July 14, 1970 J. W. KISLING III 3,520,360

SETTING TOOL APPARATUS

Filed Oct. 28, 1968 2 Sheets-Sheet 1

Fig. 1

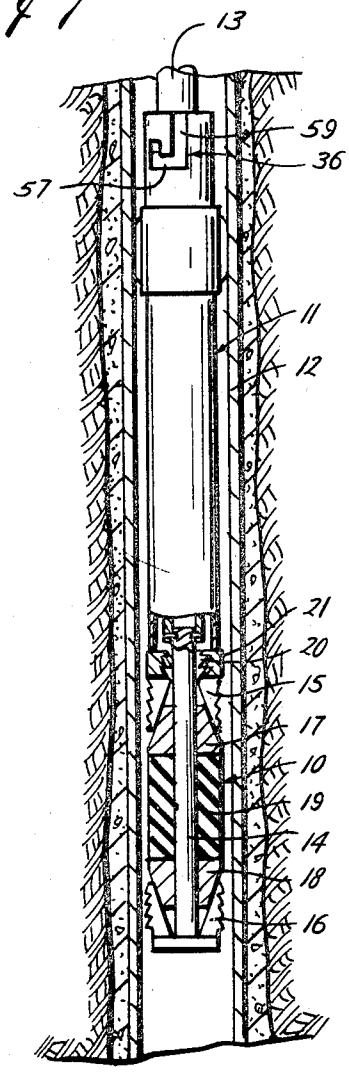


Fig. 2B

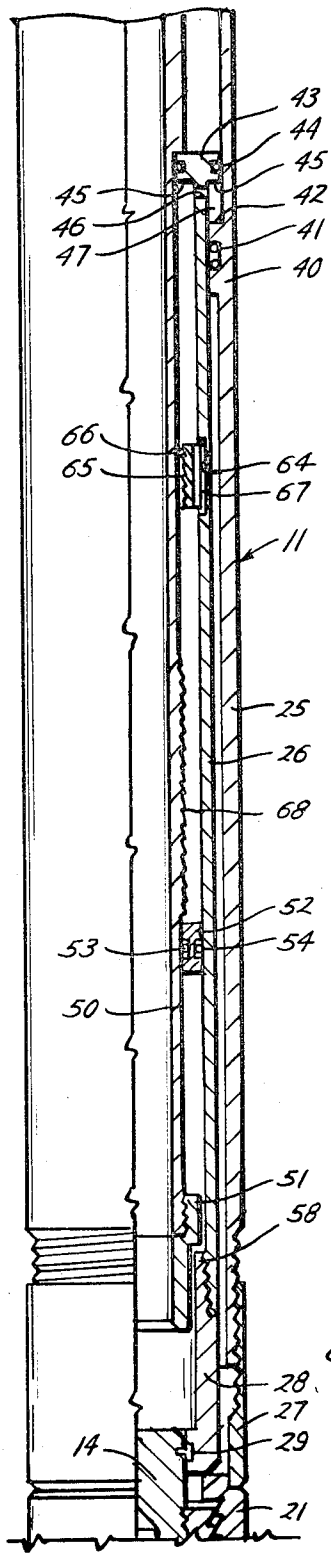
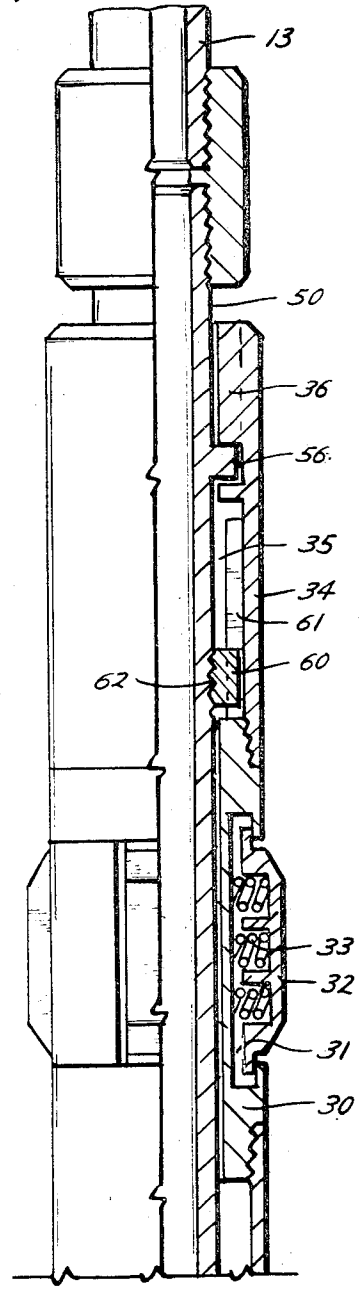


