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METHODS FOR DETERMINING THE MOVABILITY OF CONDUITS

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Fig. 1

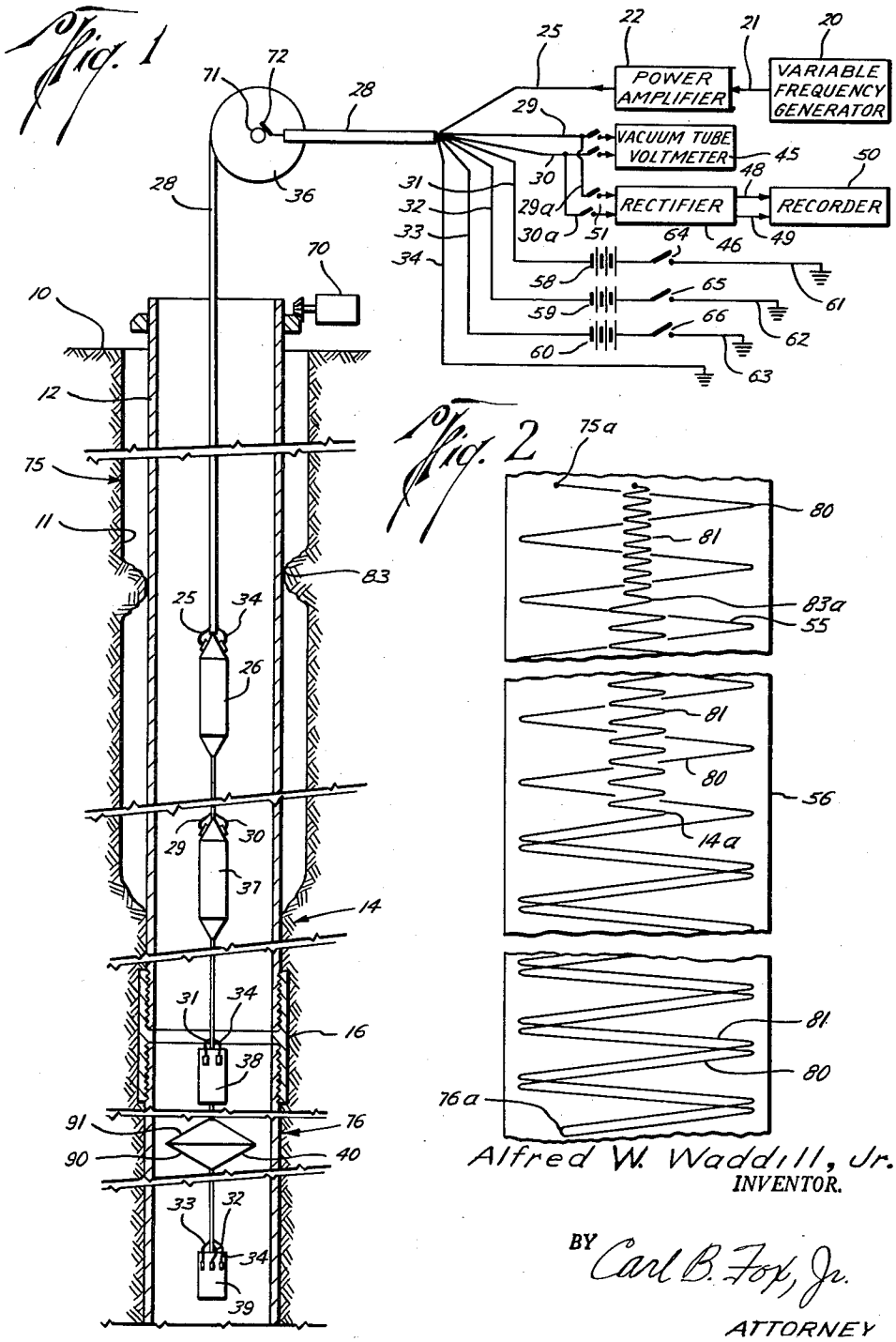


Fig. 2

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METHODS FOR DETERMINING THE MOVABILITY OF CONDUITS

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This invention relates to methods for determining points at which a conduit is stuck below the surface of the ground. More particularly, the invention relates to methods for determining at which portions of its length a well pipe, such as a drill pipe or a well tubing or casing, is stuck in a well hole at a distance below the earth's surface. The invention also includes determinations of the degree to which the well pipe is stuck.

