Sept. 9, 1958 R. SPEAROW 2,851,109

FRACTURING PACKER AND METHOD OF APPLICATION THEREOF

Filed Feb. 2, 1956 4 Sheets-Sheet 1

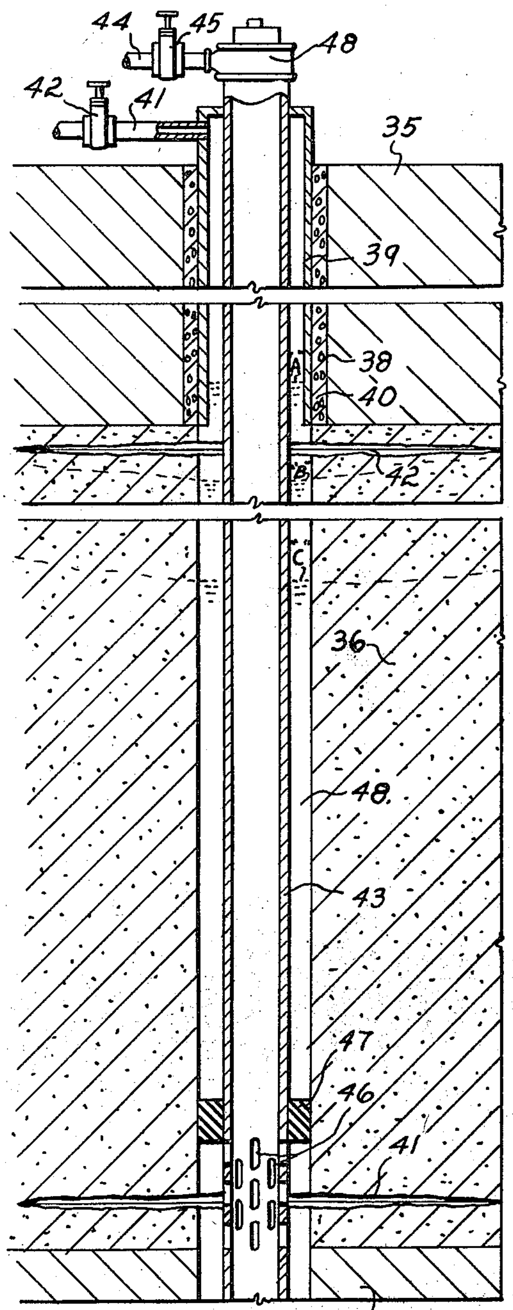

Fig. 2.

