Jan. 28, 1941. A. BOYNTON 2,229,635

WELL TESTING TOOL

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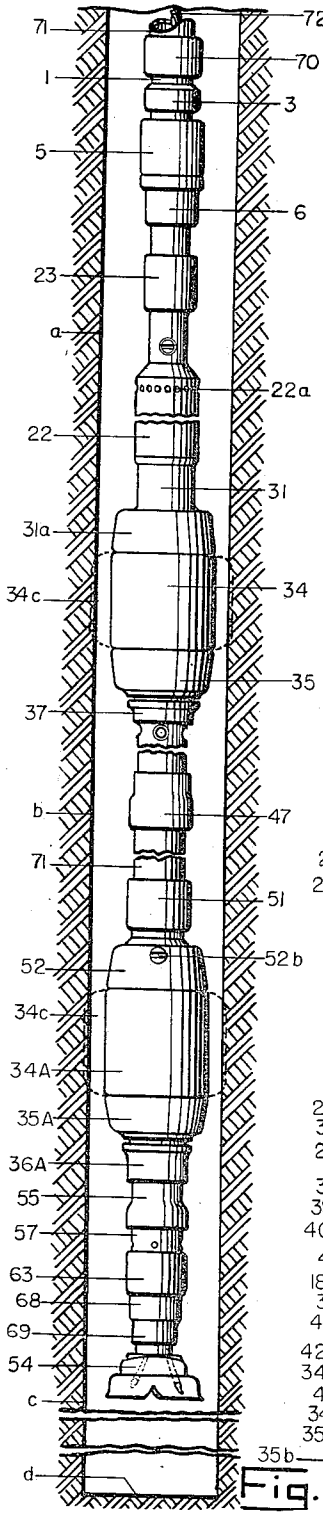

Fig. 1.

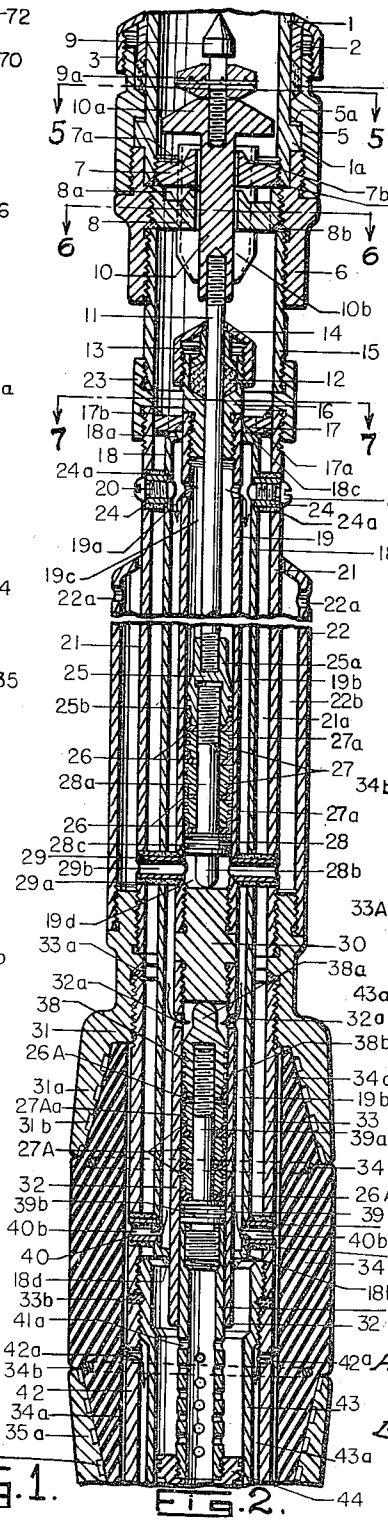

Fig. 2.

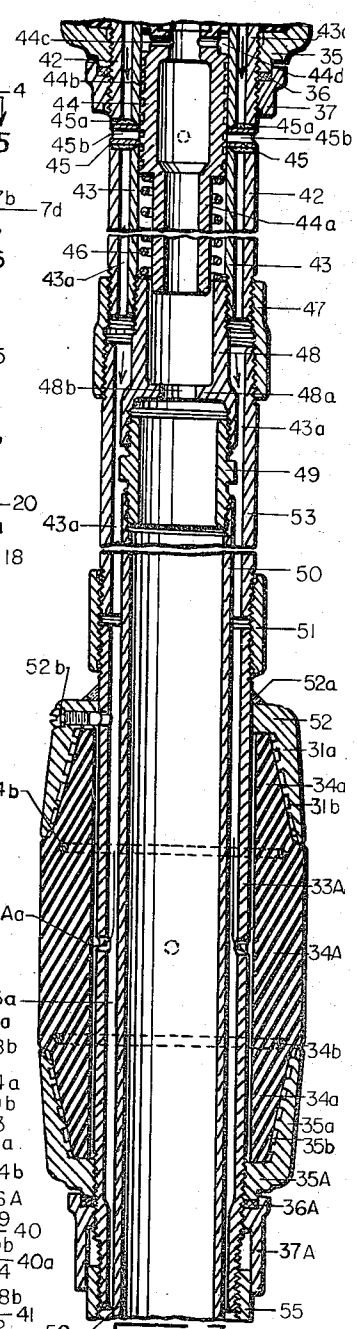

Fig. 3.

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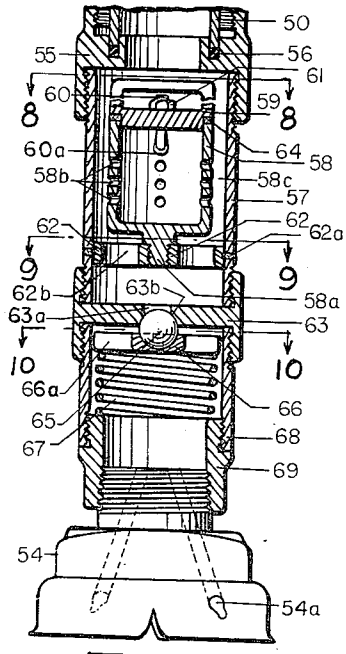

Fig. 4.

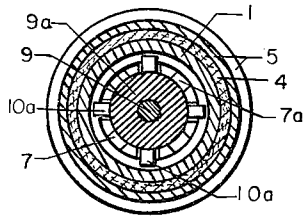

Fig. 5.

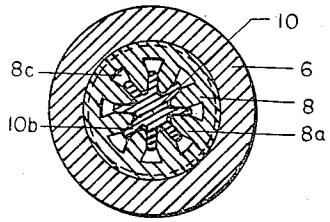

Fig. 6.

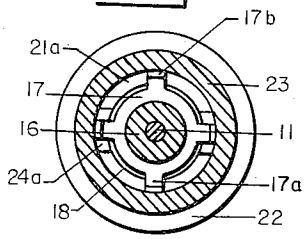

Fig. 7.

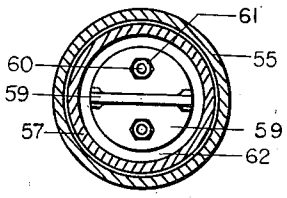

Fig. 8.

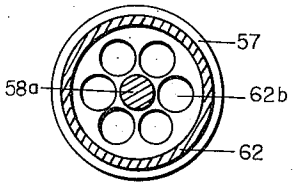

Fig. 9.

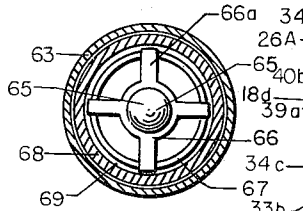

Fig. 10.

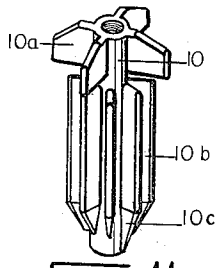

Fig. 11.