A principal object of the invention is to provide methods for determining where a conduit is stuck or wedged at its passage through a confining opening.

Another principal object of the invention is to provide methods for determining where a well pipe, such as a drill string, tubing string, or casing string, is stuck or wedged in a well hole.

Another object of the invention is to provide such methods which are accurate and may be applied in a minimum amount of time.

Another object of the invention is to provide such methods which are simple and economical, and yet which are dependable.

Still another object of the invention is to provide such methods which also provide for disconnection of a joint of the well pipe at or near a stuck point thereof.

A further object of the invention is to provide methods which will determine to what degree a well pipe is stuck at any point along its length.

Another object of the invention is to provide such methods which can continuously determine the stuck or unstuck condition of a pipe in a well progressively along the length of the pipe.

During the drilling, completion, operation or workover of a well, it sometimes happens that a well pipe becomes stuck in the hole so that it cannot be moved, whereupon it becomes necessary to discontinue the work until such time as the stuck pipe has been freed or removed. The amount of force which can be put on a well pipe is, of course, limited by the strength of the pipe and the couplings or joints thereof. Therefore, a well pipe may be considered to be completely stuck when it cannot be moved from the surface without breaking or unduly straining it. The sticking of well pipes is usually caused by caving in or sluffing off of the sides of the well hole so that the pipe becomes surrounded by earth material which is more or less firmly compacted.

In freeing or removing stuck well pipes, it has been the practice to first locate the point along its length at which the pipe is stuck by some form of strain gage device which can determine deformation of the pipe between the surface and the subsurface point at which the pipe is stuck when a deforming force is applied to the pipe at the surface. In using such devices, it is necessary to deform and relax the pipe for each determination along a section of the pipe where the stuck point is believed to occur. Thus, a plurality of determinations, each involving a deformation and a relaxation of the pipe, must be made before the exact stuck point of the pipe can be sufficiently established. The approximate location of the stuck point can usually be determined beforehand by stretching the free pipe above the stuck point and estimating the location of the stuck point from the physical pipe-stretching manifestations at the surface. After the stuck point has been

determined, the well pipe is then broken or uncoupled at a joint by application of impact force, as by setting off an explosive charge near the joint or by means of a jar. Since many pipe deformations must be made, the above practice is time-consuming and expensive, resulting in lengthy shut downs of operations.

According to the present invention, methods are provided whereby the stuck point determination may be made rapidly and accurately, thereby avoiding lengthy shut down periods when a well pipe becomes stuck and contributing greatly to the economy of operations. In applying the invention, a preliminary approximation of the stuck point is made according to the aforesaid pipe-stretching procedure. Then the stuck point is accurately determined by measuring the resonant characteristics of the pipe, stressed and unstressed, in the vicinity of the stuck point. The apparatus used in practicing the method consists of an emitter of mechanical vibrations and a receiver for said vibrations emanating from the pipe, the emitter and receiver being lowered together through the pipe in spaced relation. An impact device for disconnection of a pipe joint may be combined in the apparatus. According to the preferred form of the method, the apparatus is first lowered through the pipe to determine its resonant characteristics above and down past the stuck point, the pipe being either unstressed or stressed by a force applied at its upper end. Then, the apparatus is raised through the pipe in its other condition, stressed if the first pass was made with the pipe unstressed, unstressed if the first pass was made with the pipe stressed. The stuck point is determined by comparison of the resonant characteristics of the pipe, stressed and unstressed, at each point thereof in the vicinity of the stuck point. The resonance information can be conveniently recorded as superimposed curves for the upward and downward passes so that the stuck point or points can be determined by reference to distinctions between the curves.

Other objects and advantages of the invention will appear from the following description of the method in preferred embodiments, reference being made to the accompanying drawings, of which:

FIGURE 1 is a schematic representation showing the apparatus used in practicing the method, the figure being taken as a vertical section at the axis of a well; and,

FIGURE 2 is a chart showing the form of data of resonant characteristics of a well pipe obtainable by the method.

