

Aug. 26, 1958

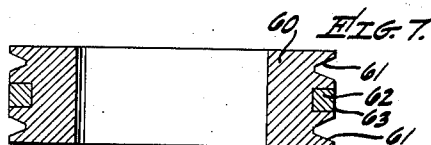
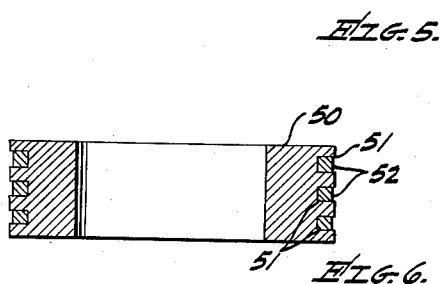
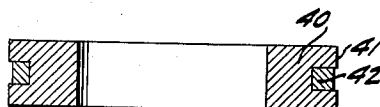
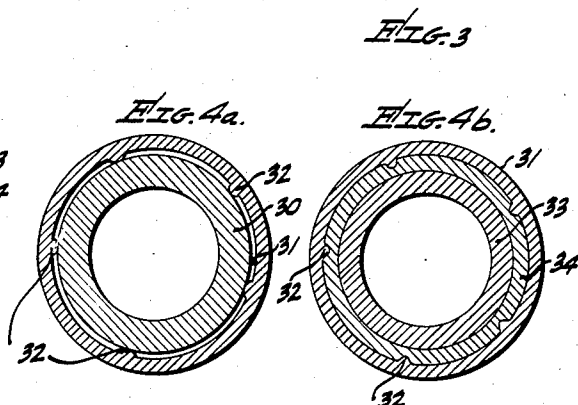
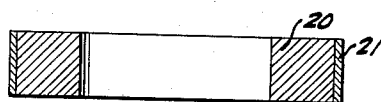
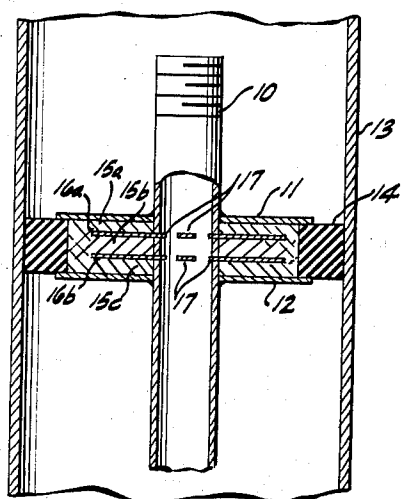
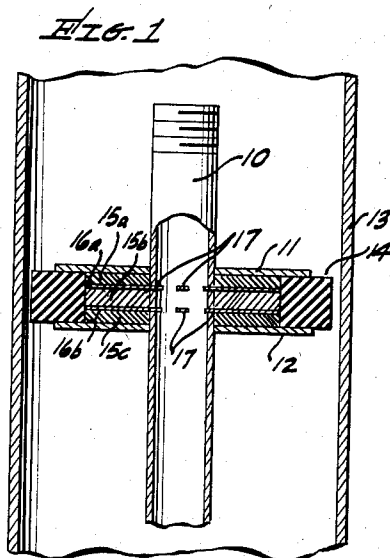
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2,849,070

