March 31, 1970 A. L. OWEN 3,503,444

ELECTRIC SETTING MECHANISM FOR SUBSURFACE WELL TOOLS

Filed Oct. 3, 1968 2 Sheets-Sheet 1

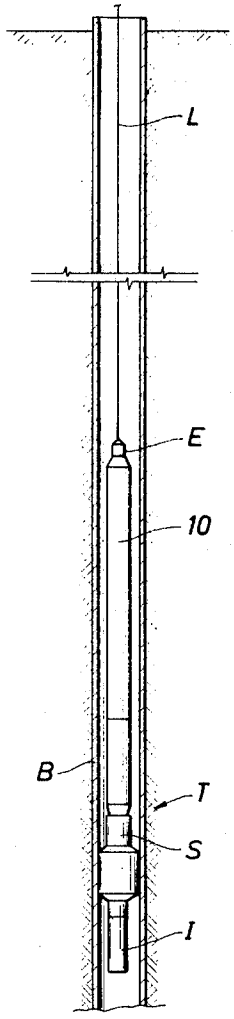


FIG. 1

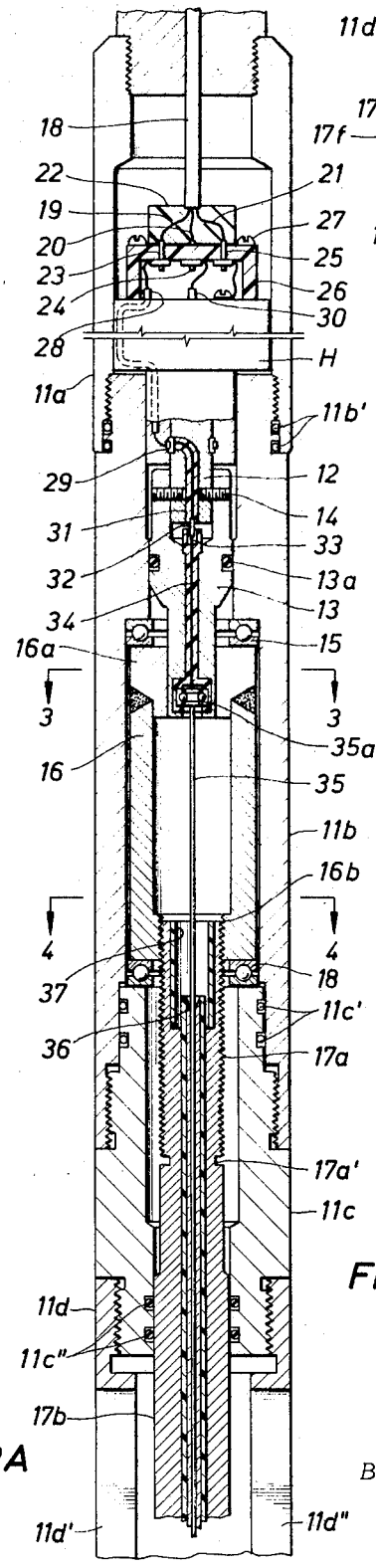


FIG. 2A

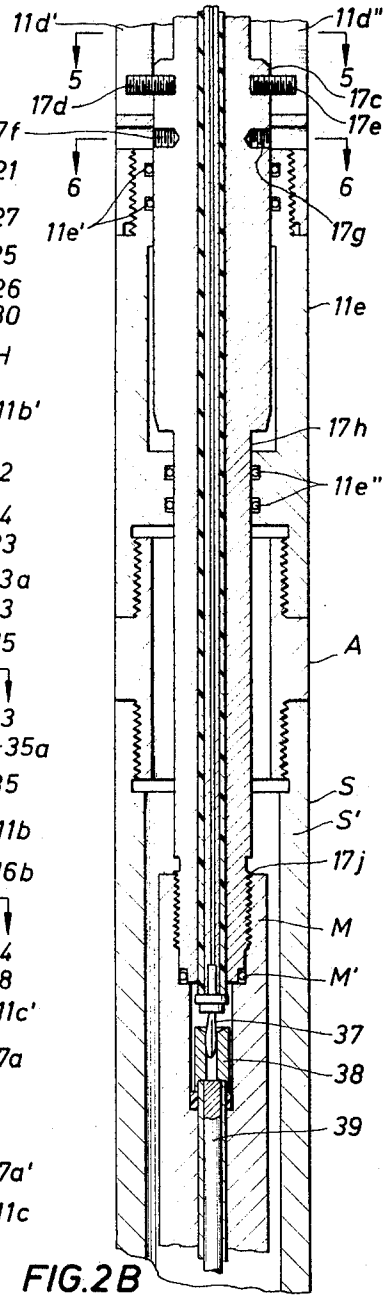


FIG. 2B

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ELECTRIC SETTING MECHANISM FOR SUBSURFACE WELL TOOLS

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FIG. 3

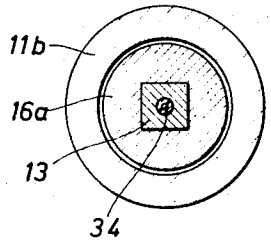


FIG. 4

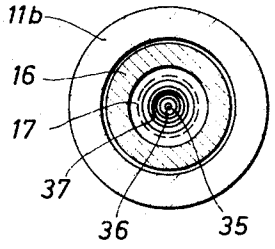


FIG. 5

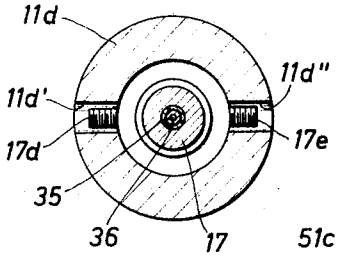


FIG. 6

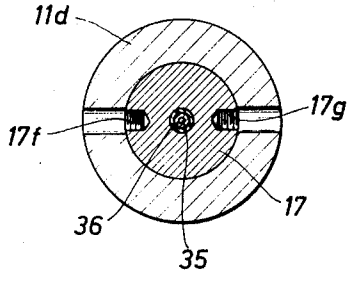


FIG. 7

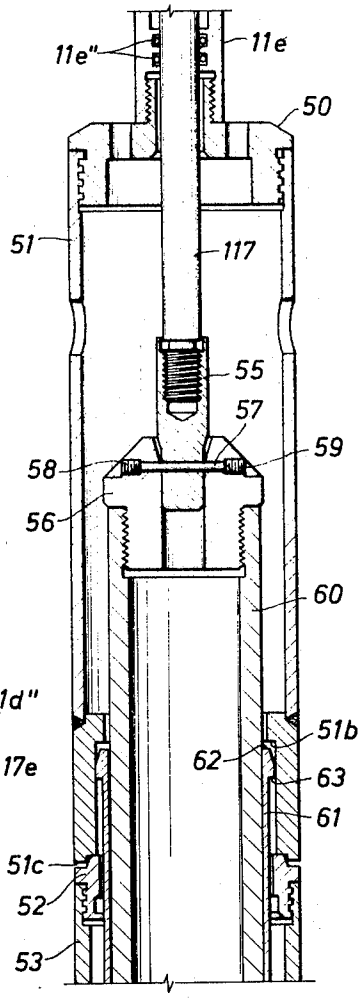
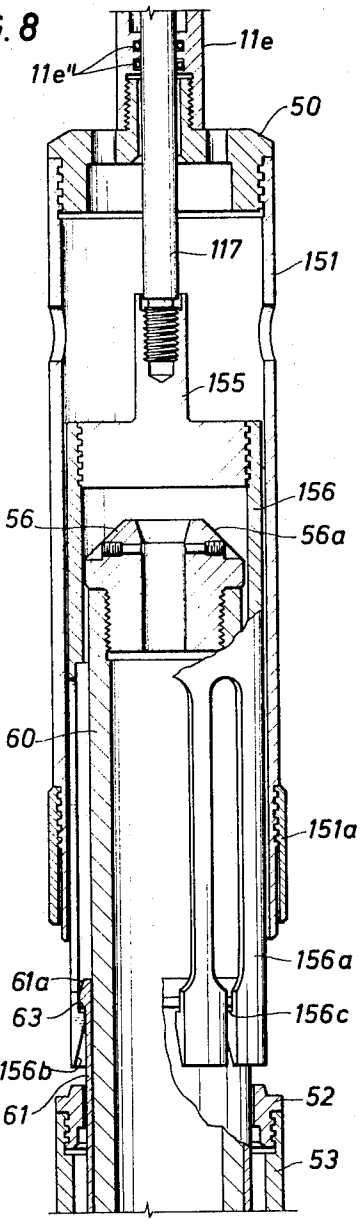


FIG. 8



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3,503,444

ELECTRIC SETTING MECHANISM FOR SUBSURFACE WELL TOOLS

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Int. Cl. E21b 43/00
U.S. Cl. 166—65 34 Claims

ABSTRACT OF THE DISCLOSURE

A reversible electric motor acting through a gear train retracts or extends an axial shaft assembly through a stationary sleeve to activate a retrieving or setting mechanism on a down-hole tool. The setting mechanism and attached tools are suspended in a well bore by an electrical wire line which supplies electrical conductors for controlling and driving the motor and for completing an electrical circuit with equipment carried below the setting mechanism. The moving shaft has a variable diameter to compensate for the differential effects of well presure and prevent the shaft from binding.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates generally to the field of well drilling, completion and production. More specifically, the present invention relates to an electric wire line setting tool for setting or retrieving down-hole equipment employed in the drilling, completion, testing and working of oil and gas wells.

Description of the prior art