Referring now to the drawings in detail, and first to FIGURE 1, there is shown the earth's surface **10** downwardly through which is a well hole **11** extending to a point beneath the earth's surface. A well pipe **12** is in the well hole, freely disposed therein as represented above a point **14** of the well hole, and closely confined therein below point **14**.

Point **14** is herein called the stuck point of well hole **11**. Above point **14** the pipe **12** is free and capable of being moved from the surface. Below point **14** pipe **12** is not free and is stuck, the sides of the well hole being in contact with the pipe as when, for example, the sides of the well hole have caved in against the pipe.

Pipe **12** is made up of separate sections of pipe joined end-to-end by threaded couplings **16**, for example. The form of the joints is variable, as will be known to those skilled in the art, but almost without exception, well pipe joints comprise some form of screwed-together coupling.

A variable frequency generator **20** usually located near the upper end of the well delivers alternating current to lead **21**. Generator **20** preferably is a variable frequency generator so that the frequency of the current may be varied, but may be a constant frequency generator (oscillator) if desired. The frequency employed is not critical, and any suitable type of generator may be employed.

The alternating current is delivered by lead 21 to a power amplifier 22, which increases the amplitude (power) of the alternating current. The power to which the current is amplified is not critical so long as the signal is sufficient to be received and measured as will be described. Any suitable type of amplifier may be employed, or, should the signal of generator 20 be of sufficient magnitude, the amplifier may be omited.

A wire 25 supplies the amplified alternating current from amplifier 22 to a sending or transmitting transducer 26. It will be noted from the drawing that wire 25 comprises an element of a multiple wire cable 28. This is the preferred arrangement, but wire 25 and the other elements of cable 28 may be separate if desired.

Cable 28, besides wire 25, includes also wires 29–34, the functions of each of which will be described. Cable 28 is wound on a reel means 36 capable of holding a sufficient length of cable for extending same into pipe 12 in well hole 11 to the desired range of depths. At its lower end, cable 28 carries sending transducer 26, already mentioned, receiving transducer 37, and one or more impacting devices 38, 39. These elements may be spaced along the lower portion of cable 28 as desired or necessary. Transducers 26, 37 may be spaced closely, for example about three feet apart, and this spacing may be made less or greater as desired. Usually the spacing between transducer 37 and impacting device 38 will be sufficient to avoid damage to transducer 37 when impacting device 38, which may be an explosive charge device, is operated. Similarly, the spacing between impacting devices 38, 39 should be sufficient to avoid damage to the upper impacting device when the lower impacting device is operated. A baffle element 40 is carried on cable 28 between the two impacting devices to minimize the effect on the upper impacting device of operation of the lower impacting device whereby the spacing therebetween may be decreased. The arrangement of the elements on the lower end of cable 28 is subject to modification, as will be apparent.

Receiving transducer 37 is connected by wires 29, 30 of cable 28 to means for converting the signal supplied by receiving transducer to a form to be read or recorded, for example to a vacuum tube voltmeter 45 on which the amplitude of the oscillatory voltage of the signal from transducer 37 may be read. A switch may be provided for disconnection of voltmeter 45 from wires 29, 30 if desired.

Wires 29, 30 are connected with branch wires 29*a*, 30*a*, respectively, which lead to a rectifier 46 of any suitable type for converting the oscillatory or alternating current signal received through wires 29, 30 from transducer 37 to direct current. The direct current flows through leads 48, 49 to a recording device 50 which records according to the magnitude of the direct current. A switch 51 may be used to disconnect recorder 50.

Recorder 50 may be any device which will serve to record data as functions of the amplitude of current and time. For example, referring to FIGURE 2, recorder 50 may record the data as a sine curve 55 indicating current amplitude in lateral directions and time in vertical directions on FIGURE 2. A recording strip or tape 56 of recorder 50 receives the sine curve which is marked thereon by a stylus or pen (not shown) of recorder 50 as tape 56 is moved longitudinally (vertically in FIGURE 2).

