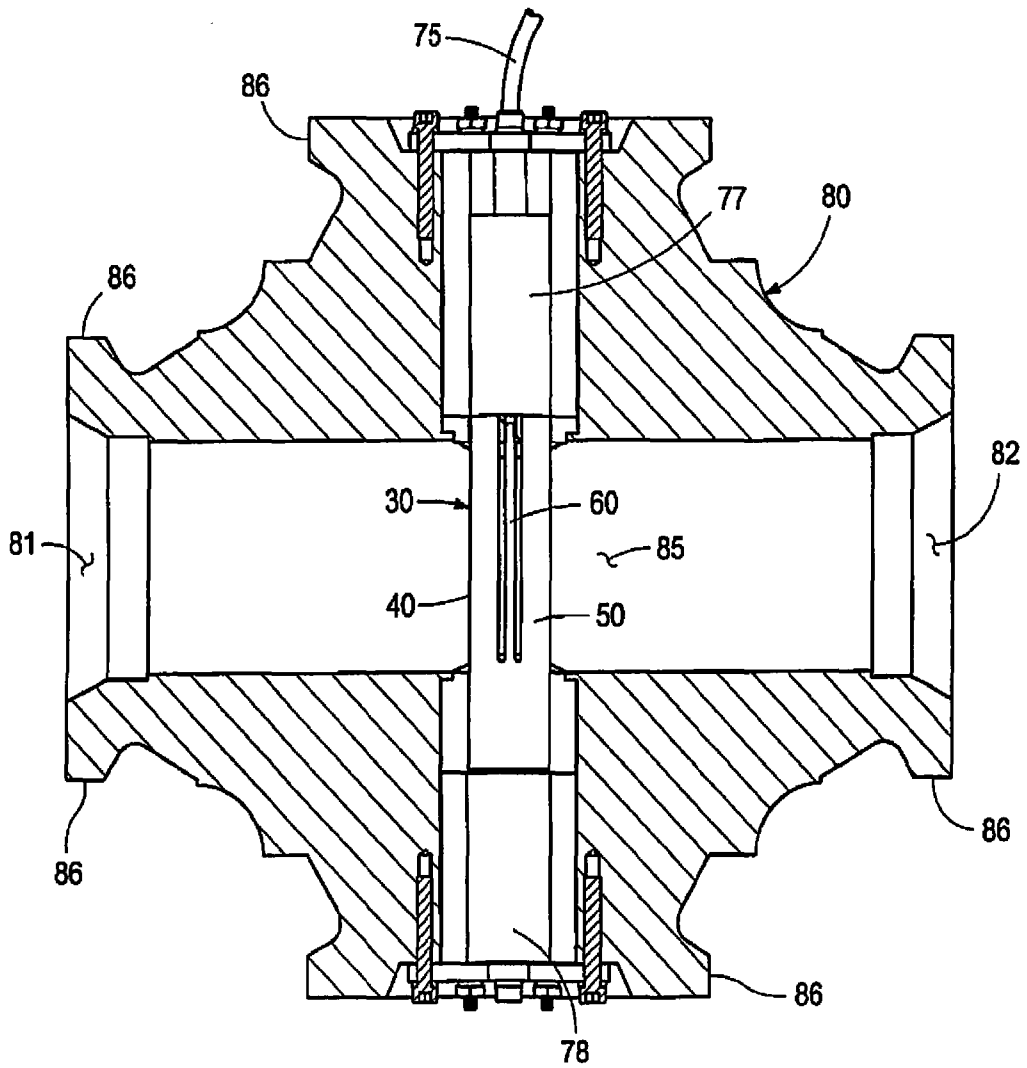
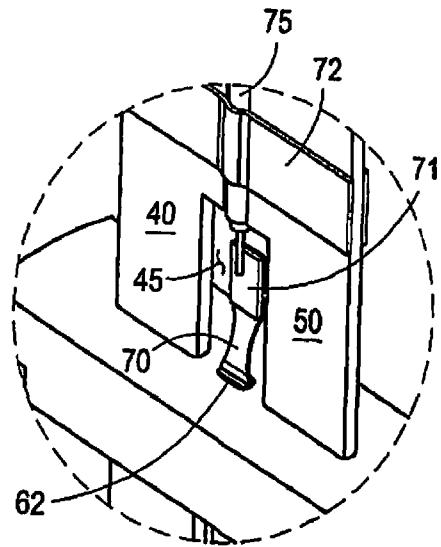
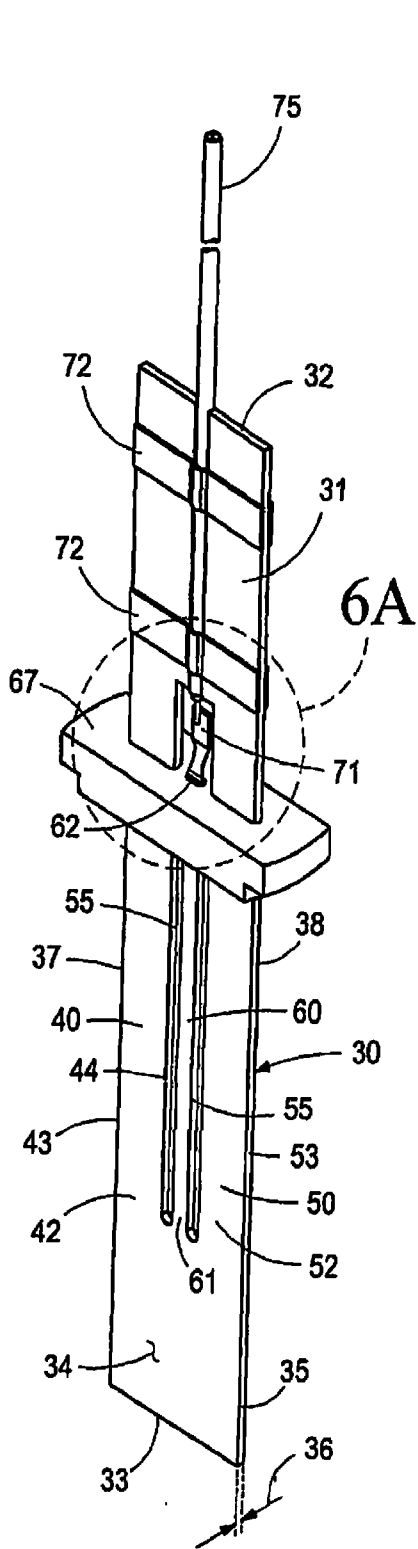