Fig. 2A



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Fig. 3B

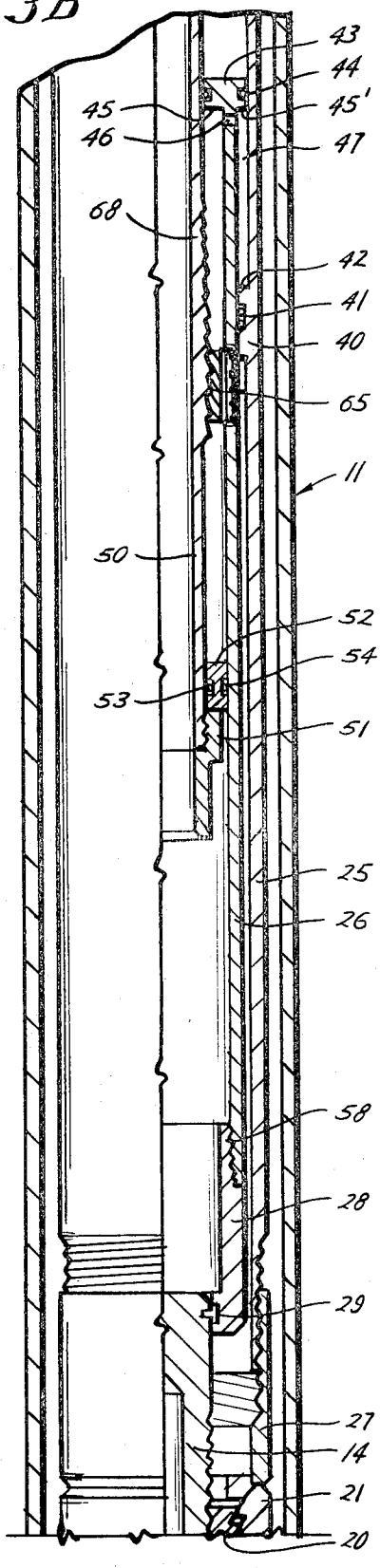
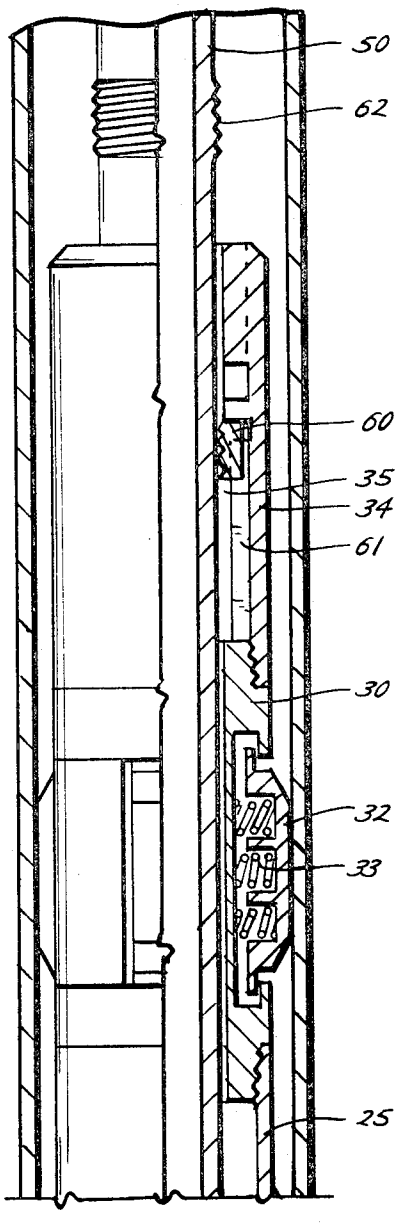


Fig. 3A



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United States Patent Office 3,520,360 Patented July 14, 1970

