Feb. 2, 1960 A. B. HILDEBRANDT 2,923,358

FORMATION FRACTURE DETECTOR

Filed June 3, 1957 3 Sheets-Sheet 1

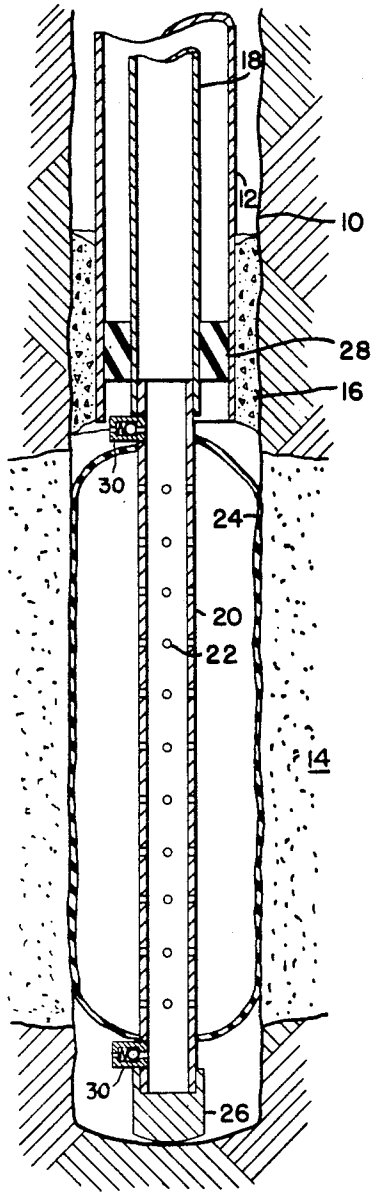


FIG.-1

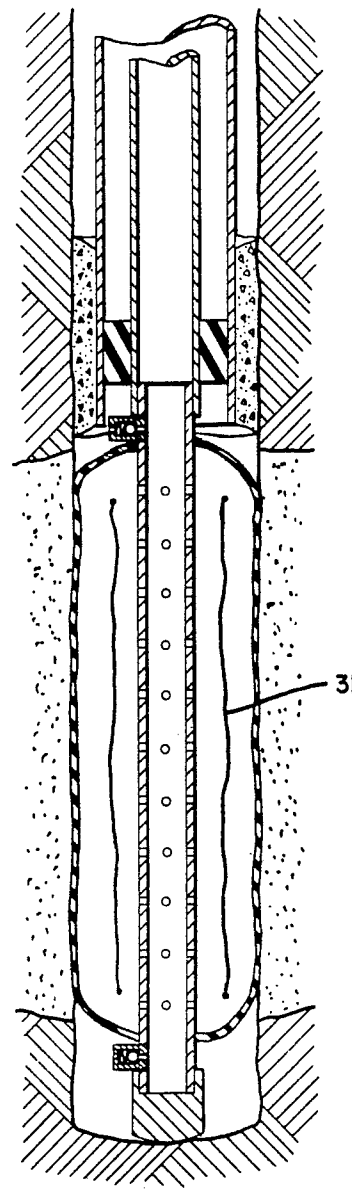


FIG.-2

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FORMATION FRACTURE DETECTOR

Filed June 3, 1957 3 Sheets-Sheet 2

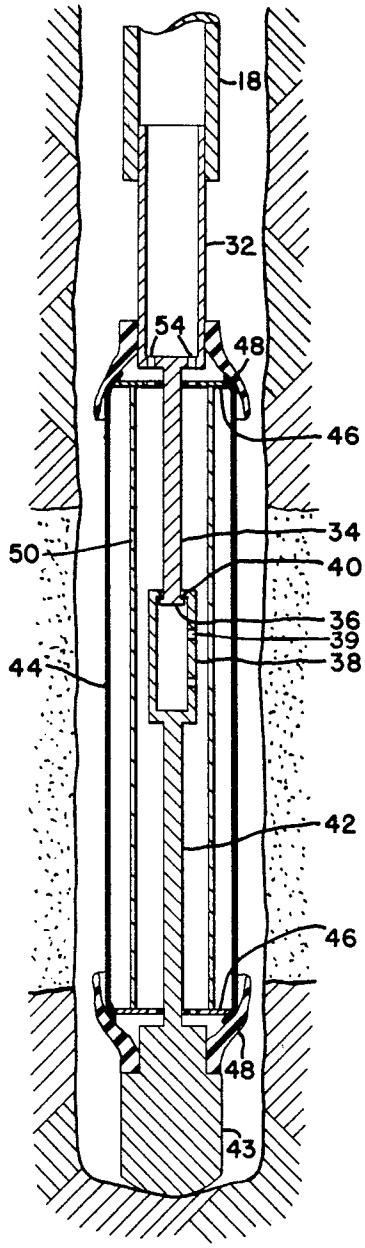


FIG.-3

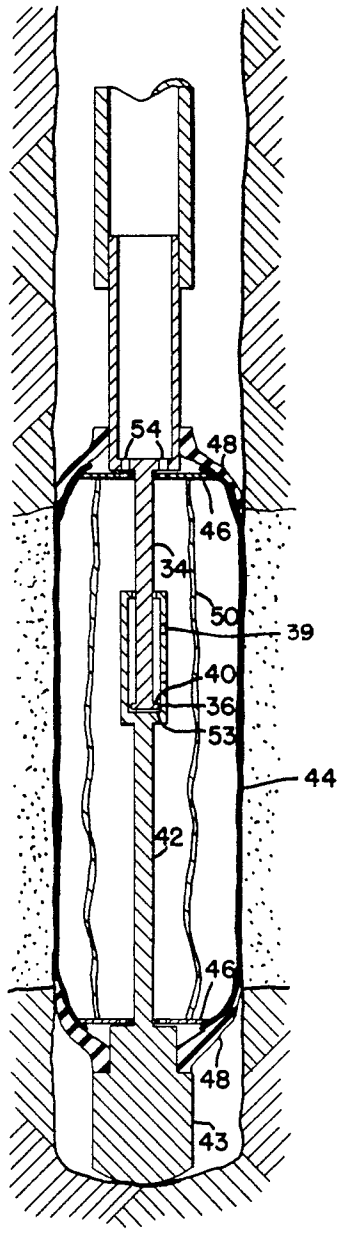


FIG.-4

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Feb. 2, 1960 A. B. HILDEBRANDT 2,923,358

FORMATION FRACTURE DETECTOR

Filed June 3, 1957 3 Sheets-Sheet 3

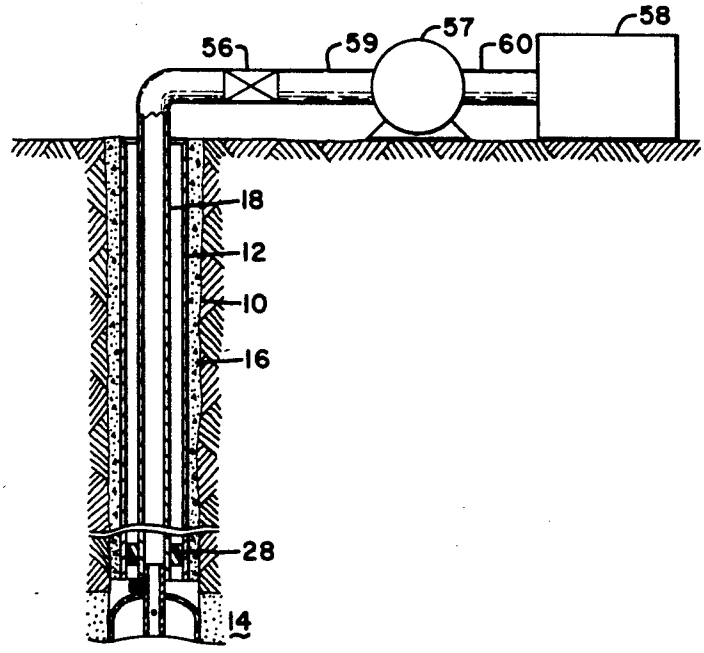


FIG. -5

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United States Patent Office 2,923,358
Patented Feb. 2, 1960

2,923,358

FORMATION FRACTURE DETECTOR

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Application June 3, 1957, Serial No. 663,216

10 Claims. (Cl. 166—177)

This invention relates to a method and apparatus for determining the characteristics of a formation penetrated by a well bore. It relates more particularly to an apparatus for determining the direction and nature of fractures within a formation penetrated by a well bore and subjected to hydraulic fracturing for the purpose of facilitating the release of oil and gas into the well.