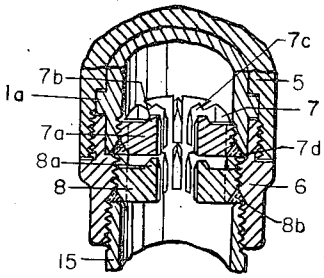

Fig. 12.

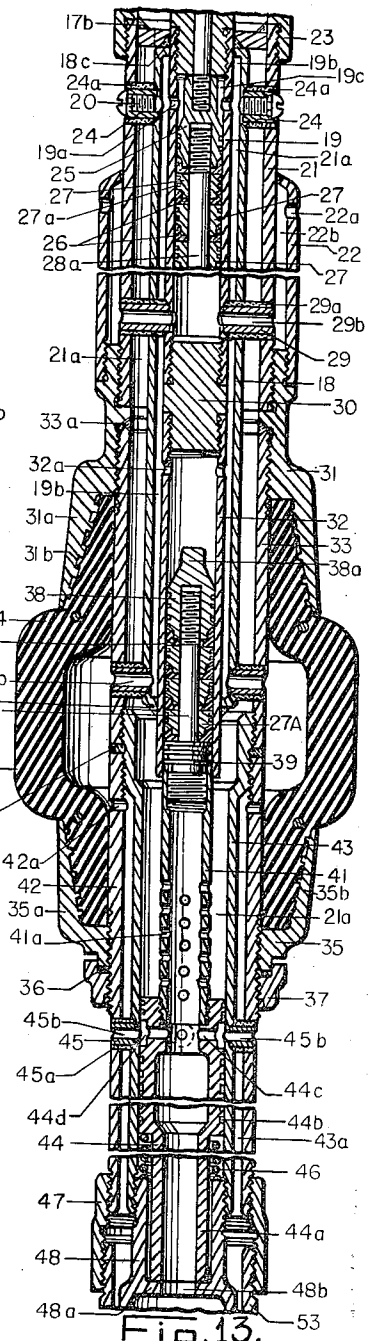

Fig. 13.

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WELL TESTING TOOL

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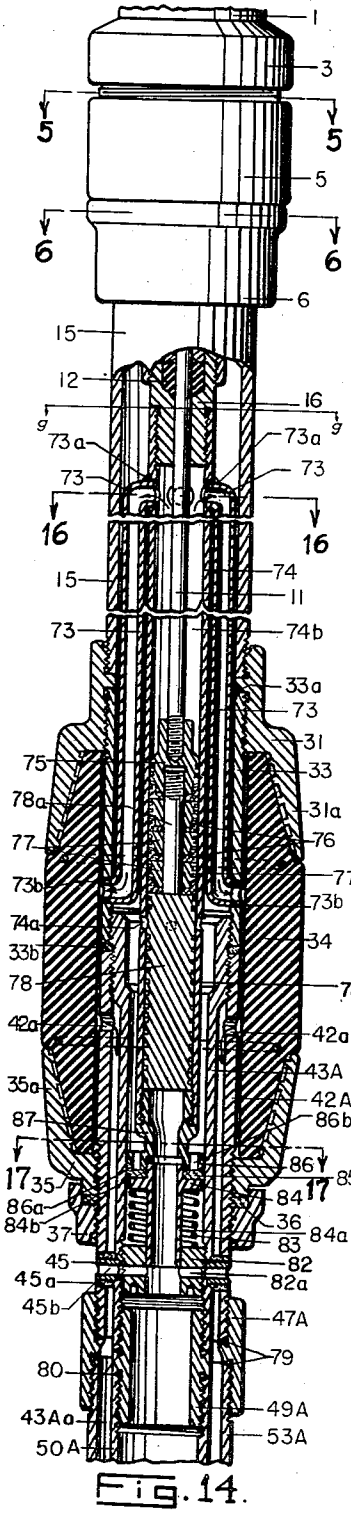

Fig. 14.

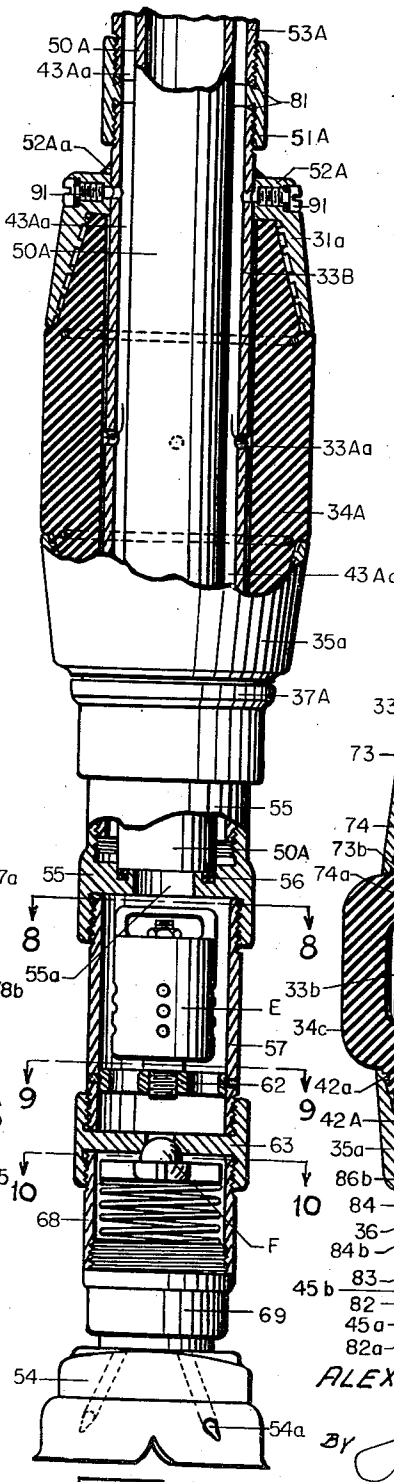

Fig. 15.

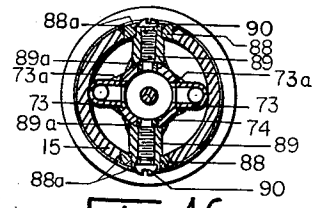

Fig. 16.

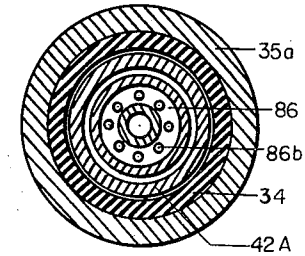

Fig. 17.

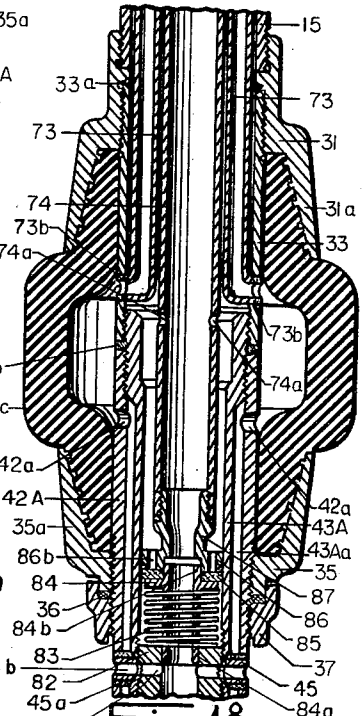

Fig. 18.

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UNITED STATES PATENT OFFICE

2,229,635

WELL TESTING TOOL

Alexander Boynton, San Antonio, Tex.

Application October 4, 1938, Serial No. 233,239

11 Claims. (Cl. 166—1)

My invention relates primarily to well formation testing tools employing two packers which are lowered into an uncased well upon the drill stem or any other suitable pipe, one packer to the top of, and the other to the bottom of the formation to be tested for the purpose of ascertaining the nature and volume of fluid which the formation will produce; of also ascertaining the existence of thief formations, and of sealing them with cement.

