July 19, 1960 G. P. MALY ET AL 2,945,541

WELL PACKER

Filed Oct. 17, 1955 2 Sheets-Sheet 1

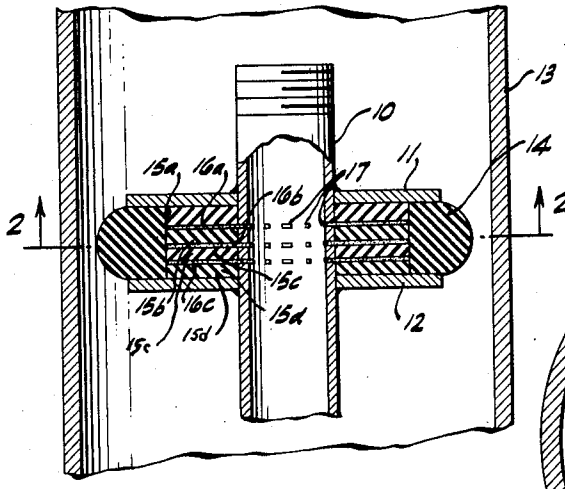


FIG. 1.

FIG. 2.

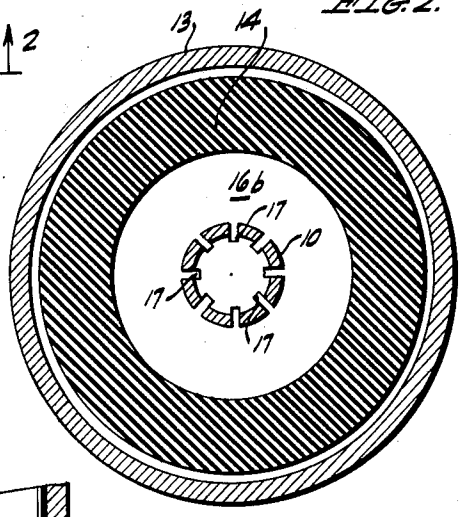


FIG. 6

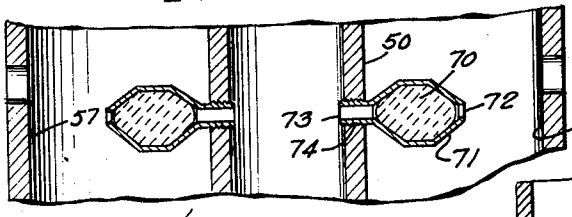


FIG. 3.

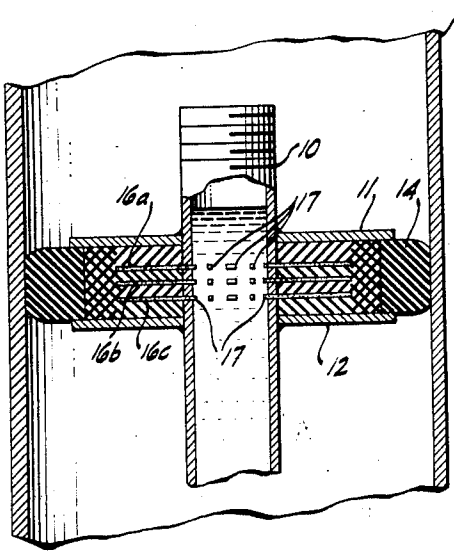
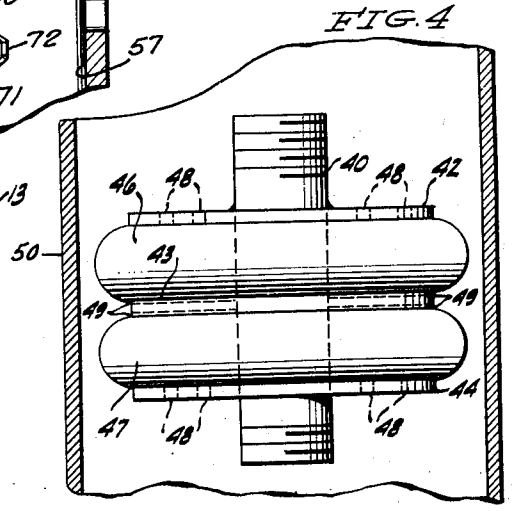


