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[54] METHOD AND APPARATUS FOR TELEMETERING INFORMATION THROUGH WELL BORES

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[52] **U.S. Cl.**.....**340/18**, 166/250, 166/66, 175/40

[51] **Int. Cl.** **G01v 1/40**

[58] **Field of Search**.....340/18; 166/250, 66; 175/40

[56] **References Cited**

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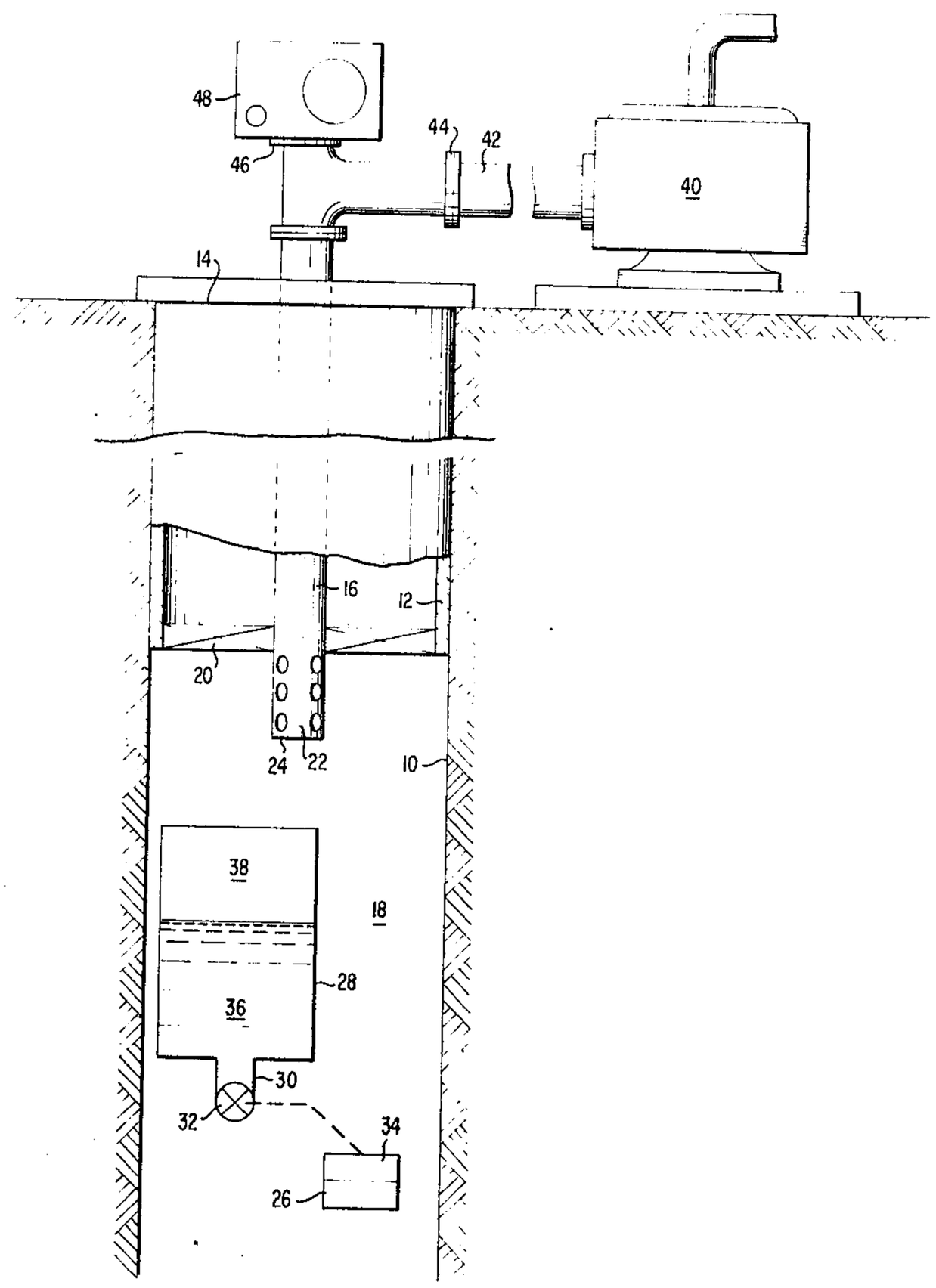
[57] **ABSTRACT**

A method and apparatus whereby the rigidity of fluid body confining, well wall means is varied in response to a condition within a well to vary the natural frequency of oscillation of the fluid body, the frequency being detected at the well head as representative of the condition.