Any pipe upon which the packers are run will be hereinafter referred to as the drill stem. The drill stem is empty and mechanism is provided to keep the well fluid from entering until the packers have been expanded against the adjacent formation so as to prevent downward movement of well fluid from above the upper packer; and also to prevent upward movement of well fluid from below the lower packer. The packers are so expanded by pressure of liquid, the liquid being forced to expand both packers simultaneously by a piston actuated by a cable pull, both packers being later deflated by releasing the cable pull. The cable is operated from the top of the well and has means for attaching to and for detaching from the device. The cable pull which expands the packers opens the device to intake between the packers and allows well fluid to enter the drill stem. This operation, in effect, instantly pumps the well dry between the packers. Whatever fluid the well then produces into the drill stem in a given time, is a fair test of what the formation between the packers will produce if casing be set and the well completed. Releasing the cable pull automatically deflates and releases the packers and, at the same time, closes the liquid inlet into the drill stem between the packers. The production of the well from the horizon between the packers enters the drill stem while the cable is attached to the device and pulled upon. This production may be recovered for measuring and testing by bailing or swabbing or by withdrawing the drill stem from the well.

These packers may be set anywhere in the well bore, no shoulder, or so-called rat hole being required for them. The packers are variably spaced at proper distance apart to embrace the formation to be tested by varying the length of two readily changeable nipples in the device. These packers are deflated or pumped loose from their contiguous formations by the pressure of the well liquid when the cable pull is released from the piston which causes their expansion. The great danger and general difficulty of the old type packers hanging or sticking fast, is largely overcome by this releasing type of packer.

A bit of the usual fish tail type is ordinarily, but not necessarily, attached to the lower end of the anchor string to facilitate mixing the drilling mud, if necessary to do so, while lowering the device into the well.

The drill stem may be pumped through at any time, as well as rotated, while going into or coming out of the well. If pumped through, the drill stem, of course, must then be bailed or swabbed dry or drained by being withdrawn from the well before a clean production test can be recovered.

In the preferred form of the invention a clutch is provided, proximately above the upper packer. This clutch is normally engaged, so that the entire drill stem will rotate as a unit from rotary to fish tail. The cable pull which expands the packers disengages the clutch.

The device also provides for the employment of means for recording pressures, temperatures, etc., obtaining in the well.

The main objects of this invention are to provide a formation testing device for wells, which has the following advantages:

First—That it may be safely run into and readily withdrawn from a drilled well for the purpose of isolating any formation or horizon of the well for a certain time, of ascertaining whether such formation will produce, and, if productive, what and how much it will produce by recovering a true sample of the production from such isolated formation during that time.

Second—That if the test shows a formation to be unproductive or that it is producing under such low pressure as to be a possible theif formation, the device may also be employed to gauge the pressure at which such formation is producing into the well, and at what rate such formation will intake fluid from the well at any higher pressure.

Third—That it operates anywhere in a straight bore, and does not require that an offset or shoulder be provided by drilling a rat hole of reduced diameter into or through the formation to be tested.

Fourth—That the device will not be mal-positioned in the well by heavy mud, cavings, or other settlings in the bottom of the well, because the device has its position determined by the length of a hanging string of pipe which does not contact bottom of the well.

Fifth—That it makes possible an entirely new method of ascertaining the facts about unknown formations of the earth by combining the use of

this device with electrical or chemical well surveying means; such means being employed to ascertain the existence of oil, gas or water in a formation, and this device being employed to ascertain how much such formation will produce, the use of this device in combination with perforating means being also of advantage in testing wells.

Sixth—That the costly method of coring in search for pay formations may be now dispensed with by using this invention in conjunction with an electrical or other surveying means; the latter means being employed to indicate where tests for production should be made with this device which will then show what the production would be if the well were completed.

Seventh—That the pipe upon which this device is run may be rotated from top to bottom, including the device itself, while it is being lowered into, or being withdrawn from the well, and which may be also pumped through during any or all such times.

Eighth—That the drill stem may be rotated above the device when a production test is being made, while the device will remain stationary.

Ninth—That, by the action of a piston, the packers may be set with more force than ordinary packers which employ the weight of the drill stem to expand them.

Tenth—That, by wholly withdrawing the internal pressure employed to expand the packers, when the cable is given slack, the packers are released and contracted by external pressure of the well fluid.

Eleventh—That the packers will not be accidentally or inadvertently expanded as ordinary packers would be by encountering mud, cavings, or other obstruction in the well.

Twelfth—That pressure and temperature recording instruments, and other instruments, if desired, may be placed in the device for the purpose of ascertaining the pressure and temperature and variations thereof, obtaining in the well during the test.

Thirteenth—That, in addition to being efficient, sturdy, and durable; employing neither gears, shear pins, nor other complicated or fragile parts; it requires no left hand rotation, no left hand threads, or other dangerous means to operate it; all packer expansion and contraction movements being controlled by a cable operable from the ground surface.

Fourteenth—That, uncased thief formations, or those into which the production of other formations will escape, may be located, their intaking capacity ascertained, and such formation sealed, or plugged with cement by employing this device for both purposes.

Fifteenth—That leaks into or out of the casing may be located, their volume determined, and the leak stopped with cement by use of this device.

With the foregoing and other related objects in view, reference is now made to the drawings, in which

Fig. 1 is an outside elevation of the preferred form of the invention shown in a well bore, the expanded position of the packers being illustrated by dotted lines.

Fig. 2 is a longitudinal section of the upper portion of the device shown in Fig. 1.

Fig. 3 is a longitudinal section of a lower portion continuing the device partially shown in Fig. 2.

Fig. 4 is a longitudinal section of the lower portion completing the device partially shown in Figs. 2 and 3.

Fig. 5 is a transverse section on the line 5—5, Figs. 2 and 14.

Fig. 6 is a transverse section on the line 6—6, Figs. 2 and 14.

Fig. 7 is a transverse section on the line 7—7, Fig. 2.

Fig. 8 is a transverse section on the line 8—8, Figs. 4 and 15.

Fig. 9 is a transverse section on the line 9—9, Figs. 4 and 15.

Fig. 10 is a transverse section on the line 10—10, Figs. 4 and 15.

Fig. 11 is a perspective view of the clutch male member indicated at 10, Figs. 2 and 6.

Fig. 12 is a longitudinal section in perspective of the female members of the clutch appearing proximate the upper end of Fig. 2.

Fig. 13 is a longitudinal section of a portion of the device shown in Figs. 2 and 3 with the upper packer expanded, it being understood that the lower packer (not shown) is likewise expanded.

Fig. 14 is mainly a longitudinal section of the upper portion of a modified form of the invention, the upper portion being an outside view.

Fig. 15 is mainly a longitudinal section of the remaining portion of the device completing the portion shown in Fig. 14.

Fig. 16 is a transverse section on the line 16—16, Fig. 14.

Fig. 17 is a transverse section on the line 17—17, Fig. 14.

Fig. 18 is a longitudinal section of a portion of the device shown in Fig. 14 with the packer expanded.

In Fig. 1, the invention is illustrated as suspended in a well bore *a*, the packers being positioned so that the space between them will embrace the formation *b* to be tested. The expanded position of the packers is indicated by dotted lines 34*c*. The drill stem 71 upon which the device is lowered into the well is shown connected to member 1, Fig. 2, by coupling 70. The well bore *a* above the device and the bore *c* between the formation being tested and bottom of the well *d*, indicate other formations which may be tested by simply raising or lowering the drill stem and manipulating the cable 72 as will be explained.

