

May 4, 1954

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2,677,272

STRESS INDICATING APPARATUS

Original Filed Jan. 23, 1950

2 Sheets-Sheet 1

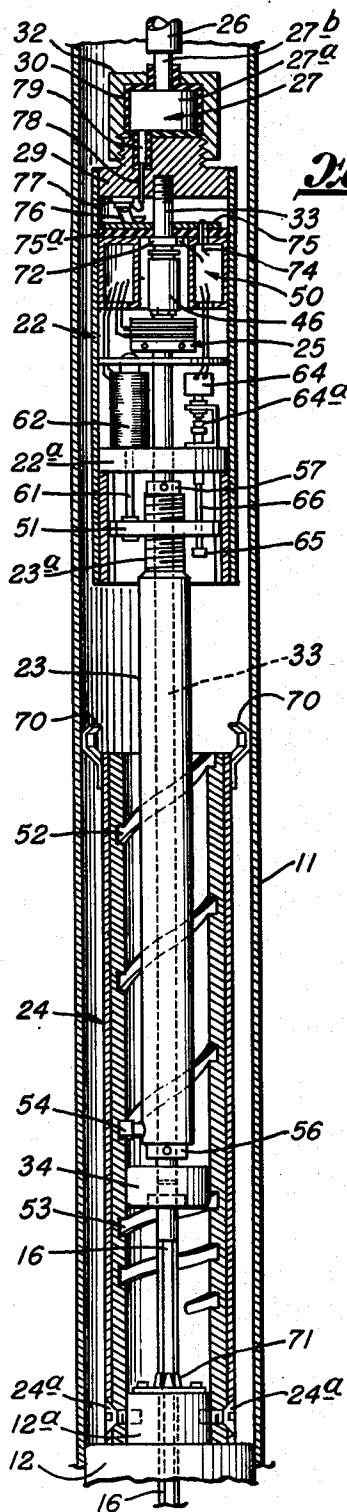


Fig. 2

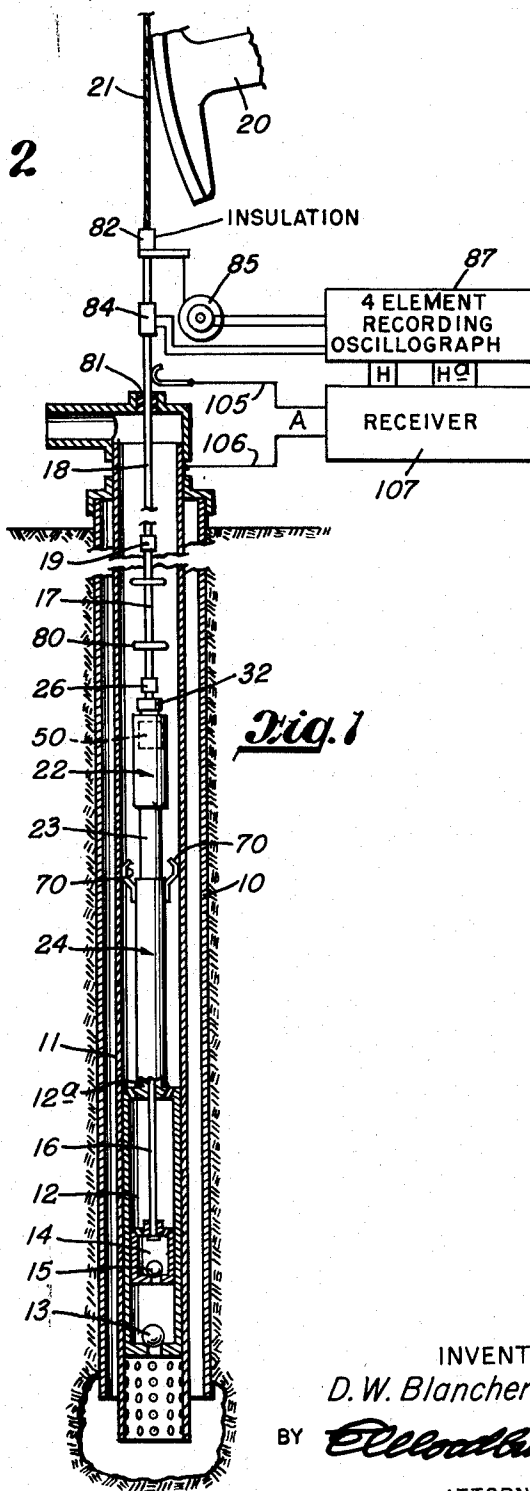


Fig. 1

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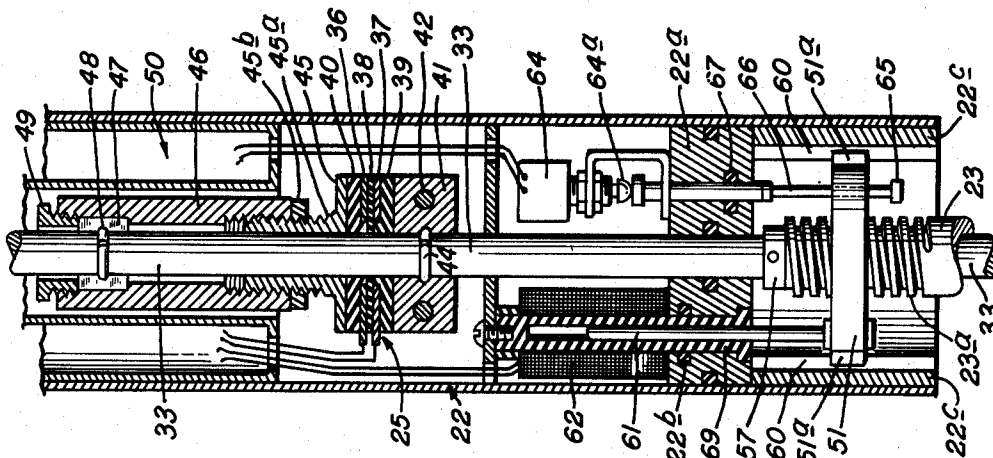
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,677,272

STRESS INDICATING APPARATUS

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Original application January 23, 1950, Serial No. 140,128. Divided and this application March 19, 1951, Serial No. 216,430

2 Claims. (Cl. 73-88.5)

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This invention relates broadly to the art of telemetering and specifically, in part, to the telemetering up a well bore of data on the operating characteristics of a pump in the well, particularly data on the stress in and the motion of the pump rod at the pump.

Pumps in deep wells, usually oil wells, are commonly reciprocated by a sucker rod extending up through the well to a pumping jack at the surface. In deep wells the long sucker rod has considerable stretch and distributed inertia. Because of this, its motion at the pump end may be radically different from that imparted to it at the upper end, and may be quite unpredictable, particularly at high pumping speeds. It is desirable to be able to ascertain just what stresses and motion are induced at the lower end of the sucker rod and their relation to the stresses and motion at the upper end.

A general object of the invention is to provide a practicable and accurate system for continuously telemetering operating data from the bottom of a well to the surface.

Another object is to provide a simple and effective apparatus for translating the stress applied to a pump plunger in a well into an electrical value that can be transmitted to the surface.