11 Claims, 1 Drawing Figure



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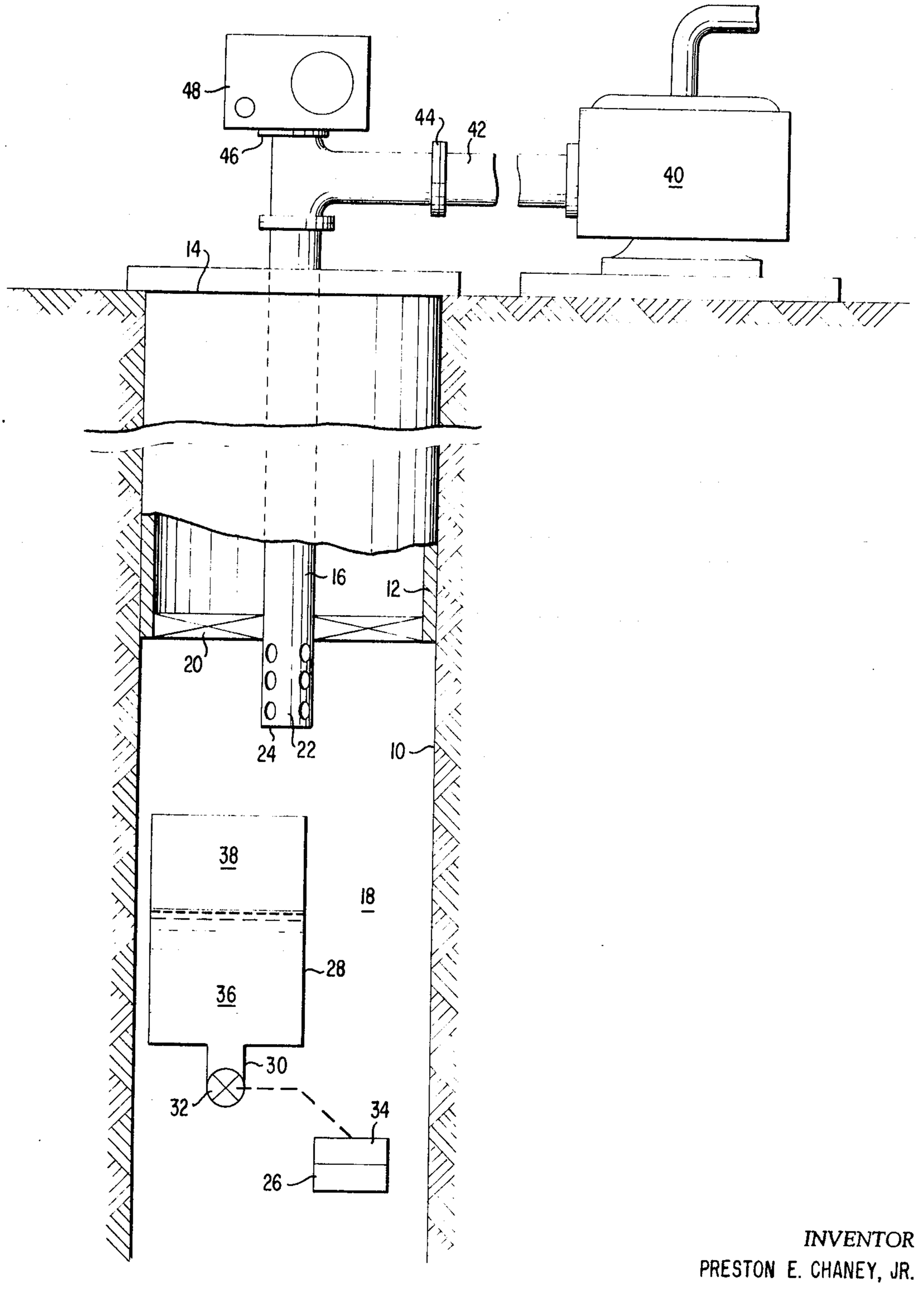

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METHOD AND APPARATUS FOR TELEMETERING INFORMATION THROUGH WELL BORES

This application is a continuation-in-part of copending application Ser. No. 672,261 filed Oct. 2, 1967 for "Method and Apparatus for Telemetering Information Through Well Bores," now abandoned.

BACKGROUND OF THE INVENTION

The monitoring of changing conditions such as electrical formation resistivity, radioactivity, acoustic velocity, formation pressure, etc., in the remote confines of a well bore and the transmission of information reflecting such changes to a wellhead is a problem of long standing in the art.

Prior art attempts at solving this complex problem have included the locating of a sensing device in the well bore at some appropriate and often substantial depth and electrically connecting the sensor to a recorder or other indicator at the wellhead. This traditional solution is costly, vulnerable to interference, and usually quite complex. Yet, a knowledge of the variations in the conditions within a well bore may be essential to optimizing production both in permanent installations and, e.g., in the testing or drilling stages.