Much of the equipment employed in oil and gas well operations must be lowered into a well bore or through tubing contained within the well bore for operation at a preselected subsurface location. To permit free travel through the well bore or tubing, the lateral dimensions of such equipment must be less than the internal dimensions of the surrounding well bore or tubing. When the equipment has been lowered to a desired depth, it must then be activated to perform its particular function.

The equipment must often be set or anchored in position to perform its intended function and to this end, various methods have been devised for expanding the lateral dimensions of the equipment to provide frictional engagement with the internal surface of the well bore or tubing. Examples of this type equipment are commonly employed tools such as straddle packers, bridge plugs and the like. In many well known tools, the tool is set in the well bore or tubing by moving one part of the tool structure relative to another stationary part of the structure.

One well known prior art technique for the down-hole setting of tools employs a string of tubing and a wire line which extend between the down-hole tool and the well surface. The string acts as a backup for holding part of the tool stationary while the wire line is used to displace the movable portion of the tool relative to the stationary portion.

Another somewhat similar setting technique employs only a string of tubing attached to the tool. When the tool is at the desired subsurface location, the tubing is first rotated to move a pin through a J-slot and then raised to activate the setting mechanism of the tool. The tool employed in the described technique must be equipped with means for preventing the tool from following the setting motions of the tubing string. Such means usually include a friction spring or the like to induce a constant frictional engagement with the conduit which is to contain the tool.

