

June 10, 1952

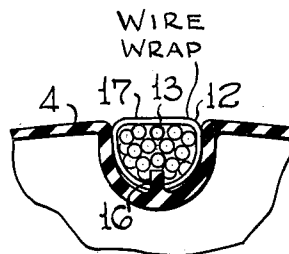
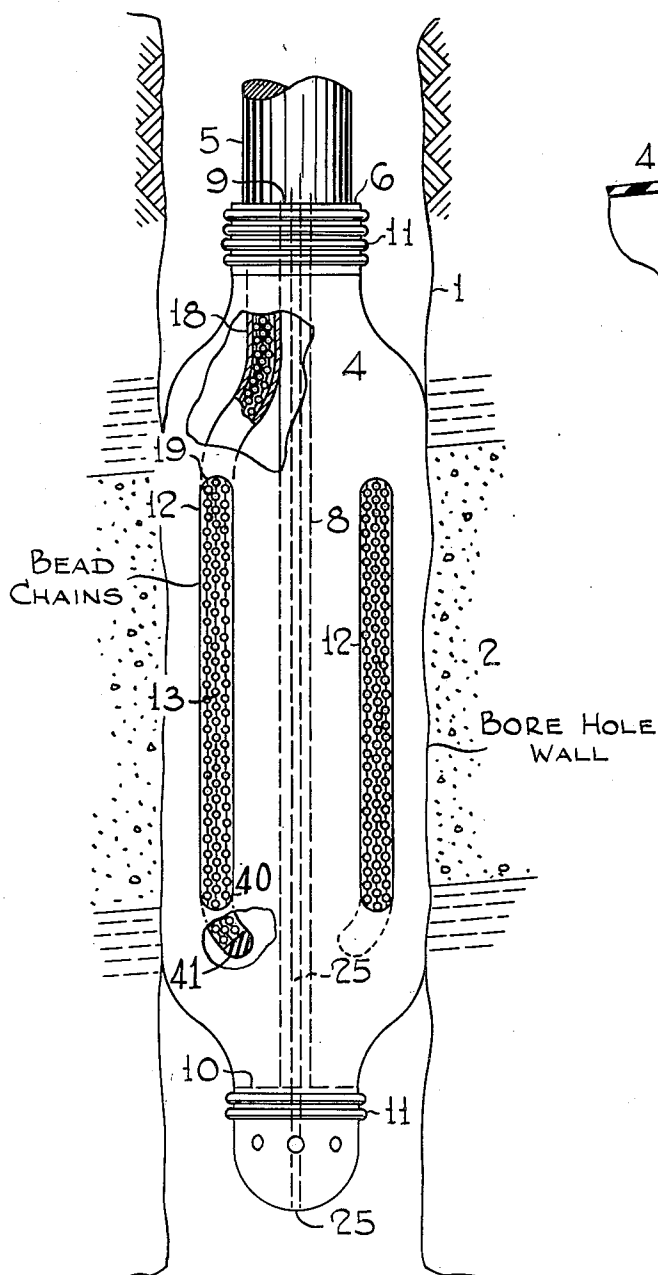
B. W. SEWELL ET AL