In recent years, hydraulic fracturing of a producing formation to increase the production of oil and gas has been used quite extensively and successfully. Well fracturing is the splitting of rock under tension. When the rock is put under tension, it will stretch in proportion to the applied stress, up to its yield point; at which point, rock, being brittle, ruptures with little or no plastic deformation. In order to obtain well fracture, hydraulic pressure is applied to the rock of the producing formation within the well bore, thus creating tensile force around the hole. As the hydraulic pressure increases, these tensile forces become great enough that they finally pull the rock apart and start the fracture or split which is lengthened by fluid being pumped into the hole. In other cases, the formation rock sometimes is not actually fractured because it already exists in a fractured state. In these cases, the fluid under hydraulic pressure must only overcome the confining stresses to open and extend the existing fractures.

To better study the effect of fracturing upon oil and gas recovery and greater production, it is necessary to know the nature and direction of such fractures. This is especially important in determining flow patterns and whether all productive portions or zones of a formation have been fractured. As this invention is a method and apparatus for determining the nature and extent of the fractures of the rock making up the walls of the well bore, its importance to the recovery of oil and gas is immediately apparent.

It is therefore one of the objects of this invention to provide a method and apparatus for determining the nature and direction of the fractures within the producing formation of an oil and gas well.

In a preferred embodiment of this invention, a flexible or expandable receptacle member comprising a sleeve or bag is suspended by means of a tubular support member within a well bore opposite or adjacent the formation to be fractured. The flexible sleeve is set on the bottom of the well bore or on a plug or packer in those instances in which the well bore extends some distance below the bottom of the formation to be fractured. A packer is set on a tubular support member just above the sleeve, thus isolating the producing formation which is to be fractured from the remainder of the bore hole. Fluid is then injected through the tubular support member into the flexible sleeve under pressure. As the pressure builds up, the flexible sleeve expands against the wall of the well bore. The fluid in the well bore is forced into the formation by the expanding sleeve. Pressure relief valves are normally provided at each end of the sleeve to maintain a controlled pressure differential between the

inside of the sleeve and that portion of the well bore which has been isolated by the packers but not occupied by the sleeve. The pressure in the sleeve is increased until the pressure is reached sufficient to split or fracture the rock. Surface pumps of sufficient size and capacity are usually provided to maintain this pressure while fluid is pumped into the cracks or splits, thereby lengthening and increasing the extent of the fracture. When the formation fractures, the flexible sleeve is ruptured in such a manner that the fractures of the sleeve conform to the fractures of the producing formation. After the fracturing job has been completed, the flexible sleeve is brought to the surface for inspection. From this inspection, it is possible to determine the nature and extent of the fracturing of the formation.

The objects and nature of this invention will become more apparent from a discussion of the following drawing in which:

Fig. 1 illustrates a vertical section in diagrammatic form of a flexible sleeve used for detecting fracture pattern suspended in a well bore opposite the producing formation;

Fig. 2 is similar to Fig. 1 and illustrates a fracture pattern upon the sleeve;

Fig. 3 illustrates a vertical section in diagrammatic form of a different embodiment of an apparatus for determining fracture pattern;

Fig. 4 is similar to Fig. 3 except that the sleeve is inflated.

Fig. 5 illustrates, in schematic form, surface equipment used in conjunction with this apparatus.