FIG. 4



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WELL PACKER

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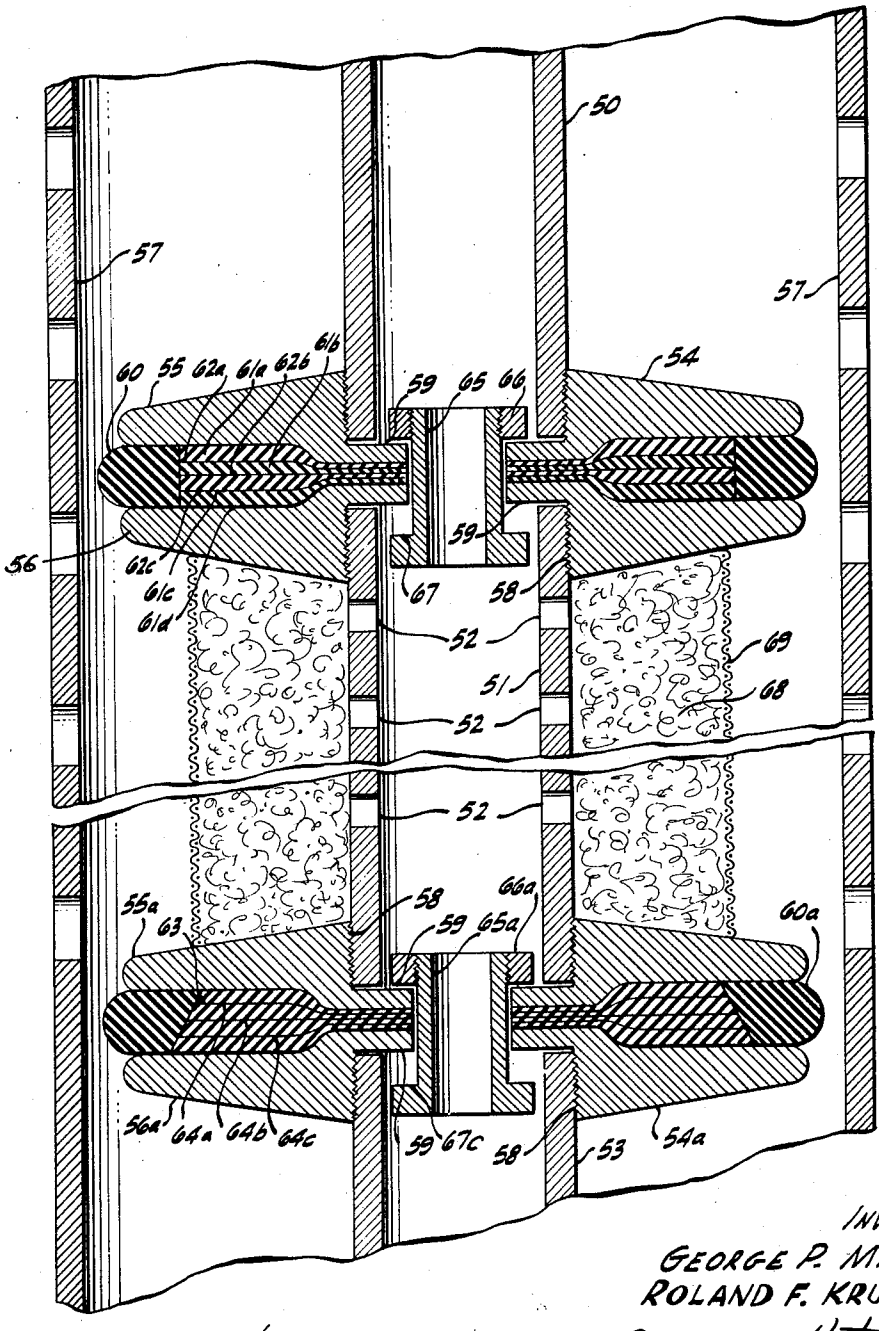

FIG. 5.

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WELL PACKER

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16 Claims. (Cl. 166—187)

This invention relates to a well packing or plugging device, and in particular concerns a well packer or plug in which the packing element is actuated by means of pressure developed within the well bore.