2,600,173

FORMATION TESTER

Filed Oct. 26, 1949

2 SHEETS—SHEET 1



Ben W. Sewell
George H. Ramsey Inventors
By W. O. J. Hulman Attorney

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2 SHEETS—SHEET 2

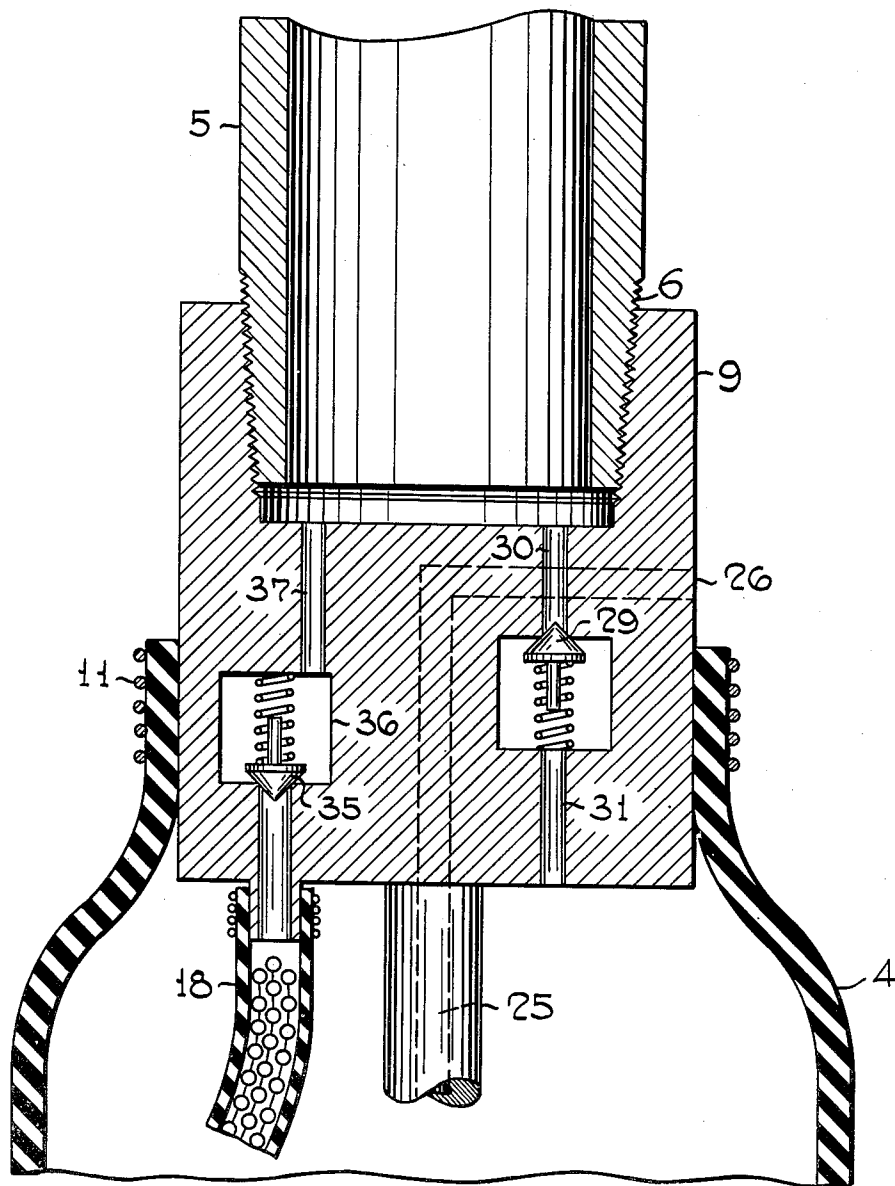


FIG. - 2

Ben W. Sewell
George H. Ramsey Inventors
By W. O. Hilman Attorney

UNITED STATES PATENT OFFICE

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FORMATION TESTER

Ben W. Sewell and George H. Ramsey, Tulsa,
Okla., assignors to Standard Oil Development
Company, a corporation of Delaware

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6 Claims. (Cl. 166-10)

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This invention relates to a novel apparatus for testing the fluids produced at a given point along a well bore hole. The apparatus of this invention is of application in the exploration for oil and is uniquely designed to provide simple and efficient means for sampling fluids produced at a given horizon, or stratum of the earth in a well bore hole.

In drilling a bore hole in the attempt to encounter oil deposits in the earth, it is conventional practice to employ a variety of tests to determine whether or not oil may be produced from the bore hole, to determine the nature of the oil, if any, and to determine from which stratum or strata production should be attempted. The type of apparatus used to provide this type of information is generally called "formation testing apparatus." This term aptly identifies the principal objective of the apparatus: to test the fluids existing at a particular stratum of the earth. For this purpose a wide variety of formation testers are known. A particularly attractive development of rather recent date has been the development of inflatable packer type formation testers. Testers of this type have an elastic packer which may be inflated by fluid pressures so as to completely seal off a particular portion of a bore hole. In one of its most desirable embodiments of portion of the inflatable packer is provided with a permeable membrane, or alternative means, through which fluids may pass from strata adjacent the sealed off section of the bore hole into channels and chambers provided in the apparatus to receive the sample fluids. This type of packer provides a convenient and effective manner of sealing off the drilling mud in the bore hole so that a sample of well fluids can be obtained from any desired stratum of the bore hole. The present invention consists of an improvement in this type of packer, the principal feature of which is the provision for an improved type of inlet for the well fluid. Thus, it is the principal object of this invention to provide an improved passageway for the well fluids from at least a portion of the sealed off area of the well bore into chambers provided in a formation tester.