Refering now to Fig. 1 and Fig. 2 in more detail, numeral **10** indicates a borehole with casing **12** set from the surface to the top of producing formation **14** and set in place by cement **16**. A tubular support member or tubing string **18** is suspended within the casing **12** and has at its lower end a perforated and normally reduced extension or support element **20** which is in fluid communication with tubular support **18** and extends through that part of the formation which is desired to be fractured. Extension **20** is perforated with slots or other openings **22** which permit fluid communication between the tubular support member **18** and the interior of inflatable elastic receptacle member or sleeve **24** which completely surrounds and encloses extension **20** and is securely sealed and attached to each end thereof. The receptacle member **24**, if desired, may be attached at its upper end only and extension **20** eliminated, particularly if such extension is not needed to aid in supporting the receptacle member. Sleeve **24** is normally made or fabricated of an impermeable, solid, expandable material such as rubber or a plastic; if added support strength is needed, the sleeve may be made to have reinforced material contained or embedded within the expandable material. This reinforcement may be either expandable or non-expandable webbing or fiber which has been embedded in an expandable material. This reinforced receptacle member may be made with a perforated member or other supporting frame impregnated with or dipped into an elastic material which adheres thereto and forms a thin membrane over the openings in the supporting element. If a reinforced material is used for the sleeve, upon fracturing of the formation, the expandable membrane fractures, and the fracturing material passes through the perforations or openings between the supporting material. If the fracturing fluid contains sand or other supporting particles to be deposited in the fractures to prop such fractures open, the openings or perforations of the support material of the sleeve should be designed such as to permit the passage of such sand or support particles therethrough. Use of reinforced material for sleeve **24** is especially desired if

substantially horizontal fractures are obtained, as an unreinforced sleeve might be severed. The resilient material of which sleeve **24** is made may have various percentages of expansion before rupture, but preferably has 100% expansion before rupture. A 100% expansion provides ample elasticity to insure that the sleeve will fit snugly against the borehole; but, upon fracturing of the formation, the expandable material of the sleeve will rupture before it expands into the fracture sufficiently to become stuck or caught therein. The material must also be capable of withstanding the temperature and pressure to be encountered, as well as resisting any deteriorating action of the fluids encountered. Sleeve **24** must be so constructed and supported that it can be retrieved from the borehole with the formation fracture pattern being preserved thereon; that is, without any additional rupturing or tearing of the sleeve. It is therefore desirable that the sleeve be supported at least at each end in a manner such that the sleeve **24** is not required to support any additional weight.

The sleeve may also be constructed of a wire screen made of a material such as bronze and coated with an elastic material such as rubber or plastic, with the openings between the wire normally being closed by a thin membrane of the elastic material. Upon fracturing the formation the fracturing material ruptures the membrane and passes therethrough into the fracture of the formation, thus showing a true fracture pattern on the sleeve. Although the membrance covering the openings in the screen would be ruptured and perhaps the coating worn off the screen where the fracturing fluid passes therethrough, the screen will retain the size and shape of the sleeve. If sand or other support material is used in the fracturing fluid, the size of the screen is selected to permit the passage of the support material into the fracture of the formation.

In some instances, it may be desirable to entrain sand or other support material in the fracturing fluid which serves to prop open the fracture after the formation is no longer subjected to the fracturing pressure. A part of the entrained sand may sometimes be deposited in sleeve **24**; and while removing the sleeve from the well bore, the weight of the sand may distort the sleeve, thus making a determination of the fracture pattern difficult. The difficulty can be eliminated by constructing the sleeve such that a small selected portion in the bottom portion of the sleeve is weaker than the remainder of the sleeve and rupturable by the weight of the sand, particularly when the receptacle sleeve is being retrieved thus permitting the escape of the sand before the sleeve is distorted. Of course, the formation and sleeve may be fractured by use of a fracturing fluid not containing a support material, and the problem of sand deposit in the sleeve is thereby eliminated. However, if support material is desired to be deposited within the fractures, this will normally require pulling the tubular support member and rerunning it for the subsequent injection of fracturing fluid carrying sand or other support material which reopens the fractures and deposits the support material in the fractures. This is time consuming, expensive, and non-productive and is normally less preferred than that which can be done in a manner hereinbefore described.