FIG. 5



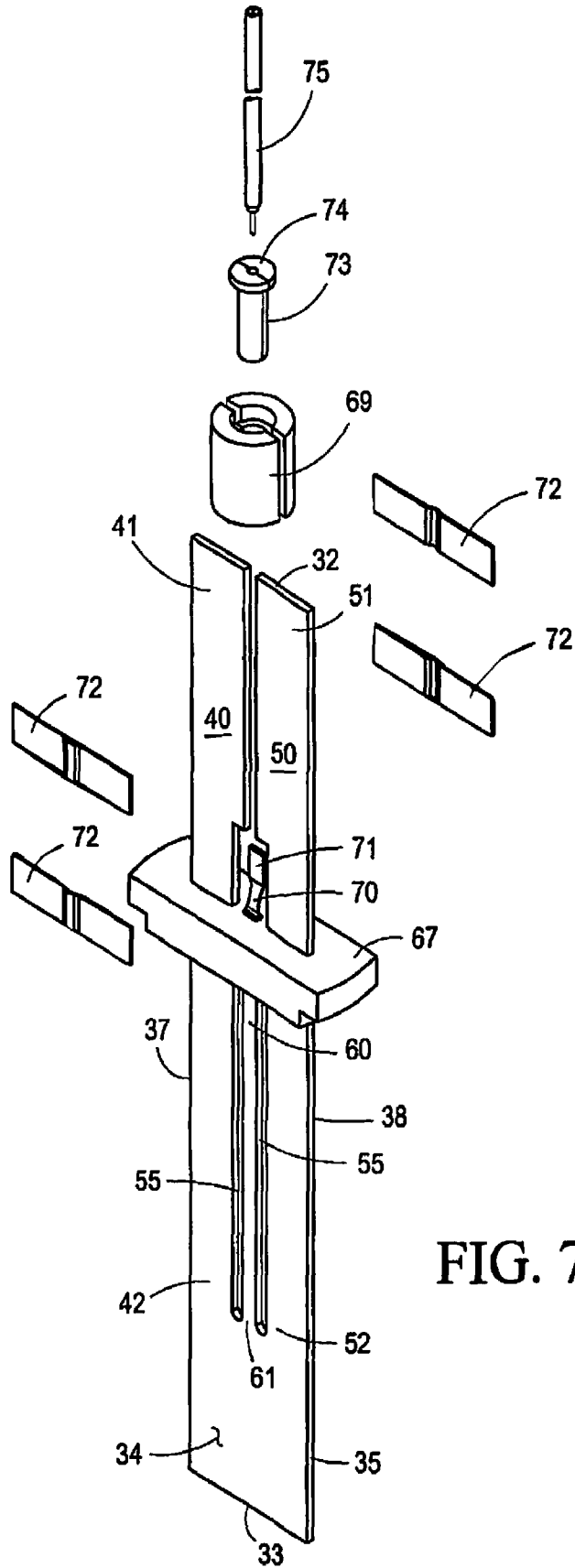


FIG. 7

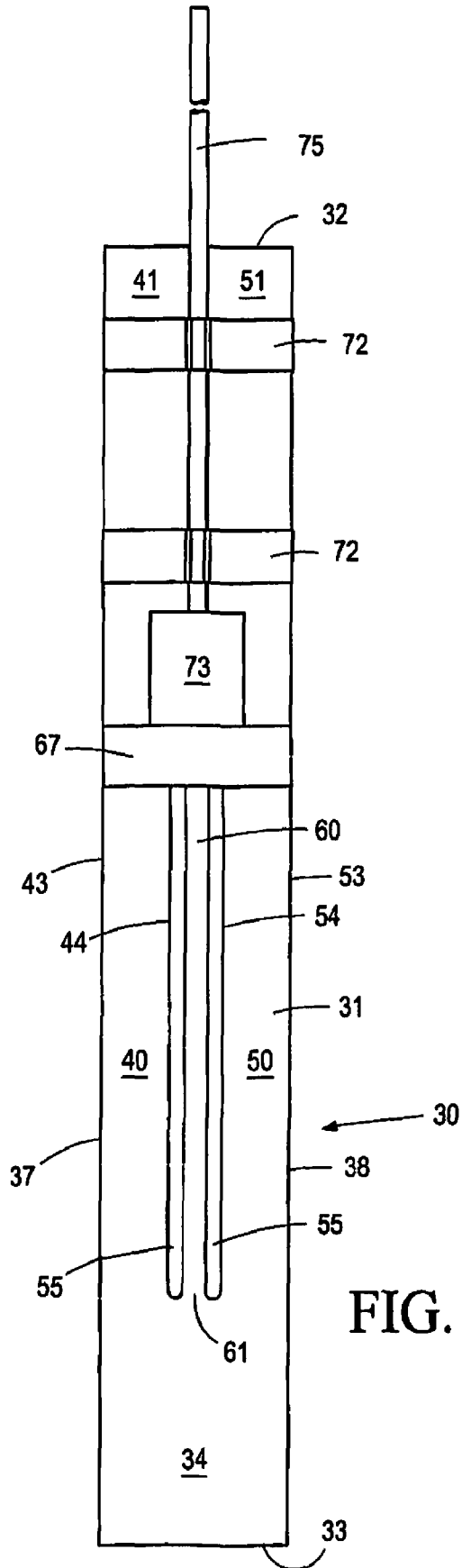


FIG. 8

