

April 3, 1962

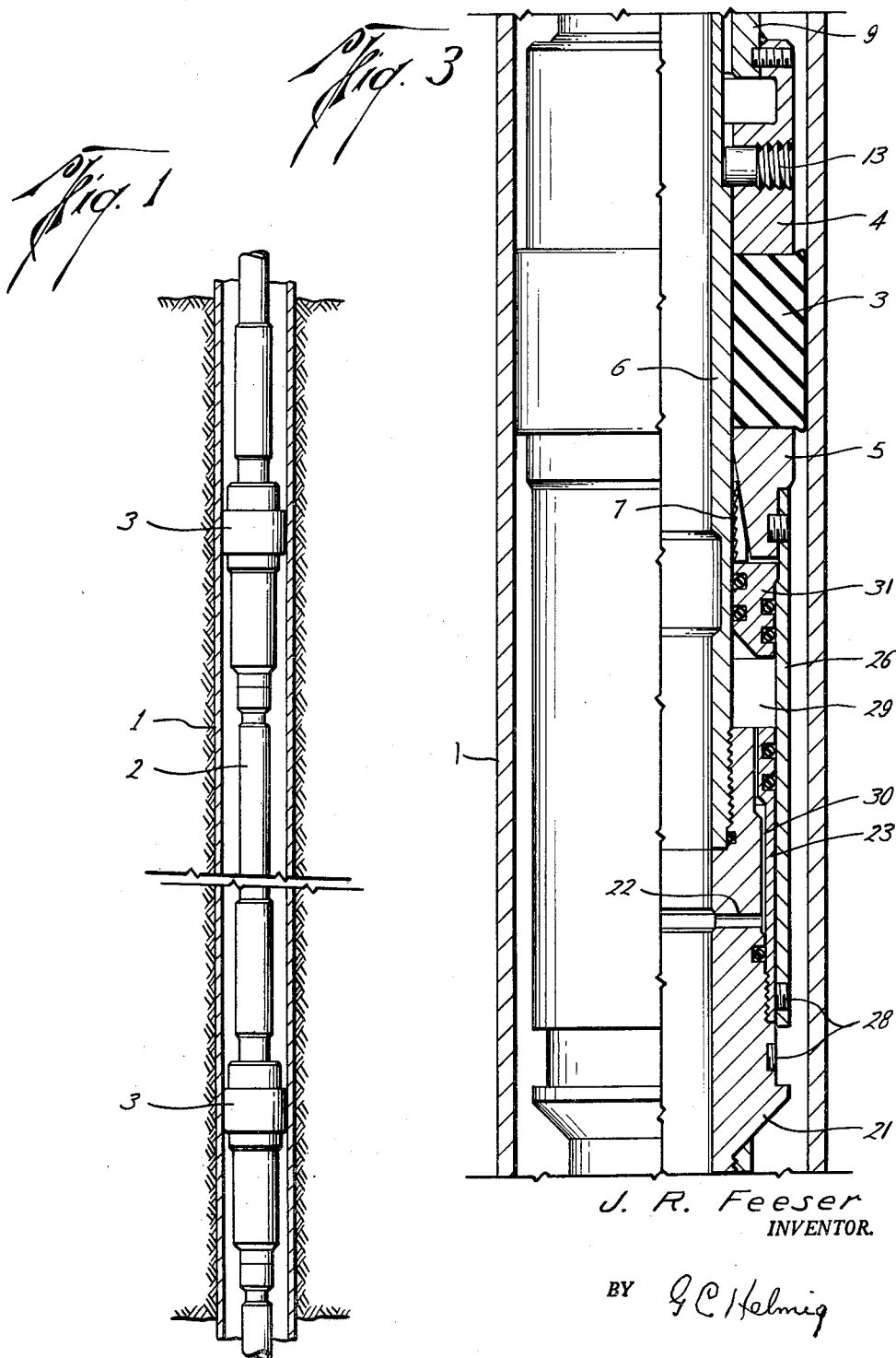
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3,027,944