An impermeable material for the receptacle member may also be used when it is desired that the formation be fractured prior to any fracturing fluid entering the formation. However, if it is desired that fracturing fluid enter the formation prior to fracturing, a permeable, expandable material such as a perforatable canvas, is used as the expandable material for the receptacle member **24**. The material must also be of such nature that, when the formation is fractured, the rush of fracturing fluid from the receptacle member into the fractures will result in rupturing the permeable material.

A tail pipe **26** is normally provided at the lower end of the perforated extension **20** which supports a sleeve

assembly upon the bottom of the hole or upon the top of a plug or packer normally set at the bottom of the formation to be fractured if the well bore extends through the formation to be treated. The annular space between the tubular support **18** and casing **12** is sealed at the top of the formation being treated by packer **28** which is set just above the inflatable sleeve **24**. Equalizing or controlled pressure differential valves **30** are provided to maintain a predetermined pressure differential between the interior of sleeve **24** and that space within the well bore at the top and bottom of the sleeve which is not occupied by said sleeve. This prevents distortion or premature rupture of the ends of the sleeve. Valves **30**, for example, may be shear relief valves, manufactured by The Cameron Iron Works, Houston, Texas, and described in their catalog for 1955–1956, page 1119, Fig. 200322–2.

Conventional means may be provided for supplying injection fluid to the expandable sleeve. As illustrated in Fig. 5, these include pumping means **57** with discharge conduit **59** which is in fluid communication with tubing **18**. A valve **56** is provided in conduit **59**. Conduit **60** conveniently connects the suction side of pump means **57** with reservoir **58** which is provided for storing fracturing fluid.

In the normal operation of this device, the expandable sleeve **24** is lowered into position opposite the formation to be fractured while suspended at the lower end of tubular support **18**. Packer **28** is then set in position to isolate that part of the well bore encountering the formation to be fractured. Fluid is then injected by injection means not shown through the tubular support **18** through the perforations **22** of the reduced extension **20** into the interior of expandable sleeve **24**. As the pressure increases, the walls of the flexible sleeve **24** expand until held tightly to the wall of the well bore by friction. Equalizing valves **30** maintain a pressure differential wherein the pressure in the isolated portion of the well bore outside of the sleeve **24** is normally about 50 pounds less than the pressure within sleeve **24**. The pressure within the sleeve is increased until the formation fracture pressure is reached. This pressure is maintained until the fracturing job is completed. When the formation is fractured, the walls of the flexible sleeve **24** are thereby fractured in the same pattern as the fractures in the wall of the producing formation within the well bore. The wall of the bore hole normally prevents the sleeve from further expansion. However, when the wall of the bore hole cracks, the walls of the sleeve expand rapidly into such cracks and very quickly reach their rupture point. The only portion of the sleeve reaching its rupture point is that unsupported portion or portions which expand into the fracture or crack of the wall of the well bore, thus assuring a true pattern of the fracture of the formation. The remainder of the sleeve is held tightly in place against the wall of the bore hole by friction. The pressure is then released or reduced and the flexible packer is brought to the surface. From an examination of the pattern of the ruptures of the flexible sleeve, the pattern of the fracture of the producing formation can readily be determined. Numeral **31** in Fig. 2 illustrates ruptures or fractures of sleeve **24**.

After sleeve **24** has been fractured, it is very important that it be retrieved without further fracturing thereof in order that the fractures in the sleeve correspond to the fractures of the formation. This is accomplished largely by proper construction and support of the sleeve **24** as hereinbefore described.

Fig. 3 illustrates a different embodiment of this invention. An adapter **32** is screwed into or otherwise secured to tubular support member **18**. A piston rod **34** is rigidly secured to the bottom portion of adapter **32** and to piston **36** which has free reciprocal movements within the cylinder **38**. Cylinder **38** has internal shoulder **40** fitted to retain piston **36** of rod **34**. Cylinder **38**