Other more specific objects and features of the invention will become apparent from the description to follow.

This is a division of my application Serial No. 140,128 filed January 23, 1950 for Telemetering System for Wells, now Patent 2,596,361, to which reference is made.

Broadly, in accordance with the invention, the stress in and motion of a pump rod in a well are translated into electrical values which are transmitted up the well to the surface and there converted into readings, the time delay between subsurface and surface data being negligible.

More specifically, a first carrier wave is generated in the well and frequency modulated in accordance with the stroke of the pump, and a second carrier wave is generated in the well and frequency modulated in accordance with the stresses developed in the pump rod. These two frequency modulated carrier waves are transmitted to the surface over a coaxial line consisting of a pair of existing elements in the well, such as the production tube and the sucker rod therewithin, or the well casing and the production tubing therewithin. The inner of whatever pair of elements is used is insulated from the outer element by insulating spacers distributed therealong.

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At the surface, the two carrier waves are separated by two filter circuits, and separately detected to produce direct currents of magnitude varying in accordance with the frequency modulations but independent of any variation in amplitude resulting from attenuation during transmission. These direct currents are preferably fed into a recording oscillograph. It is desirable to simultaneously record along with subsurface data the stresses and motion at the surface end of the sucker rod, but since equipment for doing this is in existence and does not require the use of the present invention, it will not be described in detail.