The outer shell is formed of the drill stem connection member 1 which has the following parts connected thereto in the order named, the upper clutch shell member 5, lower clutch shell member 6, the nipple 15, coupling 23, nipple 21, connection member 31, upper packer nipple 33, secured to member 31 by weld 33*a*; upper packer nipple extension 42, both nipples 33 and 42 being threadedly joined upon the upper end of pressure pipe 43 and secured by weld 33*b*; coupling 47, packer spacing nipple 53, coupling 51, lower packer nipple 33A, having packer end retaining member 52 secured upon it by weld 52*a*; coupling member 55, instrument case housing nipple 57, coupling member 63, nipple 68, connection member 69, and the bit 54.

Both packers, preferably of rubber or any other strong, tough, and durable substance, may be formed alike, and are shown to be alike; each having moulded within it the steel rings 34*b*. These rings are for reenforcing the rubber and preferably should be positioned approximately as shown in Figs. 2 and 3.

Each packer has a slight clearance over the nipple upon which it is positioned. The tapered packer ends 34a of both packers are received within the packer end shields 31a and 35a of the members 31 and 35, respectively, and of the members 52 and 35A, respectively; both shields 31a being stationary while the upper packer assembling member 35 is threadedly movable upon packer nipple extension 42 and the lower packer assembling member 35A is threadedly movable upon the lower packer nipple 33A. The locking ring 37 secures the movable member 35 in proper position to snugly engage the upper packer. The packing 36 prevents any escape of fluid under pressure along the threads between the members 35 and 42. Annular grooves 31b and 35b cause the tapered packer ends 34a to become imbedded within them when great pressure is applied interior of the packer; thus providing that the tapered ends will not be blown out of their respective shields 31a and 35a when the packers are expanded by great internal pressure. The steel rings 34b serve to confine the ends of the packer and the principal packer expansion to take place in the central portion; and these rings further aid in causing the tapered ends 34a to resist the internal pressure within the packer which is tending to force the ends out of their shields when the packers are expanded by fluid force applied through the openings 40b and pressure ports 33Aa, respectively. The lower packer assembling member 35A, packing 36A, and locking rings 37A, obviously, serve to secure the lower packer 34A upon its carrier nipple 33A in the same manner as the similar parts 35, 36, and 37 are employed to secure the upper packer.

The pressure pipe 18, Fig. 2, having its crimped upper end 18a secured upon the upper cylinder 19 by a weld 18c and its crimped lower end 18b secured upon the lower cylinder 32 by a weld 18d forms the pressure chamber 19b communicating with the piston chamber 19c through ports 19a. The pressure pipe 18 is positioned centrally within the nipples 21 and 33 by short nipples 24, 29, and 40 secured leak proof by welds 24a, 29a, and 40a, respectively. The annular pressure chamber 43a, Figs. 2 and 3, has its inner wall formed by a pressure pipe 43, connection member 48, nipple member 49, and nipple 50; the outer wall of this chamber being formed by the packer nipple extension 42, coupling 47, packer spacing nipple 53, coupling 51, and lower packer nipple 33A. The chamber 43a is closed at its upper end by the threaded engagement between the pressure pipe 43 and the packer nipple extension 42 secured by weld 33b, Fig. 2, and is closed at its lower end by the engagement of the lower extremity of nipple 50 upon packing 56, Fig. 4. The threaded engagement between coupling member 55 and lower packer nipple 33A serves to compress the packing 56 so as to make the lower packer pressure chamber 43a leak proof against high pressure within it.

It will be observed that the chambers 19b and 43a have communication between the inner wall of upper packer 34 and upper packer nipple 33 and packer nipple extension 42 through openings 40b of short nipples 40 which are secured in leak proof union between nipple 33 and pressure pipe 18 by welds 40a.

The chambers 19c, 19b, and 43a should be filled with a liquid, preferably of a viscous nature, such as glycerine, lead paint, or heavy oil. These chambers may be filled or drained through the openings shown closed by plugs 20, threadedly engaged within short nipples 24 and plug 52b similarly engaged within member 52. There must be no communication between chambers 19b and annular opening 21a. Welds 24a which secure short nipples 24 between pipe 18 and nipple 21, welds 29a which secure the short nipples 29 between upper cylinder 19 and nipple 21, and welds 18c and 18d at opposite ends of pipe 18 prevent such communication.

The chamber 19c is closed at its upper end by a cylinder plug 16 through which the pull rod sub 11 has a close sliding fit, this fit being made leak proof by a packing 12 engaged by the gland 13 urged upon the packing by stuffing a box cap 14.

The upper cylinder 19 secured within and centrally aligned with the pressure pipe 18 by welds 18c and 18d is engaged at its upper end by a spider 17, having arms 17a secured within the nipple 21 by welds 17b. Proximate its lower end the cylinder 19 is engaged by short nipples 29 of equal length, and secured therewith by welds 29a. The passages 29b through the nipples 29 communicate between the annular chamber 22b and the annular space 19d, Fig. 2. The connection plug 30 threadedly joins upper cylinder 19 to the lower cylinder 32 which has its lower end centrally secured within pressure pipe 18 by weld 18d.

The upper piston has a close sliding fit within upper cylinder 19 and is normally positioned proximate the lower end of cylinder 19. This piston is formed with a piston base 28, having annular peripheral grooves 28c, landing leg 28b, and upper extension 28a over which extension cups 26, which may be of leather or other tough, durable, and pliable substance, are spaced apart by cup spacers 27, having peripheral grooves 27a. The piston head 25, having peripheral grooves 25b and upper extension of reduced diameter 25a, has threaded engagement upon extension 28a for the purpose of securing the cups and spacers in their assembled position, as shown in Fig. 2. This piston will be referred to as piston 25—28.

The pull rod sub 11 has threaded engagement between the clutch member 10 and extension 25a of the piston. The pull rod 9, having threaded engagement with clutch member 10, is adapted at its upper end to be engaged by an attachable and detachable cable 72, Fig. 1. An overshot or other attachment is secured upon the end of this cable for the purpose of supplying means for engaging the cable with, and disengaging the cable from rod 9, at will of the operator. Such attaching and detaching means, however, is not shown because it is old and well known.

Proximate the upper end of the cylinder 32, having pressure ports 32a, the middle piston has a close sliding fit therein. This piston is formed with a base 39, having peripheral grooves 39b, and upper extension 39a, over which extension cups 26A are fitted and spaced apart by the cup spacers 27A, having peripheral grooves 27Aa. The piston head 38, having peripheral grooves 38b and upper extension of reduced diameter 38a of sufficient length to prevent ports 32a from being closed in the uppermost position of the piston, has threaded engagement upon the extension 39a for the evident purpose of securing the piston assembly which will be referred to as piston 38—39. The nipple 41, having a plurality of lateral openings 41a, has its upper end threadedly joined to the piston base 39 and its lower end similarly joined to the piston 44 closely slidable within pressure pipe 43, and having

lower extension of reduced diameter 44*a*, peripheral grooves 44*b*, lateral openings or intake ports 44*c*, and annular opening 44*d*. The coiled spring 46, Fig. 3, loosely housed within the pipe 43 rests upon the upper end of connection member 48 and engages under a circular shoulder formed upon the lower end of piston 44 at the upper end of extension 44*a*. This spring, installed under some compression and being further compressible to allow extension 44*a* to land upon flange 48*a*, urges the upper extension 38*a* of piston 38—39 to yieldably engage with the lower end of plug 30. It will be observed that the annular chamber 44*d*, Fig. 3, is so positioned that it will register with the openings 45*b* when lower extension 44*a* of the piston lands upon the annular flange 48*a*, (see Fig. 13).