Both of the setting techniques described above are objectionable to the extent that they require the use of a tubing string extending to the surface rather than the use of simple and rapid wire line procedures. The second technique, employing only a tubing string is also objectionable in the J-slot arrangement on the tool increases the danger of premature setting. Moreover, the friction drag required with such a technique increases the danger of sticking the tool in restricted or deviated portions of the conduit through which the tool is being run.

In an attempt to avoid the foregoing problems, the prior art has suggested various methods for setting the down-hole tool with a self-contained setting mechanism suspended from a wire line. One such method employs mechanical jars cooperating with a setting mechanism which employs pins acting through a slotted pathway in a sleeve. Initial lodging of the setting mechanism is effected by raising and lowering the wire line in a predetermined sequence. Final anchoring of the down-hole tool attached to the setting mechanism is then effected by the action of the mechanical jars. This described method is objectionable in that the down-hole tool often cannot be set exactly at a predetermined subsurface location. Such uncertainty in setting the down-hole tool is attributable in part to the fact that the setting mechanism lodges at an unpredictable point along the path of the up and down movement of the wire line. Moreover, the jarring force required for final setting may also displace the tool itself.

Another setting method disclosed by the prior art employs an explosive charge to effect the desired setting motion. The setting mechanism and attached down-hole tool are initially lowered by an electrical wire line to the desired subsurface location. An electrical signal is employed to ignite the explosive which in turn imparts the required setting motion to the tool. Such explosive setting mechanisms are objectionable in that the explosive force creates a violent setting movement which may exceed the structural limitations of the down-hole tool or the setting mechanism itself. If, however, the explosive charge is defective or too small, the tool may be imperfectly set. Moreover, as is also the case with certain of the other methods described above, the tool may not be partially set and thereafter be released and reset at a different location.

Still another prior art setting method suggests the use of a down-hole electric motor for powering a hydraulic pump. The pump is employed to inflate an expansible packer causing it to engage the surrounding tubing or well bore. Such method has, however, been employed in only a relatively few special purpose applications.

The use of an electrically driven mechanical subsurface setting mechanism has also been suggested by the prior art. By way of example, U.S. Patent No. 2,399,766, issued to Steward, discloses a setting mechanism consisting of an electrical motor which acts through a reduction gear, which in turn moves a setting shaft through the stationary body of the setting mechanism to anchor a down-hole tool. The setting mechanism and attached down-hole tool are suspended in the desired subsurface location by a wire line which also supplies electrical energy for powering the motor. The differential effects of the well pressure are partially equalized by filling the motor and gear housing with an incompressible fluid. A Sylphon bellows communicating between the well fluid and the housing fluid maintains a low pressure differential between the interior of the setting mechanism and the well environment.

One shortcoming of the setting mechanism disclosed by Steward is that a continuously acting friction drag is re-

quired to prevent the setting mechanism from rotating when the electric motor is energized. It is also necessary to completely withdraw the Steward mechanism from the well tubing and manually change the arrangement of a clutch drive before the direction of movement of the setting shaft may be reversed. This is particularly undesirable where it is desired to set the down-hole tool at one location and thereafter change the position of the tool. Yet another limitation in the application of the Steward setting mechanism is the absence of any means for completing an electrical circuit with the down-hole tools carried below the setting mechanism. Still another problem associated with the pressure equalization means is the loss of the housing fluid through a low pressure packing disposed about the setting shaft. The fluid loss occurs when the setting mechanism is rapidly retrieved from the well conduit which creates a partial vacuum below the mechanism and increases the pressure differential across the packing.

BRIEF DESCRIPTION OF THE INVENTION

The present invention employs an electric motor acting through a reduction gear to retract or advance a shaft through a stationary sleeve, which in turn sets or retrieves a down-hole tool. The entire setting mechanism as well as the down-hole tool are suspended in the well conduit by an electrically conductive wire line.

In both setting and retrieving a down-hole tool, the stationary sleeve on the setting mechanism prevents motion of the tool as the movable shaft is retracted, thus obviating the need for a continuous string of tubing extending to the surface or the need for continuously engaging friction slips. Further, no means are required for initial anchoring of the setting mechanism itself and as a result, the down-hole tool may be set precisely at any predetermined subsurface location. Moreover, since no continuously acting friction drags are required in the setting device of the present invention, the danger of sticking the devices within the surrounding tubing or well bore is thereby greatly reduced or eliminated.

A particularly important feature of the present invention is the provision of means for completing an insulated electrical circuit with any down-hole secured below the setting mechanism. By this means, recording or testing instruments secured below the setting mechanism may be continuously monitored at the surface.

Another particularly important feature of the present invention is the provision of a variable diameter on the movable setting shaft which offsets the differential effects of well pressure and thereby allows the shaft to move freely through its entire length of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 of the drawings is an elevational view of the setting mechanism of the present invention positioned in a cased well bore;

FIGURE 2A of the drawings is an elevation, partly in section of the top half of the setting mechanism of the present invention;

FIGURE 2B of the drawings is an elevation, partly in section of the bottom half of the setting mechanism of the present invention;

FIGURE 3 of the drawings is a cross section of the setting mechanism of the present invention taken along the line **3—3** of FIGURE 2A;

FIGURE 4 of the drawings is a cross section of the setting mechanism of the present invention taken along the line **4—4** of FIGURE 2A;

FIGURE 5 of the drawings is a cross section of the setting mechanism of the present invention taken along the line **5—5** of FIGURE 2B;

FIGURE 6 of the drawings is a cross section of the setting mechanism of the present invention taken along the line **6—6** of FIGURE 2B;

FIGURE 7 of the drawings is a partial elevation, in section, illustrating a second form of the apparatus of the present invention; and