MAGNETICALLY SET PACKER

Filed Nov. 14, 1960

2 Sheets-Sheet 1



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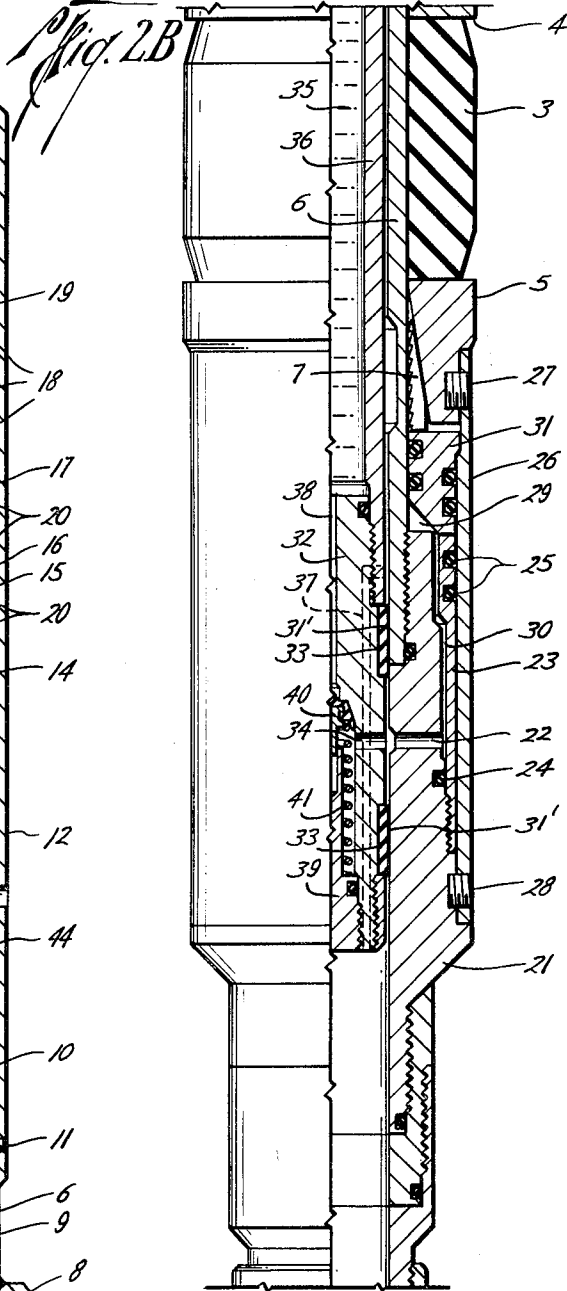
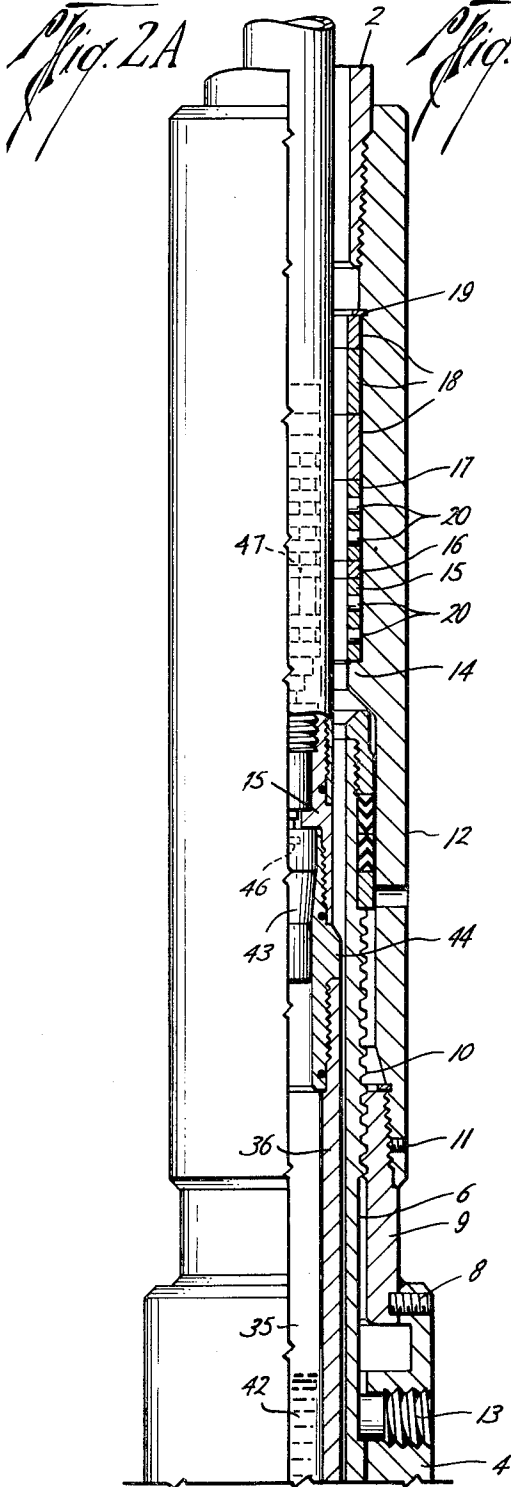
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MAGNETICALLY SET PACKER

