Nov. 18, 1952 L. D. MEDDICK ET AL 2,618,341

WELL PACKER

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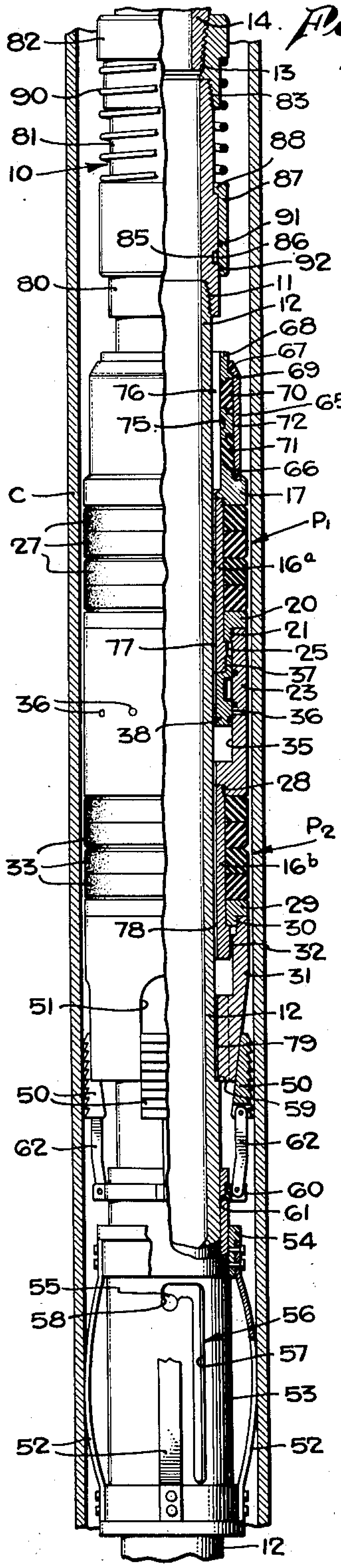


Fig. 1.

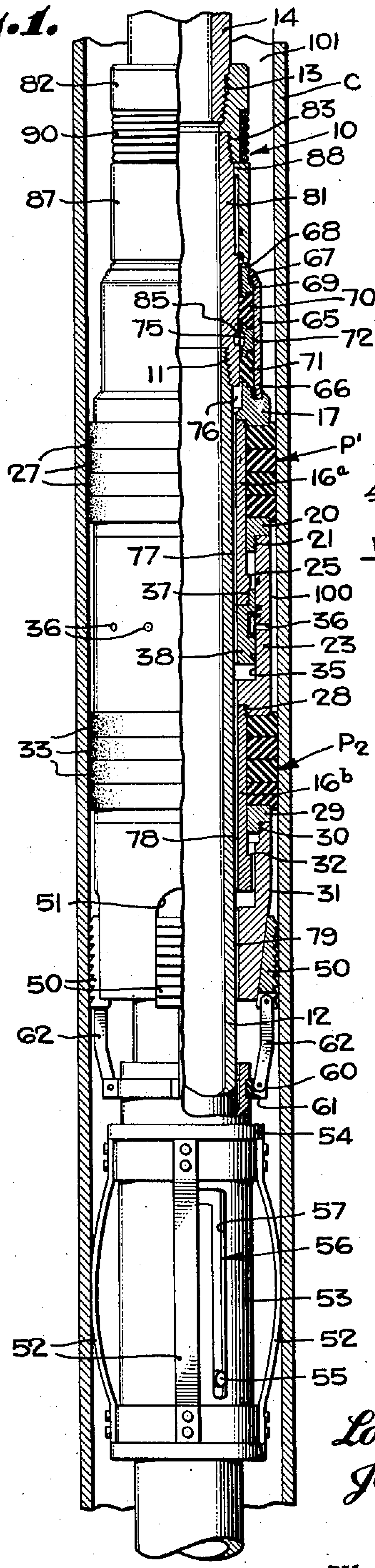
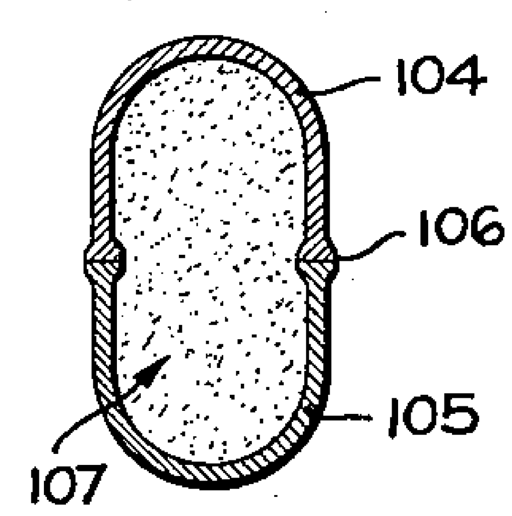


Fig. 2.

Fig. 5.



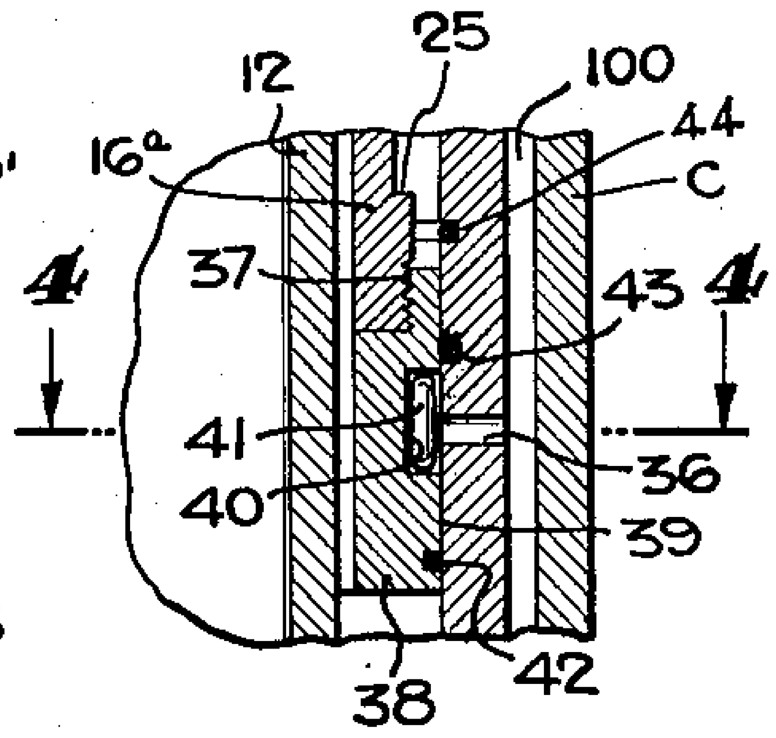


Fig. 3.