FIGURE 8 of the drawings is a partial elevation, in section, illustrating a third form of the apparatus of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGURE 1 of the drawings, illustrates a partial sectional view of a cased well bore B with a string of tools indicated generally at T suspended from an electrical wire line L. The wire line L and the tools T are raised or lowered into the well bore B by any conventional means (not illustrated). The tools T include the electric setting mechanism **10** of the present invention, a shut-in tool S and a testing instrument I. An electric switching device E, the function of which will be described hereinafter, is also included with the tool assembly T. It should be noted that the equipment illustrated in FIGURE 1 of the drawings is intended only to be illustrative of a simple assembly and that in actual practice, other standard equipment such as weight bars would also be carried by the line L. It should also be observed that the setting mechanism **10** of the present invention may be employed with a great variety of down-hole tools and that the shut-in tool S has only been described herein for purposes of illustration.

In the operation of the assembly illustrated in FIGURE 1 of the drawings, the tools T are suspended from the wire line L and positioned in the desired subsurface location within the well bore B. An appropriate electrical signal is then transmitted through a single insulated electrical conductor carried by the line L causing the electrical switching mechanism E to complete an electrical pathway between the insulated conductor and an electric motor in the setting tool T. The wire line L may advantageously include an electrically conductive armor covering which may be used as a ground for the electrical system. The electrical motor may be one of any of the well known types which has the necessary performance characteristics, including the ability to reverse direction of rotation with a change in the polarity of the electrical power supply. The switching mechanism E is well known in the art and requires no further description herein. Electrical energy from a source (not illustrated) at the surface is then supplied to the insulated conductor in the line L to power the electric motor in the setting mechanism **10**, which in turn sets the shut-in tool S. Electrical energy to the setting mechanism **10** is stopped when the shut-in tool S is properly set against the walls of the cased well bore B. Proper setting of the tool S is indicated by monitoring conventional measuring equipment (not illustrated) located at the surface.

When properly set, the shut-in tool S isolates the well bore pressure above the tool from the pressure below the tool. The electrical circuitry of the testing instrument I may then be connected to the insulated conductor in the line L by sending a second signal through the line L which appropriately changes the position of the switching contacts in the switching mechanism E. When the electrical circuit is complete, the output of the testing instrument I may then be monitored at the surface.

The tool assembly T may then be repositioned or withdrawn from the well bore B by appropriately signaling the switching mechanism E and thereafter reversing the direction of rotation of the electric motor in the setting mechanism **10**. It should be observed that the foregoing setting and retrieving function are accomplished without exerting any lifting forces on the wire line L and without any required sequence of up and down motion of the line.

With reference to FIGURES 2A and 2B, the electric setting mechanism **10** of the present invention is illustrated in greater detail in two sections, with FIGURE 2A being the top portion of the tool and FIGURE 2B being the bottom portion thereof. The tool body **11** includes

a series of threadedly interconnected cylindrical housing members **11***a*, **11***b*, **11***c*, **11***d*, and **11***e*. As illustrated in FIGURE 2B, the housing member **11***e* may be connected to a suitable adapter A which in turn is connected to the body of the shut-in tool S. The threaded joints between the body housing members **11***a* and **11***b* and the members **11***b* and **11***c* are provided with O-rings **11***b'* and **11***c'* respectively to prevent leakage into the interior portions of the housing **11**. The O-rings employed in the persent invention may be constructed of a flexible material such as rubber or other suitable matter.

The top of the body housing member **11***a* is threaded to receive a suitable connector from the wire line L or from any auxiliary equipment carried above the setting mechanism **10**. The central chamber of the member **11***a* contains an electric motor and gear train within a second internal housing H. The gear train rotatably drives a shaft **12** which extends from the lower end of the housing H with one end of the shaft **12** being received within a central bore formed in a kelly drive **13**. Relative motion between the shaft **12** and kelly drive **13** is prevented by means of a two-part pin **14** which extends through the kelly drive **13** and the shaft **12**. The upper portion of the kelly drive **13** carries a cylindrical O-ring **13***a* which engages and forms a seal with the interior cylindrical surface of the body housing member **11***b*. The lower portion of the kelly drive **13** has a rectangular cross section as illustrated in FIGURE 3 of the drawings which extends through a thrust bearing **15** and is received in a rectangularly opening adapter **16***a* at the top of a tubular nut drive **16**.

In the linkage thus far described, rotational movement of the setting motor is transmitted through a reduction gear train, shaft **12**, kelly drive **13** and nut drive **16**. The lower end of the tubular nut drive **16** is provided with internal threads **16***b* which receive the external threads **17***a* of a setting mandrel or shaft **17**. The interrelation of the nut drive **16** and setting shaft **17** may best be understood by reference to FIGURE 4 of the drawings. With reference again to FIGURE 2A, the lower axial end of the nut drive **16** engages a second thrust bearing **18**. The lower bearing **18** cooperates with the upper thrust bearing **15** to rotatably support and prevent axial displacement of the nut drive **16**.

The rotational movement of the nut drive **16** imparts a linear movement to the setting shaft **17** as the shaft threads **17***a* move through the nut drive threads **16***b*. Rotation of the nut drive **16** in one direction draws the setting shaft **17** up into the interior of the tubular body of the nut drive while rotation in the opposite direction expells the shaft. It should be noted that the internal axial length of the nut drive **16** is greater than the axial length of the threaded portion of the shaft **17** to thereby insure complete reception of the shaft within the body of the nut drive. As an added safety measure, the shaft **17** includes a reduced diameter area **17***a'* immediately below the threads **17***a* which permits the shaft **17** to be twisted apart in the event of malfunction of the down-hole tool or the setting mechanism itself. As will be more fully described hereinafter, while the shaft **17** is in its retracted position, the downhole tool remains locked against the well conduit and release of the shaft causes the tool to disengage.