The reading and recording devices 45, 50 may be any suitable devices which will sense the signal amplitude and relate it to time and make it available to be read or recorded, such as phase meters, frequency meters, or other means suitable for measuring variable electrical phenomena. It is not believed necessary to further describe devices 45, 50 or the other devices as they are well known in the art in their several forms.

Wires 31, 32, 33 of cable 28 are each connected at one end with a battery 58, 59, 60, respectively, each of which is connected at its opposite terminal with a ground wire 61, 62, 63, respectively. The ground wires 61, 62, 63 have

therein switches 64, 65, 66, respectively, for cutting off current production by the batteries. At their other ends, wires 31, 32 33 are each connected to an ignitor device of one of the impact devices 38, 39. In the arrangement shown in FIGURE 1, wire 31 is connected to an ignitor of impact device 38, and wires 32, 33 are each connected to one of dual ignitor devices of impact device 39. When any of the switches 64, 65, 66 is closed, the battery supplies electrical energy in the form of current through the connecting wire to one of the ignitors, thereby actuating it.

The impact means 38, 39 each comprises a charge of an explosive material such as "Prima Cord" which will be caused to explode when its, or one of its, ignitors is actuated. The ignitors may be detonating caps.

Completing the electrical circuits of transducer 26 and impact means 38, 39, ground wire 34 is connected to each of these so that current can pass through each from generator 20 and batteries 58–60.

Transducer 26 is a means for converting electrical energy impulses from variable frequency generator 20 and amplifier 22 into mechanical vibrations (sound) which impinges on the interior of pipe 12 near transducer 26 setting up vibrations in the pipe wall which depend on the resonant characteristics of the pipe wall. Transducer 37 is a means for receiving vibrations from the pipe wall and converts them into electrical impulses which are transmitted by wires 29, 30 to voltmeter 45 and/or recorder 50, or the like. The transducers may be microphones.

One method of determining the stuck point of a pipe in a well hole according to the invention is to first lower cable 28 into pipe 12 with pipe 12 in a relaxed condition and having no torque or other stress applied thereto, and then to raise cable 28 over the same part of the pipe at about the same rate of speed, pipe 12 then having a torque or other stress applied thereto by a stress-applying means represented symbolically by reference numeral 70, FIGURE 1.

Explaining this method in greater detail, the operator first estimates the approximate location down the hole at which pipe 12 is stuck by the pipe-stretching procedure mentioned earlier. This step is conventional, and need not be further described.

After the approximate location of the stuck point, point 14, is known, cable 28 carrying transducers 26, 37, impact means 38, 39 and baffle member 40, is lowered to that part of the pipe by appropriate rotation of reel 36 on its shaft 71. The wires of cable 28 are connected past reel 28 by some form of slip ring or other connecting means represented by reference numeral 72 so that cable 28 can be lowered and raised by appropriate rotation of the reel. The cable connections at the reel are conventional and well known in the art.

Assume, for example, that the stuck point is estimated to be somewhere between points 75 and 76 of well hole 11. Transducers 26, 37, spaced about three feet apart along cable 28, are first brought to near point 75, stress-applying means 70 not being operated and the pipe having no stress applied thereto at its upper end, and therefore relaxed. Cable 28 is lowered at constant rate to move transducers 26, 37 freely through the interior of pipe 12 to point 76. Power is applied to transducer 26 by generator 20 and amplifier 22 so that transducer 26 emits mechanical vibrations continuously as it is lowered, the vibration amplitude being constant. Transducer 37 received the vibrations caused in pipe 12 by transducer 26 and conveys impulses through wires 29, 30 to rectifier 46 and recorder 50. The uniform part 80 of sine curve 55 is drawn on moving tape 56, progressing from point 75*a* thereof to point 76*a* thereof as the transducers are lowered from point 75 to point 76 in the well.

Then device 70 is operated to put a stress on the upper end of pipe 12, which may be an azimuthal torque, a downward compression, or an upward stretching of the pipe, or any combination. Cable 28 is then raised to move

the transducers from point 76 to point 75, motion of tape 56 having been reversed in direction and the reverse speed of the tape being about equal to its speed in the first direction. Recorder 50 now records on tape 56 part 81 of sine curve 55 superimposed on its part 80.