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This invention relates to well tubing installations and more particularly to the setting of a packer across a portion of the annular space surrounding a tubing string to partition and seal off the space below and above the packer.

Either or both the well bore liner or casing tubing and one or more well production tubing strings in conventional use are commonly lowered into a well with either a single or with several expansible packers mounted at given locations on the tubing for packer expansion to seal-off relation following completion of the lowering-in operation. Hydraulically set type packers are currently favored. Before they are set, the practice of completing oil and gas wells is to bolt in place the Christmas tree and other wellhead parts and then circulate drilling mud from the well and leave light completion fluid in the tubing. The disadvantages attending the setting of such hydraulically operated packers include the need for a high pressure pumping truck at the well site and also on frequent occasions a wire line truck to set a block for insuring hydraulic pressure application, and furthermore completion technique is complicated when multiple packers are used in that pressures are not isolated to control any one packer.

An object of the present invention is to overcome disadvantages in the use of hydraulically set packers, with retention of recognized advantages. To that end, existing packer assemblies such as those involving rubber or lead seals to be set by reciprocatory motion, need but slight modification to provide an actuating piston on the packer mandrel through which fluid force can be transmitted to effect relative movement between the mandrel and the seal and its holding slips.

A further object of the invention is to provide for delivery to a subsurface packer of operating pressure fluid supplied by signaled ignition of a combustible charge contained within a wire line tool having an ignition control arranged to be triggered into action when lowering of the tool brings its pressure fluid outlet into operative relation with the packer and places the control under influence of tubing mounted signaling mechanism adjacent the packer.

Another object is to provide a well tubing string embodying multiple fluid pressure actuated packers and associated signaling devices, each different from others, and a wire line tool including a combustible charge and a signal actuated ignition control preset for response to a predetermined signal for the selective setting of packers individually.

A still further object is to provide a packer assembly having internal sealing surfaces above and below a pressure fluid inlet port leading to its actuator piston chamber and a tool having an expansible charge containing chamber from which leads an outlet port between upper and lower sealing surfaces at the tool exterior for co-operation with the tubing sealing surfaces so as to confine pressure fluid flow from port to port when tool descent has brought the parts together at the instant ignition of the charge occurs under signaled control thereof.

The invention also has for an object the provision of a set of tubing carried magnets in predetermined spaced apart relation to one another and to the packer inflow port and a packer setting force applying tool having a set of magnetic field influenced magneto devices preset in spaced apart relation to one another and to the tool out-

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flow port and in matching correspondence to the spacing of the magnets and packer inflow ports whereby the ports are in substantially aligned co-operation as the magneto devices are simultaneously influenced by the magnetic fields and release the tool stored actuating force.

Another object of the invention is to provide a tool with an expansible charge containing cavity having a choked outlet passage closed by a check valve against entry of well fluids and containing either or both liquid and air to be ejected as a force transmitting medium by the instantaneously developed power charge and at a metered rate predetermined by choke passage dimension for a relatively slow and continuous application of fluid pressure on the packer setting piston.

Additional objects will be apparent from the following specification and the accompanying drawings illustrating a preferred but not necessarily the only embodiment and wherein FIG. 1 shows a fragment of a well in vertical section and containing a pair of packers to segregate the annulus space between a pair of tubing strings; FIGS. 2A and 2B are companion views partly in elevation and partly in section, of a packer unit and a tool for supplying packer setting force in a co-operative relation at the instant of power release but before power application on the packer; and FIG. 3 is a part elevation and part sectional view of a casing engaged and expanded packer unit.