In inflatable formation testers of the character indicated, a rather unique problem is presented to conveniently establish a passageway through the inflatable packer through which sample well fluids may flow. The greater part of the surface of the inflatable packer is required for sealing off the bore hole so as to prevent contamination of the sample fluids with drilling mud, and so as to permit a decrease in the hydrostatic pressure at a

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localized point in the stratum to be sampled, so as to enable well fluids to be withdrawn from this point. Consequently, it is necessary that the passageway through the tester must extend through, or lie closely adjacent to the portion of the surface of the packer which is forced by inflation pressure tightly against the walls of the bore hole. Upon consideration, therefore, it is apparent that a rather difficult problem is involved in providing an effective passageway through a portion of the inflatable packer to permit removal of well fluids from the bore hole adjacent this point of the packer.

Such a passageway may consist of the termination of a tube at the wall of the packer so that for example a single tube within the packer may be sealed to the packer wall so as to provide a passageway for fluids through the packer wall, and through the tube to a sample chamber within the packer. However, to utilize a single tube of this nature would limit the area of the stratum which could be sampled to the inside area of the tube positioned in the packer. Such a tube would not be suitable for withdrawing fluids from more than an extremely small portion of the bore hole, and again would not be suitable for withdrawing any considerable quantities of well fluids. A further limitation relative to the tube is that it must be sufficiently flexible to permit inflation and deflation of the packer and yet it must be substantially non-collapsible to prevent blocking of the tube under the inflation pressures. Because of the difficulty of fabricating a packer having a great many tubes of this nature sealed in the walls of the packer, such a proposal is not adapted for utilization of the multitude of tubes which would be required to provide an attractive sampling area.

With this brief introduction to the nature of the problem with which this invention is concerned, the novel and advantageous features of the present invention may be more readily understood.

In accordance with this invention a number of external recesses are provided on the wall of the inflatable packer. These recesses are then filled with packing elements that have been strung on longitudinal wires so that each of the recesses on the external portion of the packer wall is filled with packing elements maintained in position by the wires on which the elements are strung. By then conducting the bundle of interconnected packing elements into a flexible passageway provided in the inflatable packer, an effective passageway is provided from the external portion of the packer to the inter-

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nal portion of the packer. Upon inflation of the packer in a bore hole, each of the recesses of the packer containing the packing elements will be forced tightly against the bore hole so as to bring the packing elements in juxtaposition with a portion of the bore hole. Utilization of inter-connected packing elements in this manner permits simple and relatively inexpensive construction of the packer; provides flexible but non-collapsible fluid passageways from desired external areas of the packer to the inside of the packer, and permits a considerable portion of the surface of the packer to be covered with the inter-connected packing elements so that a large area of the packer can be used for contacting and sampling well fluids.

In order that this invention may be fully understood a complete description of a preferred embodiment of the invention will be presented, making reference to the accompanying drawings in which:

Figure 1 diagrammatically depicts in a fragmental sectional view an inflatable packer embodying the principles of this invention and;

Figure 2 illustrates a cross-sectional elevational detail a preferred type of valve construction to control flow of sample well fluids into a sample chamber provided adjacent the inflatable packer, and;

Figure 3 shows a fragmental cross section detail of the packer troughs and bundles of packing elements.