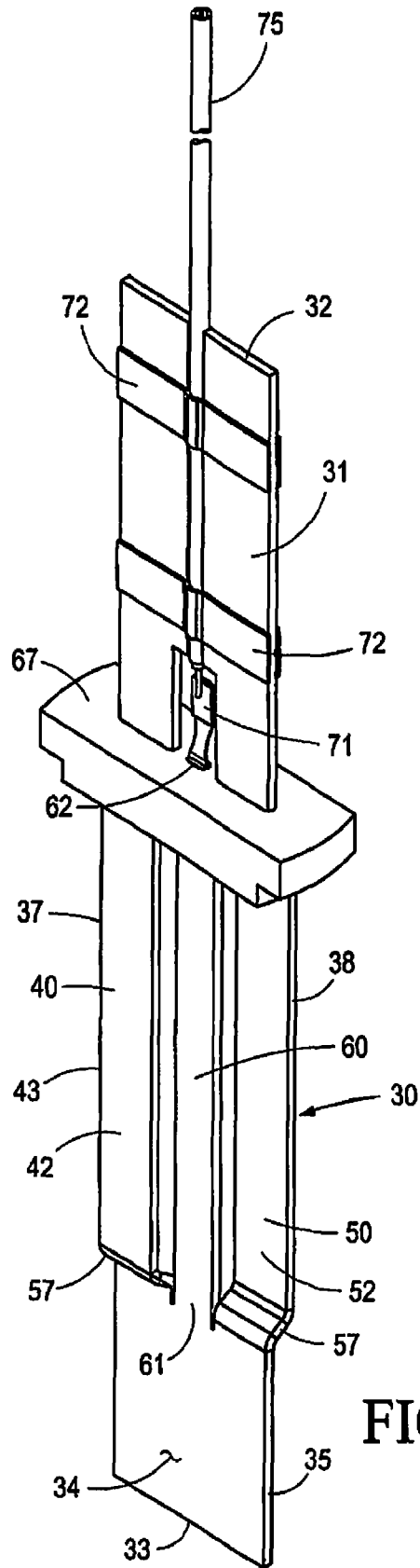


FIG. 9

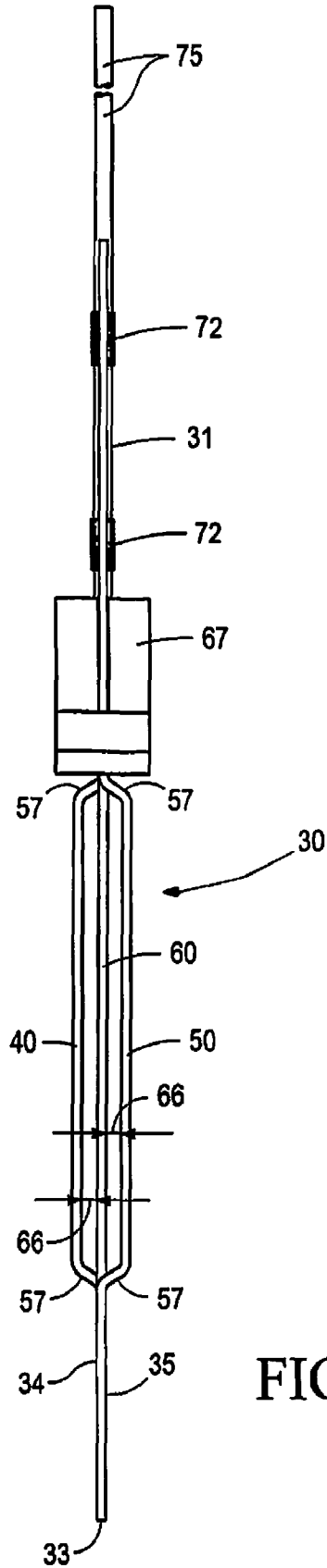


FIG. 10