The setting shaft **17** extends through two O-rings **11***c''* carried in circumferential grooves formed on the internal cylindrical surface of the housing member **11***c*. The O-rings **11***c''* cooperate with the smooth, external cylindrical surface **17***b* of the setting shaft **17** to form a leak-proof seal which prevents well fluids from entering into the chamber within the upper portion of the setting mechanism. At the lower axial end of the surface **17***b*, the diameter of the setting shaft **17** is enlarged to form a second smooth cylindrical surface **17***c*. The cross sectional area of the shaft **17** at any point along the surface **17***c* is exactly twice the cross sectional area of the shaft along the surface **17***b*. The enlarged area along the surface **17***c* produces a force equalization effect which will be more fully described hereinafter.

Two roll pins **17***d* and **17***e* are threadedly engaged with the shaft **17** and extend radially therefrom into two longitudinal slots **11***d'* and **11***d''* respectively, formed in the body member **11***d*. The roll pins **17***d* and **17***e* are free to slide axially through the length of the slots **11***d'* and **11***d''* while preventing rotational movement of the shaft **17**. The cooperation of the roll pins **17***d* and **17***e* with the slots **11***d'* and **11***d''* is further illustrated in the cross section of FIGURE 5 of the drawings. Referring jointly to FIGURE 2B and FIGURE 6 of the drawings, two threaded sockets **17***f* and **17***g* are also provided in the setting shaft **17**. In normal usage, the sockets are not employed, however, when desired, the sockets **17***f* and **17***g* may be employed to receive externally threaded locking pins (not illustrated) which extend through the housing member **17***d* and prevent any movement of the shaft **17** with respect to the member **17***d*.

A second pair of O-rings **11***e'* is carried in two circumferentially extending grooves formed along the interior cylindrical surface of the body housing member **11***e*. The O-rings **11***e'* bear against the cylindrical surface **17***c* to provide a leak-proof seal between the shaft **17** and the body member **11***e*. The shaft **17** is again reduced in diameter at the lower axial end of the shaft surface **17***c* to form a smooth cylindrical surface **17***h* having the same cross sectional area as the surface **17***b*. The surface forms a leak-proof seal with two O-rings **11***e''* carried in circumferentially extending grooves formed in the internal cylindrical surface at the lower end of the body member **11***e*. The O-rings **11***e'* and **11***e''* prevent well fluids from entering the chamber formed in the housing body **11***e*.

The shaft **17** extends through the center of the adapter A and the body S' of the tool S and terminates. The lower end of the shaft **17** is equipped with threads **17***j* which engage an internally threaded tool mandrel M. An O-ring M'' carried between the shaft **17** and the mandrel M insures a leak-proof seal between the two components.

The electrical system employed in the apparatus of the present invention includes an electrical line **18** which includes three individual conductors **19**, **20** and **21**. The line **18** terminates in a conventional three prong jack **22**. The three conductors **19**, **20** and **21** are electrically connected to the prongs **23**, **24** and **25** respectively which are mounted in the insulating body of the jack **22**. The jack **22** is removably mounted on an insulating receptacle **26** which in turn is secured to the motor housing H by means of screws **27**.

The prong **23** makes electrical contact with an insulated conductor **28** which extends through the housing H and connects to a brush and slip-ring assembly illustrated schematically at **29**. The prong **24** makes electrical contact with an insulated conductor **30** which supplies current to the electrical motor within the housing H. The third prong **25** is electrically connected to the housing H and may serve as a ground for the electrical system.

The brush and slip-ring assembly **29** completes the electrical circuit between the rotating shaft **12** and the stationary conductor **28**. An insulated conductor **31** extends axially through the body of the shaft **12** where it is connected to the male member **32** of an electrical connector. The member **32** is received in a female receptacle **33** which in turn is electrically connected to an insulated conductor **34** carried in the body of the kelly drive **13**. A thin conductive rod **35** is mechanically secured at its upper end in an insulated bearing assembly **35***a* mounted in the end of the kelly drive **13**. The bearing assembly **35***a* maintains mechanical and electrical engagement with the non-rotating rod **35**. The rod **35** is thus electrically connected to the conductor **34** and extends from the lower axial end of the kelly drive **13** and through the center of the nut drive **16**. The lower end of the rod **35** is slid-

ably received within a second externally insulated tubular conducting rod **36** carried within the body of the setting shaft **17**. The rod **36** telescopes over the rod **35** as the shaft **17** is moved axially to maintain continuous electrical contact throughout the entire range of shaft movement. The electrical conducting path is isolated from the setting shaft itself by means of insulating material carried externally of the rod **36** and an insulating sleeve **37** carried at the upper axial end of the shaft **17**. The lower axial end of the tubular rod **36** is electrically secured to the male member **37** of an electrical connector. A female portion **38** of the connector which receives the plug **37** is carried in the center mandrel M of the down-hole tool S and an insulated electrical conductor **39** is carried within the body of the mandrel M to continue the electrical pathway to a testing instrument (not illustrated) or other electrical mechanism (not illustrated) carried below the tool S.