WELL PACKER

Filed April 2, 1956

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

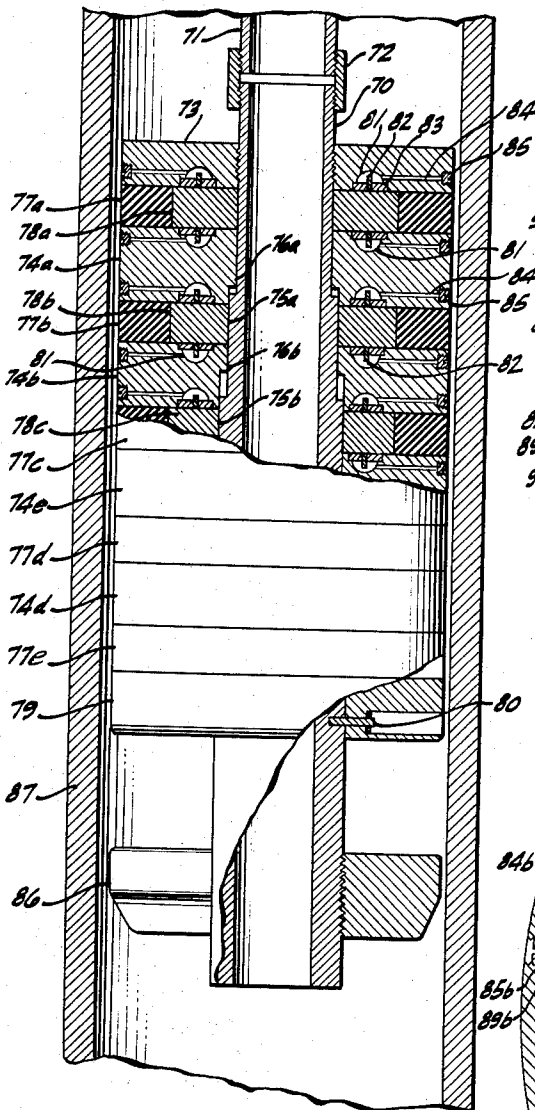


FIG. 8.

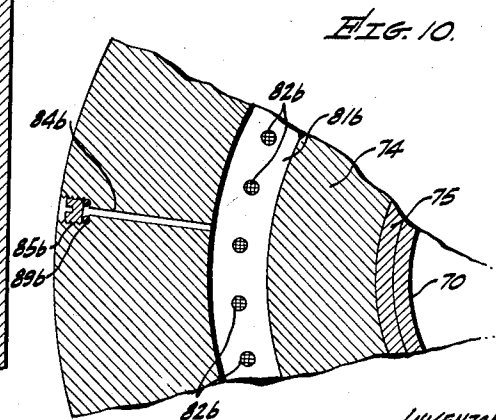
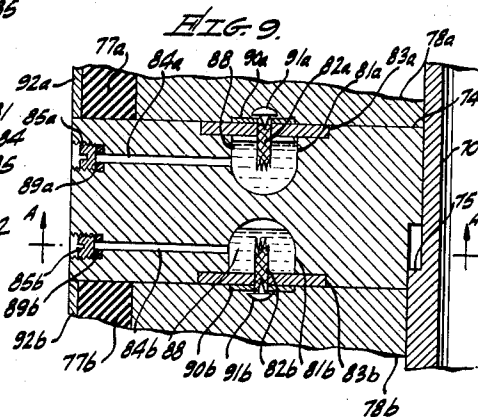


FIG. 10.

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2,849,070

WELL PACKER

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15 Claims. (Cl. 166—179)

This invention relates to a well packing or plugging device and in particular concerns a well packer or plug in which the sealing 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. Substantially all of such devices, however, comprise one or more resilient sealing 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 casing in fluid-tight relationship therewith. Such sealing elements are conventionally 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 sealing element or elements are actuated by pressure developed within the well bore rather than at the earth's surface. Another object is to provide a device of such character in which the actuating pressure is generated immediately adjacent each individual sealing element. A further object is to provide an improved sealing element particularly adapted for use in well packers and plugs. 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 longitudinal view of the device of Figure 1 after the sealing element thereof has been expanded to seal off a portion of a well bore.

Figure 3 is a cross-sectional view of a novel sealing element which may be used with the particular packing device of the invention or with prior art packers and plugs.

Figures 4a and 4b illustrate the operation of the sealing element of Figure 3.

Figures 5-7 are cross-sectional views of alternative forms which the improved sealing element may take.

Figure 8 is a longitudinal view, partially in cross section, illustrating a preferred form of packing device.

Figure 9 is an enlarged cross-sectional view illustrating in detail the means for actuating the sealing elements of the device of Figure 8.

Figure 10 is a partial view taken along line A-A of Figure 9.

Referring now to Figures 1 and 2, in which like numerals indicate like parts, the device there shown is a single element packer for closing off the annulus between a well casing and a 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

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conduit 10 in spaced relationship, and have outside diameters somewhat smaller than the inside diameter of well casing 13 in which the device is to be employed. Sealing element 14, normally having an outside diameter smaller than the inside diameter of 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 but is movable with respect thereto so that it is free to expand radially. Sealing element 14 is constructed of a resilient expandable 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 sealing element 14 and conduit 10 is filled with a body of liquid-swelling material in the form of relatively thin superimposed discs 15a, 15b and 15c separated by septums 16a and 16b which are constructed of a substantially non-swelling material capable of absorbing liquids, e. g., paper, cloth, etc. The septums are provided with a plurality of inwardly projecting lugs or tabs 17 which extend through suitable 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 and 2 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 15a-15c to swell. Such liquid contacts tabs 17 of septums 16a and 16b which act as wicks to distribute such liquid to discs 15a-15c. The latter swell or expand with great force upon contact with such liquid and since they are confined by the outer wall of conduit 10 and the opposed faces of plates 11 and 12 the force of the expansion is directed radially outward against sealing element 14. The latter, being resilient and expandable and free to move with respect to plates 11 and 12, is thus forced outwardly against the inner wall of casing 13 to form a fluid-tight seal therewith, as particularly shown in Figure 2 wherein the swollen and expanded state of discs 15a-15c is indicated by more widely spaced cross-hatching.