Referring now to the drawings, a bore hole is diagrammatically illustrated and identified by the numeral 1. In general this bore hole is preferably uncased during operations of the apparatus of this invention. However, it is to be understood that the invention may be employed with a cased bore hole which has been cemented in place and perforated in the customary manner at a selected stratum from which it is desired to extract sample well fluids. For the purpose of simplicity, it is assumed that the bore hole 1 is uncased, and that it is desired to sample the formation comprising the stratum 2. For this purpose the drilling apparatus is removed from the well and a novel formation testing apparatus, illustrated in the drawing, is attached to the drill stem and lowered into the well so as to be adjacent to stratum 2. In its simplest form the apparatus of this invention consists of the inflatable packer 4 suspended on the drill string 5. Thus, the packer may be fixed to a backing ring 9 which may be threaded on the termination of the drill string 5, at the point indicated by the numeral 6. The inflatable packer of the formation tester, illustrated in the inflated position, may consist of any suitable form of flexible, non-porous membrane. It is preferred that this membrane should consist of heavy rubber which may, or may not be enforced with fabric sealed to, or sandwiched between layers of rubber. An inner steel mandrel 8 extends centrally through the inflatable packer. By fixing metallic cylinders, or backing rings 9 and 10 to the mandrel at the upper and lowermost termination of the elastic packer, the elastic packer may be sealed to these backing rings, for example, by tightly wrapping wire 11 over the packer so as to firmly fix it to the backing rings 9 and 10. This results in the formation of a fluid tight chamber within the packer terminated at the top by the backing ring 9 and at the bottom by the backing ring 10.

In accordance with this invention, external

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longitudinal strips of the elastic packer are somewhat recessed to provide a trough to receive inter-connected packing elements. Thus, the elongated area 12 of the packer may be recessed to form a trough in which the inter-connected packing elements 13 may be positioned. Suitable recesses in the inflatable packer may be provided by particularly fabricating the packer to provide these recesses. Thus, if desired, a packer may be prepared consisting of molded rubber in which the mold is of a suitable character to provide the recessed troughs 12 in the packer. This type of fabrication is fragmentally illustrated in Figure 3. In the fragmental illustration the main surface of the packer is indicated by numeral 4, while a recess 12 is provided which may if desired be equipped with a tongue 15 consisting of a ridge at the bottom of the recess. The tongue may be used to support a wire 17 passing around the inter-connected packing elements 13 to hold them in the trough 15. Alternatively, it is possible to fabricate the elastic packer of sufficiently flexible material such as rubber so that no specially formed trough is required. It is simply necessary to fix the inter-connected packing elements to desired areas of the packer, for example, by means of wires passing around bundles of the packing elements and passing through ridges, or other suitable holding means on the surface of the packer. In this case upon inflation of the packer, in the bore hole, the inflation pressure will act to force the packer wall about the bundle of packing elements so as to essentially provide the configuration illustrated in the fragmental figure of the drawing.

Any desired type of inter-connected packing elements may be employed in the manner described. It is presently contemplated that a preferred type of packing element is of the nature known as "bean chain" as illustrated in the drawing. The beads of such a chain are preferably of a maximum diameter of about $\frac{1}{4}$ inch, or $\frac{3}{8}$ inch, although varying sizes of beads may be used. Alternatively, conventional link chains may be employed, or any other packing elements may simply be strung on suitable wires so as to be supported in the manner indicated. In this identification of the nature of the packing filling the troughs of the packer wall, the term "packing element" is used as that term is conventionally used to identify a multitude of individual solid elements of a nature such that when forced together interstices will be provided through the packing to permit passage of liquids. For the purposes of this invention any such packing elements may be strung together in a suitable manner so that they can be positioned on the outer surface of the elastic packer. It has been found most convenient to inter-connect the packing elements in a long string so that by grouping a bundle of strings of inter-connected packing elements together, suitably supported packing is obtained to position on the packer, or to position in troughs provided on the packer. It is preferred that the individual packing elements have a diameter in the range of about $\frac{1}{16}$ of an inch, to $\frac{3}{8}$ of an inch. Utilization of smaller packing elements results in interstices sufficiently fine to create the possibility of plugging due to the passage of mud, or sediment through the packing.

As described heretofore, the elastic packer has been presented as comprising an inflatable membrane, on external longitudinal strips of which, bundles of packing elements are fixed. The lon-

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itudinal strips of packing elements may be arranged in any desired pattern, or any desired spacing on the packer to cover as large an area of the packer as considered desirable. However, it is preferred that the bundles of packing elements be positioned in a plurality of longitudinal strips on the surface of the packer, extending over the external portion of the packer for about one-third of the length of the packer, and positioned equidistant from the top and bottom of the packer. However, the bundles of packing elements may be fixed over the packer for any desired portion of its length as illustrated in Figure 1, for example, wherein the elements are shown to extend over almost two-thirds of the length of the packer. While two of the longitudinal bundles of packing elements are illustrated in the drawing, any number of them may be employed.