The operation of the electric setting mechanism **10** of the present invention proceeds in the following manner. The mechanism **10** and attached tools or equipment are lowered by the conductor line L into the well conduit to the desired subsurface location. An electrical signal is transmitted from the surface through the conductor in the line L to switch the conductor into the electrical circuit of the setting motor contained within the housing H. Electrical energy is then supplied to the conductor in the line L causing the motor to rotate in a direction which will draw the setting shaft **17** into the drive nut **16**. As the shaft **17** advances into the interior of the nut drive **16**, the roll pins **17***d* and **17***e* slide upwardly through the housing slots **11***d'* and **11***d''*. During the movement of the shaft **17**, the housing body **11** and outer tool body S' remain stationary. As a result of this relative movement, the center mandrel M connected to the shaft **17** moves upwardly through the stationary tool body S' which produces the movement for setting the tool S in the well conduit. Proper setting of the tool S is indicated by the loading of the electric motor of the setting mechanism which in turn is related to the rate of energy flow through the conductor line L. When the surface instruments indicate the desired loading, the electrical energy to the motor is switched off. If the down-hole tool is designed to remain in engagement with the setting tool after it has been set, as is the case with the tool S, the tool is retained in its set position by the retracted condition of the setting shaft **17** and no auxiliary locking provision is required. The tool S may thereafter be unset or disengaged from the well conduit by simply applying a current flow in the reverse direction through the line L. The motor is thereby caused to rotate in the reverse direction which expells the shaft **17** from the drive nut **16**. Since the outer body S' of the tool S remains stationary by virtue of its mechanical connection with the housing body **11**, the mandrel M moves downwardly relative to the outer body S' to effect the required motion for freeing the tool S from the well conduit.

An important feature of the setting tool of the present invention is its ability to withstand the differential effects of the down-hole well pressure. This feature may best be described by reference to FIGURES 2A and 2B. The setting shaft **17** is provided with an increased cross sectional area along its surface **17***c* which cooperates with the smaller cross sectional areas along the surfaces **17***b* and **17***h* to equalize the effects of well pressure on the shaft **17**. The force of the well pressure acting against the shaft **17** at the O-rings **11***c''*, **11***e'* and **11***e''* is directly related to the cross sectional area of the shaft at that point. This relationship is given by the formula:

$$F=P\times A$$

where F is force, P is well pressure and A is the cross sectional area against which the pressure acts. If the cross sectional area of the shaft **17** along the surfaces **17***b* and **17***h* is A and the cross sectional area of the shaft along the surface **17***c* is 2A, the total well pressure force F acting against the shaft **17** is the vector sum of:

$$F=P\times A\text{—}\!\!+\!\!\rightarrow P\times 2A\text{—}\!\!+\!\!\rightarrow P\times A$$

Since the well pressure tends to drive the shaft **17** into the lower pressure chambers within the body of the tool, forces acting against the reduced diameter portions of the shaft at O-rings **11***c''* and **11***e''* are directed upwardly whereas the forces acting at the O-rings **11***e'* are directed downwardly. The net forces F attributable to well pressure are then:

$$F=\uparrow P\times A\text{—}\!\!+\!\!\rightarrow\downarrow P\times 2A\text{—}\!\!+\!\!\rightarrow\uparrow P\times A$$

$$F=\uparrow P\times A\text{—}\!\!+\!\!\rightarrow\downarrow 2\times PA=0$$

Thus the effect of the well pressure force acting on the shaft **17** is completely cancelled and the dangers of binding the shaft or restraining its movement in either the upward or downward direction are thereby avoided.

In those applications where a resultant force against the shaft is desired, the shaft dimensions may be altered accordingly. Thus, by way of example rather than limitation, a net downwardly directed force may be obtained with the use of a shaft having a cross-sectional area along the shaft surface **17***c* which is greater than the sum of the cross-sectional areas along the surfaces **17***b* and **17***h*. The well pressure is then employed to assist the movement of the shaft.

When the setting mechanism **10** is to be employed with down-hole tools which are to remain in the well bore over indefinite periods of time, modification of the lower portion of the mechanism is required. One such modification appears in FIGURE 7 of the drawings with only the uppermost portion of the down-hole tool being shown for illustrating the operative cooperation of the setting mechanism and the tool. In this modification of the setting mechanism of the present invention, the adapter A included in the embodiment of FIGURES 2A and 2B is replaced by an adapter **50** which is threadedly engaged with the lower axial end of the housing body member **11***e*. The setting shaft **17** of the first embodiment is also replaced by a shaft **117** which has no provision for carrying an electrical conductor but which is otherwise identical to the shaft **17**. The adapter **50** is threadedly engaged with the upper axial end of a tubular setting sleeve **51** with the lower end of the setting sleeve **51** being provided with a coller **51***a* having an internal circular shoulder **51***b* and an axial end surface **51***c*. The end surface **51***c* removably engages a fitting **52** which is threadedly engaged with the upper axial end of the outer body housing of a down-hole tool **53**.

The lower axial end of the setting shaft **117** is threadedly engaged with a connector fitting **55** which in turn is received in a smooth central bore formed in a plug fitting **56**. Relative movement between the connector fitting **55** and plug fitting **56** is prevented by means of a shear pin **57** which extends through coaxial, lateral bores provided in both members. The shear pin **57** is held in position by two set screws **58** and **59**. The plug fitting **56** is provided with external threads along its lower body which engage an internally threaded central mandrel **60** extending upwardly from the down-hole tool **53**. The mandrel **60** is adapted to move axially relative to the outer housing body of the tool **53** to provide the required setting or retrieving motions.