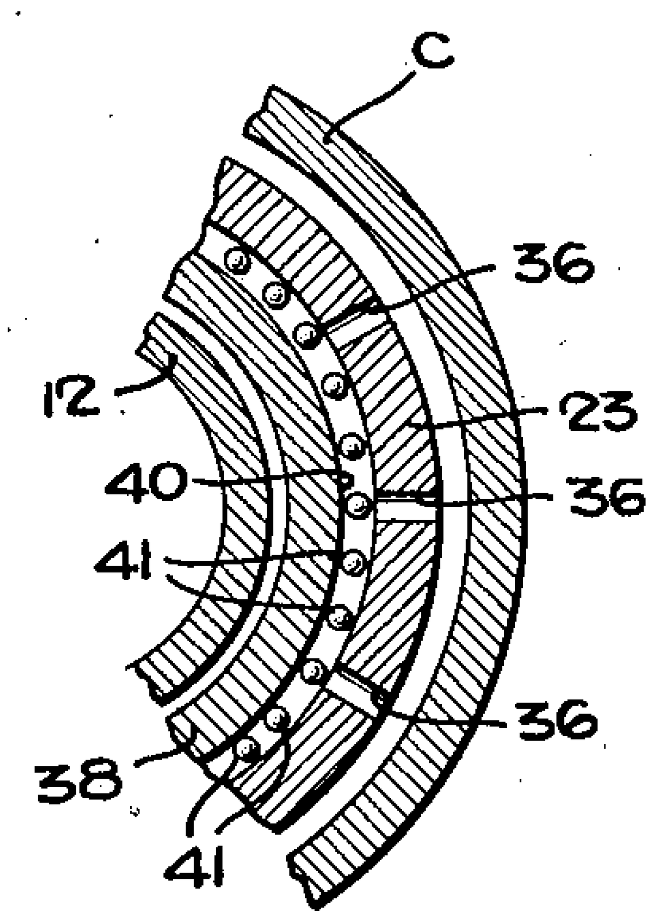


Fig. 4.

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WELL PACKER

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14 Claims. (Cl. 166—11)

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This invention relates, in general, to well packers and more particularly to well packers, bridging plugs and the like devices having means incorporated therein for indicating leakage.

This invention has its most important application to oil wells in which it is desired to carry on so-called dual production, that is, production from two different formations at separate depths in the well. In such dual production practice it is customary to set a packer between the two production zones to isolate them from one another and then produce the lower zone through the packer and the tubing and the upper zone through the annular passage between the tubing and the surrounding casing above the packer.

Under such production conditions it is important for several reasons to determine whether or not there is any leakage of fluid past the packer between the two producing zones separated by the packer either through the casing or by channeling outside of the casing. One important reason for this knowledge is to enable one to determine whether a zone of higher pressure may be losing production by leakage past the packer or by channeling along the outside of the casing to a zone of lower pressure. When this occurs the current well production rate of the higher pressure zone may not only be reduced but ultimate production thereof may be lost, and irreparable damage also may be done to one formation by contamination with the production fluid from another formation. Also the potential production rate and ultimate production of one such formation may be seriously lowered by loss of gas pressure or other fluid pressure to another formation of relatively low pressure.

Another important reason for accurate determination of whether or not a packer, serving to separate the productions in a well from two different producing zones, is free from leakage, is to enable one to obtain accurate and truly representative well potential production rates from which proper prorated production rates for the well can be calculated. If a packer in a dual production well should leak, the separate productions from the separate formations will be influenced by one another. For example, if the packer in a dual production well is leaking and thereby allowing a substantial amount of the fluid from one producing zone to flow past the packer into the fluid produced from the other zone the apparent potential of the first zone will be less and that of the second zone greater than the true potentials.

Hence it is necessary to maintain the two zones and the productions therefrom isolated, particularly at the time tests are made to establish the true well production rate potentials.

Ordinarily the determination of whether or not there is any such leakage past the packer or outside the casing as hereinbefore mentioned is a

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very difficult undertaking and at best uncertain.

It is accordingly a primary object of this invention to overcome the hereinbefore mentioned difficulties.

It is another object of this invention to provide a means and method for indicating leakage of fluid past a well packer set in a well.

It is another object of this invention to provide a means and method for determining the occurrence of leakage along the outside of casing set between two or more formations.

It is still another object of this invention to provide a well packer apparatus incorporating automatic leakage indicating means therein.

It is a further object of this invention to provide a well packer apparatus incorporating automatic leakage indicating means therein and means to provide a delayed actuation of the automatic leakage indicating means following the setting of a packer.

In general the foregoing objects of this invention are attained by and the invention is embodied in apparatus comprising a packer means for dividing the well casing or borehole into two longitudinally separated zones, an upper zone and a lower zone, with means incorporated in the packer structure for automatically releasing a tracer fluid or tracer material within the packer after a suitable time interval subsequent to the setting of the packer and occurrence of leakage of the fluid past the packer from one of said zones to the other.

Other objects, advantages and features of novelty will be evident hereinafter.

In the drawings which show by way of illustration preferred embodiments of the invention and in which like reference numerals designate the same or similar parts through the several views:

Figure 1 is a view partially in elevation and partially in longitudinal section showing the apparatus in its initial run-in position within a well casing just prior to setting;

Figure 2 is another view of the apparatus of Figure 1 as it appeared after setting in a well casing;

Figure 3 is a fragmentary, enlarged, detailed view in longitudinal section of a portion of the apparatus of Figures 1 and 2;

Figure 4 is a fragmentary cross-sectional view taken on line 4—4 of Figure 3;

Figure 5 is an enlarged detailed view, in cross-section of a tracer container employed in the apparatus of Figures 1 to 4 inclusive.