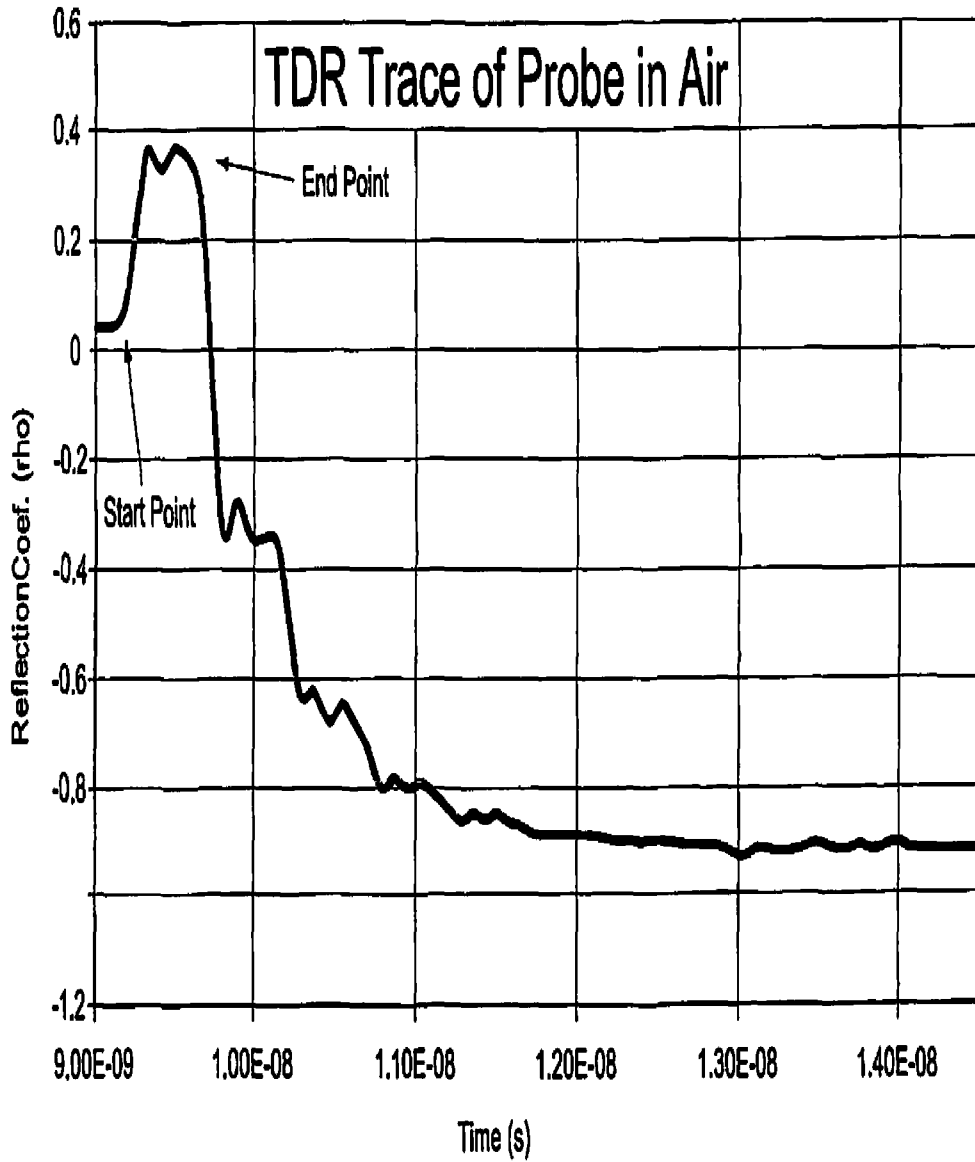


FIG. 11

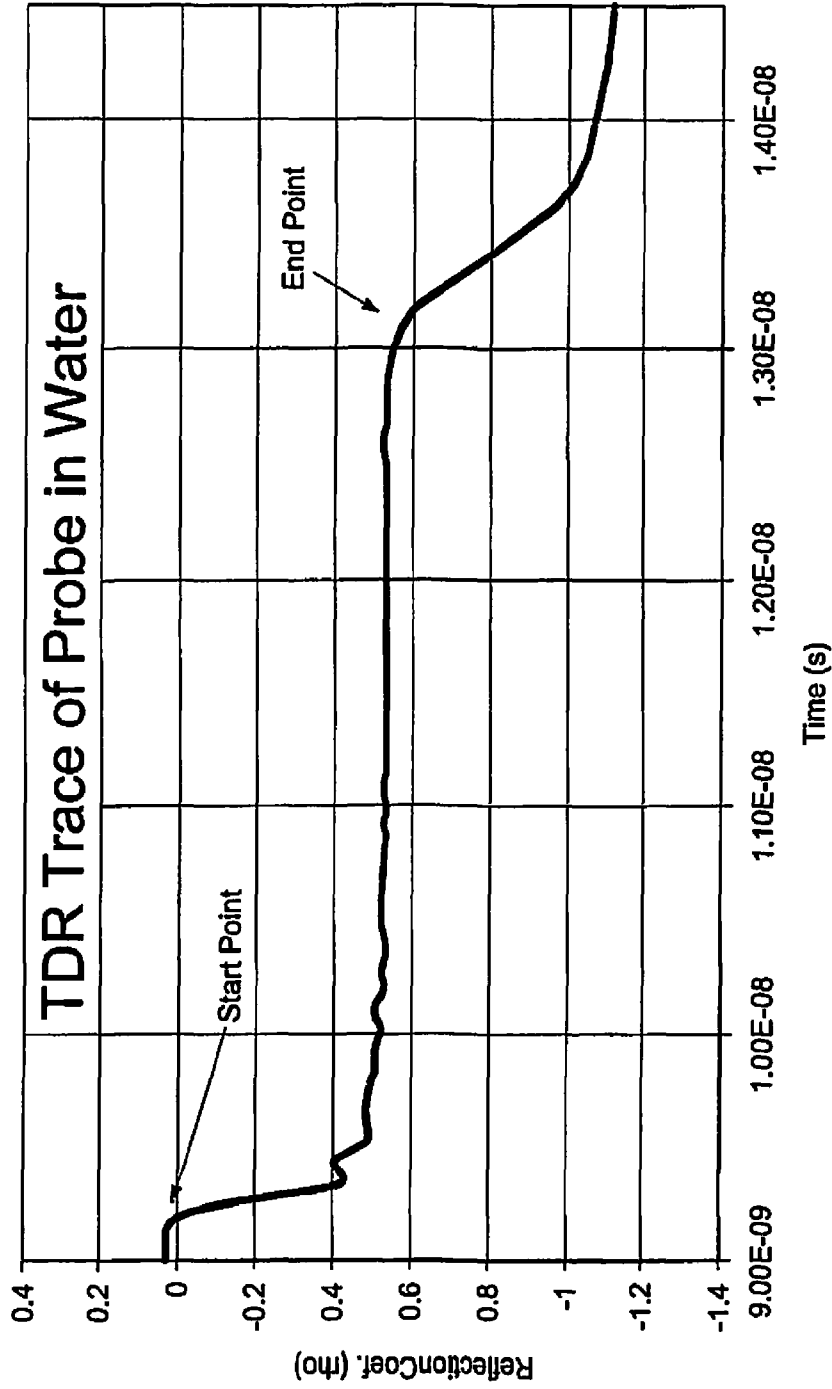


FIG. 12