Because the resonance of pipe 12 has been altered by the stress applied thereto, part 81 changes in form at point 14*a* thereof, the amplitude of the signal received by recorder 50 being reduced or increased so that the amplitude of curve 55 is reduced or increased correspondingly.

In the portion of well hole 11 below point 14 thereof, the sides of the well hole are against the outside of pipe 12, and pipe 12 is completely stuck so that it is immovable. Above point 14, pipe 12 is free to a point 83, which represents an area where pipe 12 is not completely stuck but is not completely free. Point 83 indicates a partially stuck point of pipe 12.

As the transducers are moved upwardly beyond point 14 past point 83, a further change in curve 55 indicated by reference numeral 83*a* is shown. Point 83*a* indicates a further increase or reduction in amplitude of the signal.

The variations in the curve 55 are caused by changes in the resonant characteristics of pipe 12 due to its stuck, partially stuck, or free condition at different points along its length. A stress applied to the upper end of pipe 12 does not change its resonant characteristics at point 14 or therebelow because of the immovable stuck condition of that part of the pipe. Between points 83 and 14, the pipe is partially free, so that a stress changes its resonant characteristics substantially but not to the degree that they would be changed were partial stuck point 83 absent. Above point 83, the pipe is entirely free so that its resonant characteristics are changed to the fullest degree.

The showing on tape 56 is such that decreasing amplitude (lessening in lateral width) of curve 55 represents an increase in the change of resonant characteristcs, so that the amplitude is decreased further with additional pipe freedom.

There are changes in resonant characteristics of a well pipe which occur as functions of the depth below the earth's surface, and thereby affect the form of curve 55. In FIGURE 2, curve 55 is shown only for a portion of the well so that the depth changes can be ignored.

Alternatively to the preferred method described above, the method may comprise the taking of reading at separate spaced points of pipe 12, the pipe being relaxed and stressed at each point to obtain the reading for that point. This is the procedure heretofore followed by others, but the continuous superimposed curve method is preferred since it requires much less time to determine the stuck point than is required by the many pipe stressing and relaxing steps necessary with the conventional method.

After the stuck point 14 has been located, the cable 28 is withdrawn from the well until lower impact device 39 is adjacent a coupling, such as coupling 16, which is fairly near the stuck point. Either of the ignitors of impact means 39 is then actuated by closing either of the switches 65, 66 to explode the explosive charge thereof, with the pipe being twisted at the top in a coupling unscrewing direction. The explosion then initiates unthreading and disconnection of joint 16 so that the upper part of the pipe may be removed from the well.

Should the first ignitor fail to function, or should the first ignitor function properly and yet fail to set off the explosion, another attempt may be made by means of the second ignitor of impact device 39. Should explosion of impact device 39 fail to loosen coupling 16, cable 28 can be lowered to bring impact device 38 adjacent coupling 16, and then, with the pipe under uncoupling torque, switch 64 may be closed to set off the explosive charge of impact device 38. Thus, a plurality of impacts may be imposed to open the coupling and there is no necessity for withdrawing the equipment and reinserting a fresh charge therebetween.

The baffle device 40 disposed between impact devices 38, 39 has conical lower surface 90 which deflects shock waves from explosion of impact device 39 toward the pipe wall so that the shock waves are prevented from reaching impact device 38, and has conical upper surface 91 which disperses shocks transmitted to the baffle and prevents them from being passed to impact device 38 thereabove. The conical surfaces will act in the same way to prevent explosion of impact device 39 should impact device 38 be intentionally or inadvertently set off first. Spacing between the impact devices is, of course, provided for safety considerations, and use of baffle 40 permits the safe spacing to be decreased.

Any suitable geometric design which will sufficiently dampen the shock waves between the individual impacting means to prevent unintentional firing may be used, the device shown as 90 in FIGURE 1 being only one of the many possible designs. These baffles may be placed between the impacting means and the instrument to prevent damage thereto. The described resonance changes in the pipe 12 are caused by molecular deformation of the material of the pipe. Any stuck condition along the length of the pipe will partially or totally prevent the stress applied at the upper end of the pipe from affecting the molecular structure of the pipe therebelow. A partial stuck point prevents full molecular deformation of the pipe as a result of the stress therebelow, while a complete stuck point prevents any molecular deformation therebelow. The pipe resonance is affected accordingly.