Pressure equalizing means is provided for the upper piston 25—28 whereby the pressure of well fluid will be exerted equally above and below it. It will be observed in Fig. 3 that the landing leg 28*b* is of such length that the piston base 28 will be stopped before it closes the passages 29*b*. The pressure of well fluid is exerted under the piston 25—28, through passages 29*b*, annular chamber 22*b*, and passages 22*a*, as is apparent in Fig. 2. Here it should be recalled that the chambers 19*c*, 19*b*, and 43*a* are filled with a liquid. Well pressure exterior of the packers is transmitted through the yieldable packer walls into the chamber 19*c* via the chambers 43*a* and 19*b*, and ports 19*a*.

The upper end of the middle piston 38—39 is never contacted by the well pressure, nor does the lower end of this piston contact the well pressure except when the ports 44c are intaking fluid as in Fig. 13. In the upper position of this piston the well fluid is excluded from the lower end by a check valve 65, Fig. 4, and by a piston 44. The pressure of well fluid being equal upon both ends of the upper piston 25—28, it is apparent that no well pressure will be transmitted into the chamber 19*b* and thence through ports 32*a* upon the upper end of piston 38—39. The middle piston 38—39, and lower piston 44, therefore, will remain in their upper positions, as shown in Fig. 2, until they are forced downward by pressure from piston 25—28, as will be explained under operation.

The annular chamber 22*b*, Fig. 2, within external crimped sleeve 22 may be filled with a lubricant which will be drawn through passages 29*b* into the cylinder 19 as the piston 25—28 is moved upward. On the downward stroke of that piston this lubricant will be forced back through passages 29*b* into chamber 22*b*. The breather passages 22*a* provide that well fluid will be drawn through them into the chamber 22*b* as the lubricant is drawn out by the upward movement of piston 25—28, and that the well fluid will again be forced out of this chamber as the piston returns. Preferably this lubricant should be of greater specific gravity than the well fluid so it will not tend to float out of the chamber 22*b*, lead paint being satisfactory. In this manner drilling mud is excluded from the cylinder 19 and lubrication is provided, at the same time, for the piston 25—28.

The check valve 65, Fig. 4, prevents well fluid from entering the drill stem as the device is being lowered into or being withdrawn from the well. This valve, engaging upon its seat 63*b*, closes the central opening 63*a* through the coupling member 63 against the entrance of well fluid into the drill stem. Spring 67, resting upon the upper end of connection member 69, engages under arm 66*a* of the ball support 66, resiliently urging the valve upon its seat.

In addition to excluding well fluid from the drill stem, the check valve 65 provides that the drill stem may be pumped through at any time. Drilling mud will precipitate its heavy content if a well be allowed to stand for a time and well bores will sometimes cave while the tool is being lowered or withdrawn. It is, therefore, desirable that provision be made to pump through the drill stem if mud settlings or cavings are encountered while running the testing tool into the well, or if the formation should cave while it is being withdrawn. If it should be necessary to circulate mud fluid, the path of this fluid from the pump will be through drill stem connection member 1, Fig. 2, between guide wings 10*a* of the clutch male member 10, through openings 8*c* of the lower clutch female member 8 (see Fig. 6), and similar openings registering therewith through the upper female member 7; through the openings between arm 17*a* of spider 17, (see Fig. 7), through the annular opening 21*a*, through lateral openings 41*a* in nipple 41, through piston 44, (see Fig. 3), through members 48, 49, and 50, through the annular space 58*c*, Fig. 4, through openings 62*b*, past check valve 65 (then unseated by the pump pressure), between arms 66*a*, and out through openings 54*a* of the bit.

The short nipples 45, Fig. 3, secured between the packer nipple 42 and pressure pipe 43 by welds 45*a*, are so positioned as to provide inlet openings 45*b* between the packers. These inlet openings will register with the annular space 44*d* when the lower extension 44*a* of piston 44 lands upon the annular internal flange 48*a*, (see Fig. 13). This is the only intaking means whereby well fluid can enter the drill stem. The inlet opening 45*b* and annular space 44*d* are brought into registration by the downward movement of piston 38—39 which take place only while the packers are being expanded by piston 25—28 when it is raised by pulling on cable 72, Fig. 1, as will be later explained.

A simple form of clutch is shown proximate the upper end of Fig. 2. This clutch, shown engaged, provides means whereby the drill stem and packers may be rotated as a unit while the device is being lowered into or being withdrawn from a well. Wings 10*a*, freely slidable within the drill stem connection member 1, are provided for the evident purpose of holding pull rod 9 central therein that it may be easily engaged and disengaged by the cable overshot or other means employed to engage and disengage the cable therewith. Due to disengagement of the clutch caused by the pull of the cable attached to pull rod 9, the drill stem may be rotated during the test, while the packers and all other parts below the clutch will remain stationary. The drill stem connection member 1 has an external flange 1*a*, rotatably engaged between the shoulder 5*a* and the upper end of member 6. A series of equally spaced keys 7*a*, Figs. 2, 5, and 12, having upper extensions 7*b* with inclined wedge shaped surfaces 7*c*, (see Fig. 5) are formed interiorly of the lower end of the upper clutch female member 7, which member is threaded into the lower end of member 1 and secured there by weld 7*d*. The lower female member 8, Fig. 12, threaded within member 6 and secured there by weld 8*b*, has an equal number of equally spaced similar keys 8*a* with similar inclined wedge shaped upper ex-

tensions to those indicated at 7c, Fig. 12. The members 7 and 8 are shown as made separate from the respective parts into which they are secured by threads and welds for manufacturing convenience only. The male member 10, Fig. 11, of this clutch also has an equal number of equally spaced keys 10b, having tapered wedge shaped lower ends, which keys have an easy sliding fit between the female keys 7a and 8a. The engagement between the male and female members of this clutch will lock the members 1 and 6 together against independent rotation, as shown in Fig. 2. When a cable is attached to pull rod 9 by means not shown, and the cable is pulled upon with sufficient force, the male member of the clutch will be raised out of engagement with the female members, thus disengaging the clutch; whereupon the drill stem may be rotated independent of the packers. The upper female clutch member 7 rotates with the drill stem, while the lower female clutch member 8, and all parts below it, remain stationary, as is apparent.

When the cable pull upon pull rod 9 has been released, the clutch will reengage, because the pressure of well fluid exterior of the packers will force the piston 25—28 downward from its upper position indicated in Fig. 13, to its normal position, shown in Fig. 2.

The weight 9a, Fig. 2, may be employed, if necessary, to overcome friction and resistance of heavy mud in completing the return or reengaging movement of the clutch. This weight, shown broken, may be of any length necessary to provide the required weight which, when required at all, may weigh, for example 500 to 1500 pounds.

It will be noted that the male member of the clutch has one key 10c longer than the others. This longest key, also having a wedge shaped lower end, acts as a pilot to guide all of the other male keys into proper engagement with their mating female members. In this operation an opening between the inclined wedge shaped upper ends of keys 7a of the upper female member 7 is engaged by this longest male key 10c, and, in turn, an opening between the similar upper ends of the lower female member 8 is engaged by the lower wedge shaped end of this longest key of the male member by which both of the female members are readily aligned to have all their other slots engaged by the other shorter keys of the male member.

The packing 4, within an annular recess between members 1 and 5 is engaged by a gland 2, which gland is caused to securely engage the packing by means of stuffing box cap 3 for the evident purpose of preventing leakage through the clutch.