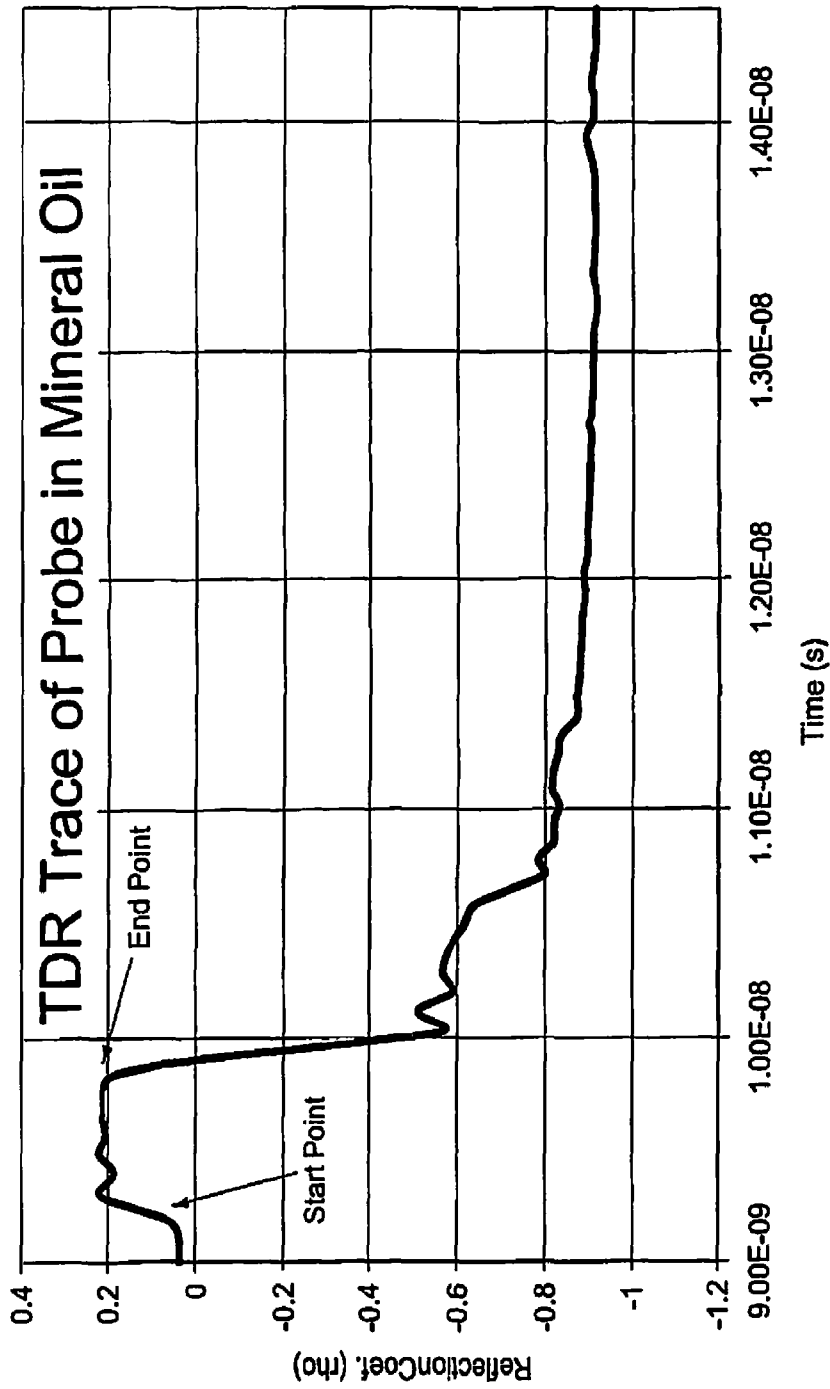


FIG. 13

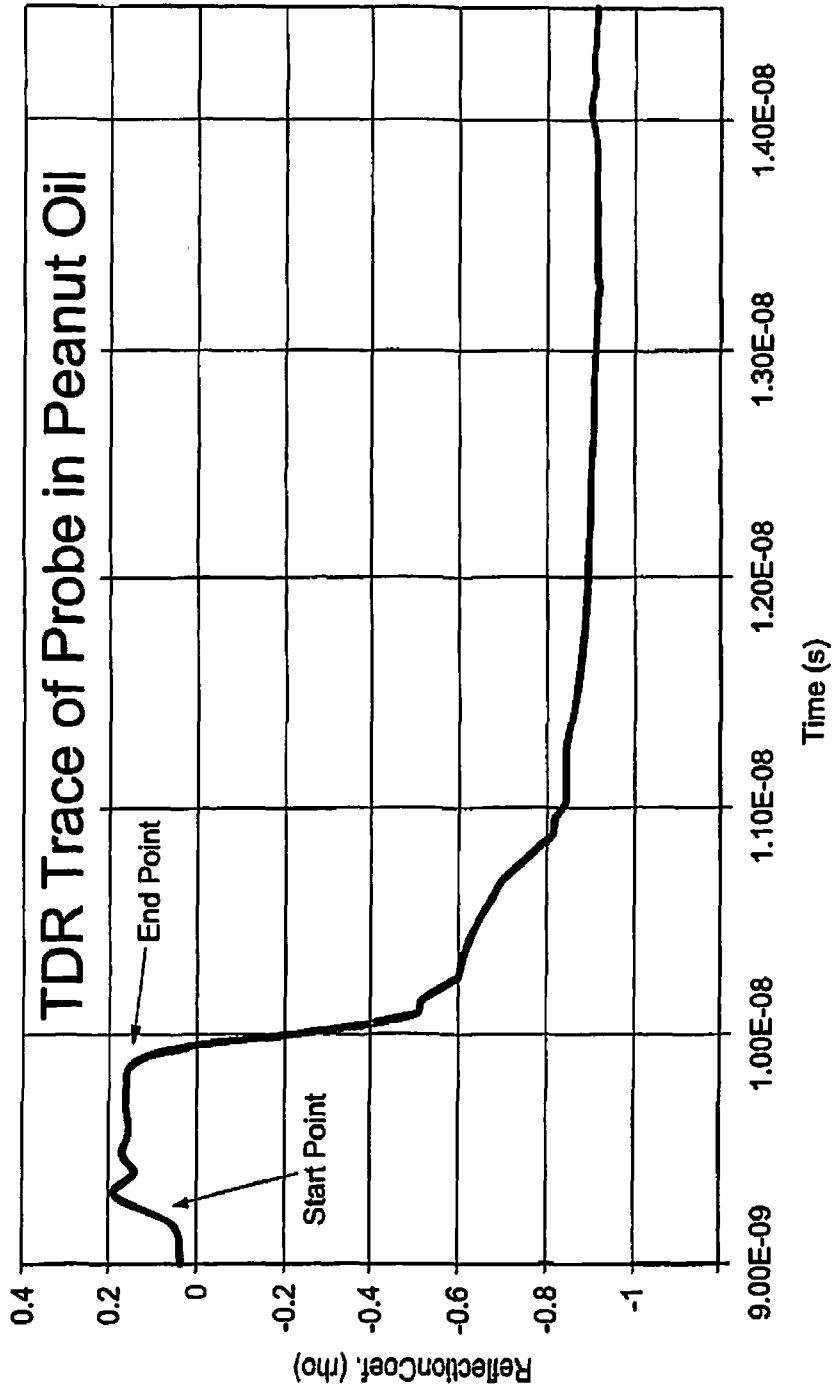


FIG. 14

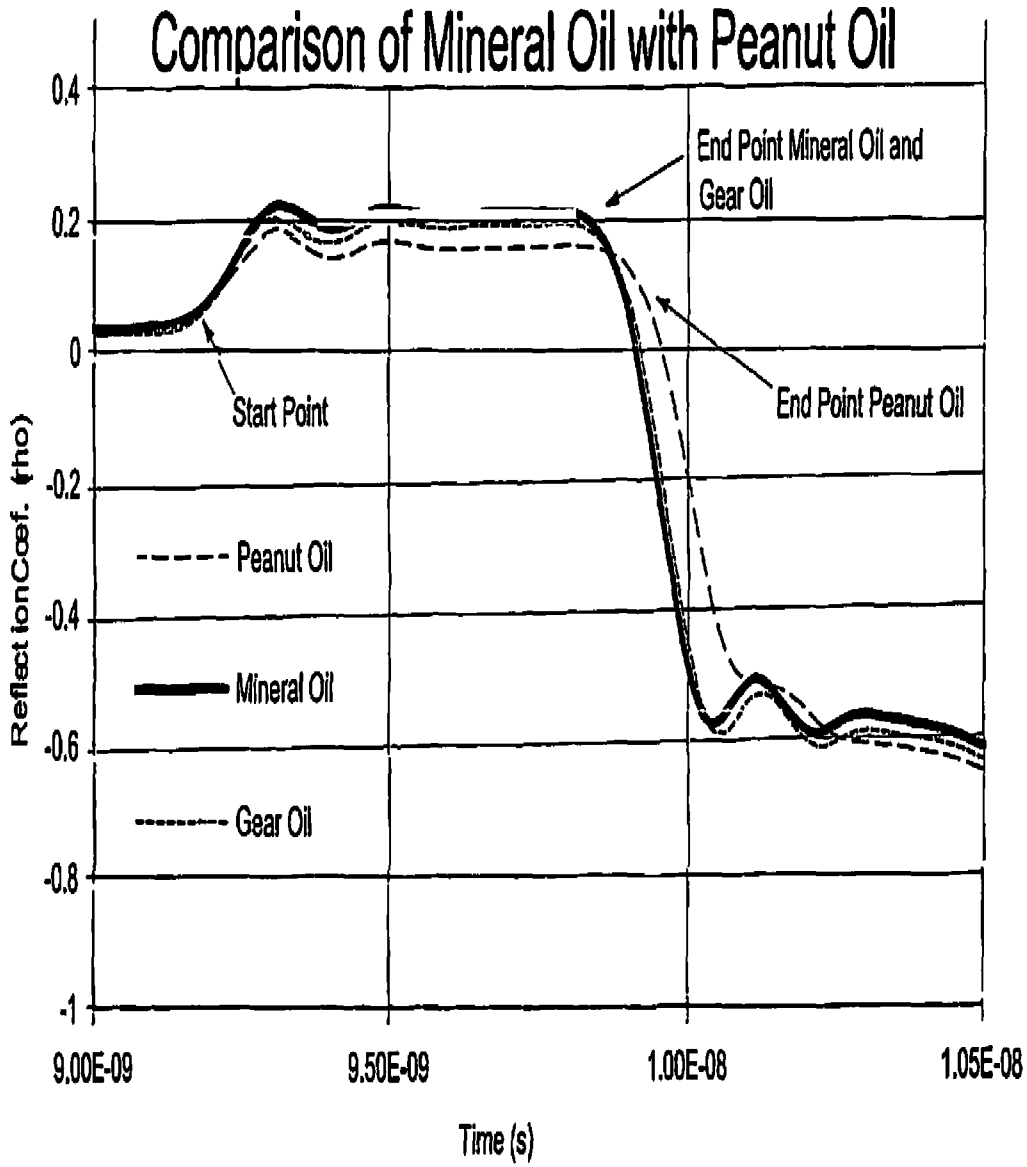