Referring now primarily to Figures 1 through 4 of the drawing the apparatus there illustrated is as follows:

A well casing is shown in longitudinal section at C which may be assumed to have been set and cemented-in in the usual fashion in a drilled well borehole and into which the packer embodying the invention is run.

The general arrangement and components of the packer, except as described hereinafter, may be similar to that shown and described in United States Patent 2,005,955 and comprises briefly the following parts:

A packer head or top collar member 10 is threadedly connected at its lower end at 11 to a packer body which comprises a hollow mandrel or tubular structure 12 which extends downward and concentrically through the packer and slip assemblies. The packer head 10 is adapted to make threaded coupling at its top end at 13 with suitable drill pipes or tubing 14 by means of which the whole packer apparatus is suspended while being lowered through the well casing and by means of which the packer is manipulated and downward force is applied to set the packer and expand the resilient packing elements into sealing engagement between the packer body and a surrounding casing after the packer is set. The drill pipe or tubing 14 also serves after the packer is set and the well put into production to define two flow channels; an inner flow channel within the pipe or tubing to convey to the well surface any fluid produced from the well below the packer and an annular flow passage between the tubing or pipe 14 and the casing 10 to convey to the well surface any fluid produced from the well above the packer all as hereinafter more fully described in connection with the operation.

Concentrically surrounding the mandrel 12 and slidably spaced therefrom and included in the packer body structure are packing means comprising a pair of longitudinally spaced packing assemblies, the upper packing assembly being shown at P_1 and the lower packing assembly being shown at P_2.

The upper packing assembly P_1 comprises a packing supporting sleeve 16*a* threadedly connected at its upper end to an annular valve member 17 of the packer circulating valve. The lower portion of the packing supporting sleeve 16*a* extends downward slidably through a packing retaining nut 20 which in turn makes threaded connection at 21 with the upper end of an intermediate cylindrical spacer body 23 which also serves as a valve member as hereinafter more fully described. The lower end of the packing supporting sleeve 16*a* is formed with an offset outwardly extending shoulder as shown at 25 which serves to limit the upward motion of the said sleeve 16*a* through the packing retaining nut 20.

A resilient packing element or sleeve or a plurality of resilient packing rings as shown at 27 encircle the supporting sleeve 16*a*, are retained in position thereon and are adapted to be axially compressed between the inner, confronting annular surfaces of the beforementioned valve member 17 and the retaining nut 20.

The lower end portion of the intermediate cylindrical spacer body 23 has a form similar to that of the hereinbefore described valve member 17 and makes threaded connection as shown at 28 with the upper end of a lower packing supporting sleeve 16*b*. The lower portion of the lower packing supporting sleeve 16*b* extends downward slidably through a lower packing retaining nut 29 which in turn makes threaded connection at 30 with the upper end of a slip cone body 31. The lower end of the packing retaining sleeve 16*b* as in the case of the upper retaining sleeve 16*a* is formed with an offset outwardly extending shoulder as shown at 32 which acts as a stop to limit the upward sliding motion of the sleeve 16*b* with respect to the beforementioned packer retaining nut 29.

A resilient packing element or sleeve or a plurality of resilient packing rings as shown at 33 encircle the lower packer supporting sleeve 16*b*, are retained in position thereon and are adapted to be axially compressed and thereby radially expanded between the inner confronting annular surfaces of the beforementioned lower end of the intermediate cylindrical spacer body 23 and the lower retaining nut 29.

The beforementioned intermediate cylindrical spacer body 23 is formed with an inner bore 35. A plurality of radially directed ducts or ports 36 extend through an intermediate portion of the spacer body 23 and interconnect the said bore 35 with the exterior of the spacer body intermediate the packing assemblies P_1 and P_2 as best shown in Figures 3 and 4. Threadedly connected at 37 to the lower end of the offset shoulder portion 25 of the upper packing supporting sleeve 16*a* is a tracer retaining ring member 38 having an outer cylindrical surface 39 making a snug sliding fit within the beforementioned inner bore 35 of the intermediate cylindrical spacer body 23.

The tracer retaining ring 38 is formed with an intermediately located outwardly facing annular groove or recess as best shown at 40 in Figures 3 and 4, adapted to retain therein a plurality of tracer containing bodies or capsules as shown at 41 and hereinafter more fully described. Annular packing ring grooves are provided at 42 in the tracer retainer ring 38 and at 43 and 44 in the inner bore 35 of the spacer body 23. These packing grooves preferably contain packing of the O-ring type for the purpose of forming a fluid tight sliding seal between the tracer retaining ring 38 and the inside surface of the bore 35 whereby when the said ring 38 is in the upper position shown in Figure 1 fluid will be excluded from the recess 40 and from contact with the tracer bodies therein. Spacer body 23, together with the ducts or ports 36, serves as a valve member for the recess or groove 40.

Means are provided for anchoring the beforementioned slip cone 31 to the inside surface of the casing in a more or less conventional manner. Such means comprises wickered slips 50 which are slidably mounted in dove tail slip guides 51 formed in the said slip cone 31 the said slip being restrained from movement outwardly from the cone by the overhanging walls of the dove tail guides but being free to slide longitudinally along the sloping slip surfaces.

The slip control mechanism includes a slip cage of more or less conventional design comprising a plurality of outwardly bowed cage friction springs 52 which are rigidly attached at their lower ends to the lower end portion of a cage sleeve 53 and at the upper end to a ring or collar 54 which is slidable longitudinally on the upper portion of the said sleeve 53 to permit lateral contraction and expansion of the bow springs.

The cage sleeve 53 is free to rotate and slide longitudinally upon the mandrel 12 except as it is limited by a dowel or latch-pin 55 which is fixed to and projects outwardly from the mandrel into slidable engagement within a J-slot 56 formed in the cage sleeve and having a vertical portion 57 and a recessed lateral portion as shown at 58.