It is accordingly an object of the present invention to provide a novel method and apparatus whereby conditions existing in a well bore can be monitored at the wellhead without the need for connecting wiring.

Another object of the present invention is to provide a novel method and apparatus whereby the natural frequency of oscillation of a fluid body may be modified in response to changing conditions within the well.

Still another object is to provide a novel method and apparatus whereby the natural frequency of oscillation of an incompressible fluid body may be modified by varying the degree of fluid communication between the fluid body and a container of a compressible fluid.

A further object is to provide a novel method and apparatus whereby the energy necessary to convey information relative to a remote condition existing in a well bore to the wellhead may be introduced at the wellhead rather than within the well bore.

These and other objects and advantages of the present invention will become more fully apparent from the claims and from the following description when read in conjunction with the appended drawing.

THE DRAWING

The FIGURE schematically illustrates a well and one embodiment of the apparatus for practicing the present invention.

THE PREFERRED EMBODIMENT

Referring now to the drawing, a conventional well bore **10** is illustrated, which has been provided with a conventional casing **12**, extending from a wellhead **14**, downwardly into the well bore **10**. A well conduit string **16** extends downwardly from the wellhead **14** into a cavity **18**, defined transversely by well bore **10**, and vertically by one or more conventional packers **20** or the limits of the well bore **10**. The presence of packer **20** is not necessary to the practicing of the present invention and cavity **18** may extend upwardly to the wellhead **14** and downwardly to the bottom (not shown) of the well bore **10**. The conduit string **16** may terminate in an apertured conduit **22** or may as an alternative be open at the lower end **24** thereof to provide fluid communication with the cavity **18**.

A conventional self-contained bore hole condition sensor **26** is installed within the cavity **18** of the well bore **10**. The sensor **26** may be of any commercially available type and may be adapted to respond to any condition which may exist in a well bore. Parameters of interest may include electrical formation resistivity, radioactivity, acoustic velocity, or even formation pressure so long as the formation of interest is isolated from cavity **18**.

Located in proximity to the condition sensor **26** is a pressure vessel **28**, the configuration of which is not critical but which may conveniently take the form of an inverted chamber or tank having a relatively narrow neck portion **30** at the lower extremity thereof.

A convention valve **32** is installed in the neck portion **30** of the pressure vessel **28**. Valve **32** is operably connected to an actuator **34** which operates to open and close the valve **32** in response to the value of the condition detected by sensor **26**. Vessel **28**, valve **32**, actuator **34**, and sensor **26** are mounted within a well bore. This mounting may be fixed in character and achieved with conventional well tool positioning means such as slips. It is also possible in certain circumstances for all or portions of the assembly to be mounted on a movable well tool.

The specific construction of the actuator **34** is not critical to the practicing of the present invention. Actuator **34** may, for example, consist of a simple mechanical linkage between the valve **32** and a bellows pressure detector isolated, of course, from the oscillatory pressures of the fluid body within cavity **18**. Alternatively, the actuator may be a conventional solenoid, the position of which may be controlled by an electric current generated by a conventional scintillation detector and photomultiplier tube. The use of a battery powered, nonreversible electric motor driving against an appropriate mechanical bias such as a spring may also be utilized, the sensor taking the form of a condition responsive element in one arm of a battery energized conventional bridge circuit.

Pressure vessel **28** is at least partially filled with a compressible fluid such as air prior to installation within the well bore **10**. The opening of valve **32** allows the lower portion **36** of the vessel **28** to fill with fluid from cavity **18**. The compressible fluid is thus compressed by the fluid pressure of cavity **18** into the upper portion **38** of the pressure vessel **28**.

Means are provided at the wellhead for imparting an oscillatory impulse to the fluid contained in cavity **18**. In actual practice a satisfactory impulse has been obtained by pumping fluid from a conventional pump **40** of the reciprocating piston type into the tubing **42** and conduit string **16**, and quickly "-clutching out" the pump **40** against a check valve **44** at a pressure between 400 and 600 pounds per square inch. In this manner the last stroke of the fluid displacing piston within pump **40** imparts a terminal pressure impulse to the fluid body. The fluid body at this time may be "static," herein defined as a condition of non-flow.

The fluid body, i.e., the fluid within conduit string **16**, cavity **18** and the lower portion **36** of the pressure vessel **28** provided valve **32** in the narrow neck portion **30** thereof is open, will then oscillate or undergo cyclical changes in pressure. By allowing this natural oscillation to continue without interference from additional pressure impulses, the fluid body will resonate.