In FIG. 1 the casing tubing 1 lines a well bore and receives a production tubing string 2 which includes a pair of packing rings 3—3 which, according to the present invention, are to be set selectively and in any desired order. Each packing ring 3 is represented in the drawing as consisting of a collar of rubber or other elastic deformable material and constitutes a part of an assembly or hollow packer unit whose opposite ends are to be joined in end to end succession with other joints of a tubing string. Opposite end faces of the packing collar 3 are in seating abutment with a pair of relatively shiftable metal rings 4 and 5 in embracing relation to a tubular mandrel 6. In its unstressed relation, the collar has an outside diameter somewhat less than the internal diameter of the casing 1 for clearance passage during installation.

Upward movement of the bearing ring 5 with the opposite end bearing ring 4 remaining stationary, will stress the collar longitudinally and displace the material thereof for a radial growth into tight seating contact with the interior face of the casing 1. This will be the set position illustrated in FIG. 3 and will be maintained by segmental slips or wedges 7 interposed between the peripheral surface of the mandrel 6 and the upwardly tapered interior surface of the ring 5 according to conventional packer design.

For freeing a packer which has been set, the upper pressure ring 4 will need to be lifted or moved away from the slip held pressure ring 5. Accordingly, the ring 4 at its upper end is secured and locked by a set screw 8 to a short tubular member 9 whose upper end is internally threaded and engaged with external threads 10 on the mandrel 6 so that rotation of the tubular part 9 relative to the mandrel will, by reason of the screw threads, shift the tubular part 9 and carry the pressure seat 4 upwardly. For effecting such relative rotation, the upper end of the tubular part 9 is threadedly connected to and secured by a set screw 11 on the lower end of a tubular nipple 12 constituting the upper end of the packer assembly and having end to end connection with the tubing string section 2 thereabove. In other words, rotation of the tubing string in the proper direction while the mandrel 6 is held to the casing 1 by the expanded packer collar 3, will relieve the collar from stress and accommodate its radial contraction away from the casing

1. To establish opposite limits of relative longitudinal travel and to maintain the parts against complete separation, the seating ring 4, as seen in FIG. 2A, carries a lateral screw stud 13 whose inner tip projects into an annular groove in the peripheral surface of the tubular mandrel 6 just below the screw threads 10 and provides top and bottom shoulders or stop abutments for the screw stud 13. The packer assembly as thus far described is generally similar to various units that have long been on the market.

In the present instance, the nipple 12 is of special design and it provides an interior pocket above an internal annular boss 14 of a length to receive a stack of interchangeable rings 15, 16, 17 and 18. A removable snap ring 19 is fitted to an internal groove in the nipple 12 and bears against the uppermost ring of the stack. The nipple 12 and the spacer rings 16 and 18 are of magnetic material such as steel, while the rings 15 and 17 are of nonmagnetic material such as brass or aluminum and each of the nonmagnetic rings carries two longitudinally spaced apart rows of permanent magnets 20 preferably of short bar form. Preferably, the magnets in one row of the set carried by the ring 15 have their north poles facing radially inwardly and the magnets of the companion set have their north poles facing radially outwardly for presenting a strong field inwardly of the subular space within the nipple. The same arrangement of magnets is employed with the companion ring 17. Thus there is provided a set or pair of longitudinally spaced apart magnetic fields and the spacing between these fields can be variously adjusted by substituting for or adding to the spacer 16 one or more of the spacers shown at 18. Thus in an installation involving multiple packers, the spacing of the magnetic fields at each packer will be determined beforehand and will be set up so as to be unlike the spacing at any other packer. As will later be described in more detail, the magnetic field combination affords a signal means for magneto devices incorporated in a wire line tool whereby the tool can be preconditioned for response at any selected packer unit.