A locking sleeve **61** encircles the mandrel **60** with the upper axial end of the sleeve **61** being provided with a radially outwardly developed lip having an upper axial end surface **62** and a lower shoulder surface **63**. It should be noted at this point that the elements **52**, **53** and **56** through **63** are components of the down-hole setting tool **53** and are related to the setting mechanism of the present invention only to the extent that they aid in illustrating one form of the operation and structure of such setting mechanism. Thus, the form of the invention illustrated in FIGURE 7 is employed for setting down-hole tools which

are to completely disengage the setting mechanism and remain in the well conduit after having been set. Examples of such tools are the many conventional packers and plugs employed in various well treating procedures. It should also be observed that for such application of the setting mechanism, no electrical circuitry is customarily required by the down-hole equipment and consequently, there is no provision for conveying electrical energy through the setting mechanism.

In the operation of the apparatus illustrated in FIGURE 7 of the drawings, the setting mechanism and tool **53** are initially positioned at the desired subsurface location within the well conduit. The electric motor of the setting mechanism is then energized to cause the setting shaft **117** to move upwardly through the stationary housing body member **11***e*. While the axial movement of the shaft **117** is transmitted to the central mandrel **60** of the down-hole tool **53**, the setting sleeve **51** remains stationary by virtue of the mechanical linkage with the body member **11***e*. The tool fitting **52** engages the sleeve surface **51***c* to prevent the outer body of the tool **53** from following the upward movement of the mandrel **60**. Upward movement of the lock ring **61** is also prevented by engagement of the axial end surface **62** with the internal sleeve shoulder **51***b*. In the lower portion of the tool **53** (not illustrated) the upward movement of the mandrel **60** through the stationary external body of the tool **53** sets the metal slips of the tool and compress one or more rubber packing elements against the internal surface of the well conduit. During this upward movement, the lower portion of the locking ring is adapted to permit free travel of the tool components.

When the magnitude of the upward force of the setting shaft **117** exceeds a predetermined value, the pin **57** is sheared and the setting mechanism is disengaged from the tool **53**. When thus freed, the mandrel **60** tends to move axially downward causing the lower portion of the locking ring **61** to lock which prevents any further movement of the tool components. The tool is then securely set in the well conduit in a self-locking condition and the setting mechanism may be completely withdrawn from the well.

When it is desired to retrieve the tool from the well conduit, the setting mechanism may be modified in the manner illustrated in FIGURE 8 of the drawings. The setting sleeve **51** is replaced by a retrieving sleeve **151** which carries a strengthening coller **151***a* threaded onto its lower external surface. The connector fitting **55** is replaced by a second connector fitting **155** which is threadedly engaged with a cylindrical overshot **156**. The overshot **156** includes a plurality of downwardly directed fingers **156***a* having internally tapered surfaces **156***b* and internal shoulders **156***c*.

In the operation of the apparatus illustrated in FIGURE 8 of the drawings, the setting mechanism is run into the hole with the shaft **117** in its extended position. As the setting mechanism is lowered over the tool **53**, the tapered surfaces **156***b* of the fingers **156** engage and slide over the surface **56***a* of a conical frustum formed on the plug fitting **56**. As the setting mechanism is further lowered, the surfaces **156***b* engage a tapered external surface **61***a* on the lock ring **61** which forces the fingers **156** to open radially. When the shoulder surface **156***c* falls below the shoulder surface **63** of the lock ring **61**, the fingers **156** are free to spring back and close radially to their original position. The electric motor in the setting mechanism is then energized to retract the setting shaft **117** upwardly. This causes the retrieving sleeve **151** to move downwardly over the fingers **156** until the sleeve engages the tool fitting **52**. The presence of the sleeve **151** over the lower end of the fingers **156** prevents any outward radial movement of the fingers and ensures proper latching with the lock ring **61**. As the shaft **117** continues to move upwardly, the fingers **156** begin to exert a lifting force on the lock ring **61**. Upward movement of the mandrel **60** at this point is prevented by engagement of the plug fitting **56** and the connector fitting **155**. When sufficient lifting force is exerted on the locking ring **61**, the center mandrel **60** is released and the slips and packers of the tool **53** disengage the well conduit. This occurrence is also indicated by the monitoring equipment at the well surface and the electric motor is de-energized. The entire assembly of setting mechanism and down-hole tool may then be withdrawn from the well. Again, it should be noted that both the setting and the retrieving actions described hereinabove are effected without the application of lifting forces on the wire line L.

It should also be noted that if desired, the connector fitting **55** of FIGURE 7 and **155** of FIGURE 8 may be centrally bored to accommodate the banana plug connector **37** illustrated in FIGURE 2B. By means of this expedient, the shaft **17** of FIGURES 2–6 may be employed with the setting and retrieving apparatus illustrated in FIGURES 7 and 8 of the drawings.

I claim:

1. An electric setting mechanism for setting or retrieving subsurface equipment in a well comprising:
- (a) an axially extending central shaft;
- (b) an axially extending housing disposed about said shaft;
- (c) driving means for moving said shaft axially with respect to said housing; and
- (d) compensating means disposed between said shaft and said housing for eliminating the differential effects of well pressure acting against said shaft.

2. The electric setting mechanism as defined in claim **1** further including an insulated electrical conducting means extending axially through the length of said housing.

3. The electric setting mechanism as defined in claim **1** wherein said driving means includes a reversible electric motor.

4. The electric setting mechanism as defined in claim **3** further including an insulated electrical conducting means extending axially through the length of said housing.

5. The electric setting mechanism as defined in claim **1** wherein:
- (a) said shaft includes external threads formed along a portion of its length; and
- (b) said drive means include an internally threaded tubular nut drive which is threadedly engaged with said threads on said setting shaft whereby rotation of said nut drive moves said setting shaft axially with respect to said housing.