The fluctuations in the pressure of the fluid body are detected at the wellhead **14** by a conventional and commercially available pressure transducer **46** and recorder **48**. Recorder **48** may include pressure indicating means such as a bellows (not shown) positioned within the interior of conduit **16** and exposed to the pressure of the fluid body. This bellows, through conventional linkage arrangements or other force transmitting means, may be used to modulate the frequency of an electronically generated waveform or may be utilized to directly generate such a waveform by moving a coil through an electromagnetic field.

The resonant frequency of oscillation of a fluid column has been determined, as a part of this invention, to vary with the rigidity of the fluid column defining walls. Consequently, the opening and closing of the valve **32** in the neck portion **30** of the pressure vessel **28** modifies the resonant frequency of the fluid body within the well bore **10** by placing the interior of the pressure vessel into and out of fluid communication with the fluid body. With the valve **32** closed the resonating fluid body is contained entirely by rigid walls. With valve **32** open the fluid body includes the incompressible fluid in the lower por-

tion **36** of pressure vessel **28**. The fluid body thus is contained in part by the pressure of the compressible fluid in the upper portion **38** of the pressure vessel **28**. The interface between the fluid body and the compressible fluid obviously lacks the solidity which would otherwise exist. Modifications in the position of the valve **32** are thus reflected as changes in the resonant frequency of the fluid body as detected and displayed in the recorder **48**.

Numerous changes and modifications may be made in the specific embodiment of the present invention without departing from the true spirit or essential characteristics thereof. Those skilled in the difficult art of well drilling and familiar with the disclosure of this invention may well recognize additions, deletions, substitutions, or other modifications with reference to the disclosed techniques. The disclosed techniques are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

I claim:

1. Well condition monitoring apparatus comprising:

means for establishing a fluid body at least partially within a well bore,

means for causing said fluid body to oscillate at its natural frequency,

means within said well bore for changing the natural frequency of said fluid body in response to a change in a well condition by varying solidity of a portion of a structure confining said fluid body, and

means for detecting a change in the natural frequency of said fluid body.

2. The apparatus of claim **1** wherein said means for oscillating said fluid body includes a pump in fluid communication with said fluid body.

3. The apparatus of claim **1** wherein said means for monitoring the frequency of oscillation of said fluid body includes means for generating an electrical signal indicative of the pressure of said fluid body, and means for indicating the value of said electrical signal.

4. The apparatus of claim **3** wherein the frequency of said generated electrical signal is indicative of the pressure of said fluid body and wherein said indicating means includes a frequency discriminator and a recorder.

5. The apparatus of claim **1** wherein said condition responsive means for varying the solidity of a portion of the structure confining said fluid body comprises:

a pressure vessel having a valved aperture in the lower extremity thereof, said pressure vessel being partially filled with a compressible fluid, and

an actuator for said valved aperture, the position of said actuator being responsive to the condition to be monitored.

6. Well condition monitoring apparatus comprising:

means for establishing an incompressible fluid body at least partially within a well bore,

means for initiating pressure fluctuations in said fluid body at the natural frequency of said fluid body,

means for detecting the natural frequency of said fluid body,

a container partially filled with a compressible fluid and partially filled with an incompressible fluid, and

condition responsive means for varying the degree of communication between said fluid body and the interior of said container.

7. The apparatus of claim **6** wherein said container is a pressure vessel mounted within the well bore, said pressure vessel having an aperture in the lower extremity thereof and

wherein said condition responsive means includes a valve in the aperture of said pressure vessel and a condition responsive actuator for said valve, the position of said actuator being responsive to the condition to be monitored.

8. A method of monitoring conditions in a well bore comprising the steps of:

a. providing a substantially incompressible fluid body at least partially in a well bore;

b. oscillating said fluid body at its natural frequency;

c. varying the natural frequency of the fluid body by varying the solidity of a portion of the structure confining the fluid body in response to the condition to be monitored, and

d. detecting the frequency of oscillation of the fluid body.

9. The method of claim **8** wherein the solidity of a portion of the structure confining said fluid body is varied by varying the degree of fluid communication between said fluid body and a container partially filled with a compressible fluid.

10. A method of monitoring conditions in a well bore comprising the steps of:

a. providing a fluid body at least partially in a well bore,

b. oscillating said fluid body at its natural frequency,

c. varying the solidity of a portion of the structure confining said fluid body to vary the natural frequency of said fluid body in response to the condition to be monitored, and

d. detecting the frequency of oscillation of the fluid body.

11. The method of claim **10** wherein the solidity of a portion of the structure confining said fluid body is varied by varying the degree of fluid communication between said fluid body and a container partially filled with a compressible fluid.

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