At its lower end the tubular mandrel 6 is joined to a thickened tubular wall section 21 whose lower end may be coupled by suitable fittings in end to end succession with a tubing section therebelow. At an intermediate point in its length, the tube section 21 has a lateral port 22 extending therethrough from an internal annular groove and this lateral port constitutes a fluid pressure inlet flow passage leading to an annular clearance space 30 leading upwardly from the port between the peripheral face of the tubular section 21 and a sleeve 23 which terminates upwardly at the upper end of the section 21. At its lower end below the lateral port 22, the sleeve 23 is threaded or otherwise secured to the tube section 21 and is sealed thereto as by means of an O-ring 24. Additional O-rings 25 are carried in peripheral grooves at the upper end of the sleeve 23 and have sealing engagement with the interior face of a slide sleeve 26 which is rigidly secured as by means of a set screw 27, to the pressure ring 5 and constitutes a downwardly extending skirt which telescopically slidably fits on the exterior of the sleeve 23 and is releasably secured, as by means of a shear pin 28, to the tubular extension 21 of the mandrel 6. The annular space 29 between the upper ends of the tubular parts 21 and 23 and the bottom of the pressure ring 5 and between the mandrel 6 and the slide sleeve 26 affords an expansible chamber in open communication at all times with the clearance space 30 around the mandrel extension 21 and with the entry port 22. A slidable ring piston 31 is contained within the expansible chamber 29 and preferably has internal and external annular grooves to contain sealing O-rings engaged with adjoining wall surfaces of the mandrel 6 and slide sleeve 26 to seal the chamber against pressure fluid escape. The upper face of the ring piston 31 bears directly on the bottom of the slip 7 so that upon receipt of pressure fluid into the chamber

29 the action will be to raise the piston and the force will be transmitted through the slip segments 7 to the pressure ring 5 to squeeze the rubber collar 3 and cause its radial expansion. After expansion has occurred, resistance will be offered to further upward movement of the pressure ring 5 whereupon the slips 7 will slide on the interior tapered face of the ring 5 and will be wedged into tight clutching action with the peripheral surface of the mandrel 6 and will hold the parts against return to original position after all pressure fluid actuating forces have been dissipated.

The interior surface of the packer mandrel in the regions immediately above and below the inlet port 22 in the mandrel extension 21 is accurately and carefully machined to a uniform diameter and smooth finish to afford annular sealing surfaces 31' and these are for bearing engagement by complementary sealing surfaces peripherally carried on the wall of a tube member 32 forming the lower part of a sectional body of the wire line tool. More particularly, the tool carried sealing surfaces are constituted by a pair of longitudinally spaced apart packing rings 33—33 located above and below a lateral port 34 through the wall of the tool body section 32. In the final operative position of the wire line tool as seen in FIG. 2B, the lateral port 34 is in substantial alignment with the lateral port 22 in the wall of the tubing or packer mandrel and constitutes an outlet leading from a power gas expansion chamber or cavity 35 interiorly of the tool body as provided by the tubing section 32 in conjunction with a tubing section 36 thereabove. A pressure equalizing passage 37 to by-pass the peripheral packing seals is shown in dotted lines in FIG. 2B as opening at its lower end through the bottom terminal face of the body section 32 below the lowermost packing ring 33 and as opening at its upper end above the uppermost group of packing rings 33 into the interior of the tubing string. The outlet flow passage from the cavity 35 includes a restricted axially extending central bore 38 in the upper end of the body section 32 terminating in a larger diameter valve cage from which leads the lateral port 34. At its lower end the valve cage is closed by a plug 39 which guides an inwardly seating check valve 40 normally biased upwardly to closed position by a coil spring 41.

When seated, the check valve 40 closes the lower discharge end of the cavity 35 and precludes entry into the cavity of well fluids during lowering of the tool prior to the operation of supplying motive force for setting the packer. Preparatory to the lowering operation of the tool, the cavity 35 is partially filled with a body of force transmitting water or other liquid 42, leaving a space above the liquid for a predetermined volume of force cushioning air or gas, and additionally is fitted at its upper end with an explosion squib or combustible charge, shown at 43. Prior to final tool assembly, the body of liquid 42 and the squib 43 fitted to a receiver tube 44 at the upper end of the tool body section 36, are introduced through the open upper end of the tubular part 44. There is then assembled or attached as by screw threads to the upper end of the tool body an additional tubular body section 45 enclosing suitable ignition control mechanism by which the firing of the combustible charge 43 is effected in response to receipt of a proper signal, and which signal, according to the present disclosure, consists of the field influence of the set of axially spaced magnets 20—20 carried by the tubing string. In other words, the ignition fuse or cap 46 of the combustible charge 43 is electrically actuated by connection in a circuit which includes a pair of series connected relay switches or current supply elements, each responsive to a separate magneto device. The twin magneto devices, preconditioned for action in a control circuit by a master switch, are arranged in spaced apart relation in matching correspondence to the spaced apart relation of the magnetic fields provided by the tubing magnet means.