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SETTING TOOL APPARATUS

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Filed Oct. 28, 1968, Ser. No. 771,179
Int. Cl. E21b 23/06
U.S. Cl. 166—123 8 Claims

ABSTRACT OF THE DISCLOSURE

A setting tool apparatus for use in setting well tools in well bores includes inner and outer members movable in opposite directions relative to one another for applying oppositely directed forces to the well tool. The outer member has an upwardly facing pressure surface and the inner member has a downwardly facing pressure surface forming movable walls of a fluid-filled hydraulic chamber. An operator member connected to the lower end of a pipe string can be moved upwardly by the pipe string into engagement with a piston ring, and upward strain on the pipe string and piston ring will generate a fluid pressure in the chamber which acts on the pressure surfaces of the members to cause relative movement in opposite directions. The area of the pressure surface on said inner member is larger than the area of said piston ring, whereby the upward force on said inner member tending to cause relative movement is a multiple of the upward strain on the pipe string.

This invention relates generally to well tools used in well bores, and more specifically to mechanical setting tools operable by manipulation of a pipe string for setting well tools such as packers, plugs and retainers in a well conduit.

The aforementioned well tools which can be lowered into a well conduit on a pipe string and then set by manipulation of the pipe string to pack off the well bore, generally include a mandrel which carries upper and lower normally retracted slips and a packing element arranged to be expanded into contact with the well conduit wall. Expansion of the slips and packing element can be effected by the application of oppositely directed forces, usually a downward force on the upper slip together with an upward force on the mandrel. In response to such forces, the slips are shifted outwardly by cooperatively arranged expander cones, and the packing element is compressed and expanded into sealing engagement with the well conduit.

The application of such oppositely directed forces may be accomplished through use of a mechanical setting tool which is coupled between the well tool and the pipe string. A typical mechanical setting tool includes an inner member having its lower end connected to the packer mandrel by a shear stud or the like, and its upper end connected to the pipe string, and an outer member having friction blocks engaging the conduit and which is coupled in force transmitting relationship with the upper slips. By appropriate manipulation of the pipe string, the upper slip can be shifted into gripping contact with the conduit, after which an upward strain on the pipe string at the earth's surface will effect expansion of the lower slip and the packing element.

In the past, mechanical setting tools have not been usable at very great depths because the upward strain which can be applied at the surface to operate the setting tool and set the packer is limited by the tensile strength of the pipe string. The deeper the setting depth, the greater the weight of pipe in the well, so that a lesser amount of strain can be applied at the surface to operate

the setting tool without exceeding the recommended tensile strength of the pipe. However, in recent times, wells are being driller deeper and deeper below the earth's surface requiring setting of packers at corresponding greater depths. Thus, the foregoing limitations in using conventioal mechanical setting tools are becoming more critical.

A general object of the present invention is to provide a new and improved setting tool for packers or the like, which is constructed and arranged for setting a well tool on a pipe string, and which incorporates a hydraulic force multiplying means enabling a reduction in the strain applied to the pipe string at the surface to produce an adequate setting force to the tools. Although the present invention may be used at any depth in a well bore, it has particular utility in setting tools at great depths below the surface.

With this and other subjects in view, apparatus in accordance with the concepts of the present invention includes inner and outer telescopically arranged members movable in opposite longitudinal directions and coupled in force transmitting relationship to relatively movable parts of a well tool. Piston means on said members have opposed transverse pressure surfaces and provide a fluid-filled chamber. A pressure generating means is disposed in said inner member and connected to the pipe string and is movable upwardly by the pipe string for generating a fluid pressure in said chamber. The fluid pressure in said chamber acts on said opposed pressure surfaces to force said members in opposite longitudinal directions. The transverse pressure area of one of said piston means is greater than the transverse pressure area of said generating means, so that the force on one of said members due to fluid pressure in said chamber is a multiple of the force applied to said generating means by the pipe string. Thus, it will be appreciated that a lesser strain can be applied to the pipe string at the surface to obtain the required setting force for the packer, which enables setting at greater depths for the packer without exceeding the strength of the pipe string.

The present invention has other concepts and advantages which will become more apparent in connection with the following detailed description of an exemplary embodiment. Such embodiment is shown in the accompanying drawing in which:

FIG. 1 is a somewhat schematic view of a well packer and setting tool disposed in a well bore on a pipe string;

FIGS. 2A and 2B are sectional views with portions in side elevation, of the setting tool of the present invention with parts in their relative positions before setting of the well packer, FIG. 2B forming a lower continuation of FIG. 2A; and

FIGS. 3A and 3B are views similar to FIGS. 2A and 2B, but with parts in their relative positions after the well tool has been set in the well bore.