I am aware that it has been proposed to construct packing and plugging tools in which a resilient sealing element is forced outwardly against the well casing by means of a fluid which is forced down the well tubing under pressure. The present device, however, operates under an entirely different principle in that the pressure which forces the sealing 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 material undergoing swelling as a result of being contacted with a swelling liquid which is supplied under only nominal pressure. I 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 device of the present invention operates on the principle of making use of such high pressures to actuate the sealing element.

The swellable material employed in the devices within the scope of the invention is preferably rubber, although swelling clays, cellulosic materials, 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

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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 extensively milled swells more readily than a non-milled material, and rubber compositions which contain a high proportion of fillers swell to a lesser extent than compositions which contain only nominal amounts of fillers. 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 ultimately capable of swelling. The latter is of importance only insofar as it determines the dimensions of the device. Thus, in the device of Figure 1, if the swellable discs 15a—15c are made of rubber which is capable of swelling only to the extent of 20%, the outside diameter of sealing element 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%. However, this is because in the latter instance sealing element 14 will be expanded a greater radial distance rather than because of any substantial difference in the pressure developed by the two rubbers. As a practical matter I prefer to employ a rubber which is capable of swelling to an extent of at least about 200% in toluene, although it should be understood that toluene is not 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.

In the device illustrated by Figures 1 and 2, sealing element 14 is shown as an integral ring constructed of a material which is substantially non-swelling in the fluids normally present in the well bore. While sealing elements of such type operate satisfactorily when the inside wall of the well casing is substantially smooth, they are subject to improvement for use in rough or irregular casings since if made stiff enough to withstand any substantial pressure differential across their lateral faces they are too stiff to extend around irregularities in the casing or to enter into crevasses with negative angles. I have found that such improvement may be accomplished by constructing the sealing face of the sealing element of a material which is capable of swelling in one or more components of the well fluid. A simple embodiment of such an improved sealing element is shown in Figure 3, wherein the element comprises a body ring 20 composed of a resilient expandable material which is substantially non-swelling in well fluids and having a relatively thin continuous sealing ring 21 composed of a material capable of being swelled by well fluids vulcanized or otherwise attached to its peripheral face. Preferably, sealing ring 21 is composed of a rubber composition capable of being swelled by petroleum hydrocarbons.

The manner in which the sealing element of Figure 3 operates is shown in Figure 4a and 4b. Figure 4a shows a sealing element consisting of an integral ring 30, such as sealing element 14 of Figure 1, as it presses against the inside wall of a well casing 31. The latter is irregular, having imperfections in the form of projections 32 extending radially from its inside wall. As will be apparent, irregular projections 32 decrease the effectiveness of the seal between casing 31 and the sealing element 30 by decreasing the area of contact between the two. Figure 4b shows a two-piece sealing element of the type illustrated by Figure 3 and comprising a substantially non-swelling resilient body ring 33 having a petroleum hydrocarbon-swellable sealing ring 34 attached to its peripheral face. When the sealing ring comes in contact with the hydrocarbon-containing well fluid it swells and

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surrounds projections 32 as shown, thereby increasing the area of contact between the sealing element and the well casing and improving the seal.

Figure 5 illustrates an alternative form of sealing element, wherein the element is composed of a resilient expandable body ring 40 constructed of a material which is substantially non-swelling in petroleum hydrocarbons. A groove is provided in the peripheral face 41 of ring 40, and carries between its walls a sealing ring 42 of a resilient material which is readily swelled by petroleum hydrocarbons.

In Figure 6, the sealing element is shown composed of a substantially non-swelling body ring 50 having three grooves 51 provided in its peripheral face and a sealing ring 52 of swellable material carried in each of said grooves.

Figure 7 illustrates another form of sealing element, said element comprising a resilient substantially non-swelling body ring 60 having grooves 61 more or less in the shape of a V or U provided in its peripheral face adjacent the upper and lower lateral faces, and having a third groove 62 cut into its peripheral face more or less midway between the two V-shaped grooves. Groove 62 carries between its walls a sealing ring 63 of resilient material which is relatively readily swelled by petroleum hydrocarbons.