A suitable arrangement of magnet influenced switch-

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ing devices is indicated generally by broken lines at 47 in FIG. 2A and is shown in detail in copending patent application Serial No. 17,385, filed March 24, 1960, by W. G. Ownby. It consists of a stack of spaced apart magnetic field sensing elements or semiconductors to receive current and produce a Hall effect output voltage. The semiconductors in disc form are arranged between pole pieces with means for the selective activation of the several semiconductors in any desired paired combination to match the pole pieces of selected semiconductors to the field spacings provided by the magnets of the packer unit to be set. It follows that when the pre-selected set of Hall effect semiconductors traverses any magnetic field during descent of the tool, each will respond to close its control circuit switch, but such individual response will be ineffective to fire the explosive charge unless both devices which have been selected traverse magnetic fields simultaneously and respond to concurrently close relay switches for the transmission of electric current to the igniting fuse 46.

Due to the same spatial relationship between the tubing inlet port 22 and the magnets 20 and between the outlet port 34 and the ignition control devices indicated by dotted lines in FIG. 2A, the instant that tool descent effects the firing, the ports 34 and 22 will be in substantial alignment for the transfer from one to the other of fluid force to project the piston 31 to packer setting relation. Burning of the charge 43 provides an expanding gas energy whose suddenness of application will be cushioned to some extent by the entrapped air within the cavity 35 and whose force will be transmitted by the liquid body 42 ejected from the cavity and into the piston chamber 29. During such outflow, the check valve 49 is pushed away from its seat and the predetermined dimension of the choke 38 controls the rate of outflow or retards and gives a continuous and relatively slow delivery of pressure fluid for setting the packer without unduly stressing or shocking the parts. As the pressure force is received by the piston 31, it first shears the holding pin 28 to allow upward movement of the outer sleeve 26 and the pressure applying ring 5 for deflection and deformation outwardly of the peripheral face of the packer 3. Thereafter, the wire line tool is removed from the tubing string and may be recharged for further use at other packer locations. By selective space coding of the magnet rings, a large number of packers on a single or multiple tubing strings, including casing strings and production strings, may be selectively set each without interference to other packers. In any event, the packer actuating piston and the magnet rings are incorporated within the packer assembly but the renewable combustible charge is a part of the wire line tool. Such provision of application of packer setting forces provides a small self-contained unit and eliminates the need for high pressure pumping trucks heretofore required for the use of hydraulically set packers.

What is claimed is:

1. In combination, a well tubing string, a plurality of spaced apart packer units incorporated in the tubing string and each comprised of a fluid pressure expansible packing element and a pressure fluid receiving chamber therefor having an entry port leading into the chamber from the tubing interior, a set of spaced apart magnets mounted by the tubing string adjacent each packer element with the relative positions of the magnets being predetermined as to each set and varied in different sets, a well tool body for passage through the tubing string, a set of spaced apart magneto devices carried by the body and responsive to the fields of magnets traversed thereby, means to adjust the position relation of said magneto devices selectively to match the predetermined position relation of the tubing string magnets in any set, a combustible charge mounted in said tool body and connected with the magneto devices for firing upon their concurrent responses to magnetic fields, a chamber confined within

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the tool body and into which the charge expands upon burning thereof, a body of expellable force transmitting liquid initially partially filling the chamber and a body of force cushioning gas initially contained within the remainder of the chamber, a chamber outlet passageway positioned by the body for directing expelled liquid into the aforementioned entry port and an outwardly opening check valve closing said passage in the absence of charge expanding force to expel the force transmitting liquid body.

2. A tool to be passed through tubing and to be actuated in response to and upon reaching the location of a tubing carried signal means for supplying motive power to a tubing carried work performing device, said tool comprising a body, a releasable energy storing charge contained by the body in an initially inactive state, means in the body operable on said charge to release the energy thereof and responsive to receipt of a signal from said signal means and energy transference means positioned by the body for receiving such released energy and imposing the same on the tubing carried work performing device as the motive power supply therefor.

3. In combination, a well tubing string having a series of work performing devices in spaced apart relation and arranged each for actuation in response to selective application thereto of operating force, signal means on the tubing string adjacent the respective devices providing sets of signals which are unlike at the respective devices, a well tool for passage through the tubing string, adjustable signal receiving means on the tool adjustable to be unresponsive to all but any selected one of the several signal means upon traversing the range thereof, releasable energy storing means mounted by the tool and connected with the signal receiving means and responsive to signal receipt thereby to release stored energy and tool carried means directing the application of released energy as the operating force to the work performing device adjacent the preselected signal means.