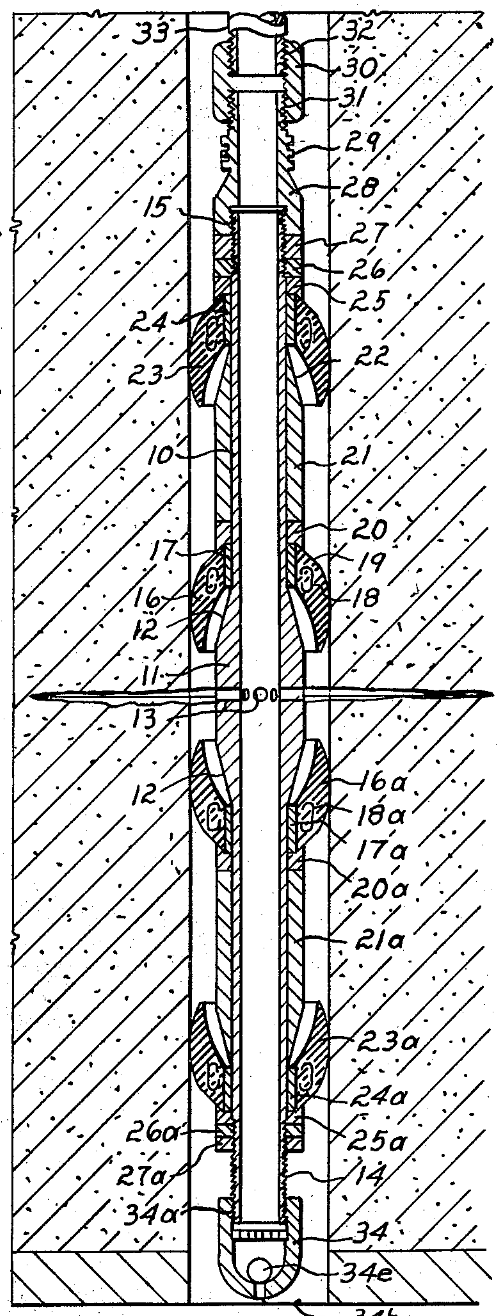

Fig. 1

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FRACTURING PACKER AND METHOD OF APPLICATION THEREOF

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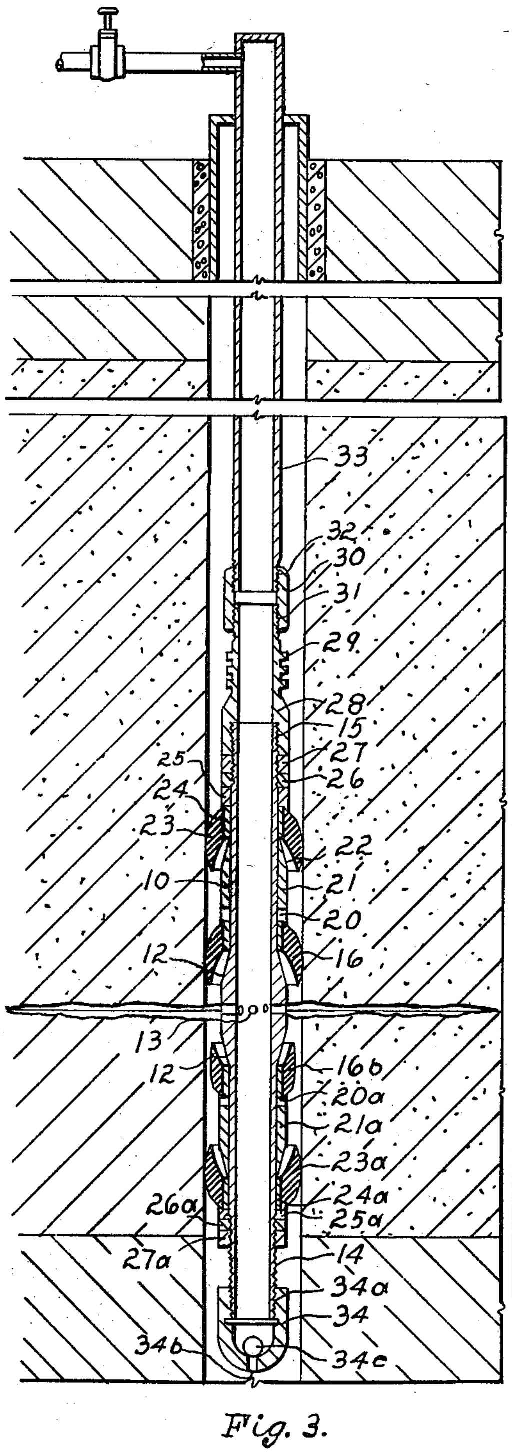

Fig. 3.

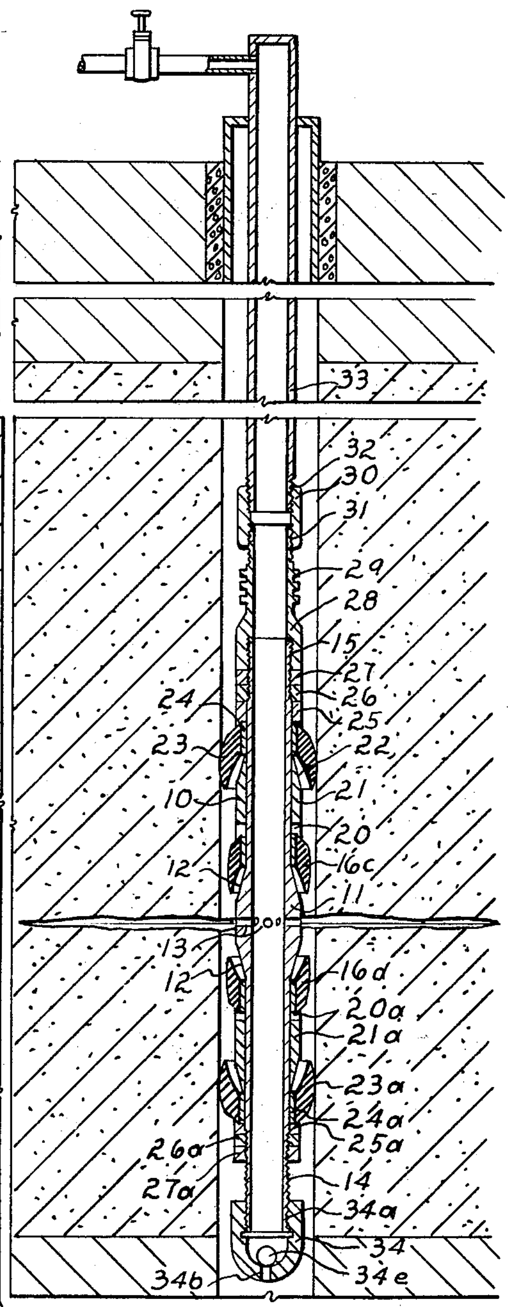

Fig. 4.