In the foregoing description of the sealing elements illustrated by Figures 5—7, said elements have been described as body rings of substantially non-swelling material having one or more grooves cut into their peripheral faces, and sealing rings of swellable material carried in said grooves. As will readily be apparent, equivalent devices may be constructed of superimposed laminae, the requisite grooves being attained by varying the diameter of the laminae. Also, it should be understood that while the ring which forms the main body of the sealing element is described as being substantially non-swelling, all resilient materials eventually swell to some extent in petroleum hydrocarbons. Accordingly, the term "substantially non-swelling" is to be understood as being relative only and to distinguish the material from that which is referred to as capable of being readily swelled by well fluids.

Referring now to Figure 8, there is there shown a preferred form of multi-element packing device embodying the principle of the invention. Said device consists of a central conduit 70 which is attached to well tubing string 71 by means of collar 72. Upper retaining plate 73 threadedly engages the outer wall of conduit 70, and intermediate retaining plates 74a—74d slidably engage the outer wall of conduit 70. The latter is provided with shoulder portions 75a and 75b which engage corresponding shoulder portions 76a and 76b on each of intermediate retaining plates 74 so that when conduit 70 is raised intermediate retaining plates 74 are likewise raised one at a time in sequence starting from the top. Sealing elements 77a—77e in the form of substantially non-swelling resilient rings are carried between the opposed faces of adjacent retaining plates. Each of sealing elements 77 has an outside diameter substantially the same as that of the retaining plates and an inside diameter substantially larger than the outside diameter of conduit 70. A body of swellable material 78a—78c fills each of the annular spaces between the outside wall of conduit 70 and the inner diameter of each of sealing elements 77. The entire assembly is held together by means of lower retaining plate 79 which is affixed to conduit 70 by means of a shear pin 80. As is explained in greater detail hereinafter, each of intermediate retaining plates 74 bears circular hollowed-out portions or cavities in its lateral faces, each of which cavities forms a reservoir 81 for a body of liquid which is capable of causing swellable material 78 to swell and expand against sealing elements 77. A plurality of wicks 82 held in place by retaining washers 83 communicate between each

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of reservoirs 81 and bodies of swellable material 78. A duct 84 communicates between each of reservoirs 81 and the peripheral face of retaining plates 74, and provides a means for filling the reservoirs with liquid. Ducts 84 are normally closed by plugs 85. Guiding shoe 86 threadedly engages conduit 70 somewhat below lower retaining plate 79, and serves to guide the device within well casing 87.

The operation of the device of Figure 8 is as follows: After filling each of reservoirs 81 with a swelling liquid, e. g. toluene, and closing ducts 84 with plugs 85, the entire assembly is lowered to the desired location in well casing 87. The packer is held at this location until the swelling liquid passes into the bodies of swellable material 78 via wicks 82, thereby causing the swellable material to expand and force sealing elements 77 firmly against the inside wall of well casing 87. When it is desired to remove the packer from the casing, well tubing 71 is raised by operation of the rig hoist at the earth's surface. Since the sealing elements frictionally engage the walls of the casing, shear pin 80 fractures, thereby permitting conduit 70 to move upwardly with respect to the remainder of the assembly. Since upper retaining plate 73 is rigidly affixed to conduit 70 it is likewise raised, thereby increasing the width of the space between upper retaining plate 73 and the next adjacent intermediate retaining plate 74a. The uppermost sealing element 77a is thereby permitted to contract away from the walls of well casing 87. As conduit 70 is raised further its first shoulder portion 75a engages shoulder portion 76a of intermediate retaining plate 74a, thereby causing the latter to rise and increase the gap between intermediate retaining plates 74a and 74b. Sealing member 77b is thus permitted to contract away from the walls of the well casing. Similarly, as conduit 70 is raised still further, shoulder portion 75b engages the shoulder portion 76b of intermediate retaining plate 74b and causes it to rise, thereby allowing sealing element 77c to contract away from the walls of the casing. The particular arrangement of cooperating shoulder portions 75 and 76 of intermediate retaining plates 74 and conduit 70 thus permits only one of sealing elements 77 to contract away from the wall of the well casing at any one time, and the force thus required to remove the device from the well is minimized. If desired, other means of disengaging the assembly may be employed, e. g. the conventional J-slot arrangement or a shear pin which is broken by positive action such as a weight dropped down the well.