At the lower end of the longitudinal bundles of packing elements the elements may be terminated as desired. Thus the packing elements if desired may be cut in lengths to coincide with the lowermost end of the trough on the packer. As one of many alternates, if desired, the lower end of the packing bundles may be contained in a tube 40 extending within the wall of the packer which may simply be plugged, or may contain sealing material 41 to fix the lower termination of the packing bundles in the tube somewhat within the wall of the packer. The uppermost ends of the packing bundles, where the longitudinal exposure on the packer is terminated, are positioned in a suitable tubing fixed to the walls of the packer at that particular point. Thus, as illustrated, the packing elements 13 are passed into an interior tube 18 at the point 19 where the tube intersects the trough provided in the packer. The tube 18 is preferably composed of flexible material such as rubber, or fabric tubing. A very desirable type of construction comprises flexible metal pipe covered with rubber hose. In this type of construction the metal tubing prevents collapse whereas the rubber tube prevents leakage. The manner in which the tubing is fixed to the trough of the packer is illustrated more clearly in Figure 3. It is apparent that as many tubes 18 are provided as there are troughs, so that at least one tube extends from the uppermost portion of each of the troughs containing the packing elements. The tubes 18 may terminate within the packer in a manifold arrangement supplying a single tube which may then be passed through the metal backing ring 9 to the upper portion of the formation tester. However, if a comparatively small number of troughs, or recesses are utilized, such as the two depicted in the drawing, then it is preferred to simply conduct the individual tubes 18 through the metal backing ring 9. At a point adjacent the metal backing ring 9, the bundles of packing elements 13 may be terminated within the tubes 18. By virtue of this arrangement of packing elements on a part of the exterior portion of an elastic packer, with the extension of the packing elements within tubes provided in the packer, well fluids may effectively be withdrawn from a point exterior of the packer through the tubes. Thus, upon inflation of the elastic packer the packer will be caused to expand outwardly to firmly force itself against the bore hole. This will have the effect of sealing off the passage of any liquid upwardly, or downwardly through the bore hole and will have the effect of forcing the bundles of packing elements tightly against the bore hole.

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Consequently, a suitable passageway will be provided for fluids contained in the stratum 2 through the interstices of the packing elements on the exterior of the packer, and thence to the tubes 18 positioned on the inside of the packer. Regardless of the pressure used to inflate the packer, or of external pressures applied on the packer, the bundles of packing elements will prevent collapse or closure of the indicated fluid passageway.

Any suitable apparatus may be employed for the remaining essentials of an operative formation tester. It is, therefore, to be understood that this invention is not to be limited to any particular features as regards the method of inflating the elastic packer, of withdrawing a sample of well fluids, or of deflating the elastic packer. However, for the purposes of clarity, the remaining portions of the drawing directed to an operative and complete formation tester will be described.

As formerly indicated, a metal mandrel 8 runs within the packer throughout the length of the packer. This mandrel may be provided with an interior chamber 25, which consequently provides a fluid passageway through which fluid may pass completely through the elastic packer. By this means it is possible to permit the flow of drilling mud, or well fluids between the sealed off upper and lower portions of the bore hole when the packer has been inflated. This provision has the effect of equalizing the hydrostatic pressure acting on the elastic packer so that no pressure will exist tending to force the packer either upwardly, or downwardly in the bore hole. To accomplish this the passage 25 may be extended to a fluid outlet port 26 positioned at the upper portion of the metal backing ring 9. Thus the channel 25 provided on the inside of the mandrel 8 will be terminated at the upper portion of the mandrel where it forms a junction with a suitable port 26. It is to be seen that this provides a fluid passageway from a point exterior to and beneath the elastic packer directly through the packer to the outlet port 26 at the upper portion of the packer.