A slip rein ring or collar 60 is retained on the upper end portion of the slip cage sleeve 53 in an annular groove as shown at 61 providing freedom for rotational movement but preventing lateral movement of the ring with respect to the sleeve. A plurality of slip reins 62 interlink the collar 60 and the slips 50; one ring for each slip. In operation the slips 50 are set and released in response to vertical movement of the cage sleeve 53 relative to the slip cone 31 as hereinafter more fully described in connection with the operation of the device.

The beforementioned annular valve member 17 of the packer circulating valve carries an upwardly extending valve housing sleeve 65 threadedly connected thereto at 66. The valve housing 65 is formed or counterbored to provide an inwardly extending annular shoulder 67 at its upper end. An annular packing retaining bushing 68 having an outwardly extending annular stop shoulder 69 is slidably retained in the upper end portion of the beforementioned valve housing sleeve 65, the beforementioned inwardly extending annular shoulder 67 of the housing 65 being adapted to act as a stop in conjunction with the shoulder 67 of the bushing 68 to limit the outward motion of said bushing 68 from the housing 65.

A pair of annular or ring shaped resilient packing members 70 and 71 are retained on the inside surface of the housing 65 between the upper end of the valve member 17 and the lower end of the retainer bushing 68. An annular separator ring 72 is positioned between the resilient packing rings 70 and 71 and makes a slidable fit within the bore of the valve housing sleeve 65. The spacer ring 72 which is preferably made of a rigid material such as a suitable metal, carries an inwardly facing counterbored channel or annular recess as shown at 75.

Normally when the packer is in the unset position as illustrated in Figure 1 the inside surfaces of the resilient packing rings 70 and 71 and the spacer ring 72 are flush forming thereby an annular clearance space of uniform inside diameter as shown at 76 intermediate the outside surface of the mandrel 12 and the inside surfaces of the said packing rings 70 and 71 and the spacer ring 72 into which a portion of the packer head 10 is adapted to enter upon imparting downward motion of the tubing and the mandrel with respect to the packing assemblies P_1 and P_2 as hereinafter more fully described.

When the packer apparatus is in the unset position as illustrated in Figure 1 a bypass fluid passage is formed through the packer intermediate the mandrel 12 and the inside of the packing assemblies through the circulating valve and the interconnecting annular clearance spaces provided there as shown at 76, 77, 78 and 79.

The packer head 10 is formed with a lower cylindrical portion 80 and intermediate cylindrical portion of reduced diameter 81 and a top coupling head member 82 of increased diameter threadedly connected at 83 to the intermediate portion 81. The outside surface of the beforementioned lower end portion 80 is of uniform outside diameter and adapted to make an initial free sliding fit within the inside surfaces of the packing rings 70 and 71 and spacer ring 72 approximately as illustrated in Figure 2.

An annular recess 85 is formed in the outside surface of the lower end portion 80 of the packer head a short distance above the lower end thereof. This annular recess 85 is adapted to contain a capsule or a plurality of capsules as illustrated at 86 and as hereinafter more fully described.

The packer head carries longitudinally slidable thereon, a cover sleeve member 87 having at its top end an inwardly extending annular shoulder 88. Normally when the packer is unset as illustrated in Figure 1, the cover sleeve 87 covers the annular recess 85 and is supported in the position with the annular shoulder 88 resting on top of the offset shoulder formed between the lower and intermediate portion of the packer head 10. A helical spring 90 acting under compression between the top head member 82 and the upper end of the cover sleeve 87 serves normally to retain the said cover seat 87 in its lowermost position as shown in Figure 1.

A pair of packing rings preferably of the O ring type are retained within a pair of annular recesses formed in the lower inner portion of the beforementioned cover sleeve 87 as shown at 91 and 92 and so positioned as to form a fluid tight seal above and below the annular recess 85 and the cover sleeve 87 when the cover sleeve is in its lowermost position as illustrated in Figure 1.

As hereinbefore mentioned the tracer material is contained in a plurality of hollow container bodies or capsules adapted to be placed in the main body of the packer as shown at 41 and in the circulating valve as shown at 85. The tracer-containing capsules are preferably of the type illustrated in enlarged detail in Figure 5 and adapted to effect a time delay interval between the initial exposure thereof to well fluid and the subsequent release of tracer material into the fluid. The capsule as illustrated in Figure 5 is formed of two cup shaped portions 104 and 105 joined together at their open ends as shown at 106 to form a relatively thin walled, approximately spherical or spheroidal fluid tight envelope. One cup-shaped end portion, for example, end portion 104 is composed of a suitable gelatin, glue or other water soluble material. The other end portion, for example, end portion 105 is preferably composed of oil soluble material such as ethyl cellulose or a suitable high melting point, oil-soluble wax. One or the other or both end materials preferably should be suitably plasticized to remove brittleness and permit the capsule when subjected to high fluid pressures such as encountered in deep oil wells to flex or be deformed as required to distribute the pressure equally throughout its contents.

Alternatively, instead of employing tracer containers, formed of two dissimilar materials, one water soluble and one oil soluble as hereinbefore described, two separate types of container capsules may be employed, one type composed in its entirety of water soluble material such as gelatin and the other type composed in its entirety of oil soluble material such as ethyl cellulose, wax and the like, and a suitable mixture of these two types employed in the packer. The packer will thus be adapted to be employed under either condition which may be encountered in a well, that is, under a condition where the leakage fluid may be largely water or largely oil or both.

Where the packer device of this invention is employed in a water well, for example, or for packing off a fluid in a well which is known to be largely water, only the water soluble types of tracer containers or capsules would be required to be employed in the packer tracer containing grooves 40 and 85. Conversely, where the fluid in the well to be encountered is known to be largely oil, only the oil soluble types of tracer containers or capsules need to be used. The tracer material contained as shown at 107, sealed within the capsule 104, 105 may be any one or a mixture of two or more of the well known dyes which have been employed to trace the flow or source of fluids, such as, for example, fluorescein, uranine, eosin, gentisin and the like.