Referring now to Figures 9 and 10, in which like numerals indicate like parts, which represent a fragmentary cross-sectional view of one of intermediate retaining plates 74 of Figure 8. Said plate takes the form of a rigid metallic disc 74 having a central longitudinal opening, the upper portion of which opening has a diameter corresponding closely to that of central conduit 70 and the lower portion of which has a diameter corresponding closely to that of shoulder portion 75 of conduit 70. Circular cavities 81a and 81b milled in the lateral faces of disc 74 form reservoirs into which a body of liquid 88 can be introduced through ducts 84a and 84b communicating with the peripheral face of the disc. Ducts 84a and 84b are closed by threaded plugs 85a and 85b and resilient sealing rings 89a and 89b. The lateral faces of disc 74 are milled to receive metallic retaining washers 83a and 83b coaxially with cavities 81a and 81b. Wicks 82a and 82b, composed of an absorbent non-swelling material such as cotton or the like and having their exterior ends fanned out as at 90a and 90b, extend into cavities 81a and 81b through the central openings in washers 83a and 83b, and are held therein by pins 91a and 91b. The latter are provided with tapered shanks which force the sides of the wicks outwardly against the walls of the openings in the retaining washers 83a and 83b. Wicks 82a and 82b serve to conduct liquid 88 to

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the bodies of swellable rubber 78a and 78b which are in contact with the lateral faces of disc 74, whereby said bodies are caused to swell and expand radially against resilient sealing elements 77a and 77b to force them outwardly against the wall of the well casing, not shown. If desired, an absorbent septum may be interposed between swellable material 78 and the exterior ends of wicks 82 to improve the distribution of liquid 88 from wicks 82 to swelling material 78. Sealing elements 77a and 77b are shown to be of the type illustrated by Figure 3, i. e., their peripheral faces 92a and 92b are composed of a material such as natural rubber which is swelled by petroleum hydrocarbons.

In order to avoid premature swelling of bodies 78a and 78b, wicks 82a and 82b are saturated with paraffin wax or other entity which is soluble in liquid 88. The latter is likewise saturated with the wax or other entity at a temperature which is above that at which the assembly is stored and shipped but below that of the well bore in which it is to be used. Suitably, liquid 88 is toluene saturated with paraffin at 100°-140° F. As will be apparent, so long as the device encounters temperatures below 100°-140° F., the toluene will remain saturated with paraffin and will be incapable of dissolving the paraffin with which the wicks are saturated and which acts as a plug within the wicks to prevent liquid from being conducted therethrough to swellable material 78. However, when the assembly is positioned in a well bore where it encounters temperatures above 100°-140° F., the toluene will no longer be saturated with paraffin, and the paraffin contained in the wicks will be dissolved out of the same, whereby the wicks become unplugged to allow the toluene to pass therethrough to swellable material 78. Thus, by constructing the assembly as described, the swelling of swellable material 78 and expansion of sealing elements 77 against the walls of the well casing can be controlled so as to occur only after the device has been positioned within the well bore.

As will be apparent to those skilled in the art, the principle of the 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 aspects consists of a well packing or plugging device 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 longitudinal axis thereof, a resilient substantially non-swelling sealing element in the form of a ring held between adjacent retaining members adjacent the peripheries thereof, a body of fluid-swellable material held between adjacent retaining members and occupying the space between the body portion and the sealing element, and means for directing a swelling fluid into the body of liquid-swellable material. The invention also comprising a sealing element suitable for use in contact with petroleum hydrocarbons and essentially comprising a resilient ring-shaped member which is substantially non-swelling in petroleum hydrocarbons and at least one body of a resilient material capable of being swelled by petroleum hydrocarbons encircling the peripheral face of said member. The invention further comprises the particular means herein described for directing a swelling liquid into a body of liquid-swellable material.

In the appended claims, the term "inert resilient expansible sealing element" is employed to define an extensible elastic sealing means which is not substantially 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 substantially increases in volume upon being contacted with a suitable liquid but does not substantially dissolve therein.

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

I, therefore, particularly point out and distinctly claim as my invention:

1. A well tool comprising an elongated body portion adapted to be lowered into a well bore; at least two rigid imperforate retaining plates coaxially positioned along said body portion in substantially parallel spaced relationship, each of the opposed faces of adjacent retaining members extending over a substantial portion of the cross-sectional area of said well bore; a ring-shaped inert resilient expansible sealing element extending between the opposed faces of adjacent retaining plates adjacent the peripheries thereof and surrounding said body portion at a distance therefrom; at least one sealing ring composed of a resilient material capable of being swelled by petroleum hydrocarbons encircling the peripheral face of said sealing element; a body of a liquid-swella-
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

2. A well tool in accordance with claim 1 wherein the said liquid-swella-
3. A well tool in accordance with claim 1 wherein the said sealing ring is composed of a rubber composition capable of being swelled by petroleum hydrocarbons.