A complete understanding of the invention may be had from the following detailed description, with reference to the drawings, in which:

Fig. 1 is a schematic diagram showing the general arrangement of apparatus in a system in accordance with the invention;

Fig. 2 is a vertical sectional view showing the portion of the apparatus of the invention that is located in the well;

Fig. 3 is a vertical sectional view showing a portion of the apparatus of Fig. 2 drawn to larger scale; and

Fig. 4 is a schematic circuit diagram of the transmitter of the system.

Referring first to Fig. 1, there is shown a well having the usual well casing 10 extending from the surface to the bottom thereof. Positioned within the well casing 10 is the usual production tubing 11 having the usual pump barrel 12 at the lower end thereof. The pump barrel 12 contains the usual standing valve 13 and a plunger 14 containing the usual traveling valve 15. The plunger 14 is actuated by the usual pump rod 16 which is connected by a strain rod 33 (Fig. 2) to the usual sucker rod 17 that extends up through the production tubing to the surface and is connected at its upper end (within the production tubing) by a coupling 19 to the usual polished rod 18 which extends through a packing joint in the well head to any desired reciprocating mechanism, which in this instance is shown as a pumping beam 20, the polished rod being shown connected to the beam by a cable 21.

With the exception of the strain rod 33, the apparatus so far described is in accordance with the usual practice. The present invention resides in the addition to the usual apparatus of equipment responsive to the motion and stresses at the pump rod to produce frequency modulation of alternating currents, and transmit them to the surface where they are detected in a re-

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ceiver 107 and recorded by an oscillograph 87.

The apparatus in the well is, in part, contained in a fluid-tight housing 22 and comprises additional elements including a torque tube 23 and a helix tube 24 positioned below the housing 22 and above the pump barrel 12, the helix tube 24 being mounted on the pump barrel 12. For reasons which will appear later, the pump rod 16 must not rotate with respect to the pump barrel 12 and the helix tube 24, and for that reason it is preferably of non-circular cross section (hexagonal as shown in the drawing, Fig. 2) and passes through a similar non-circular opening in the upper end of the pump barrel.

As previously indicated, the readings to be transmitted to the surface are the stroke and the stress at the pump rod 16. The stress is measured by means of a condenser 25 (Figs. 2 and 3) the capacitance of which varies with stretch in a short section of the strain rod 33. The way in which this condenser 25 is mechanically inserted in the system will now be described with reference to Figs. 1, 2 and 3.

Referring first to Fig. 1, as there shown, the lower end of the sucker rod 17 is connected by a screw coupling 26 to a coupling member 27 (Fig. 2) which consists of a head 27a on the lower end of a stem 27b, the upper end of which stem is threaded into the coupling 26. The head 27a is secured to the upper end member 29 of the housing 22. The sucker rod is used in combination with the production tubing as a coaxial electrical transmission line, and is electrically insulated from the housing 22. To this end, the head 27a and lower portion of the stem 27b are enclosed with insulating material 30, such as fibre glass, to electrically insulate it from the housing top 29. The head 27a is secured to the housing top 29 by a screw cap 32 which is threaded onto the top 29. In this way the insulating material 30 has only to resist compressive forces.

The housing top 29 has threaded into its lower end the upper end of the strain rod 33 which extends down through the housing 22, and through the torque tube 23, and is secured to the upper end of the pump rod 16 by a coupling 34 which also functions as a centering device for centering the strain rod with respect to the helix tube 24.

Referring now to Fig. 3, the condenser 25 consists of a pair of plates 36 and 37 of flat annular shape which are separated from each other by a resilient dielectric member 38 which is positioned therebetween. The condenser plates 36 and 37 are pressed together by a pair of insulating blocks 39 and 40 positioned on opposite sides thereof and having central apertures slideably fitting the strain rod 33. The lower insulating block 39 rests on a clamp 41 that is rigidly clamped as by bolts 42 to the strain rod 33. The clamp may have an annular groove in its inner periphery engaging a snap ring 44 which is also engaged in an annular groove in the outer surface of the strain rod 33, the object being to fix the clamp rod 41 to the strain rod for movement therewith. Resting on the top of the upper insulating block 40 is a pressure plate 45 which has an upwardly extending, externally threaded, neck 45a which is screwed into the lower end of a sleeve 46. The upper end of this sleeve is locked to the strain rod by a split clamp 47 and a snap ring 48 which engages grooves in the strain rod and split clamp respectively. The split clamp 47 is fitted in a counterbore in the upper end of the sleeve 46 and is locked in place by a lock nut 49, to force the