FIG. 15

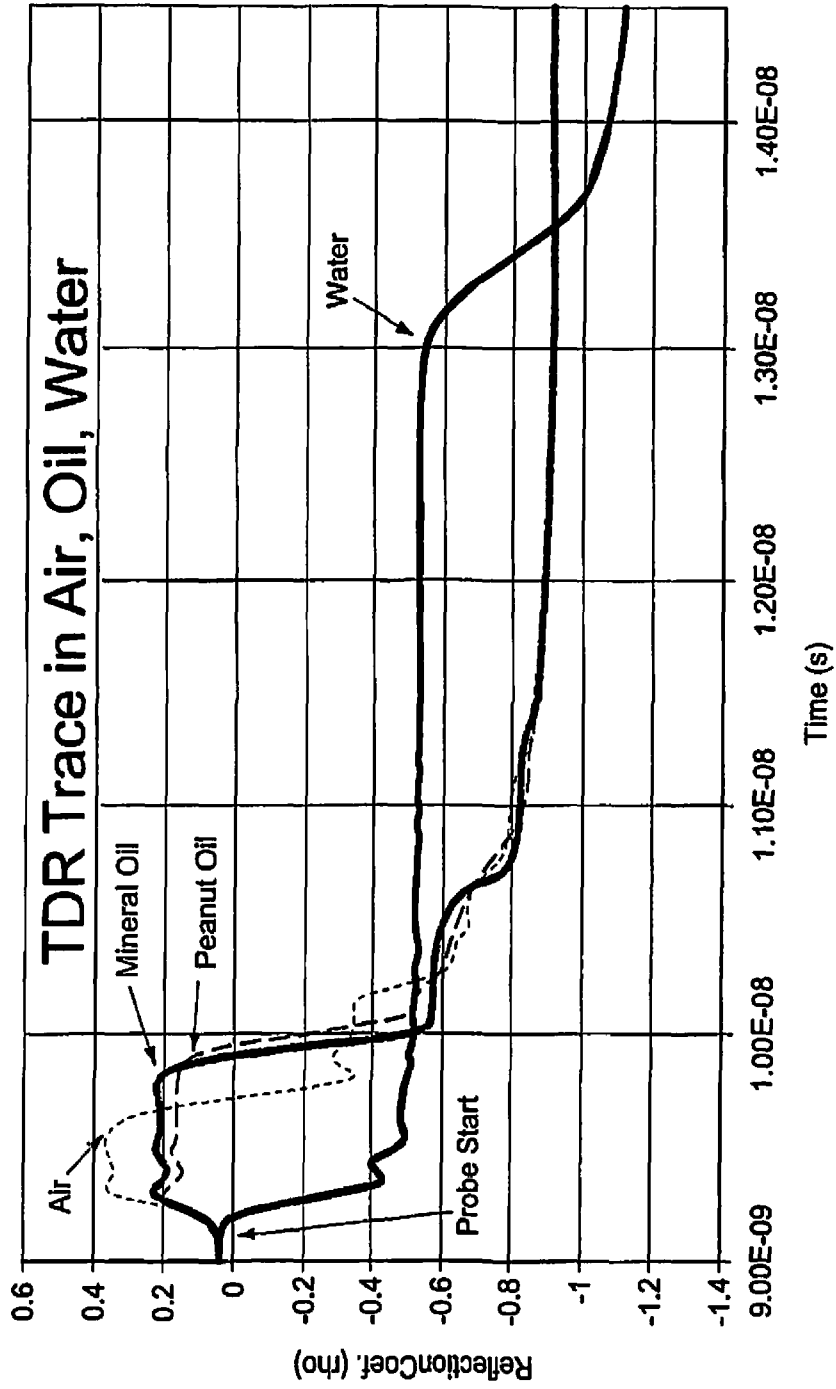


FIG. 16

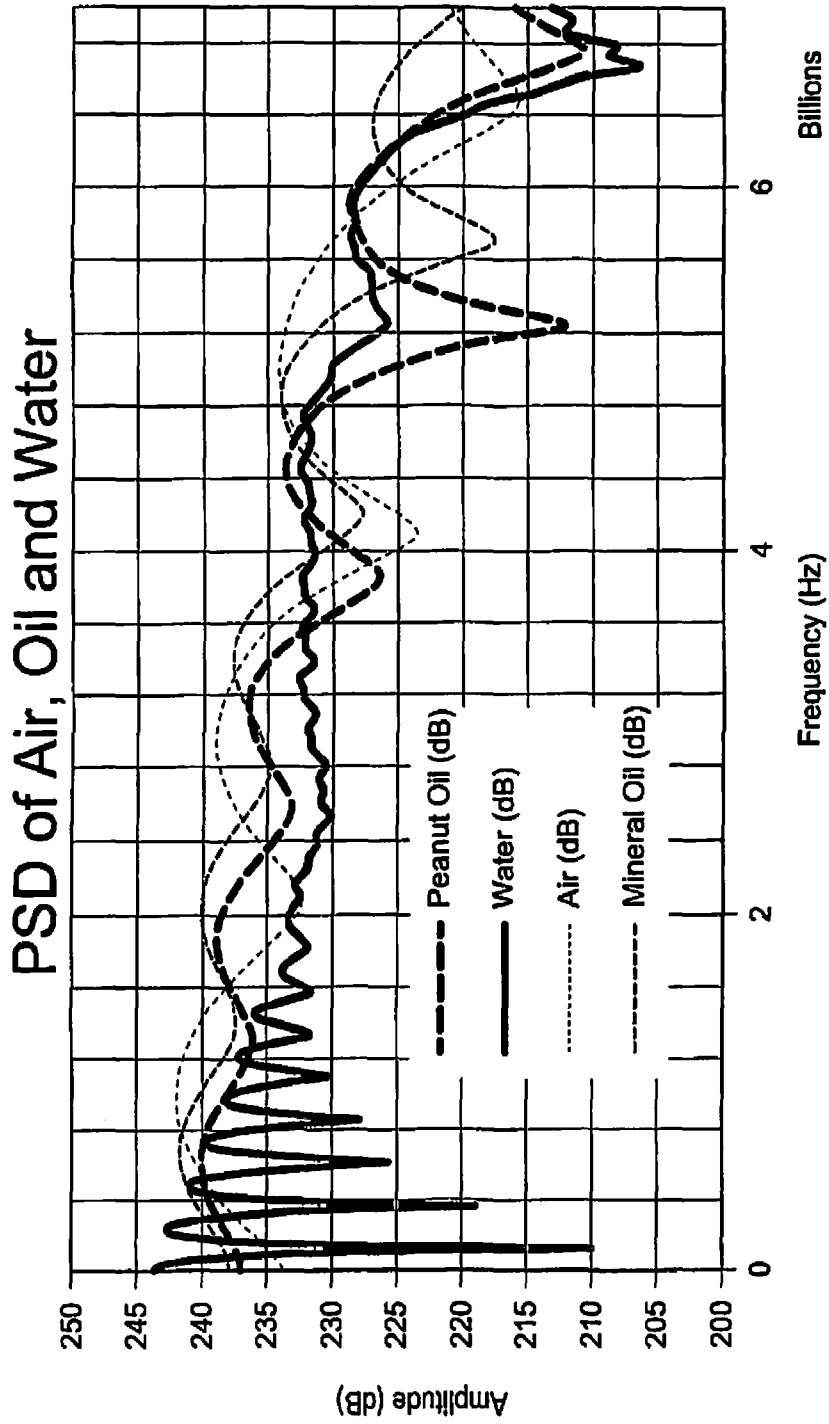