The use of packers or plugs in well bores in connection with such operations as cementing, repressuring, testing, etc. is well known, and a great variety of such tools has been proposed. All of such devices, however, comprise one or more packing elements which are capable of being lowered into the well bore and therein laterally expanded until they meet the walls of the bore or the well casing in fluid-tight relationship therewith. Such packing elements have been actuated by mechanical or hydraulic means controlled from the earth's surface.

It is an object of the present invention to provide a well packer or plug in which the packing element or elements are actuated by pressure developed within the well bore. Another object is to provide a device of such character in which the actuating pressure is generated immediately adjacent the packing element itself. A further object is to provide such a device in which the actuating pressure is that developed within a body of swellable rubber as it expands in contact with a swelling liquid. Other and related objects will be apparent from the following detailed description of the invention, and various advantages not specifically referred to herein will be apparent to those skilled in the art upon employment of the invention in practice.

In the drawings which form a part of this specification:

Figure 1 is a longitudinal sectional view of a simple embodiment of the invention illustrating the principle thereof.

Figure 2 is a transverse sectional view of the device of Figure 1 taken along line 2—2 thereof.

Figure 3 is a longitudinal sectional view of the device of Figure 1 after expansion of the packing element thereof.

Figure 4 is a longitudinal view of another embodiment of the invention in which multiple packing elements are provided.

Figure 5 is a longitudinal sectional view of a portion of a testing or plugging tool embodying the principle of the invention.

Figure 6 is a fragmentary vertical section of alternative means for containing the fluid sensitive material.

Referring now to Figures 1, 2 and 3, in which like numerals indicate like parts, the device there shown is a packer for closing off the annulus between a well casing and the well tubing. Said packer consists of a hollow mandrel or conduit **10** provided with screw threads at its upper end, whereby it may be attached to and made a part of the well tubing string. Upper and lower plates **11** and **12**, respectively, are rigidly affixed to conduit **10** in spaced relationship, and have outside diameters smaller than the inside diameter of well casing **13** in which the device is to be employed. Packing ring **14**, having an outside diameter smaller than the inside diameter of well casing **13** and an inside diameter considerably larger than the outside diameter of conduit **10** but smaller than the outside diameter of plates **11** and **12**, is held between plates **11** and **12**. The packing ring is constructed of a resilient expansible material which is not attacked by the well fluids or by the fluid which is introduced into conduit **10** as described below, and may suitably be a hydrocarbon-resistant synthetic rubber such as Thiokol or neoprene. The annulus between packing ring **14** and conduit **10** is packed with a swellable material in the form of relatively thin discs **15***a*, **15***b*, **15***c*, and **15***d* separated by septums **16***a*, **16***b* and **16***c*. The latter are provided with a plurality of inwardly projecting lugs or tabs **17** which extend through perforations in the wall of conduit **10** and thus come in contact with any liquid contained in conduit **10**.

Operation of the device of Figures 1, 2 and 3 is as follows: The assembly is coupled to the well tubing by means of the screw threads on conduit **10** and is lowered into the well casing to the desired level. There is then introduced into the tubing, and thence into conduit **10**, a liquid such as benzene, toluene, crude oil, etc. which is capable of causing discs **15***a*–**15***d* to swell. Such liquid contacts tabs **17** of absorbent septums **16***a*–**16***c* which act as wicks to distribute the liquid to discs **15***a*–**15***d*. The latter swell or expand with great force upon contact with such liquid, and since they are confined by conduit **10** and plates **11** and **12** the force of expansion is directed radially and outwardly against packing ring **14**. The latter, being resilient and expansible, is thus forced outwardly against casing **13** to form a fluid-tight seal therewith, as shown in Figure 3.

We are aware that it has been proposed to construct packing and plugging tools in which a resilient packing element is forced outwardly against the well casing by means of a fluid which is forced down the well tubing under pressure. The device of the present invention, however, operates under an entirely different principle in that the pressure which forces the packing element outwardly against the well casing is developed, not by a pump at the earth's surface and transmitted to the tool via a column of fluid or even by the hydrostatic head of a column of fluid, but rather by a body of swellable material undergoing swelling by a suitable liquid. We have found that such swelling pressures are remarkably high; for example, pressures as high as 10,000 pounds per square inch are developed when certain types of rubber are contacted with a hydrocarbon liquid such as toluene. The essence of the invention lies in making use of such high pressures to actuate the packing element of a well packer or plug.