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sleeve 46 to move with the strain rod. The construction described causes the insulating blocks 39 and 40 to move apart, in response to elongation of the strain rod 33, thereby permitting the resilient dielectric 38 to separate the condenser plates 36 and 37, and forces the plates together, compressing the dielectric 38, when the strain rod contracts. The condenser 25 constitutes one of the frequency determining elements of an oscillating circuit of an electronic unit, which will be described later.

In addition to performing the mechanical function of causing the plates 36 and 37 to follow the movements of the blocks 39 and 40, the resilient dielectric 38 performs the important function of increasing the capacity between the plates 36 and 37. Suitable rubber-like materials having a dielectric constant of about 5 are available for this use.

For convenience in illustration, in Fig. 2 the electronic unit is indicated as located within an annular container 50 within the housing 22, and the leads from the condenser 25 are shown entering this container. Actually, the elements of the electronic unit are physically distributed within the housing 22 because of the limited space therewithin.

The resilient dielectric 38 of the condenser 25 is preloaded to a desired value so that under the greatest elongation of the strain rod 33, the dielectric 38 will still have an expansive force to separate the condenser plates. This preloading adjustment is made by loosening a lock nut 45b on the stem 45a and rotating the pressure plate 45 with respect to the sleeve 46 until the desired pressure is obtained, after which the lock nut 45b is tightened.

The stroke-measuring portion of the apparatus will next be described. The stroke of an oil well pump is relatively great, varying from 3 feet to 20 feet, and it is desirable to apply a shorter movement to the electrical pick-up unit which effects the modulation of the electric current. This stroke reduction is effected by means of the helix tube 24 and the torque tube 23 in conjunction with a traveller 51 which is threaded on the upper end of the torque tube 23. As clearly shown in Fig. 2, the helix tube 24 is secured as by screws 24a to a neck 12a on the upper end of the pump barrel, and extends upwardly therefrom. The helix tube 24 contains a continuous helical groove formed in two sections 52 and 53. The two sections are of different pitch, the upper section 52 being of relatively high pitch whereas the bottom section 53 is of much lower pitch. The torque tube 23 which extends down into the helix tube 24 has a cam follower 54, in the form of a roller, which extends radially therefrom into the helical groove. The torque tube 23 is supported on the strain rod 33 for vertical movement therewith but for free rotation therearound. To this end, it is shown secured between two thrust collars 56 and 57 which are locked to the strain rod in any desired manner. As the strain rod 33 is reciprocated, the cam follower 54 and the helical groove into which it extends force rotation of the torque tube. When the cam follower 54 is in the upper section 52 of the helical groove, the rotation of the torque tube in response to vertical movement of the strain rod is relatively small, whereas it is much more rapid during movement of the cam follower 54 through the groove 53 of lower pitch. The purpose of this will be described later.

The rotation of the torque tube 23 in response

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to vertical movement of the strain rod produces a lesser vertical movement of the traveller 51, because the threads 23a on the torque tube 23 and the cooperating threads on the traveller 51 are of very low pitch as compared to that of the grooves 52 and 53. The traveller 51 is restrained from rotation by tongues 51a thereon which register with vertical grooves 60 in a downwardly extending skirt 22c on the housing 22.

The traveller 51 actuates the core or plunger 61 of a variable inductance element 62, and also a rod 66 that actuates a switch 64 for energizing and de-energizing the electronic unit.

The plunger 61 is fixed rigidly to the traveller 51 so that it is always moved thereby. However, the inductance element 62 is only utilized during that portion of the stroke of the strain rod corresponding to movement of the cam 54 in the high pitch groove 52. The switch 64, on the other hand, is intended to be actuated only in response to movement of the strain rod near its lower limit and below the normal lower limit of the stroke during a pumping operation. It is to insure sufficient movement of the traveller 51 to engage the head 65 on the lower end of the switch-actuating rod 66 in response to a relatively limited movement of the strain rod below the lowermost pumping stroke limit that the low pitch groove 53 is employed. This causes a relatively large downward movement of the traveller 51 after the cam 54 gets into the low pitch groove 53.