The operation of the apparatus of the invention is as follows:

The packer apparatus is lowered through the well casing in the condition shown in Figure 1 to the level in the well or opposite the formation at which it is desired to be set. When the packer apparatus has been thus lowered to the setting position the latch-pin 55 is released from the lateral recess 58 of the J-slot 56 in the slip cage 53 by imparting slight lefthand rotational movement to the mandrel 12 through the supporting tubing 14. Relative rotation is thus imparted between the latch-pin 55 and the cage sleeve 53 by reason of the fact that the cage sleeve 53 is restrained against rotation by the frictional engagement of the cage springs 52 with the inside surface of the casing C, whereas the mandrel 12 is free to rotate with the string and tubing 14 to which it is attached. After the latch-pin 55 has been thus released from the J-slot recess 58, the tubing is again lowered a short distance resulting in downward movement on the mandrel 12 with respect to the cage sleeve 53. Due to the frictional engagement of the cage springs 52 with the inside surface of the casing C, the sleeve 53 remains substantially stationary. The whole packer mechanism including packing assemblies P_1 and P_2 will then be free to move downward with the mandrel 12, the whole assembly thereof initially riding upon and being supported by the shoulder 59 provided in the lower portion of the mandrel. The sleeve 53, slip collar 60, slip reins 62 and slips 50 will thus be caused in effect to move upward relative to the downwardly moving packer assembly including the slip cones 31, and the slips 50 will thus be caused to move upward along the slip cone guides and outward into gripping engagement with the inside surface of the casing thereby locking the slip cone 31 to the casing and preventing any further downward movement thereof relative to the casing. Thereafter further downward movement of the mandrel 12 is continued while the packing assemblies P_1 and P_2 remain stationary, supported upon the slip cone 31, until the lower cylindrical portion 80 of the casing head 10 enters the annular space 76 within the packing ring members 70 and 71 and spacer ring 72 and moves downward until the lower end of the cover sleeve member 87 comes into contact with the upper end of the annular packing retaining bushing 68 and is moved thereby upward upon the packer head 10 against the compressive action of the helical springs 90 until the upper end of said cover sleeve member 87 is brought into contact with the lower end of the coupling head members 82. Further downward movement of the tubing 14, the packer head 10 and the mandrel 12 thereafter applies downward force through the cover sleeve 87 to the annular bushing member 68 and thereby applies axial compressive force to the packing rings 70 and 71 to expand them radially into sealing engagement with the outside surface of the lower portion 80 of the packer head, as shown in Figure 2. Under this latter condition the circulating valve of the top of the circulating passage within the packer will have been closed and the recess 85 will have been moved downward within the casing head to a position adjacent to and in communication with the annular recess 75 in the separating ring 72. The annular recess 85 and the tracer bodies 86 therein will thereby normally be sealed off by the packing rings 70 and 71 from surrounding well fluid.

Further downward movement of the tubing string with respect to the said packer thereafter forces the valve seat 17 and packing retaining sleeve 16*a* downward with respect to the packing retaining nut 20 thereby applying longitudinal compressive force and motion to the resilient packing sleeve or rings 27. This longitudinal or axial force is in turn transmitted through the packing retainer nut 20 and the intermediate cylindrical spacer body 23 to the lower packing sleeve or set of packing rings 33 resulting in downward motion of the said intermediate cylindrical spacer body 23 and the lower packing retainer sleeve 16*b* relative to the beforementioned packing retainer nut 29 and the slip cones 31 and thereby also applying longitudinal compressive force to the resilient packing sleeve or rings 33.

Downward motion and pressure is continued to be applied through the tubing 14, the packer head 10 and the circulating valve assembly comprising packing rings 70 and 71, to the packing assemblies P_1 and P_2, until the packer is firmly seated and set with the packings 27 and 33 expanded into sealing engagement with the inside surface of the casing C as illustrated in Figure 2.

As the upper packing retainer sleeve 16*a* and the tracer retainer ring 38 threadedly attached at 37 to the lower end thereof moves downward with respect to the intermediate cylindrical spacer body 23 during the setting operation and as the packing rings 27 are compressed longitudinally, the annular recess 40 in the ring 38 moves downward from its sealed off position between the packing rings 43 and 44 to a position adjacent to and in communication with the plurality of the radially directed ducts or ports 36 extending through the walls of the spacer body 23. In this position the annular recess 40, except for the ducts 36 communicating therewith, is otherwise sealed off between the packing rings 42 and 43 as shown in Figures 2 and 3.

In this position the tracer containing bodies or capsules 41 are, after a delay sufficient to permit the packing 27 to be compressed longitudinally sufficiently to cause it to be expanded radially into contact with the inside surface of the casing, exposed to the entrance of well fluid, which under the pressure in the well, will flow through the ducts 36 and into the annular recess 40. Tracer material released, after a suitable delay, from the tracer body or bodies 41, as hereinafter more fully described, may then pass by circulation or diffusion outward through the ducts 36 into the annular space 100 which normally has by the setting of the packer been sealed off by the packing bodies 27 and 33 intermediate the outer surface of the spacer body 23 and the inside surface of the casing C. Any leakage of fluid in either direction past the packing assemblies P_1 and P_2 between the upper and lower portions of the well casing above and below the packer mechanism will then result in carrying a portion of the tracer fluid from the annular space 100 along with the leakage fluid. In event of such leakage the tracer material will thus eventually appear in the well fluid produced from the well either through the well tubing 14 or through the annular space 101 intermediate the well casing C and the tubing 14 depending upon the direction of such leakage past the packings 27 and 33 or 70 and 71.

For example, if the pressure in the casing C is greater above the packer than it is below the packer, there is a downward differential pressure across the packing elements 27 and 33 and across the circulating valve packing rings 70 and 71 and if under these conditions there is any substantial leakage past either the packing elements 27, 33 or rings 70 and 71 the tracer fluid which has been released into the annular space 100 between the packings 27 and 33 or into the recesses 75, 85 of the circulating valve will be carried downward into the annular space below the packer and between the mandrel 12 and the casing C. The tracer fluid will then be carried downward through the lower annulus and if the well is being produced through the tubing will eventually enter the tubing at its lower end below the packer and flow together with the production through the tubing 14 to the well surface where it may be detected by suitable means.