may have perforations 39 to prevent the accumulation of fluid therein from impeding the movement of piston 36. Arm 42 is rigid and connects and secures cylinder 38 with the lower portion of the flexible sleeve unit or more specifically with base 43. Flexible sleeve 44 which may be constructed or material similar to the material for sleeve 24 as hereinbefore described, is secured at each end to annular rings 46. The annular rings are fitted and secured to heavy expanders 48 which are preferably made of rubber and may be reinforced with steel springs so arranged that the expanders 48 normally exert a pressure upon the walls of bore hole. Flexible expanders 48 are kept in a flexed position and away from the wall of the bore hole by the tension on wire ropes or lines 50 while the unit is being lowered into position. Wire lines 50 connect the annular rings at each end of sleeve 44, with the weight of the lower portion of the unit causing tension on line 50. The device is designed such that when piston or shoulder 36 is in contact with internal shoulder 40 of cylinder 38 there is sufficient tension on line 50 to hold expander 48 in a flexed position and away from the walls of the well bore but with no weight being supported by sleeve 44. Base 43 encloses the lower end of the sleeve unit and may be made of neat cement or may be cast of the same material as and an integral part of arm 42 and cylinder 38. When base 43 rests upon the bottom of the bore hole, the tubular support 18 is lowered an additional distance to permit the weight to be taken off wire ropes 50 and allowing the expanders 48 to assume a normal expanded position and with shoulder 36 normally coming to rest on the bottom end 53 of cylinder 38 as shown in Fig. 4. The expanders will be flexed against the wall of the bore hole and will seal or isolate that portion of the bore hole between the expanders from the remainder of the bore hole. Fracturing fluid is then introduced through ports 54 in the lower portion of adapter 32. The pressure is then built up until the formation fracture pressure is reached, at which time the flexible sleeve will also be fractured or ruptured, with its fracture conforming to the fracture pattern of the formation. When the fracturing is completed, the tool is removed from the bore hole. As the tubular support 18 is raised, the weight of the bottom or lower portion of the unit will cause tension on wire ropes 50, thus causing rubber expanders 48 to flex away from the walls of the bore hole. The device is then removed from the bore hole and from an examination of the sleeve the pattern of the fracture of the formation is then determined at the surface. This apparatus is so designed that when piston 36 is in contact with internal shoulders 40, lines 50 are under tension but are slack when piston 36 is positioned at the closed end of cylinder 38. This device is further designed such that at no time is any weight carried by the flexible sleeve which bears the fracture pattern; this assures a true formation fracture pattern being indicated upon the sleeve.

Although the drawing and the discussion has concerned itself primarily with determining the fracture pattern within an open hole completion, it is to be understood that an indication of the fracture pattern can also be determined where a well has been completed by perforating the casing which has been set through the formation being fractured.

It is also apparent that this method may be utilized for determining fracture pattern of a formation which has previously been subjected to hydraulic fracturing.

It is apparent that numerous modifications and variations may be made in the apparatus described without departing from the spirit and scope of the present invention and it is intended that the invention be limited only by the scope of the following claims.

What is claimed is:

1. An apparatus for determining the fracture pattern of an underground formation traversed by a well bore comprising a tubular support member, an inflatable sleeve having substantially uniform resistance to flow of liquid throughout attached to and supported from the bottom of said tubular support member with fluid communication between the bore of said tubular support member and the interior of said sleeve, an equalizing valve capable of maintaining a set pressure differential between the interior of said sleeve and the exterior thereof, and injection means operative to inject fluid through said tubular support member and said sleeve under sufficient pressure to fracture said formation and simultaneously rupture said sleeve in the same pattern as the fracture of said formation.

2. An apparatus for determining the fracture pattern of an underground formation traversed by a well bore comprising a tubular support member suspended in said well bore, an inflatable sleeve having substantially uniform resistance to flow of fluid therethrough attached to the bottom of said member with fluid communication between the bore of said member and the interior of said sleeve, with said sleeve adapted to fit tightly against the walls of the bore hole, means for supporting said sleeve at least at each end, a packer set above said sleeve and sealing the annular space between said member and the wall of said well bore, equalizing valves capable of maintaining a set pressure differential between the interior of said sleeve and the bore hole below said packer not occupied by said sleeve, and injection means operative to inject fluid through said tubular support member and said sleeve under sufficient pressure to fracture said formation and simultaneously rupture said sleeve in the same pattern as the fracture of the formation.