The push rod 66 for actuating the switch 64 extends through the end wall 22a of the housing 22 with a seal fit, the seal being indicated at 67 in Fig. 3, since the interior of the housing 22 is maintained at atmospheric pressure and must be maintained dry because of the equipment it contains. The plunger 61 associated with the inductance element 62 is surrounded by a closed-top sleeve 69 of non-magnetic material which extends into the inductance element 62 and is fluid tight. Where this sleeve 69 extends through the lower end wall 22a of the housing 22 it is sealed with a conventional seal 22b. The sleeve 69 is preferably of non-magnetic non-conductive material, such as plastic, its sole purpose being to provide for free motion of the plunger 61 into and out of the inductance winding 62 while preventing entrance of pressure fluid into the housing 22.

The switch 64 is of a common type which opens in response to one actuation and closes in response to the next actuation. Downward movement of the traveller 51 sufficient to engage the head 65, withdraws the push rod 66 and permits the switch button 64a to move outwardly by virtue of a spring within the switch 64. On the next upward movement of the traveller 51, the push rod 66 is forced upwardly by the oil pressure in the production tubing 11 and the switch is reset, i. e. if it was in open position before, it is closed, and if it was in closed position before, it is opened. The result is that the apparatus can be lowered into the well with the switch in open position, and the switch then actuated by first lowering the sucker rod all the way until the cam 54 is in the lower end of the helical groove 53, and then lifting the sucker rod to carry the cam 54 upwardly through the cam section 53. In an actual apparatus in which the useful stroke of the pump is 10 feet, the distance travelled by the cam 54 while traversing the lower groove section 53 may be only 3 feet. However, because of the difference in pitch of the helical groove section 53 as compared to that of the groove section 52, the traveller 51 will move a sufficient

distance to insure positive actuation of the switch 64 despite the fact that the vertical movement of the strain rod 33 that is utilized to produce the switching action is relatively short as compared to the normal pumping stroke.

A plurality of brush elements 70 are preferably provided on the upper end of the helix tube 24 for bearing against the production tube 11 and insuring good electric contact therewith to complete the electrical return circuit from the electronic equipment, since the production tubing is used as one element of the coaxial line over which the electrical currents are transmitted to the surface. A wiper or brush 71 is also provided on the upper end of the neck 12a of the pump to bear against the pump rod 16 and insure good electrical contact therewith. The circuit from the electronic unit 50 to the production tubing 11 may be traced in Fig. 2 from the electronic unit 50 to the strain rod by means of a bonding clamp 72, down the strain rod through the coupling 34 to the pump rod 16, from the pump rod 16 through the wiper 71 to the pump head 12a, thence through the helix tube 24, which is directly secured to the pump neck, and thence through the brush 70 to the production tubing 11.

Connection from the electronic unit 50 to the sucker rod may be traced over a conductor 74 to a slip ring 75 supported on an insulating partition 75a, thence through a brush 76, which is insulated from the housing top 29 by an insulator 77, and thence over an insulated conductor 78 to a projection 79 on the head 27, which in turn is connected through the coupler 26 to the sucker rod.

The conductor 78 is in fluid sealing relation with the housing top 29 so as to prevent the entry of pressure fluid from the well into the housing 22.

Referring to Fig. 1, the sucker rod 17 which extends up through the well must be maintained in spaced relation with the production tube 11 to prevent it from being electrically "shorted" thereagain. To this end, spacing and insulating elements 80 of rubber or the like, are distributed along the sucker rod at sufficiently close intervals to insure against contact between the sucker rod and the production tubing.

At the well head, the polished rod 18, which constitutes a continuation of the sucker rod 17, passes through an insulating bushing 81 to maintain it insulated from the production tubing, and the upper end of the polished rod 18 is mechanically connected to the hanger cable 21 by an insulating connector 82.