The swellable material employed in the devices of the invention is preferably rubber, although swelling clays, cellulosic material and the like may also be employed. All resilient natural rubber and certain synthetic rubbers are swelled by hydrocarbons, natural oils and many organic solvents. The extent of swelling in any particular liquid is dependent in part upon the extent to which the rubber has been vulcanized, polymerized, or otherwise treated. Thus, well-vulcanized rubber swells to a less extent and more slowly than crude rubber, presumably because the vulcanized material contains a greater number of cross-linkages. Also, rubber which has been milled swells more readily than an unmilled material. By controlling these and other factors it is possible to prepare natural and synthetic rubbers which swell to almost any desired extent. In the practice of the present invention, any of such rubbers may be employed since the maximum pressure developed upon swelling is more or less independent of the total extent to which the rubber is capable of swelling. The latter is of importance only insofar as it determines the dimensions of the de-

vice. Thus, in the device of Figure 1, if the swellable discs 15*a*–15*d* are made of rubber which is capable of swelling only to the extent of 20 percent, the outside diameter of packing ring 14 will have to be more nearly equal to the inside diameter of casing 13 than if the swellable rubber is capable of swelling to an extent of, say, 500 percent. However, this is because, in the latter instance, packing ring 14 will be expanded a greater radial distance rather than because of any substantial difference in the pressure developed by the rubbers. As a practical matter, we prefer to employ a rubber which is capable of swelling to an extent of at least about 200 percent in toluene, although it should not be understood that toluene is necessarily the only liquid which may be employed in setting the packer; hydrocarbons, such as crude oil, benzene, kerosene, and gasoline, carbon tetrachloride, vegetable oils, tetralin, turpentine, and the like may also be employed. However, it is preferred to employ aromatic hydrocarbons since they usually induce maximum swelling in minimum time.

Referring now to Figure 4, which illustrates a plan view of a plugging tool inserted in a well casing prior to being set by means of a rubber-swelling liquid, solid mandrel 40 is shown provided at its upper end with screw threads by which it may be attached to a tubing string running to the earth's surface. Spaced plates 42, 43, and 44, are rigidly affixed to conduit 40, with resilient expansible packing rings 46 and 47 being held between each pair of adjacent plates. The internal construction of the device is very similar to that of the device of Figure 1, i.e., the packing rings have an inside diameter substantially larger than the outside diameter of conduit 40, and the annuli between the packing rings and conduit 40 are substantially filled with a body of swellable rubber. However, instead of employing absorbent threads or cords to direct the swelling liquid to the body of swellable rubber, plates 42 and 44 are provided with a plurality of small perforations 48, and plate 43 is provided with narrow radial grooves 49 through which such liquid may enter and contact the swelling rubber. Thus, when the tool is submerged in a swelling liquid, e.g., crude oil, such liquid will be carried to each body of rubber through perforations 48 and grooves 49 and will cause it to swell, thereby expanding packing rings 46 and 47 until they form a fluid-tight seal with well casing 50. As an alternative arrangement, plates 42, 43 and 44 may be constructed of a porous material, e.g., porous metal or a high-strength ceramic, or comprise porous inserts through which the swelling liquid may pass to the swellable material.

Referring now to Figure 5, there is there shown a longitudinal sectional view of a portion of a plugging or testing tool embodying the principle of the invention. In essence, said tool consists of a central conduit having a plurality of packing elements spaced along the length thereof, said central conduit being perforated between adjacent packing elements and having a plugging or indicating material positioned in the space between adjacent packing elements in such manner that any fluid which passes into the conduit through the perforations must traverse said material. Such type of tool is described in detail in the copending application of Stegemeier and Maly, Serial No. 523,476, filed July 21, 1955, now Patent 2,814,947.