4. In combination, a well tubing string having a series of work performing devices in spaced apart relation and each arranged for response to the application thereon of an operating force, magnets carried by the tubing string and arranged in sets, one for each device, means mounting the magnets in spaced apart relations different in each set, a tool to be passed through the tubing string, a releasable force storing means carried by the tool as a unit therewith and adapted to be brought by tool passage through the tubing string into co-operative relation with and to be thereupon released to supply operating force to a selected work performing device, a set of magneto devices carried by the tool and influenced individually by each magnet when brought by tool passage into the field of each magnet, means to precondition said magneto devices in matching correspondence to the spaced apart relation of and for concurrent response to the magnets of a preselected set and means active upon such concurrent response to effect release of said operating force.

5. The combination of claim 4 wherein said work performing devices each includes a fluid pressure actuated member and said force storing means is a tool mounted combustible charge which when fired provides an expanding pressure fluid force, a chamber in the tool confining said charge, a body of force transmitting fluid within the chamber, a force transmitting fluid outlet passage leading from the chamber and positioned by the tool for communication with the fluid pressure actuated member of the selected work performing device and an inwardly biased check valve closing said passage and yieldable to accommodate force transmission through said fluid.

6. A well tool to be passed through a tubing string having a pressure fluid actuatable device and a magnet to provide a signaling field adjacent said device, said tool comprising a body enclosing a chamber, an explosive charge contained within the chamber, charge firing control means mounted in the tool and responsive to magnetic

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field impression thereon, a body of liquid in the chamber for ejection therefrom under the fired expansion force of said charge, a liquid ejection passageway leading from the chamber and an outwardly opening check valve in said passageway.

7. For setting a pressure fluid actuated device in a well tubing having magnet means adjacent the device to present a field signaling arrangement for application of actuating fluid pressure to said device, a well tool for passage through the tubing, a combustible charge carried by the tool and ignitable to provide pressure fluid, a chamber containing said charge and having an outlet through which pressure fluid outflow is to be directed to a tubing carried pressure fluid actuated device and charge igniting control means connected to said charge to fire the same in response to field influence on the control means of tubing carried magnet means.

8. For actuating a selected one of several pressure fluid actuated mechanisms incorporated in a well tubing string having sets of differently spaced apart magnets arranged one for each mechanism for selectively signaling such actuation, a tool to be passaged through the tubing string, a group of magnetically influenced devices carried by the tool and arranged for co-operation in preselected settings in corresponding matching spacing with the spacing of magnets in any one of said sets, a combustible charge connected with said devices and adapted to be fired upon the simultaneous responses of said devices of a selected setting, a chamber confining the charge and having an expanding gas outflow passageway directed to supply pressure fluid to the tubing string mechanism adjacent said devices of the selected setting.

9. In a tool as in claim 8, a body of liquid contained in said chamber for ejection as an expanding gas force transmitting medium and an inwardly situated check valve in the outflow passage from the chamber.

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10. In combination, a well tubing having a piston enclosing chamber provided with a lateral inlet port leading from the interior face of the tubing, annular sealing surfaces on said face above and below the inlet port, a tool to be passaged through the tubing and having a chamber provided with a lateral outlet port leading to the exterior face of the tool for communication with said inlet port upon substantial alignment therewith, annular sealing surfaces on said tool above and below said outlet port for sealing engagement with the sealing surfaces on said tubing when the ports are in communication with one another, a combustible charge in the tool chamber adapted to be ignited to supply pressure fluid, magnetically responsive charge igniting control means connected with the charge and magnet means carried by the tubing for supplying magnetic influence on said control means as tool travel brings said ports into communication with one another in the region between the engaged upper and lower sealing surfaces.

11. In a structure as in claim 10, said tool having a passage in the wall thereof opening at its opposite ends to the exterior of the tool in regions above and below the upper and lower sealing surfaces on the tool for the equalization of tubing pressures above and below the tool.

12. In the structure as in claim 10, said tool chamber and its outlet port being provided with pressure fluid flow choke means which retards the rate of fluid flow resulting from ignition of said combustible charge.

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