FIG. 17

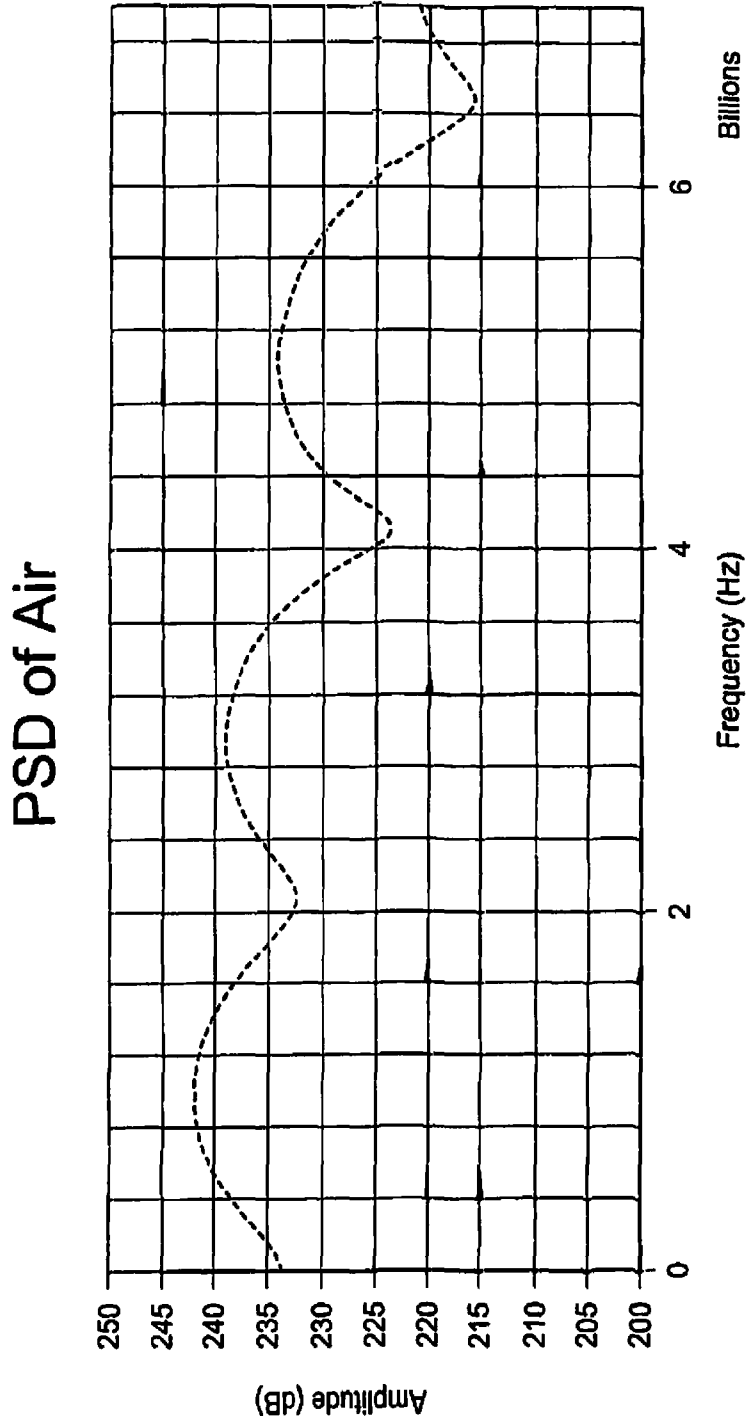


FIG. 18

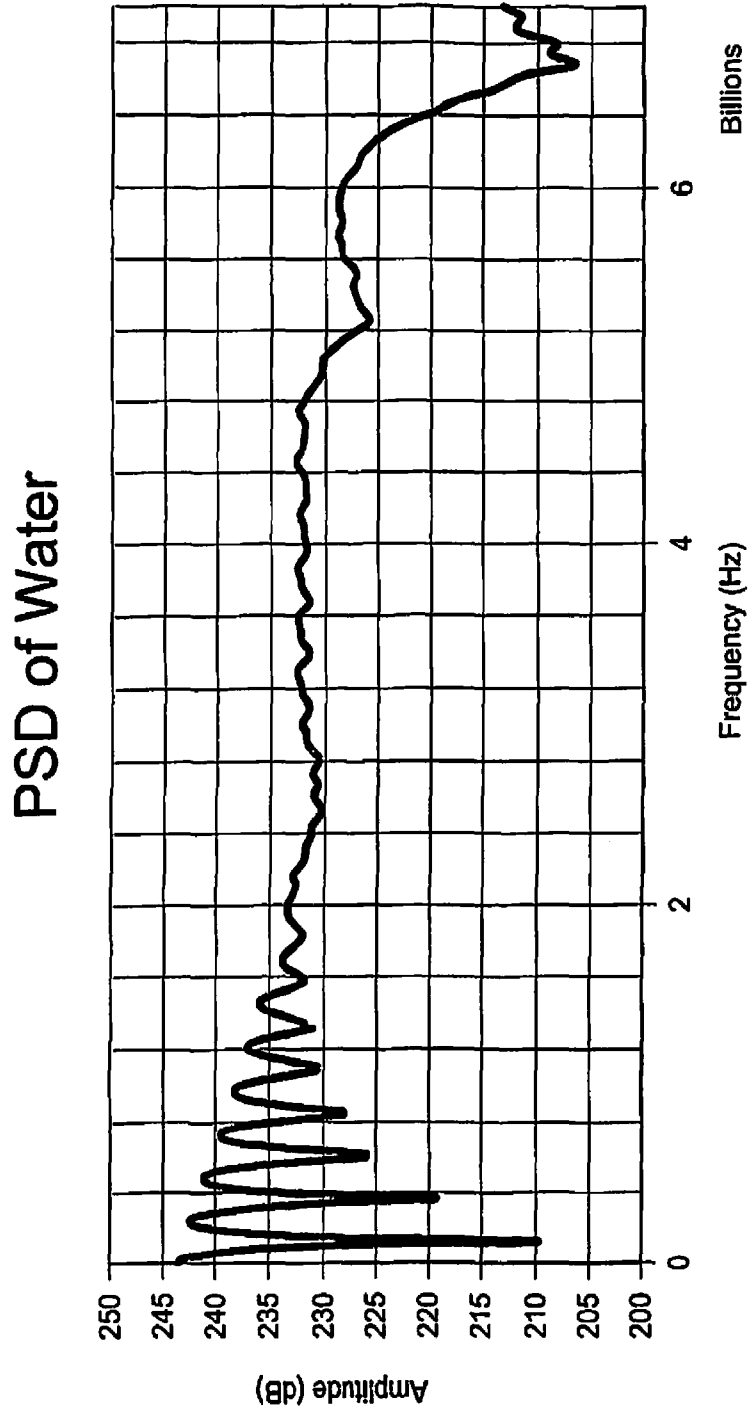