Referring initially to FIG. 1, a schematic representation of a well tool **10** such as a packer, plug or retainer, is coupled to a mechanical setting tool **11**, which incorporates the principles of the present invention, and is suspended in a well casing **12** on a running-in string **13** of tubing or drill pipe. The well tool **10** includes a central mandrel **14** carrying normally retracted upper and lower slips **15** and **16** which can be shifted outwardly by upper and lower companion expander cones **17** and **18**. A packing element **19** is disposed between the expander cones and is arranged to be expanded outwardly when subjected to longitudinal compression force. A conventional body lock ring **20** is cooperable within a setting head **21** to grip the mandrel **14** and trap the slips **15** and **18** and the packing element **19** in expanded positions.

Turning now to FIGS. 2A and 2B for details of the setting tool apparatus **11**, an outer tubular member **25** is

telescopically disposed upon an inner tubular member **26**, the members being arranged for longitudinal movement in opposite directions relative to one another. The lower end portion of the outer member **25** can be constituted by a threadedly attached sleeve **27** which extends downwardly into abutting relationship with the setting head **21** and is accordingly coupled to force the setting head downwardly relative to the mandrel **14**. The lower end portion of the inner member **26** can be constituted by a threadedly attached sleeve **28** which extends over the upper end portion of the mandrel **14** and which is releasably coupled thereto by a conventional shear ring **29**. Thus, the inner member **26** is coupled to the mandrel **14** for transmitted upward force thereto until the shear value of the ring **29** is reached, at which point the ring can shear and release the inner member **26** from the well tool **10**. Although the use of an annular shear ring as shown enables a full-opening bore through the setting tool, it will be equally appreciated that a conventional tension stud could be used to connect the inner member **26** to the mandrel **14**.

The upper end of the outer member **25** is connected to a cage member **30** having a plurality of radially directed recesses **31**, each of which receives a drag block **32** which is urged outwardly by a coil spring **33** or the like. The drag blocks **32** can slide along the inner wall of the well casing and yieldably resist both longitudinal and rotational movement. A coupling sleeve **34** extends upwardly from the cage member **30** and has an internal splined recess **35** and an upwardly opening J-slot **36** for purposes which will be described hereafter.

The outer member **25** has a shouldered piston section **40** extending inwardly toward the inner member **26** and sealed against the outer periphery of the inner member by a seal ring **41**. The shoulder configuration of the piston section **40** provides an upwardly facing transverse pressure surface **42**. The upper end of the inner member **26** is formed by an annular piston head **43** which is sealed against the inner periphery of the outer member **25** by a seal ring **44**. The piston head **43** has downwardly facing pressure surfaces **45** and **45'** which are communicated via a radial port **46**, the pressure surfaces on the piston head **43** and the outer member **25** being disposed so as to face one another. The annular space between the piston section **40** and the head **43** provides a chamber **47** which is filled with a suitable hydraulic fluid.

Telescopically disposed within the inner member **26** is a tubular operating member **50** having its upper end connected to the lower end of the running-in string **13** by a collar or the like. An annular shoulder **51** is formed near the lower end of the member **26**, and an annular, floating piston ring **52** is disposed between the operator member **50** and the inner member **26**. Suitable seal rings **53** and **54** prevent fluid leakage past the ring **52**.

During lowering into a well bore, relative longitudinal movement between the various members **50**, **26** and **25** is prevented by engagement of a lug **56** on the operator member **50** within the closed segment **57** (FIG. 1) of the J-slot **36**. Moreover, an inwardly extending shoulder **58** on the outer member **26** engages below the shoulder **51** on the operator member **50**. Thus, the parts are held in the positions shown in FIG. 2A and 2B until, by appropriate manipulation of the running-in string **13**, the lug **56** is indexed into the open-ended segment **59** of the J-slot to enable upward movement of the operator member **50** relative to the inner member **26**.