While preferred embodiments of the methods according to the invention have been shown and described, many modifications thereof may be made by a person skilled in the art without departing from the spirit of the invention, and it is intended to protect by Letters Patent all forms of the invention falling within the scope of the following claims.

I claim:

1. A method for determining where pipe in a well is stuck comprising recording the resonant characteristics of the pipe along a portion of its length encompassing the stuck point, altering the stress on the pipe and again recording the resonant characteristics of the pipe along said portion, and superimposing the said recordings whereby the same may be compared to determine the stuck point.

2. A method for determining where a pipe is stuck, said method comprising

recording the resonant characteristics of the pipe at a plurality of points along its length encompassing the stuck point,

altering the stress on the pipe and re-recording the resonant characteristics of the pipe at said points, and

superimposing the recordings of the resonant characteristics of the pipe before and after said alteration of stress thereon whereby the stuck point may be determined.

3. Method for determining at which points along its length a pipe is stuck, comprising making recordings of the resonant characteristics of the pipe along its length in differing conditions of stress of the pipe, and

superimposing a first recording on a subsequent recording which is made upon different conditions of stress of the pipe than when the first recording was made.

4. A method for determining at which points along its length a pipe is stuck, comprising the steps of vertically moving a vibration emitting means and a vibration detecting means together freely through the pipe to detect and record resonant vibrations of the pipe caused by said vibration emitting means with said vibration detecting means over a length of the pipe, changing the stress condition of the pipe to change its resonant characteristics where it is not stuck, again vertically moving

said vibration emitting means and said vibration detecting means together freely through said length of the pipe to detect and record the changed resonant characteristics, and superimposing the recorded data for comparison so that the stuck points may be ascertained.

5. A method for determining the point that a pipe in a well is stuck along its length, said method comprising the steps of vertically moving a vibration emitting means and a vibration detecting means together freely through the pipe to detect and record resonant vibrations of the pipe caused by said vibration emiting means with said vibration detecting means over a length of the pipe including the stuck point, changing the stress condition of the pipe to change its resonant characteristics where it is not stuck, again vertically moving said vibration emitting means and said vibration detecting means together freely through said length of the pipe to detect and record the changed resonant characteristics, and superimposing the recorded data for comparison so that the stuck point may be ascertained.

6. A method for determining the point that a pipe in a well is stuck along its length, said method comprising the steps of vertically moving a vibration emitting means and a vibration detecting means together freely in one vertical direction through the pipe to detect and record resonant vibrations of the pipe caused by said vibration emitting means with said vibration detecting means over a length of the pipe including the stuck point, changing the stress condition of the pipe to change its resonant characteristics where it is not stuck, vertically moving said vibration emitting means and said vibration detecting means together freely in the opposite vertical direction through said length of the pipe to detect and record the changed resonant characteristics, and superimposing the recorded data for comparison so that the stuck point may be ascertained.

7. A method for determining at which points along its length a pipe in a well is stuck, comprising the steps of vertically moving a vibration emiting means and a vibration detecting means together freely in one vertical direction through a length of the pipe while resonance detections are transmitted to the surface and recorded continuously, changing the stress condition of the pipe to change its resonant characteristics where it is not stuck, vertically moving said vibration emitting means and said vibration detecting means together freely in the opposite vertical direction through said length of pipe while resonance detections are transmitted to the surface and recorded continuously on a second recording which is superimposed on the first recording, and directly comparing said recordings to ascertain stuck points of the pipe.

8. A method for determining stuck points of pipe comprising the steps of continuously moving vibration emitting means and vibration detecting means through a portion of the pipe to detect and record resonant vibrations of the pipe caused by said vibration emitting means with said vibration detecting means, changing the stress condition of the pipe thereby changing its resonant characteristics where the pipe is not stuck, again continuously moving said vibration emitting means and said vibration detecting means through the same portion of pipe to detect and record the changed resonant characteristics and superimposing the recorded data for comparison whereby the stuck points may be ascertained.

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