FIG. 19

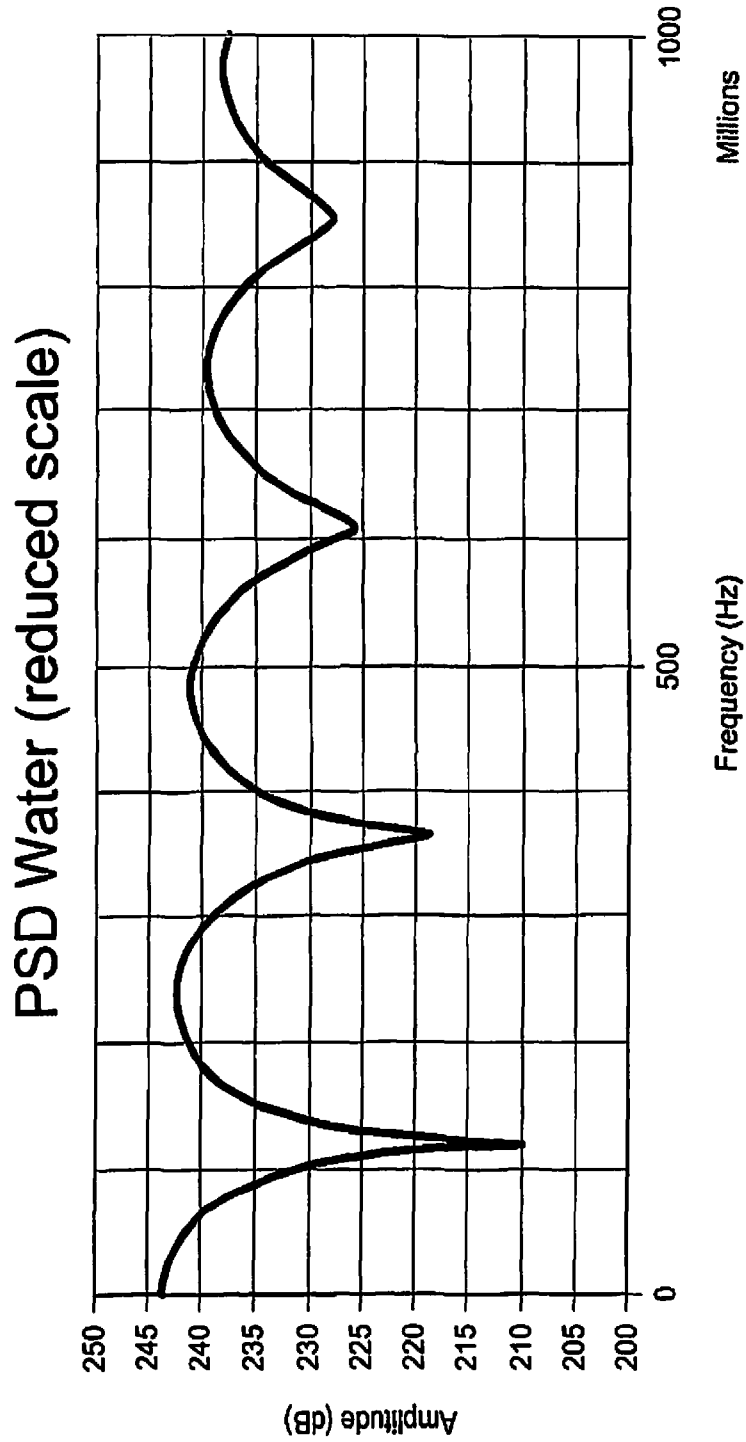


FIG. 20

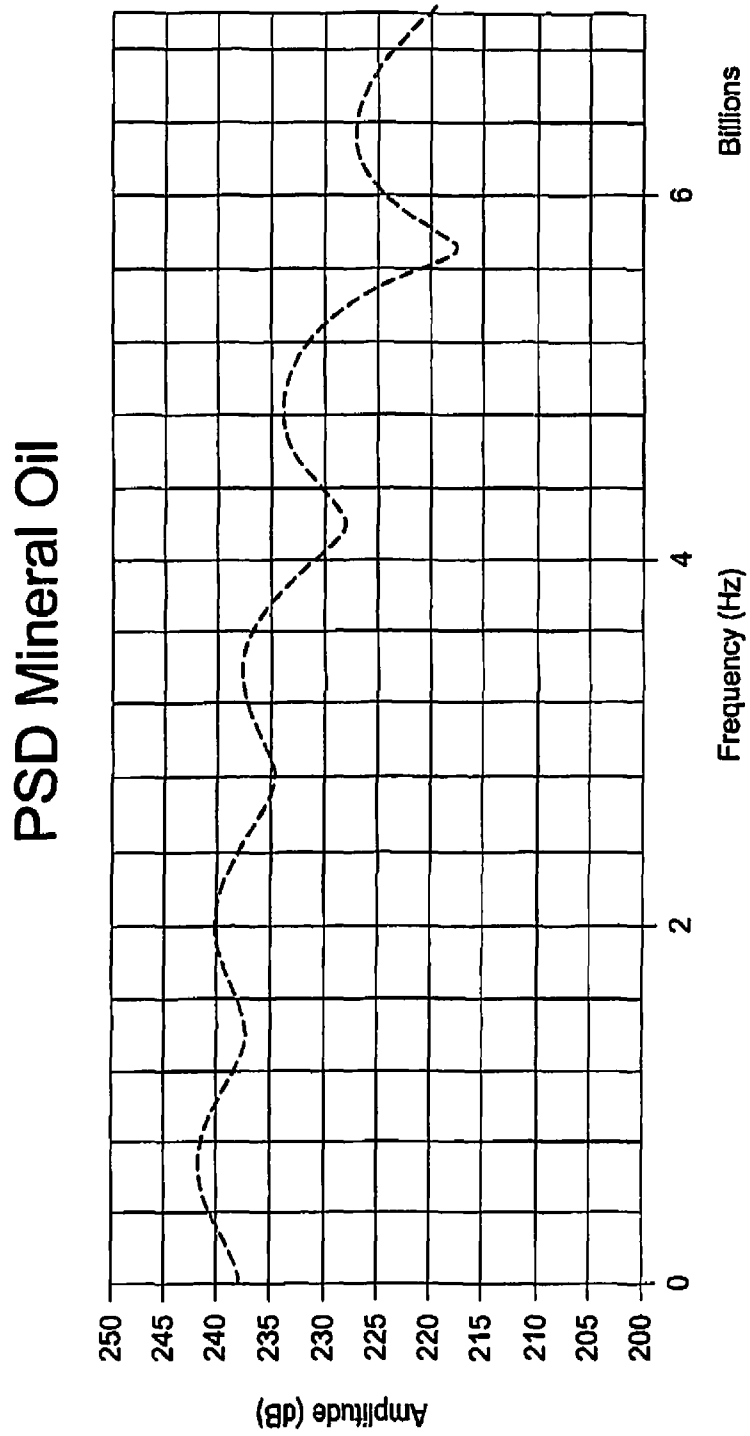


FIG. 21