The illustrated portion of the particular tool of Figure 5 consists of an upper conduit section 50, a middle conduit section 51 provided with perforations 52, and a lower conduit section 53. Each of said conduit sections is threadedly joined to the adjacent conduit section through a packing element assembly 54 or 54*a*. Each of assemblies 54 and 54*a* consists of upper and lower disc-shaped jaws 55, 55*a* and 56, and 56*a* respectively, having outside diameters less than the inside diameter of casing 57 in which the tool is to be employed. Each jaw is provided with a threaded central opening 58 which receives and engages the end of one of the conduit sections, and is further provided with an inwardly projecting shoulder 59 which extends part-way across the inner diameter of the particular conduit section which engages the jaw. The adjacent faces of upper and lower jaws 55, 55*a*, 56 and 56*a* are hollowed out back from their peripheries so that when the jaws are placed with said faces adjoining an annular space exists between each pair of jaws. Packing rings 60 and 60*a*, having outside diameters less than the inner diameter of casing 57 and having inner diameters considerably greater than that of the aforesaid hollowed out portions of said jaws, are interposed between said jaws. A body of swellable rubber fills the remainder of the hollowed out space between each pair of jaws, and extends inwardly so as to be coextensive with shoulder portions 59. In upper packing assembly 54, said body of swellable rubber is shown comprising four layers of rubber 61*a*–61*d* with adjacent layers being separated by septums 62*a*–62*c*. The latter are constructed of paper, cellulosic material or other substance which is capable of absorbing and/or transporting liquids, and extend across shoulder portions 59 so that their inner ends will come in contact with any liquid introduced into the conduit sections. An alternative arrangement is shown in lower packing assembly 54*a*, wherein the body of swellable rubber 63 consists of an integral mass having absorptive threads or cords 64*a*–64*c* interposed therethrough and extending to the inner surfaces of jaws 55 and 56. The swellable rubber may also comprise a body of granulated or powdered rubber having absorptive threads or absorptive particles interspersed therein.

Spool-shaped members 65 and 65*a* having upper and lower shoulder portions 66, 66*a* and 67 and 67*c* respectively, are positioned within the conduit in such manner that upper shoulder portions 66 and 66*a* overlap shoulder portions 59 of upper jaws 55 and 55*a*, respectively, and lower shoulder portions 67 and 67*c* overlap shoulder portions 59 of lower jaws 56 and 56*a*, respectively. Spool-shaped members 65 and 65*a* are of such length that the upper and lower shoulder portions thereof are separated by a distance greater than the combined thickness of shoulder portions 59 of upper and lower jaws 55, 55*a*, 56 and 56*a* and the body of swellable rubber interposed therebetween. Accordingly, when upper conduit section 50 and upper jaw 55 are raised, spool member 65 will likewise be raised by reason of shoulder portion 66 engaging shoulder portion 59 of upper jaw 55, but lower jaw 56 will not be raised until its shoulder 59 is engaged by lower shoulder portion 67 of spool 65. As a result, when a lifting force is placed on upper conduit section 50, the jaws 55 and 56 of upper packing element assembly 54 will be pulled apart allowing the body of rubber and packing ring 60 to contract. If such lifting force is continued, jaws 55*a* and 56*a* of lower packing assembly 54*a* will similarly be pulled apart by engagement of spool 65*a* with shoulder portions 59 of jaw members 55*a* and 56*a*. This arrangement permits the tool to be removed from the well after it has been set and packing rings 60 and 60*a* expanded against casing 57. By constructing the packing rings with their inner surfaces at an angle to the perpendicular, as shown in packing element assembly 54*a*, contraction of the body of swelled rubber and the packing ring is facilitated, thereby facilitating removal of the tool from the well after it has been set.

The space between upper and lower packing assemblies 54 and 54*a* and the exterior of middle conduit section 51 contains a body of a foraminous fluid-sensitive material 68 held in place by a screen or other foraminous retainer 69. Fluid-sensitive material 68 is of such nature that it undergoes an observable chemical or physical change upon being contacted with a particular well fluid. For example, it may comprise sawdust impregnated with a cobalt salt which changes color upon contact with water

or brine. When the tool is positioned in the well bore and the well is placed on production, the fluids produced by the strata opposite the space between packing element assemblies **54** and **54***a* will pass through fluid-sensitive material **68** and into conduit section **51** via perforations **52**. Upon withdrawing the tool and examination of fluid-sensitive material **68** it can be determined from the color thereof whether such fluid is water or brine rather than oil. Fluid-sensitive material **68** may also be of such nature that it swells in contact with water, so that the tool serves as an automatic plugging or water-shutoff device. Fluid-sensitive material **68** may also be oil- or gas-sensitive in order to indicate or plug off such fluids.