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 substantially circular rigid imperforate retaining plates coaxially positioned along the length of said conduit in substantially parallel spaced relationship, said retaining plates having a diameter somewhat smaller than that of the bore in which the tool is used; a ring-shaped inert resilient expansible sealing element extending between the opposed faces of adjacent retaining plates adjacent the peripheries thereof and surrounding said conduit at a distance therefrom; at least one sealing ring composed of a material capable of being swelled by petroleum hydrocarbons encircling the peripheral face of said sealing element; a body of petroleum hydrocarbon-swella-
5. A well tool in accordance with claim 4 wherein the said body of petroleum hydrocarbon-swella-
6. A well tool comprising an elongated body portion adapted to be lowered into a well bore; at least two substantially circular rigid imperforate retaining plates positioned along the length of said body portion in substantially parallel spaced relationship, each of said retaining plates having a diameter smaller than that of the bore in which the tool is used and at least one of said retaining plates having a cavity in the lateral face opposing the adjacent retaining plate; means for closing the opening of said cavity in the lateral face of said retaining plate; means for introducing a liquid into said cavity; a ring-shaped inert resilient expansible sealing element extending between the opposed faces of adjacent retaining plates adjacent the peripheries thereof; a body of liquid-swella-
7. A well tool in accordance with claim 6 wherein the said cavity takes the form of a circular groove in the face of said retaining plates and said means for introducing liquid into said cavity comprises a radial duct extending from said cavity to a removable closure at the periphery of said retaining plates.
8. A well tool in accordance with claim 6 wherein the said body of liquid-swella-
9. A well tool in accordance with claim 6 wherein said means for introducing liquid into said cavity comprises at least one radial duct extending from said cavity to a removable closure at the periphery of said retaining plate.
10. A well tool comprising a hollow elongated conduit capable of being lowered into a well bore on a tubing string, the outside diameter of said conduit increasing in a plurality of steps along its length to form a plurality of conduit shoulder portions; an upper substantially circular rigid imperforate retaining plate affixed to said conduit at its upper end; a guide shoe affixed to said conduit at its lower end; a lower substantially circular rigid imperforate retaining plate; frangible means affixing said lower retaining plate to said conduit at its lower end adjacent to and spaced above said guide shoe; a plurality of substantially circular parallel rigid imperforate intermediate retaining plates corresponding in number to the number of said conduit shoulder portions, each of said intermediate retaining plates having an inwardly projecting shoulder portion slidably engaging one of said conduit shoulder portions between said upper and said lower retaining plates, each of said inwardly projecting shoulder portions being of shorter length than the conduit shoulder portion which it slidably engages and the lateral faces of said intermediate retaining plates having at least one cavity therein; means for closing the opening of said cavity in said faces; means for introducing a liquid into said cavity; a ring-shaped inert resilient expansible sealing element extending between the opposed lateral faces of adjacent retaining plates adjacent the peripheries thereof; a body of liquid-swella-
11. A well tool in accordance with claim 10 wherein the said cavity takes the form of a circular groove cut into the face of said retaining plate and said means for introducing liquid into said cavity comprises at least one radial duct extending from said cavity to a removable closure at the periphery of said retaining plate.
12. A well tool in accordance with claim 10 wherein each of said sealing elements comprises an inert resilient expansible body ring, and a sealing ring composed of a material capable of being swelled by petroleum hydrocarbons encircling the peripheral face of said body ring.
13. A sealing element for well packers and plugs comprising a ring-shaped body portion composed of an inert resilient expansible material, and a sealing ring composed of a material capable of being swelled by petroleum hydrocarbons encircling the peripheral face of said body portion.
14. A sealing element for well packers and plugs comprising a ring-shaped body portion composed of an inert resilient expansible material having grooves in its peripheral face adjacent the upper and lower edges thereof, the walls of said grooves tapering inwardly from said edges; and a sealing ring composed of a material capable of be-

ing swelled by petroleum hydrocarbons encircling the peripheral face of said body portion between said grooves.

15. A sealing element according to claim 14 wherein the said sealing ring is composed of a rubber composition capable of swelling to an extent of at least about 200 per cent in toluene.

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