An instrument case 58 is shown within the nipple 57, Fig. 4. The lower central extension 58a may be threadedly connected within the instrument case base 62 which is secured within nipple 57 by welds 62a. The openings 58b communicate between the interior of the instrument case and annular space 58c. When the device is intaking test fluid into the drill stem this fluid is in contact with the instrument case, there being no barrier between inlet openings 45b and the case, as will appear by reference to Figs. 3 and 4. The lid 59 is secured upon the packing 64 by nuts 61 engaging upon studs 60 secured within case 58 by welds 60a, in order that all outside communication with the interior of the instrument case will be through the openings 58b. Within this case, suitable instruments may be placed for the purpose of recording pressures and temperatures and variations therein while the device is being lowered into the well, while the test is being made, and while the device is being withdrawn from the well. Such instruments being provided, many of which are available, the operator sees that his watch and the timing mechanism of the instruments agree. He keeps a record of the time when running the device in, when it is intaking, and when being withdrawn. The operator then checks his instrument charts with the time record. This check should reveal the place in the well where all recording instrument data was made.

It will be understood that the break in the drawings, Fig. 2, indicates that the parts shown cut by the break may be of any length to provide ample space for liquid in chamber 19c to properly expand the packers.

Before discussing the operation, attention is directed to the fact that the packers may be readily spaced at such distance apart as may be necessary to test formations of different thicknesses. The distance between the packers may be increased or decreased by simply changing the length of packer spacing nipples 50 and 53, an equal length being added to or taken from each, as required.

The effective area of the piston used to expand the packers, the maximum travel provided for this piston, the diameter of the packers, thickness of packer walls, length of the packers, and the clearance between the packers and the wall of the well bore, are all factors to be considered in designing the packers and piston assembly for different diameters of well bores. For wells, having a diameter of seven to ten inches, the pistons may ordinarily have an effective area of 3 to 6 square inches and a maximum travel of six to sixteen feet. The packer walls should preferably be at least twice as thick as the clearance between the packers and the wall of the well. If, for example, the latter clearance be three quarters of an inch, the packer wall should not be less than one and one half to two inches thick, and, of course, may be thicker if diameters will permit. Ordinarily, no difficulty will be experienced in running the device into a well if the diameter of the well bore be one inch to one and one half inches greater than the diameter of the packers. For use in a 9⅞" diameter well bore, for example, the distance between the steel rings 34b may be ten to eighteen inches and the tapered ends 34a may each be six to eight inches long.

Tests may be made over any period of time, fifteen to forty-five minutes ordinarily being ample.

In operation, the device may be lowered into the well upon the drill stem (or any other suitable pipe) 71, Fig. 1 to which is connected by a coupling 70 which, of course, will be run in empty. The device being properly positioned in the well, with the packers above and below the formation to be tested, such as b in Fig. 1, a cable 72, Fig. 1, having an overshot or other suitable means attached for the purpose of engaging pull rod 9, Fig. 2, is lowered through the drill stem and such engagement made. The cable is then pulled upon with sufficient force to raise the piston 25—28 until both packers are expanded into strong sealing off engagement with the wall of the well bore. When the piston is so raised, fluid in the chamber 19c is thereby forced out through

pressure ports 19a into chamber 19b which, through openings 40b, communicates with the inner surface of the upper packer 34. This packer instantly expands and allows the fluid pumped by the piston to proceed through the annular opening thus formed between packer 34 and nipples 33 and 42, through pressure ports 42a, annular pressure chamber 43a, and pressure ports 33Aa, Fig. 3, where this fluid contacts the inner surface of lower packer 34A, and expands it also. Manifestly, if one packer should expand to a firm contact with the wall before the other packer forms such contact, the piston will continue to travel and discharge all of its fluid into the other packer until both packers are expanded by an equal force.

A small portion of the fluid pumped out of chamber 19c passes out of chamber 19b through ports 32a and forces pistons 38—39 and 44 downward, (see Fig. 13), until extension 44a lands upon internal circular flange 48a, having through it the central opening 48b, at which time the inlet ports 45b and annular opening 44d, having intake ports 44c, are in registration. With the packers expanded by one piston traveling upward, and the intake ports opened by the other two pistons traveling downward, the formation test is begun. Well fluid from between the packers then enters the drill stem via inlet ports 45b, annular opening 44d, intake ports 44c, nipple 41, lateral openings 41a, the annular opening 21a, openings 8c through the clutch, (see Fig. 6) and thence upwardly in the drill stem.

The force required to compress the spring 46 far enough to open the intake ports should be somewhat more than enough to expand the packers into sealing off engagement with the well formation, but less than the total force exerted to hold them expanded. Such relation between the force required to compress the spring and that employed to expand the packers provides that no fluid from above the upper packer and no fluid from below the lower packer can find entrance into the drill stem. If, for example, 1,000 pounds per square inch is exerted by piston 38—39, and 200 pounds per square inch will expand the packers into sealing off engagement, and 300 pounds per square inch will compress the spring until the intake ports are open, it follows that the packers are sealed off by 100 pounds per square inch when the intake ports open, and that during the test the packers are engaged with the well formation by 800 pounds per square inch. An ordinary one half inch bailing or swabbing line, such as is generally on hand with drilling rigs, will withstand a pull of over 18,000 pounds. If, then, the piston has an area of four square inches, a one half inch cable can be employed to exert a pressure of 2,500 pounds per square inch within the packers, this being considerably more force than ordinarily will be required.

At termination of the intaking period, the cable pull is released, the overshot, or other means by which the cable was attached to the pull rod is detached therefrom, and the cable removed from the drill stem. The test fluid, as stated, may then be recovered for examination by bailing, swabbing, or by withdrawing the drill stem.

When the cable pull is released the pressure of well fluid exterior of the packers will instantly deflate them, causing the upper piston to assume its lowermost position and the clutch to reengage, as shown in Fig. 2, while the spring 46 will cause the lower piston 44 to close inlet openings 45b and, at the same time, restore the other piston 25—28 to its uppermost position, also shown in Fig. 2.

If the test fluid be recovered from the drill stem by swabbing or bailing, it is evident that such tests may be repeated in rapid succession, and at small cost compared to the great value of accurate information concerning a well's production before the usual large investment to complete it is made.

Another valuable use of this tool is to discover, measure, and stop leaks going out through thief formations, a thief formation being any formation that will receive or take in fluid produced by other formations of the well. Such use of the tool is made by operating it as for recovering incoming production. If the test shows nothing coming into the well from the formation being tested or that the incoming fluid has a low pressure, and it is feared that such formation may be a thief, oil, water, or other fluid may be placed in the drill stem while the packers are set. If this fluid depletes in the drill stem it must be going out into the formation between the packers. By measuring the fluid so entering the formation in a given time and under a given pressure it is ascertained whether or not the formation should be sealed. If so, cement slurry may be employed for the purpose. The device may be used to force this cement slurry through openings in casing and/or into uncased formations by merely placing and expanding the packers as explained, and then pumping the cement into the drill stem. However, before making such use of the device, the lower extension 44a of the piston 44 must be closed in order to prevent the cement from going out through the bit, thereby forcing it out through openings 45b.

A modified form of the invention is illustrated in Figs. 14 and 15 in which a capital letter suffixed to reference numerals indicates that the part so designated is similar and serves a similar purpose to the corresponding part in the preceding form but is somewhat different therefrom in construction.

The outer shell is formed of drill stem connection member 1 which has the following parts connected thereto in the order named, the upper clutch shell member 5, having stuffing box cap 3 screwed upon it; lower clutch shell member 6, nipple 15, connection member 31, upper packer nipple 33, secured to member 31 by weld 33a, upper packer nipple extension 42A, nipples 33 and 42A both being threadedly joined upon the upper end of pressure pipe 43A and secured by weld 33b; coupling 47A, packer spacing nipple 53A, coupling 51A, lower packer nipple 33B, having packer end retaining member 52A secured upon it by weld 52Aa; coupling member 55, instrument case nipple 57, coupling member 63, nipple 68, connection member 69, and the bit 54.