6. The electric setting mechanism as defined in claim **5** wherein said driving means further includes a reversible electric motor.

7. The electric setting mechanism as defined in claim **5** wherein said shaft and said nut drive include an insulated electrical conducting means extending axially through their length.

8. The electric setting mechanism as defined in claim **5** wherein said compensating means includes variable diameter sections on said shaft cooperating with variable diameter sealing means disposed between said shaft and said housing.

9. The electric setting mechanism as defined in claim **8** wherein said driving means further includes a reversible electric motor.

10. The electric setting mechanism as defined in claim **9** wherein said shaft and said nut drive include an insulated electrical conducting means etxending axially through their length.

11. The electric setting mechanism as defined in claim **10** including stop means for preventing said shaft from rotating with respect to said housing wherein said stop means includes at least one pin extending from said shaft into an axially developed slot formed in said housing.

12. The electric setting mechanism as defined in claim

5 including stop means for preventing said shaft from rotating relative to said housing as said nut drive rotates.

13. The electric setting mechanism as defined in claim 12 wherein said stop means includes at least one pin extending from said shaft into an axially developed slot formed in said housing.

14. The setting mechanism as defined in claim 1 wherein:

(a) said housing includes first and second axially spaced chambers;

(b) said first chamber includes enclosure means for sealing said first chamber from fluids and gasses in the well;

(c) said enclosure means includes a first seal means disposed between said shaft and said housing for forming a sliding seal between said shaft and said housing;

(d) said second chamber includes second and third axially spaced seal means disposed between said shaft and said housing for forming a sliding seal with said shaft to seal said second chamber from fluids and gasses in the well;

(e) said second seal means is disposed axially between said first and third seal means; and

(f) the cross sectional area of said shaft where it slidably engages said second seal means is equal to the sum of the cross sectional areas of the shaft where it slidably engages said first and third seal means.

15. The electric setting mechanism as defined in claim 14 further including an insulated electrical conducting means extending axially through the length of said housing.

16. The electric setting mechanism as defined in claim 14 wherein said driving means includes a reversible electric motor.

17. The electric setting mechanism as defined in claim 16 wherein:

(a) said shaft includes external threads formed along a portion of its length; and

(b) said drive means include an internally threaded tubular nut drive which is threadedly engaged with said threads on said setting shaft whereby rotation of said nut drive moves said setting shaft axially with respect to said housing.

18. The electric setting mechanism as defined in claim 17 wherein said shaft and said nut drive include an insulated electrical conducting means extending axially through their length.

19. The electric setting mechanism as defined in claim 17 wherein said electric motor and said nut drive are disposed within said first chamber.

20. The electric setting mechanism as defined in claim 19 further including a gear train operably connected between said motor and said nut drive.

21. The electric setting mechanism as defined in claim 17 wherein said shaft and said nut drive include an insulated electrical conducting means extending axially through their length.

22. The electric setting mechanism as defiend in claim 21 wherein said shaft and said nut drive include an insulated electrical conducting means extending axially through their length.

23. The electric setting mechanism as defined in claim 21 wherein said electrical conducting means includes:

(a) means for maintaining electrical connection between a stationary electrical conductor and a rotating electrical conductor; and

(b) means for maintaining electrical connection between an axially stationary conductor and an axially moving conductor.

24. The electric setting mechanism as defined in claim 23 further including:

(a) a plurality of electrical conductors carried within said housing; and

(b) switching means for electrically connecting any one of said plurality of conductors to a single electrical conductor disposed externally of said housing.

25. The electric setting mechanism as defined in claim 21 further including:

(a) holding means for holding a first member of the subsurface equipment stationary; and

(b) moving means for moving a second member of the subsurface equipment relative to said first member.

26. The electric setting mechanism as defined in claim 25 wherein:

(a) said holding means includes a collar rigidly secured to said housing: and

(b) said moving means includes means for securing said shaft to said second member of said subsurface equipment.

27. The electric setting mechanism as defined in claim 26 wherein said moving means further includes means for releasing said second member of the subsurface equipment when the force exerted by said shaft exceeds a predetermined value to set the equipment in place.

28. The electric setting mechanism as defined in claim 26 wherein said moving means further includes retrieving means for locking to said movable portion of the subsurface equipment to release the equipment from its set condition.

29. The electric setting mechanism as defined in claim 28 wherein:

(a) said retrieving means includes a tubular body having a plurality of radially movable fingers for engaging said equipment; and

(b) said collar includes means for moving axially over said tubular body to hold said fingers in engagement with said equipment.

30. The electrical setting mechanism as defined in claim 1 further including:

(a) holding means for holding a first member of the subsurface equipment stationary; and

(b) moving means for moving a second member of the subsurface equipment relative to said first member.

31. The electrical setting mechanism as defined in claim 30 wherein:

(a) said holding means includes a collar rigidly secured to said housing; and

(a) said moving means includes means for securing said shaft to said second member of said subsurface equipment.

32. The electric setting mechanism as defined in claim 31 wherein said moving means further includes means for releasing said second member of the subsurface equipment when the force exerted by said shaft exceeds a predetermined value to set the equipment in place.

33. The electric setting mechanism as defined in claim 31 wherein said moving means further includes retrieving means for locking to said movable member of the subsurface equipment to release the equipment from its set condition.

34. The electric setting mechanism as defined in claim 33 wherein:

(a) said retrieving means includes a tubular body having a plurality of radially movable fingers for engaging said equipment; and

(b) said collar includes means for moving axially over said tubular body to hold said fingers in engagement with said equipment.

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