If on the other hand the differential pressure past the packing elements 27 and 33 and across the circulating valve packing rings 70 and 71 is upward and leakage occurs, at either place the tracer fluid contained in the annular cavity 100 or in the circulation value recesses 75, 85 will be carried upward into the annular space 101 between the tubing 14 and the casing C and production of fluid from the well through the annulus will thereby carry the tracer material along with it to the well surface where the presence of the tracer material may, as beforementioned, be detected there by suitable means.

One of the important features of this invention resides in employing tracer bodies illustrated at 41 and 86 and as hereinbefore described in connection with Figure 5, which include delayed action means for causing a delay in releasing the tracer materials after they are exposed to fluid entering the recesses 40 and 85 respectively upon setting the packer in the well casing whereby ample time will be afforded for completely and firmly setting the packer in the well casing prior to the release of any tracer material. If such delayed action is not provided for, tracer material may be released prematurely to the well fluid surrounding the packer before the packer is fully set, and tracer material would thus not only be wasted but upon subsequently producing the well a false indication of leakage might result.

Typical of the testing procedure employed in connection with the use of the apparatus of the invention hereinbefore described is as follows:

In a cased well 9000 feet deep with a producing sand of gas distillate at 7500 feet the bottom hole pressure is approximately 3800 pounds. Also at 8950 feet a sand exists producing oil at a fluid pressure at that point of 3000 pounds per square inch. It is desired to produce the top sands through the casing and the lower sands through the tubing. The casing is perforated at approximately 7500 feet opposite the upper gas distillate producing sands and at an approximate 8950 feet opposite the lower oil producing sands respectively. 1400 feet of tubing is first run into the casing and the packer device, hereinbefore described, containing the tracer materials is installed at its top end. The said packer device carrying the 1400 feet length of tubing depending therefrom is then run into the well casing in the well on a suitable string of tubing or drill pipe and set about 10 feet below the upper perforations. As the packer device is set the annular recess 40 containing the tracer capsules 41 in the ring 38 is moved downward from its sealed-off position between the packing rings 43 and 44 to a position adjacent to and in communication with the plurality of radial ducts or ports 36 extending through the walls of the spacer body 23. At the same time the recess 85 or the circulating valve, containing tracer capsules 86 is moved down into registry with the recess 75 of the circulating valve packing spacer ring 72. In this position the tracer containing bodies or capsules 41 are exposed by way of said ducts 36 to the entrance of well fluid which has been entrapped, by the setting of the packer, in the annular space 100 sealed off between the packing bodies 27 and 33 intermediate the outer surface of the spacer body 23 and the inside surface of the casing "C." After a short period of time required for the fluid thus entering the recess 40 through the ducts 36 to dissolve at least a portion of the tracer containers or capsules 41, tracer material will then be released for circulation or diffusion outward through the ducts 36 into the beforementioned annular space 100.

Similarly, the fluid admitted to the recess 85 and entrapped in the space formed by the registry of the recesses 75 and 85 when the circulating valve is closed will cause release of the tracer material therein, from the capsules, after a suitable delay period.

After the packer has thus been set, connections are then installed at the casing head with provisions for separately controlling and separately collecting the flow from the tubing and the casing. The lower zone sealed off below the packer is then flowed through the tubing and the upper zone sealed off above the packer is flowed through the annulus between the casing and the tubing. Under such conditions if a leak occurs it is usually past the packer between the packing and casing or through leaks in the tubing walls or joints or through channeling in the cement along the outside of the casing.

After the well flow or production is established as hereinbefore described, one or other of the formations is first shut-in, for example, the upper producing zone may be first shut-in and the production from the bottom producing zone allowed to flow through the tubing at as high a rate as possible. Since flowing of the production through the tubing at a high rate materially decreases the pressure at the bottom of the well below the packer the differential pressure downward across the packings is then a maximum. If the packer leaks under this condition either around the packing elements 27 and 33 or through the circulating valve packing rings 70 and 71 the tracer material, released as hereinbefore described, is carried into the lower portion of the casing below the packer along with the leakage fluid and eventually is produced through the tubing along with the lower zone production. If no tracer fluid is produced through the tubing the packer is obviously holding under this condition without leakage. Next the tubing is shut-in and the production from the upper producing zone allowed to flow from the well through the casing annulus at as high a rate as possible. Under this condition the differential pressure upward across the packings is a maximum. If the packer leaks under this condition tracer fluid is carried along with the leakage fluid into the upper portion of the casing above the packer and is produced through the casing annulus along with the upper zone production. If no tracer fluid appears in the production from the well through the casing annulus the packer is obviously also holding under this condition without leakage.

Now if in the first test hereinbefore mentioned, tracer fluid is produced but in the second test no tracer fluid is produced this is an indication of failure of the lower packing element 33 of the packer, or the lower packing ring 71 of the circulating valve allowing some of the tracer fluid to leak down and be produced through the tubing. However, the fact that no tracer fluid is produced through the casing annulus production, indicates that the upper packing elements are still intact and functioning properly. The reverse of this is true if the casing annulus production contains tracer fluid but the tubing production contains none, that is, it indicates that the lower packing elements are intact but that the upper packing elements have failed and are leaking. In a perfect pack-off no tracer fluid is produced at any time either through the tubing or the casing.

If, however, no tracer fluid is produced either through the tubing or casing when the well is tested as hereinbefore described but the tubing and casing pressures substantially equalize when both casing and tubing are shut-in it is then apparent that a leak exists somewhere else. In this latter case the leak may be through defects in the tubing or possibly the leakage may occur by channeling through or around the cement outside of the casing between the upper and lower producing zones, and in event of such indication, measures may then be taken to check the condition of the tubing and if necessary also to perform squeeze cementing in the manner well known in the art to eliminate any channeling leakage.

While a circulation type of casing packer mechanism is shown and described herein as a preferred apparatus to which the present invention is applicable it is not necessarily so limited, since the present invention is applicable to advantage to any type of packer which operates in a manner similar to that herein illustrated to place, expand or to form a resilient packing body radially into sealing engagement with a surrounding case or formation wall.

The process and apparatus of this invention is furthermore not limited in its application to production type packers as herein illustrated but is also applicable to various other types of packers such as packers similarly constructed and adapted to be set in direct engagement with well borehole formations or in connection with bridging plugs adapted to be set within casing or in uncased holes.