The remaining requirements of the apparatus described are suitable means for inflating and deflating the elastic packer. This may be readily accomplished by use of the check valves positioned in a head member or in the backing ring 9 connecting the inflatable packer to the drill stem 5. Thus a check valve 29 may be positioned in a passageway 30 operative to permit the flow of fluid downwardly through the passageway 30, but normally operative to prevent passage of fluid upwardly through passage 30. A channel 31 is then provided connecting to passageway 30, and opening on the interior of the elastic packer 7. Consequently, if drilling mud, or any other fluid is pumped downwardly through the drill stem 5, sufficient hydrostatic pressure will be established to open the check valve 29 to permit the flow of this fluid into the interior of the elastic packer causing the packer to inflate. If desired, an auxiliary check valve, which has not been illustrated, may be positioned in a passageway extending from the interior of the packer to a point external of the drill stem and external to the packer. This check valve may be of the type to permit flow of fluid from the packer to the bore hole whenever a predetermined pressure within the packer has been exceeded.

In order to prevent flow of fluid on inflation from passing through the lines 18, provided for withdrawing well fluid, it is further necessary to position a check valve 35 in a channel leading to

the tubes 18. Thus, the tube or tubes 18 may terminate in a chamber 36 from which a channel 37 leads upwardly into the drill stem. The check valve 35 is operative to prevent flow of fluid downwardly through channel 37 and chamber 36, but permits flow of fluid upwardly through chamber 36, and channel 37 into the drill string.

In the operation of the formation tester which has been described, when desired to test the well fluids existing in a stratum 2, the formation tester illustrated and described is suitably connected to the lower termination of a drill stem. The packer is then lowered to a point in the well of sufficient depth so that the packing elements arranged on the exterior of the packer are adjacent the stratum to be tested. During this portion of the operation, the elastic packer must be maintained in a deflated position so that it can be positioned at any desired depth in the bore hole.

When the deflated packer has been lowered to the proper depth in the bore hole, water, drilling mud, or any other liquid may be pumped into the drill stem so as to pass downwardly through the drill stem and into the interior of the elastic packer so as to inflate the packer and so as to force the bundles of packing elements against the walls of the bore hole. By then lowering the pressure in the drill string as much as required, fluid may be withdrawn from the stratum 2, through the packing elements 13, through the tubes 18, chamber 36, channel 37, and thence to the interior of the drill string. By this means a sample of the well fluids existing in stratum 2 may be pulled upwardly into the drill string. If desired, this operation can be continued until the fluids are actually drawn to the surface of the earth through the drill string.

As described, therefore, this invention concerns an improved type of formation tester in which bundle of inter-connected packing elements are maintained on an exterior portion of an elastic packer. The bundles of packing elements are preferably maintained in troughs, or pockets, on the exterior of the packer, and lead into tubes which extend within the packer so as to provide a fluid passageway through the packer to the inside of the drill stem supporting the packer. It is apparent that this invention is subject to many modifications and may be utilized with any type of elastic packer formation tester. Thus, samples withdrawn through the packer may be conducted through the drill stem or may be collected in a suitable sample chamber. Again, any desired type of valve arrangement may be used for inflating and deflating the elastic packer. The tester of the present invention

may be used for any number of tests, at different levels, before removing the same from the well.

What is claimed is:

1. In a formation tester including an inflatable elastic packer, the improvement which comprises at least one tubular member extending from a point interior of the packer to the exterior of the packer, said tubular member being substantially filled with inter-connected packing elements; and said inter-connected packing elements extending from a point within the said tubular member to cover at least a portion of the exterior surface of the said elastic packer.

2. The apparatus of claim 1 in which the said inter-connected packing elements consist of a plurality of bead chains.

3. The apparatus of claim 1 in which the said inter-connected packing elements consist of a plurality of link chains.

4. The apparatus of claim 1 in which the said inter-connected packing elements consist of a multitude of individual packing elements strung upon a supporting wire.

5. In a formation tester including an inflatable elastic packer, the improvement which comprises at least one tubular member extending from a point interior of the packer to the exterior of the packer; the said packer adjacent the termination of the said tubular member at the exterior of the packer being formed as a trough, and inter-connected packing elements positioned in said trough to cover at least a portion of the exterior surface of the said packer.

6. In a formation tester including an inflatable elastic packer, the improvement which comprises at least one tubular member extending from a point exterior of the packer to the interior of the packer; and a plurality of inter-connected packing elements positioned on and covering at least a portion of the exterior surface of the packer, including the exterior termination of said tubular member, said inter-connected packing elements defining interstices through which fluid may flow.

BEN W. SEWELL,

GEORGE H. RAMSEY.

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