When the tool is in place in the well bore with its lower end resting on the bottom of the bore or on a tool support, the entire weight of the tubing string will be applied upon that portion of the bodies of rubber which extend between shoulder portion **59** of each of the jaws. This portion of the bodies of rubber will then be very highly compressed—so much so that the swelling liquid (which is not employed until the tool is in place) does not cause this particular portion of the bodies of rubber to swell. Also, even if such swelling occurs and the rubber does actually swell so as to extrude into the bore of the conduit, it will extrude only a fraction of an inch until it meets the wall of the spool member. This will not cause the device any difficulty and it will operate as explained herein.

An alternative means for containing the fluid-sensitive material is shown in Fig. 6 being the section of the tool immediately above packing element assembly **54**. According to such modification, the body of fluid-sensitive material **70** is held in a cup or capsule **71** having one end **72** open to the space exterior of conduit section **50** and the opposite end **73** communicating with the interior of conduit section **50** via a threaded opening **74**. In order to insure efficient contact between the well fluid and sensitive material **70**, the inner surface of capsule **71** may be provided with spiral grooves through which such fluid passes on its way into the conduit. Also, a check valve may be provided in opening **74** to prevent fluid from passing from the conduit out into capsule **71**.

As will be apparent to those skilled in the art, the principle of the present invention may be applied to a wide variety of packers and plugs, and the device of the invention may take many forms other than those illustrated and described herein. As so applied, the invention in its broadest aspect consists of a well packing or plugging tool comprising an elongated body portion adapted to be lowered into a well bore, at least two spaced retaining members extending from the outer surface of the body substantially perpendicular to the axis thereof, a resilient nonswelling packing ring held between adjacent retaining members adjacent the peripheries thereof, a body of liquid-swellable material held between adjacent retaining members and occupying the space between the body portion and the packing ring, and means for directing a swelling fluid into the body of swellable material. In the appended claims, the term "inert resilient expansible packing element" is employed to define an extensible elastic packing means which is not swelled by well fluids or by the liquid which is eventually employed to swell the body of swellable material. The term "liquid-swellable material" is employed to define a substance which increases in volume upon being contacted with a suitable liquid.

While the principle of employing swellable rubber and a swelling liquid to generate pressure and/or motion has been described above as applied to various well tools and devices, such principle has a variety of other applications in the useful arts. For example, in the art of forming sheet metal into irregular shapes, the pressure developed by a body of swellable rubber undergoing swelling by a suitable liquid may be employed to force the sheet metal into a female die of the desired shape, thereby obviating the necessity of providing a corresponding male die and eliminating large presses. Since the rubber swells relatively slowly, the sheet metal is made to conform to the contours of the die over a relatively long period of time, thereby avoiding the creation of internal stresses and eliminating annealing. Gaskets and similar sealing devices may be constructed of a swellable rubber and means provided for feeding a swelling liquid into intimate contact with the rubber; in the swollen state the rubber will conform to all irregularities in the surfaces of the parts between which the gasket or seal is interposed, thereby obviating the need for carefully machining the opposed faces of such parts. Also, a body of swellable rubber contained in a cylinder provided with means for introducing a swelling liquid may be caused to expand against a movable piston which closes one end of the cylinder, and the motion of such piston may be mechanically transferred to operate a variety of mechanisms or to apply a tensive or compressive force at remote locations. Since the swellable rubber and swelling liquid may be so selected that the rubber swells at a uniform and predetermined rate, the piston will move at a uniform rate and in a given time will move over a given distance; accordingly, the motion of the piston may be employed to trip a time delay switch or to operate recording instruments in which the variation of some measured variable is recorded with respect to lapse of time. The principle of the invention may also be applied to the creation of internal stresses. For example, in the manufacture of golf balls it is desirable that the rubber windings in the finished ball be under maximum tension, but such residual tension is limited by the breaking strength of the rubber during the winding operations. This difficulty can be overcome by winding the ball in the conventional manner on a core of swellable rubber, molding the outer cover around the windings, and thereafter injecting a swelling liquid into the central core of swellable rubber. As the core swells in the liquid, high pressure is exerted on the windings and results in increased residual tension within the ball.

In its broadest aspects, the invention thus consists in motion-generating devices comprising a body of swellable rubber or other swellable material substantially entirely enclosed by confining means having a movable portion against which the swellable material can expand and increase its volume, and also in hollow articles of manufacture having substantially rigid walls completely enclosing a body of liquid-swellable rubber or other swellable material and a swelling liquid therefor.