Both packers 34 and 34A are the same as specified for the preferred form of the invention and both packers have their upper tapered ends received within shields 31a and have their tapered lower ends received within shields 35a as in Figs. 2 and 3. The threadedly movable member 35, Fig. 14, packing 36, and locking ring 37; also locking ring 37A, Fig. 15, serves to secure the packers as was explained in connection with the preferred form.

To lengthen or shorten the distance between the packers the spacing nipples 50A and 53A may

be substituted by longer or shorter nipples, an equal length being added or taken from each as required.

A pressure chamber 43A*a* is formed at its upper end between the packer nipple extension 42A and pressure pipe 43A, Figs. 14 and 15. This chamber extends downwardly between nipples 53A and 33B forming its outer shell, and packer spacing nipple 50A forming its inner shell, and communicates with pressure ports 33A*a*. The nipple member 49A has threaded connection between pipe 43A and spacer nipple 50A, this connection being adapted to withstand high pressure by means of packing 80. Packing 79, Fig. 14, and 81, Fig. 15, are similarly employed to adapt the pressure chamber 43A*a* to withstand high pressure from within. Packing 56, tightened by coupling member 55, causes this chamber to be capable of retaining fluid under high pressure. Pressure pipes 73, secured upon cylinder 74 by welds 73*a* and upon nipple 33 by welds 73*b*, place the pressure chamber 43A*a* and piston chamber 74*b* in communication via the annular space between nipple 33 and extension 42A, and the packer 34, and the ports 42*a*.

The cylinder 74, having ports 74*a*, is secured centrally within the outer shell by its welded connection with pressure pipes 73 and by its threaded connection with piston landing reducer 87. The flange 86 and pipe 43A are secured together by means of welds 86*a*, as appears in Fig. 14.

The chamber 74*b*, pressure pipes 73, and annular pressure chamber 43A*a*, Figs. 14 and 15, are filled with a liquid employed to expand the packers as was explained in the specification of the first form. These chambers and pipes may be filled or drained through the openings shown closed by plugs 90, Fig. 16, and plugs 91, Fig. 15. The plugs 90 have threaded engagement within the short nipples 89, secured upon cylinder 74 by welds 89*a*. The short rings 88 merely provide a manufacturing convenience in closing the annular space around nipples 89 through which space the welds 89*a* are made.

Welds 88*a* secure the rings 88 between short nipples 89 and nipple 15, as appears in Fig. 16. Due to the considerable length of the annular chamber 43A*a*, and the slight clearance between packer 34 and nipples 33 and 42A which slight clearance might prevent the chamber 43A*a* from being readily filled or drained through the openings closed by plugs 90, the plugs 91, Fig. 15, are provided.

The piston member 78, Fig. 14, having peripheral grooves 78*b*, has an upper extension 78*a*, over which cups 76 are spaced apart by spacers 77, having peripheral grooves 77*a*. The head 75 having threaded engagement over the upper end of extension 78A secures the piston assembly which will be referred to as piston 75—78. This piston has a close sliding fit within the cylinder 74 and normally engages upon the reducer 87. The pull rod sub 11 has threaded engagement with the head 75 and, extending through plug 16 and packing 12, connects the piston with the clutch, as appears in Fig. 2.

Well fluid contacts the bottom of piston 75—78 through openings 45*b* and the central opening through reducer 87, as appears in Fig. 14. Pressure of well fluid is transmitted above this piston through the elastic wall of the packer and pipes 73. It, therefore, is apparent that the cable pull which actuates the piston will not be resisted by the pressure of well liquid unless the pressure between the packers becomes depleted while the packers are expanded during the test. In case of such depletion it is apparent that more force must be exerted upon the cable in order to keep both packers expanded into sealing-off engagement with the formation than would be required in operation of the first form wherein this equalizing pressure comes from above the upper packer where the pressure remains constant.

The pump-through port flange 86, Fig. 14, of the upper check valve assembly has ports 86*b* over which the annular check valve 85 seats. This valve, which may be of rubber, leather, belting, or other tough resilient substance, is pressed over the upper extension 84*b* of its base 84. The spring base ring 82, threadedly engaged within pipe 43A supports spring 83, which spring contacting the base 84, normally holds the check valve 85 resiliently seated under flange 86, thereby closing the ports 86*b* against entrance of well fluid from below, but allows that the drill stem may be pumped through at any time. The check valve base has a depending tubular extension 84*a* slidable within the base ring 82. In the closed position of the valve, the lower end of this extension is opposite the upper edge of the inlet openings 82*a* which register with the inlet openings 45*b* through short nipples 45 secured between pipe 43A and nipple 42A by welds 45*a*. If, for any reason, it should be necessary to pump through the drill stem the pump fluid will unseat valve 85 which movement will cause the depending extension 84*a* to close ports 82*a* thereby preventing the pump fluid from going out through openings 45*b* and forcing it to take exit through openings 54*a* of the bit. It will be noted that the upstanding tubular extension 84*b*, which has a close sliding fit within the member 87, is of such length that the depending tubular extension 84*a* will close inlet opening 82*a* when the check valve opens. This is true because the check valve will not allow pump fluid to pass through ports 86*b* until the spring 83 has been compressed far enough to cause upstanding tubular extension 84*b* to pass out of the member 87, as is apparent in Figs. 14 and 18. Manifestly, the pump pressure from above when the valve is open will supplant the spring pressure from below when the valve is closed by holding the valve constantly upon the outwardly flanged portion of its base 84.

The lower check valve within nipple 68, Fig. 15, referred to generally at F, is similar to the corresponding check valve shown in Fig. 4 and serves the same purpose.

The fluid intake ports 74*a* are normally closed by the piston member 78. These ports are uncovered when the piston is raised by the cable pull in expanding the packers, as appears in Fig. 18. The test fluid then enters through inlet openings 45*b* and 82*a* and passes up into the drill stem through intake ports 74*a* and the annular opening exterior of cylinder 74.

The clutch and other members above the line *g*—*g*, Fig. 14, are the same as shown and discussed in connection with the preferred form to which reference is made.

The instrument case within nipple 57, Fig. 15, supported by threaded connection within its base 62, and referred to generally at E, is the same in construction and purpose as the corresponding assembly shown and discussed in connection with the preferred form.

In the operation of this modified form, the de-

vice is positioned and the cable pull applied to the piston in the same manner as was explained for the preceding form. In Fig. 18 the upper packer is shown expanded, in which position of the parts it will be noted that the piston 75—78 has traveled upward and uncovered intake ports 74a. Obviously, well formation fluid then enters the drill stem through inlet openings 45b and intake ports 74a as has been previously explained.

In order to employ this modified form of the invention as a cementing means, the central opening 55a through member 55 should be closed with a plug to prevent the cement from going out through the bit, and the depending tubular extension 84a should be removed or shortened so that it will not close the openings 82a when the cement is pumped through the check valve, these openings then becoming discharge ports for the cement slurry.

Otherwise than stated, the operation of this modified form is the same as the preceding form, to which reference is made in completing this specification.

It is understood that all references to positions and directions, such as "upper" and "lower," "upward" and "downward," "above" and "below" apply to the tool as illustrated in the accompanying drawings wherein the upper portion of the tool is shown uppermost.

It is obvious that mechanical changes may be made in the structure, and equivalents may be substituted for the parts shown; and I reserve the right to make such mechanical changes, substitutions, and adaptions within the scope of the invention as comprehended by the stated objects and appended claims.

What is claimed is:

1. A formation testing device for wells including a string of pipe, a pair of spaced expansible packers thereon, a reservoir for actuating liquid, means connecting said reservoir to both of said packers, and additional means operable in the reservoir to force liquid from said reservoir to expand both of said packers.