In practice, it is highly desirable, in order to utilize the present invention to its fullest extent, to simultaneously record the stroke motion and stress in the sucker rod at the surface, so that these values can be compared with the stroke and stress at the bottom of the well. To this end, the polished rod 18 would ordinarily be equipped with a strain gauge 84 of any known design, and a stroke-measuring device 85 would be connected to the polished rod, the devices 84 and 85 being shown connected to the recording oscillograph 87 into which the readings from the bottom of the well are also fed, so that all four readings can be recorded simultaneously with respect to time.

As previously indicated, the stroke at the bottom of the well is converted into an electrical value by means of the variable inductance 62 having the movable plunger 61 moving in synchronism with and proportional to the pump

plunger. This causes the inductance of the element 62 to vary in accordance with the movement of the pump rod. It has also been pointed out that the stress applied to the pump rod in the well is measured by the variations in capacity of the condenser 25 shown in Fig. 3, the capacity varying in accordance with the stretch of the strain rod 33 between the rings 44 and 48.

Referring now to Fig. 4, which indicates schematically the circuit of the electronic equipment located in the well and previously identified with the container 50, the condenser 25 is shown connected to an inductance element 90 and forming therewith the frequency determining circuit of an oscillator tube 91. Stabilizing capacitors 92 and 93 are connected between the cathode and anode, and between the cathode and control grid of the tube 91 to stabilize its operation, and a blocking condenser 94 is connected between the cathode and the center tap of the inductance 90. The oscillator 91 oscillates continuously whenever it is energized by closure of the switch 64 to the filament energizing battery 95. The anode of tube 91 is coupled through a condenser 97 to the control grid of an amplifier tube 98, the anode of which is coupled by an output transformer 99 to the coaxial line consisting of the sucker rod and the production tubing for transmission to the surface.

The inductance element 62 having the movable core 61 constitutes, with a pair of condensers 100 and 101, the frequency controlling circuit of a second oscillator tube 102, the anode of which is coupled through a coupling condenser 103 with the grid of an amplifier tube 104, the anode of which is connected, in parallel with the anode of tube 98, to the output transformer 99.

I find it desirable in practice to so choose the constants of the circuit associated with the tube 91 that its normal oscillating frequency is about 50 kc. and so choose the constants of the frequency determining circuit of the tube 102 that its normal operating frequency is about 10 kc., these two frequencies being transmitted simultaneously up the well to the surface. The variations in capacity of the condenser 25 produced by variations in stress applied to the pump plunger produce a total frequency variation of about 2 kc. Likewise, the variations in the inductance of the inductance elements 52 produced by movement of the plunger 61 in response to the stroke movement of the pump plunger produce a frequency variation of about 2 kc.

At the surface, the two frequency-modulated waves transmitted over the coaxial line consisting of the sucker rod and production tubing are applied over conductors 105 and 106 to the receiver 107 where they are separately detected and applied to the recording oscillograph to produce

curves showing the stress in, and the stroke of, the pump rod.

The characteristic, or surge, impedance of a coaxial line consisting of the production tubing and sucker rod of a well, is about 50 ohms, and the output transformer 99 matches the relatively high impedance of the tubes 98 and 104 to the relatively low impedance of the line.

Although for the purpose of explaining the invention, a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art, and I do not desire to be limited to the exact details shown and described.

I claim:

1. Apparatus for measuring variations in strain in a rod comprising: a condenser having annular electrically conductive plates encompassing and normal to said rod and having a yieldable dielectric interposed between said plates, at least one of said annular plates being of larger internal diameter than said rod and spaced therefrom; a pair of pressure members on opposite sides of said plates for variably compressing said dielectric and thereby varying the capacity of the condenser; means for securing said respective pressure members rigidly to said rod at spaced points thereon; at least that pressure member adjacent said one plate comprising a rigid insulating element interposed between said one plate and said rod and electrically insulating them from each other; and means for indicating variations in capacity of said condenser, said yieldable dielectric having a high dielectric constant and having negligible resistance to compression relative to that of said rod.

2. Apparatus according to claim 1 including: means locking one of said pressure members directly to said rod for movement with the portion of the rod it encompasses, the other pressure member being slideable on said rod, and means mechanically connecting said other pressure member to said rod at a point longitudinally displaced from said first member a distance greater than the spacing between said members.

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