Other modes of applying the principle of our invention may be employed instead of those explained, change being made as regards the elements or means employed, provided the apparatus stated by any of the following claims, or the equivalent of such stated apparatus, be constructed or employed.

We, therefore, particularly point out and distinctly claim as our invention:

1. A well tool comprising an elongated body portion adapted to be lowered into a well bore; at least two spaced rigid retaining members affixed to said body portion and extending outwardly from the longitudinal axis thereof, the opposed faces of adjacent retaining members extending over a substantial portion of the cross-sectional area of the well bore; an inert resilient expansible packing element of continuous annular shape extending between the opposed faces of adjacent retaining members adjacent the peripheries thereof and surrounding said body portion at a distance therefrom; a body of liquid-swellable material positioned between the opposed faces of adjacent retaining members and between said body portion and said packing element; and means for directing a swelling liquid into intimate contact with said body of liquid-swellable material.

2. A well tool in accordance with claim 1 wherein the said swellable material is a rubber composition capable of swelling to an extent of at least about 200 percent in toluene.

3. A well tool in accordance with claim 1 wherein the said liquid-directing means comprises a material capable of absorbing liquids without substantial swelling and is interposed within the said body of liquid-swellable material.

4. A well tool comprising a hollow elongated conduit capable of being lowered into a well bore on a well tubing string; at least two spaced rigid retaining members affixed to said conduit and extending outwardly therefrom, the opposed faces of adjacent retaining members being substantially circular and having a diameter smaller than the inside diameter of the bore in which the tool is employed; an inert resilient expansible packing element of continuous annular shape extending between the opposed faces of adjacent retaining members adjacent the peripheries thereof and surrounding said conduit at a distance therefrom; a body of liquid-swellable material positioned between the opposed faces of adjacent retaining members and between said conduit and said packing element; and a substantially non-swelling liquid-absorbing material interposed within said body of liquid-swellable material and communicating with the interior of said conduit.

5. A well tool in accordance with claim 4 wherein the said swellable material is a rubber composition capable of swelling to an extent of at least about 200 percent in toluene.

6. A well tool in accordance with claim 5 wherein the body of swellable rubber composition takes the form of a plurality of relatively thin superimposed discs and said liquid-absorbing material takes the form of relatively thin sheets interposed between said discs and having inwardly projecting tabs extending through perforations in the wall of said conduit.

7. A well tool comprising an upper hollow conduit section capable of being lowered into a well bore on a tubing string; an upper rigid retaining member affixed at the lower end of said upper conduit section and extending outwardly therefrom, said upper retaining member having a substantially circular lower face the outside diameter of which is smaller than the inside diameter of the bore in which the tool is employed, and having a shoulder portion extending inwardly across the lower end of said upper conduit section; a lower hollow conduit section; a lower rigid retaining member affixed at the upper end of said lower conduit section and extending outwardly therefrom, said lower retaining member having a susbtantially circular upper face the outside diameter of which is smaller than the inside diameter of the bore in which the tool is employed, and having a shoulder portion extending inwardly across the upper end of said lower conduit section; a body of a liquid-swellable rubber composition extending between the upper and lower faces of said lower and upper retaining members, the diameter of said body of rubber composition being less than that of said faces; an inert resilient expansible packing ring extending between the upper and lower faces of said lower and upper retaining member adjacent the peripheries thereof; means for directing a swelling liquid into intimate contact with said body of rubber; and a hollow spool-shaped member extending within said upper and lower conduit sections, said spool-shaped member having an upper shoulder portion extending above and across the shoulder portion of said upper retaining member and a lower shoulder portion extending below and across the shoulder portion of said lower retaining member, the distance between said upper and lower shoulder portions of said spool-shaped member being greater than the combined thickness of the shoulder portions of said upper and lower retaining members.

8. A tool in accordance with claim 7 wherein each of said upper and lower faces of said lower and upper retaining members is hollowed out over a portion of the distance back from their peripheries and the said body of swellable rubber comprises a thick portion extending between the hollowed out portions of said faces and a thin portion extending across the shoulder portions of said retaining members.