3. An apparatus as defined in claim 2 wherein said sleeve has flexible fiber embedded in the walls thereof.

4. An apparatus as defined in claim 2 wherein said sleeve is fabricated of a screen coated with a resilient material forming thin membranes over the opening of said screen.

5. An apparatus as defined in claim 2 wherein said sleeve is permeable to said fracturing fluid.

6. An apparatus for determining the fracture pattern of an underground formation traversed by a well bore comprising a tubular support member, a flexible sleeve in fluid communication with said member, an annular ring fitted and secured to each end of said flexible sleeve, two flexible expanders with one secured and fitted to each of said annular rings, a base to which is secured one of said expanders, the combination of said ring, said expander, and said base closing one end of said sleeve, a plurality of lines connecting said rings, an adapter detachably attached to said support member and to which is secured the other of said expanders, the combination of said ring, said expander and said adapter effecting fluid communication between said sleeve and said support member; a cylinder closed at one end, a piston and piston rod insertable through the other end of said cylinder adapted for reciprocal movement within said cylinder and with said piston rod rigidly connecting said piston and said adapter, an annular internal shoulder portion at the other end of said cylinder forming a limit stop for said piston, an arm rigidly connecting the closed end of said cylinder and said base, said apparatus being so constructed that said lines are under tension when said piston is in contact with said internal shoulder but said lines are loose when said piston is at the closed end of said cylinder.

7. An apparatus as defined in claim 6 with the further improvement of providing ports in said adapter and with the walls of said cylinder being perforated.

8. An apparatus for determining the fracture pattern of an underground formation traversed by a well bore comprising a tubular support member suspended within a well bore, an adapter secured to the lower end of said tubular support member, an expander fitted around and attached to the exterior of said adapter, an annular ring fitted and attached to the inner side of said expander, a

flexible sleeve fitted and attached at one end to said annular ring, at least one port in said adapter establishing fluid communication between the interior of said sleeve and said tubular support member, a second annular ring fitted and attached to the other end of said sleeve, a second expander to which said second ring is fitted and attached, a base to which said second expander is fitted and attached, the combination of said second ring, said second expander and said base forming a closure of the lower end of said sleeve, a plurality of lines connecting said rings, a piston, a rod rigidly connecting said piston and said adapter, a cylinder with one end closed and designed to receive said piston, internal shoulders on the other end of said cylinder adapted to contain said piston within said cylinder with said piston having free reciprocal movement within said cylinder, an arm rigidly connecting said cylinder and said base, said apparatus so designed that said lines are under tension when said piston is in contact with said internal shoulder but are slack when said piston is positioned at said closed end of said cylinder and said sleeve is so designed in relation to said lines that at no time does said sleeve support any of the weight of said base.

9. An apparatus for determining the fracture pattern of an underground formation traversed by a well bore comprising a tubular support member, an inflatable elastic receptacle member of substantially uniform permeability throughout supported from said support member and adapted to be positioned within the borehole opposite said formation, the interior of said receptacle member in fluid communication with the interior of said support member, an equalizing valve capable of maintaining a set pressure differential between the interior of said receptacle and the exterior thereof, means to inflate said receptacle member with fluid from said support member, said receptacle member being adapted to expand against the wall of the borehole and to rupture and provide a fluid passageway where unsupported by a fracture in the wall.

10. An apparatus for determining the fracture pattern of an underground formation traversed by a well bore comprising a tubular support member removably suspended within said well bore, an inflatable elastic impermeable receptacle member supported from said support member being retrievable with said support member from the borehole and adapted to be positioned within the borehole opposite said formation, the interior of said receptacle member being in fluid communication with the interior of said support member, an equalizing valve capable of maintaining a set pressure differential between the interior and the exterior of said receptacle member, injection means operative to inject fluid through said tubular support member and said receptacle member, said receptacle member being adapted to expand against the wall of the borehole and to rupture and provide a fluid passageway where unsupported by a fracture in the wall of the borehole.

References Cited in the file of this patent

UNITED STATES PATENTS

2,611,436	Carr et al.	Sept. 23, 1952
2,687,179	Dismukes	Aug. 24, 1954
2,798,557	Sewell	July 9, 1957