Further provision is made for controlling the extent of longitudinal relative movement between the various members, including a stop nut **60** threadedly engaging the operator member **50** and co-rotatively secured to the inner member **26** by splines **61**. After the lug **56** is released from the J-slot **36** as previously described, the operator member **50** can be reciprocated upwardly until the nut **60** engages the top of the recess **35**, at which point the operator member must be rotated by the running-in string **13** to the right to unthread the nut **60** from threads **62** to enable further upward movement of the operator member **50**. As shown in FIG. 2B, the piston ring **52** is initially spaced upwardly from the shoulder **51** a distance to permit the operator member **50** to be moved upwardly to the extent necessary to unthread the nut **60** before the shoulder **51** picks up the ring **52**.

If it is desired to maintain the members telescoped after the setting tool has been operated, the inner member **26** may be provided with an internal annular recess **64** which receives an annular, split clutch ring **65** having upwardly facing teeth **66** on its inner periphery. A longitudinally disposed spline **67** on the inner member **26** engages within the split in the clutch ring **65** to prevent relative rotation. Downwardly facing teeth **68** are formed on the outer periphery of a central section of the operator member **50** below the clutch ring **65**, so that when the operator member is moved upwardly relative to the inner member **26**, the teeth **68** will ratchet through the clutch ring **65**, and the clutch ring will trap the operator member **50** in an upper position relative to the inner member.

In operation, the parts can be assembled as shown in FIGS. 2A and 2B and coupled to the well tool **10** to be lowered and set in the well bore. During lowering, the lug **56** on the operator member **50** is positioned within the closed segment **57** of the J-slot **36**, and the drag blocks **32** engage the casing wall and are pushed downwardly in the casing by the weight of the running-in string **13**. At setting depth, the assembly is halted, the running-in string **13** is torqued a part turn to the left and then lifted to disengage the lug **56** from the J-slot **36**, and then the running-in string is rotated several turns to the right to unthread the stop nut **60** from the operator member **50**, the drag blocks **32** preventing rotation of the cage member **30** and the stop nut. After the stop nut **60** is disengaged, the operator member **50** is free to be moved upwardly by the running-in string relative to the inner and outer members **26** and **25** to cause setting of the well tool **10**.

Elevation of the running-in string **13** at the top of the well bore causes the shoulder **51** to pick up the piston ring **52**. Due to the resistance afforded by the drag blocks **32** to upward movement of the outer member **25**, upward force on the piston ring **52** generates a fluid pressure in the chamber **47** which acts upwardly on the lower surfaces **45** and **45'** of the piston head **43**, and downwardly on the surfaces **42** of the outer member **25**. The respective upward and downward forces developed on the members **26** and **25** causes lifting of the mandrel **14** relative to the setting head **21** sufficiently to set the upper slips **15** against the well casing wall. Of course, the upper slips can be of any conventional design requiring a relatively low initial setting load. After setting, the upper slips **15** grip the casing and prevent upward movement of the upper expander cone **17**, and further setting force applied to the mandrel **14** will effect expansion of the packing element **19** and the lower slips **16** against the casing wall, setting being completed when the setting tool parts are telescoped as shown in FIGS. 3A and 3B.

The upward setting force applied to the mandrel **14** is fully developed in the following manner. As previously described, upward strain on the running-in string **13** will generate a fluid pressure in the chamber **47** which is a function of the force applied and the transverse area of the piston ring **52**. This pressure acts upwardly on the downwardly facing transverse surfaces **45** and **45'** of the piston head **43**, and downwardly on the upwardly facing transverse surface **42** of the outer member **25**. Inasmuch as the downwardly facing surfaces **45** and **45'** provide a cumulative area which is considerably larger than the transverse area of the piston ring **52**, the upward force on the inner member **26** is considerably larger than the upward force being applied to the

running-in string **13** at the surface. As an illustrative example, the area of the piston ring **52** may be one square inch, while the sum of the areas of the surfaces **45** and **45'** may be two square inches. Therefore, an upward pull on the operator member **50** of 20,000 lbs. will develop 20,000 p.s.i. fluid pressure in the chamber **47** which acts on the inner member **26** as an upward force of 40,000 lbs. The area of the surface **42** on the outer member **25** may be, for example, one square inch, so that a downward force of 20,000 lbs. is also developed on the outer member **25**. The upper slips **15**, however, are gripping the casing wall, so that the net result is an upward setting force of 40,000 lbs. applied to the mandrel **14** to firmly set the packing element **19** and the lower slip **16** against the casing. The lock ring **20** will trap the setting load in the tool in a conventional manner, and when a predetermined force is applied to the shear ring **29**, it will fail and release the setting tool **11** from the packer **10** so that the setting tool can be withdrawn from the well, leaving the packer permanently set. During upward movement of the operator member **50** within the inner member **26** during setting, the threads **68** will ratchet through the clutch ring **65** which will lock the operator member in a upper solid position relative to the inner member **26**, so that the pipe string can be further manipulated to operate a valve or the like in the packer.