9. A tool in accordance with claim 8 wherein said liquid directing means comprises a material capable of absorbing liquids without substantial swelling interposed within said body of said liquid-swellable rubber, and communicates with the interior of said conduit sections.

10. A well tool comprising a hollow elongated conduit laterally perforated over a portion of its length and adapted to be lowered into a well bore on a tubing string; an upper pair of spaced rigid retaining members affixed to said conduit above the perforated portion thereof and extending outwardly from the longitudinal axis thereof, the opposed faces of said retaining members being substantially circular and having diameters smaller than the inside diameter of the well bore; a lower pair of spaced rigid retaining members affixed to said conduit below the perforated portion thereof and extending outwardly from the longitudinal axis thereof, the opposed faces of said pair of lower retaining members being substantially circular and having diameters smaller than the inside diameter of the well bore; an inert resilient expansible packing element in the form of a continuous ring extending between the opposed faces of each pair of retaining members adjacent the peripheries thereof and surrounding said conduit at a distance therefrom; a body of liquid-swellable material positioned between the opposed faces of each pair of retaining members and between said packing ring and said conduit; means for directing a swelling liquid into intimate contact with said bodies of liquid-swellable material; and a body of a foraminous fluid-sensitive material extending between the said pairs of retaining members exterior of said conduit.

11. A well tool as defined by claim 10, wherein the said fluid-sensitive material is a material capable of undergoing swelling when contacted with water.

12. A well tool comprising a hollow elongated conduit laterally perforated over a portion of its length and adapted to be lowered into a well bore on a tubing string; an upper pair of spaced rigid retaining members affixed to said conduit above the perforated portion thereof and extending outwardly from the longitudinal axis thereof, the opposed faces of said retaining members being substantially circular and having diameters smaller than the inside diameter of the well bore; a lower pair of spaced rigid retaining members affixed to said conduit below the perforated portion thereof and extending outwardly from the longitudinal axis thereof, the opposed faces of said pair of lower retaining members being substantially circular and having diameters smaller than the inside diameter of the well bore; an inert resilient expansible packing element in the form of a continuous ring extending between the opposed faces of each pair of retaining members adjacent the peripheries thereof and surrounding said conduit at a distance therefrom; a body of liquid-swellable material positioned between the opposed faces of each pair of retaining members and between said packing ring and said conduit; means for directing a swelling liquid into intimate contact with said bodies of liquid-swellable material; and a body of foraminous fluid-sensitive material positioned exterior of said conduit and extending across each of the perforations therein.

13. A well tool as defined by claim 12, wherein the said fluid-sensitive material is a material capable of undergoing swelling when contacted with water.

14. A well tool comprising an elongated body portion adapted to be lowered into a well bore; at least two spaced rigid retaining members affixed to said body portion and extending outwardly from the longitudinal axis thereof, the opposed faces of said retaining members being substantially circular and having diameters substantially smaller than the inside diameter of the well bore, said retaining members being permeable to liquids; an inert resilient expansible packing ring extending be-

tween the opposed faces of adjacent retaining members adjacent their peripheries and surrounding said body portion at a distance therefrom; and a body of liquid swellable material positioned between the opposed faces of adjacent retaining members and between said body portion and said packing ring.

15. A motion-generating device comprising a fixed body portion and a movable body portion, said body portions cooperating to enclose a fluid-tight space into which a rubber swelling liquid may be introduced; a body of swellable rubber substantially filling said enclosed space; and means for feeding the swelling liquid into said fluid tight space into intimate contact with said body of rubber, said liquid-feeding means being held in contact with said body of rubber and comprising a material capable of absorbing said liquid without substantial swelling; whereby said movable body portion is caused to move with respect to said fixed body portion when said body of rubber swells under the influence of a swelling liquid introduced into contact therewith.

16. An article of manufacture comprising a shell inert to rubber swelling liquid, said shell including relatively movable portions, one of which is outwardly movable with respect to the other, a mass of substantially uniform swollen rubber within said shell and formed when said mass of swollen rubber is acted upon by a swelling liquid, means for supplying said swelling liquid into said shell,

the shell being impervious with respect to said mass of swollen rubber, said mass of swollen rubber exerting a continuous substantially uniform pressure outwardly against said outwardly movable portion whereby the latter is continuously maintained under tension.

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