The tracer material adapted to be employed and to be contained in the delayed action containers or capsules hereinbefore described may be any one or a mixture of two or more of the well known dyes as hereinbefore mentioned which have been employed to trace the flow or course of fluids such as, for example, fluorescein, uranine, eosin, gentisin and the like.

When fluorescein is employed as the tracer material its presence in the production from the well may be detected by drawing or trapping samples of the produced liquid and allowing them to stand quiescent in an open container for a relatively short period of time. If the produced liquid is mainly oil, the fluorescein being relatively insoluble in oil and lighter than oil will flow to the top surface and appear there upon inspection as a thin surface film or blotch or as thin thread-like or striated discolorations on the surface when the sample is stirred gently. If the produced liquid is water or oil containing sufficient water to separate therefrom the presence of fluorescein can be detected by the characteristic greenish yellow color which it imparts to the settled-out water phase. Inspection of the liquid samples under ultra violet light is advantageous in detecting the presence of fluorescein, by reason of the added fluorescence which the fluorescein exhibits under such condition.

If uranine dye is employed as the tracer material within a liquid solution or in dry powdered form its presence will be indicated by the yellowish color it imparts to the water phase.

While the term "tracer material" has been used frequently herein it is to be understood that this is intended to include not only finely divided or powdered solid materials but also suitable liquid and gaseous tracers. In the case where fluorescein, uranine or eosin and the like dyes are employed as the tracer materials in the delayed action containers or capsules of the types hereinbefore described it is preferable that they be employed in dry powdered form in order to avoid having any solvent action of themselves upon the soluble portions of the containers or capsules. However concentrated solutions of these and other suitable dyes may be employed in liquids in which they are soluble or in suitable liquid dispursing agents which do not have solvent power for the materials employed for the tracer containers or capsules.

Tracer materials which can be detected by their characteristic odors may also be employed and these have particular advantage when the fluid produced from the well in which the tracer may be carried is extremely viscous or highly opaque which would render detection of solid tracer materials difficult. One such tracer is carbon di-sulphide, the characteristic odor of which may be readily recognized when present even in extremely small quantities in entrapped samples of water, petroleum or natural gas which may be produced from a well.

Other tracers which may be employed to advantage under certain conditions are radioactive materials either in the form of finely divided solids or gases. For example, powdered carnotite, radium oleate, radium naphthenate or radium bromide may be employed where a material having substantially permanent radioactivity is desired. However, it is usually more desirable to employ a suitable material having radioactivity of limited life to minimize any danger of permanent contamination of a well with radioactive material. Radon, a gaseous radium emanation which has a relatively short period of radioactivity is an example of a gaseous material of this type. Examples of solid materials of this type having temporary radioactivity are sulphur, potassium, iron, copper, aluminum, zinc, tungsten and others which have been irradiated with slow neutrons in a manner such as described in the patent to Fermi et al. 2,206,634. Other known means may be employed to induce radioactivity in such materials.

In employing such radioactive substances, as tracer materials, as hereinbefore described, detection of their presence in the well production fluid may be conveniently accomplished by means of conventional radioactivity detecting apparatus, for example, the now well-known gamma ray detectors employing Geiger-Müller counters or high pressure ionization chambers. Such detectors may be located in any convenient position or positions adjacent the flow lines leading from the well or adjacent the tanks in which samples of the produced fluids are collected. The use of such apparatus in connection with the radioactive tracers lends itself conveniently to the actuation of permanently or temporarily installed automatic alarm systems for indicating the occurrence of leakage or failure of a packer at any time after testing or putting the well in production.

It is to be understood that the foregoing is illustrative only of preferred methods and apparatus and that the invention is not limited thereby but may include various modifications and changes made by those skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims.

We claim:

1. Packer apparatus comprising: a pair of interconnected packing assemblies; longitudinally spaced-apart packing elements on said packing assemblies; movable setting means on said assemblies including at least a pair of instrumentalities operative by relative longitudinal movement therebetween to expand said packing elements into sealing engagement with a surrounding bore wall; a chamber in said apparatus having an outlet communicable with the exterior of said apparatus intermediate said spaced-apart packing elements; a movable valve element for said outlet movable between positions closing said outlet from and opening said outlet to communication with said exterior of said apparatus; and means operatively coupling said valve element with said movable setting means to move therewith, said valve element being thereby normally positioned to close said outlet when said packing elements are in unexpanded position and movable thereby to open said outlet into communication with said exterior of said apparatus intermediate said spaced-apart packing elements when said movable setting means are operated to expand said packing elements into sealing engagement with the bore wall.

2. Packer apparatus comprising: a packer body; a pair of longitudinally spaced packing elements surrounding said packer body; a pair of packing element setting means on said packer body and operative by movement relative to one another to place said packing elements into sealing engagement between said packer body and a surrounding wall, to form thereby a sealed-off cavity in the space between said spaced packing elements and between said packer body and said wall; a chamber in said apparatus and having an outlet opening therefrom, communicable with said cavity; and valve means initially closing said outlet opening, said valve means being operatively coupled to and actuatable by said pair of setting means upon movement thereof relative to one another to open said outlet opening into communication with said sealed-off cavity.

3. Packer apparatus comprising: a packer body; a pair of longitudinally spaced packing elements surrounding said packer body; a pair of packing element setting means on said packer body and operative by movement relative to one another to place said packing elements into sealing engagement between said packer body and a surrounding bore wall, to form thereby a sealed-off cavity in the space between said spaced packing elements and between said packer body and said wall; a chamber in said body and having an outlet opening therefrom, communicable with said cavity; valve means initially closing said outlet opening, said valve means being operatively coupled to and actuatable by said pair of setting means upon movement thereof relative to one another to open said outlet opening into communication with said sealed-off cavity, to expose tracer material in said chamber to contact with fluid contained in said sealed-off cavity; a source of tracer material in said chamber; and means to release tracer material from said source into said chamber after the said opening of said outlet opening and the entry of fluid therethrough into said chamber from said cavity.