It will now be apparent that a new improved setting tool operable by a pipe string to set well tools in well bores has been disclosed. Due to the greater transverse pressure area of the inner member relative to the piston ring, the upward setting force applied to the packer mandrel is amplified above the strain applied to the running-in string at the earth's surface. Thus, the packer can be set at much greater depths than is possible with conventional mechanical setting tools while staying within the allowable tensile strength of the running-in string.

Since certain changes and modifications will occur to those skilled in the art in view of the present disclosure without departing from the concepts of the present invention, it is the aim of the appended claims to cover all such changes and modifications falling within the true spirit and scope of the present invention.

I claim:

1. A setting tool apparatus for use in a well bore, comprising: inner and outer telescopically disposed members, said members being movable in opposite longitudinal directions relative to one another and coupled in force transmitting relationship to relatively movable parts of a well tool; piston means on said members having opposed transverse pressure surfaces and forming a fluid filled chamber; and means disposed within said inner member and movable upwardly relative to said members for generating a fluid pressure in said chamber, whereby the pressure of fluids therein can act upwardly on the pressure surface of said inner member and downwardly on the pressure surface of said outer member to effect telescoping movement of said members in opposite longitudinal directions, said pressure generating means having a transverse pressure surface with lesser area than the pressure area of one of said opposed pressure surfaces.

2. A setting apparatus for use in setting a well tool having normally retracted means movable to expanded positions in response to oppositely directed forces applied thereto, comprising: an inner tubular member adapted for connection to a pipe string; an intermediate tubular member telescopically movable on said inner member; first piston means on said inner member; second piston means on said intermediate member, said second piston means having a larger pressure area than said first piston means; an outer tubular member telescopically movable on said intermediate member; and third piston means on said outer member, said piston means forming wall portions of a fluid-filled chamber so that upward force on said inner member due to upward strain on the running-in string will generate a fluid pressure in said chamber which acts on said second piston means in one longitudinal direction and on said third piston means in the opposite direction to apply oppositely directed forces to parts of the well tool and cause expansive movement of said normally retracted means.

3. The apparatus of claim **2** further including releasable means for preventing longitudinal relative movement between said members during lowering into a well bore, said releasable means being releasable in response to manipulation of the running-in string.

4. The apparatus of claim **2** further including friction drag means on said third member for yieldably resisting movement of said third member in the well bore.

5. A setting apparatus adapted for use at the lower end of a running-in string to set a well tool in a well bore, comprising: inner and outer tubular telescoping members adapted for movement in opposite longitudinal directions, said members being coupled in force transmitting relationship to relatively movable parts of a well tool; first piston means on said outer member sealingly slidable on said inner member and having an upwardly facing transverse pressure surface; second piston means on said inner member sealingly slidable on said outer member and having a downwardly facing transverse pressure surface, a fluid-filled chamber being provided between said pressure surfaces; and means adapted for connection to the lower end of the running-in string and disposed within said inner member and movable upwardly relative to said members by the running-in string for generating a fluid pressure in said chamber, said fluid pressure acting upwardly on said downwardly facing transverse surface and downwardly on said upwardly facing transverse surface to force said members in opposite longitudinal directions, the upward force on said inner member being a multiple of the upward force applied to said generating means by the running-in string.

6. The apparatus of claim **5** further including drag means on said outer member yieldably engageable with a well conduit wall for resisting movement of said outer member along the well conduit wall.

7. The apparatus of claim **6** further including releasable means for preventing relative movement between said generating means and said members, said releasable means being releasable in response to manipulation of the running-in string.

8. The apparatus of claim **6** further including one-way clutch means for permitting upward movement of said generating means relative to said inner member and for preventing downward movement of said generating means relative to said inner member.

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U.S. Cl. X.R.

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