2. A formation testing device for wells including a string of pipe, a pair of spaced expansible packers thereon, a reservoir for actuating liquid, means connecting said reservoir to both of said packers, additional means operable in the reservoir to force liquid from said reservoir to expand both of said packers, and a third means operable by said additional means to open the device to admit a sample of fluid from the well at elevation between said packers.

3. A formation testing device for wells including a string of pipe, a pair of spaced expansible pakers thereon, a reservoir for actuating liquid, means connecting said reservoir to both of said packers, additional means operable in the reservoir to force liquid from said reservoir to expand both of said packers, and means to admit well pressure from above the top packer to cooperate with said additional means.

4. A formation testing device for wells including a string of pipe, a pair of spaced expansible packers thereon, a reservoir for actuating liquid, means connecting said reservoir to both of said packers, and additional means operable in the reservoir to force liquid from said reservoir to expand both of said packers, said additional means including a flexible cable operable from the surface.

5. A formation testing device for wells including a string of pipe, a pair of spaced expansible packers thereon, a reservoir for actuating liquid, means connecting said reservoir to both of said packers, additional means to force liquid from said reservoir to expand both of said packers, and clutch means normally holding said pipe and packers together but operable by said additional means to release said string of pipe for rotation independent of said packers.

6. A formation tester including a housing, a pair of spaced packers thereon, means to admit a sample from the well between said packers, and means operable from the surface to simultaneously expand said packers and open said means.

7. The combination of a string of drill pipe, a formation tester device, a releasable clutch connection therebetween, a pair of spaced packers on said device, means to admit a sample of fluid from the well at a point between said packers, and a single means operable from the surface and independent of said string of drill pipe to release said clutch, expand said packers and open said means.

8. A supporting string of drill stem or pipe, a lower tubular extension thereto, two packers upon said extension, three cylinders secured within said extension, means for aligning and separating said cylinders, closure means for the upper end of the upper cylinder, a piston in each of said cylinders, the upper or first piston having an upward extension slidable through said closure means and the second and third of said pistons each having a downward tubular extension, a pressure pipe surrounding the upper two of said aligned cylinders and having its ends hermetically joined thereto, thereby forming an annular space between said pipe and cylinders, an annular chamber having its upper end in communication with the well bore and having its lower end in communication with said upper cylinder below the piston therein, liquid in said annular chamber, liquid in both of said upper cylinders above the pistons therein, such liquid being adapted to expand the packers and to force downward the second and third pistons, liquid in said annular space surounding the two upper cylinders, openings in both of said cylinders proximate the upper ends thereof, openings communicating between the upper packer and the annular space surrounding the two upper cylinders, an opening communicating between the inner surfaces of the upper and lower packers, openings communicating between said third cylinder and the well bore between the packers, an axial opening through said third piston, lateral openings through said downward tubular extension of said second piston, a recess or opening around said third piston, openings communicating between said recess around said third piston and the axial opening therethrough and with openings through the downward extension of said second piston, a spring under said third piston, said spring urging the said second and third pistons upward to normally engage the second piston with said means for aligning and spacing said two upper cylinders, a landing for said third piston adapted to limit the downward movement thereof so that sample well fluid from the bore between the packers may enter the drill stem or pipe when the upper piston is raised and the packers are expanded by liquid thereby pumped into them, a pull rod connected to the upper piston, a cable with means thereon to releasably engage said pull rod, the cable being operable from above the well, a clutch in said drill stem or pipe above the upper packer, said clutch being

normally engaged and being adapted to become disengaged when said pull rod and upper piston are raised, an instrument case or gadget box in said lower extension of the drill stem, said instrument case being in communication with test fluid which enters the tool from between the packers, a check valve in said extension, said valve being normally closed and adapted to be opened by pump pressure from the pipe, and a drill bit upon the lower end of said extension.

9. A supporting string of drill stem or pipe, a lower tubular extension thereto, two packers upon said extension, three cylinders secured within said extension, means for aligning and separating said cylinders, closure means for the upper end of the upper cylinder, a piston in each of said cylinders, the upper or first piston having an upward extension slidable through said closure means and the second and third of said pistons each having a downward tubular extension, a pressure pipe surrounding the upper two of said aligned cylinders and having its ends hermetically joined thereto, thereby forming an annular space between said pipe and cylinders, an annular chamber having its upper end in communication with the well bore and having its lower end in communication with said upper cylinder below the piston therein, liquid in said annular chamber, liquid in both of said upper cylinders above the pistons therein, said liquid being adapted to expand the packers and to force downward the second and third pistons, liquid in said annular space surrounding the two upper cylinders, openings in both of said cylinders proximate the upper ends thereof, openings communicating between the upper packer and the annular space surrounding the two upper cylinders, an opening communicating between the inner surfaces of the upper and lower packers, openings communicating between said third cylinder and the well bore between the packers, an axial opening through said third piston, lateral openings through said downward tubular extension of said second piston, a recess or opening around said third piston, openings communicating between said recess around said third piston and the axial opening therethrough and with openings through the downward extension of said second piston, a spring under said third piston, said spring urging the said second and third pistons upward to normally engage the second piston with said means for aligning and spacing said two upper cylinders, a landing for said third piston adapted to limit the downward movement thereof so that sample well fluid from the bore between the packers may enter the drill stem or pipe when the upper piston is raised and the packers are expanded by liquid thereby pumped into them, a pull rod connected to the upper piston, a cable with means thereon to releasably engage said pull rod, the cable being operable from above the well, and a check valve in said extension, said valve being normally closed and adapted to be opened by pump pressure from the pipe.

10. A supporting string of drill stem or pipe, a lower tubular extension thereto, two packers upon said extension, a cylinder secured within said extension, closure means for the upper end of said cylinder, a piston in said cylinder, said piston having an upward extension slidable through said closure means, pressure pipes communicating between the cylinder above the piston therein and the upper packer, liquid in said pressure pipes and in said cylinder above the piston therein, said liquid being adapted to expand the packers, an opening communicating between the inner surfaces of the upper and lower packers, openings in said lower tubular extension between the packers, said openings communicating between the piston and the well bore, openings in the cylinder below the piston, said openings being normally closed by the piston and being adapted to be uncovered when the piston is raised and the packers are expanded thereby, a check valve adapted to exclude well fluid from the drill stem until the packers are expanded, another check valve adapted to exclude well liquid from the drill stem at all times, both of said valves being adapted to allow pump fluid to be forced through the drill stem from above, a pull rod connected to the piston, a cable with means thereon to releasably engage said pull rod, the cable being operable from above the well, a clutch in said drill stem or pipe above the upper packer, said clutch being normally engaged and being adapted to become disengaged when said pull rod and upper piston are raised, an instrument case in said lower extension of the drill stem, said instrument case being in communication with test fluid which enters the tool from between the packers, and a drill bit upon the lower end of said extension.

11. A supporting string of drill stem or pipe, a lower tubular extension thereto, two packers upon said extension, a cylinder secured within said extension, closure means for the upper end of said cylinder, a piston in said cylinder, said piston having an upward extension slidable through said closure means, pressure pipes communicating between the cylinder above the piston therein and the upper packer, liquid in said pressure pipes and in said cylinder above the piston therein, said liquid being adapted to expand the packers, an opening communicating between the inner surfaces of the upper and lower packers, openings in said lower tubular extension between the packers, said openings communicating between the piston and the well bore, openings in the cylinder below the piston, said openings being normally closed by the piston and being adapted to be uncovered when the piston is raised and the packers are expanded thereby, a check valve adapted to exclude well fluid from the drill stem until the packers are expanded, another check valve adapted to exclude well liquid from the drill stem at all times, both of said valves being adapted to allow pmp fluid to be forced through the drill stem from above, a pull rod connected to the piston, a cable with means thereon to releasably engage said pull rod, the cable being operable from above the well.

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