4. Packer apparatus comprising: a packer body; a pair of longitudinally spaced packing elements surrounding said packer body; movable setting means on said body, movable relative to said body to place said packing elements in sealing engagement between said packer body and a surrounding bore wall, to form thereby a sealed-off cavity between said spaced packing elements and between said packer body and said wall; an initially closed chamber carried by said body and having an outlet opening therefrom; valve means initially closing said outlet opening, said valve means being operatively coupled to and actuatable by said setting means upon movement thereof relative to said body to open said outlet opening to expose a tracer material source in said chamber to contact with fluid contained in said sealed-off cavity; and a source of radioactive tracer material in said chamber, including means to delay the release of tracer material therefrom for a substantial period of time subsequent to the contact of said source with said fluid.

5. Packer apparatus comprising: a packer body; a pair of longitudinally spaced packing elements surrounding said packer body; movable setting means on said body, operative by movement thereof relative to one another to place said packing elements into sealing engagement between said packer body and a surrounding wall to form thereby a sealed-off cavity between said spaced packing elements and between said packer body and said wall; an initially closed container in said body, said container having an opening communicable with said cavity; and valve means initially closing said opening, said valve means being operatively coupled to and actuatable by said setting means upon movement thereof to open said container opening into communication with said cavity.

6. Packer apparatus comprising: a packer body assembly; a pair of longitudinally spaced packing elements surrounding said packer body assembly; movable setting means included in said packer body assembly, operative by movement relative to one another to place said packing elements into sealing engagement between said packer body assembly and a surrounding bore wall to form thereby a sealed-off cavity between said packing elements and between said packer body assembly and said wall; an initially closed chamber in said packer body assembly; valve means coupled to and actuatable by said setting means upon said movement thereof to interconnect said chamber and said sealed-off cavity to permit entrance of fluid contained in said cavity into said chamber; a tracer material source in said chamber; and means associated with said tracer material source to delay the release of tracer material therefrom for a substantial period

of time subsequent to said contact of said source with said fluid.

7. Packer apparatus comprising: a packer body; a pair of longitudinally spaced packing elements surrounding said packer body; movable setting means on said packer body and operative by movement thereof relative to one another to expand said packing elements into sealing engagement between said packer body and a surrounding borehole wall to form thereby a sealed-off cavity between said packing elements and between said packer body and said wall; a member having walls defining a chamber carried by said packer body and adapted to contain a quantity of a tracer material, said chamber having an opening communicable with said cavity; a movable valve member normally closing said chamber opening and movable to a position opening said chamber opening into communication with said cavity; and means coupled to and actuatable by said setting means upon said movement thereof to move said valve member to said position opening said chamber opening into communication with said sealed-off cavity.

8. Packer apparatus comprising: a packer body; a pair of longitudinally spaced packing elements surrounding said packer body; a member having walls defining a chamber in said packer apparatus and having an outlet opening; movable setting means on said packer body operative by movement thereof to place said packing elements into sealing engagement between said packer body and a surrounding borehole wall to form thereby a sealed-off cavity between said packing elements and between said packer body and said wall; a soluble, tracer material containing means in said chamber; a movable valve member having therein a flow passageway interconnectable between said chamber and said sealed-off cavity, said valve member normally being positioned with said passageway disconnected from said chamber and movable to a position interconnecting said chamber and said cavity; and means operatively coupled to and actuatable by said setting means upon said movement thereof to move said valve member to place said passageway into position interconnecting said chamber and said cavity and thereby to expose said tracer material containing means to fluid entering said chamber through said passageway from said cavity.

9. Packer apparatus comprising: packing means adapted to be placed between and into sealing engagement with adjacent surfaces of inner and outer enclosing walls; movable setting means movable relative to one another to place said packing means into sealing engagement between said walls; an initially closed chamber carried by said apparatus for containing a tracer material; and means coupled to said setting means, for actuation by said movement thereof for opening and placing the interior of said chamber into communication with a portion of the said adjacent surface of at least one of said enclosing walls, at a point longitudinally intermediate the opposite ends of said packing means, upon said movement of said setting means sufficient to place said packing means into said sealing engagement between said enclosing walls.

10. Packer apparatus comprising: a mandrel adapted to be secured to the lower end of a tubing string; a pair of longitudinally spaced, coaxial sleeve elements supported slidably with respect to one another on said mandrel; a deformable packing element on each of said sleeve elements; setting means carried by said sleeve elements and movable thereon when said sleeve elements are moved longitudinally relative to one another, for compressing said packing elements axially and thereby expanding said packing elements radially into sealing engagement between said sleeve elements and a surrounding casing; a body portion forming a recess and carried by one of said sleeve elements; a valve instrumentality extending from the other of said sleeve elements and positioned initially to overlap and close said recess; and a passageway extending through said valve instrumentality to an exterior location adjacent and between inner adjacent ends of said packing elements, said valve instrumentality being positioned so that said passageway is out of communication with said recess when said setting means are in the position where said packing elements are unexpanded, and said valve instrumentality being positioned so that said passageway is in interconnecting communication with said recess and said exterior location upon said movement of said setting means sufficient to expand said packing elements into said sealing engagement between said sleeve elements and said casing.

11. Packer apparatus according to claim 10, with a soluble, initially fluid-tight container in said recess for releasably containing a tracer material.

12. Packer apparatus according to claim 10 having in said recess an initially fluid-tight container for releasably containing a tracer material, at least a portion of said container being water-soluble.

13. Packer apparatus according to claim 10 having in said recess an initially fluid-tight container for releasably containing a tracer material, at least a portion of said container being oil-soluble.

14. In a well packer, apparatus comprising: a pair of interconnected, longitudinally spaced-apart, annular packing elements; inner and outer concentric cylindrical sleeve members between which said packing elements are adapted to be expanded into sealing engagement therewith; movable setting means to compress said packing elements longitudinally and thereby expand said packing elements radially into sealing engagement between said inner and outer cylindrical sleeve members; a tracer container chamber in said apparatus having an outlet therefrom; a movable valve member normally closing said outlet; and means included in said setting means to move said valve member relative to said outlet, and said chamber relative to said packing elements, to open said outlet and to position said open outlet intermediate said spaced-apart packing elements and intermediate said inner and outer cylindrical sleeve members when said packing elements are expanded into sealing engagement therebetween.

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