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FRACTURING PACKER AND METHOD OF APPLICATION THEREOF

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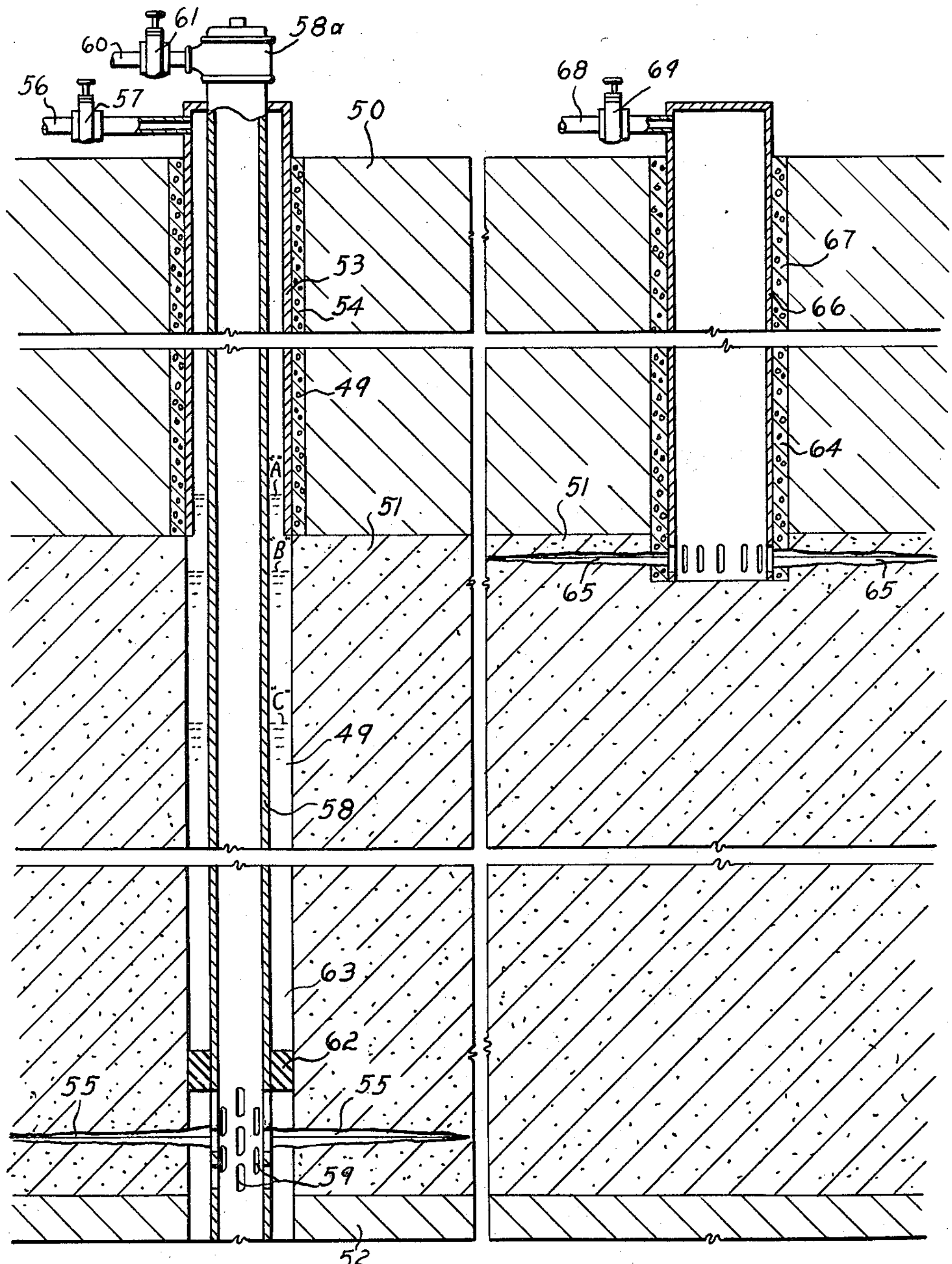

Fig. 5.

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FRACTURING PACKER AND METHOD OF APPLICATION THEREOF

Filed Feb. 2, 1956 4 Sheets-Sheet 4

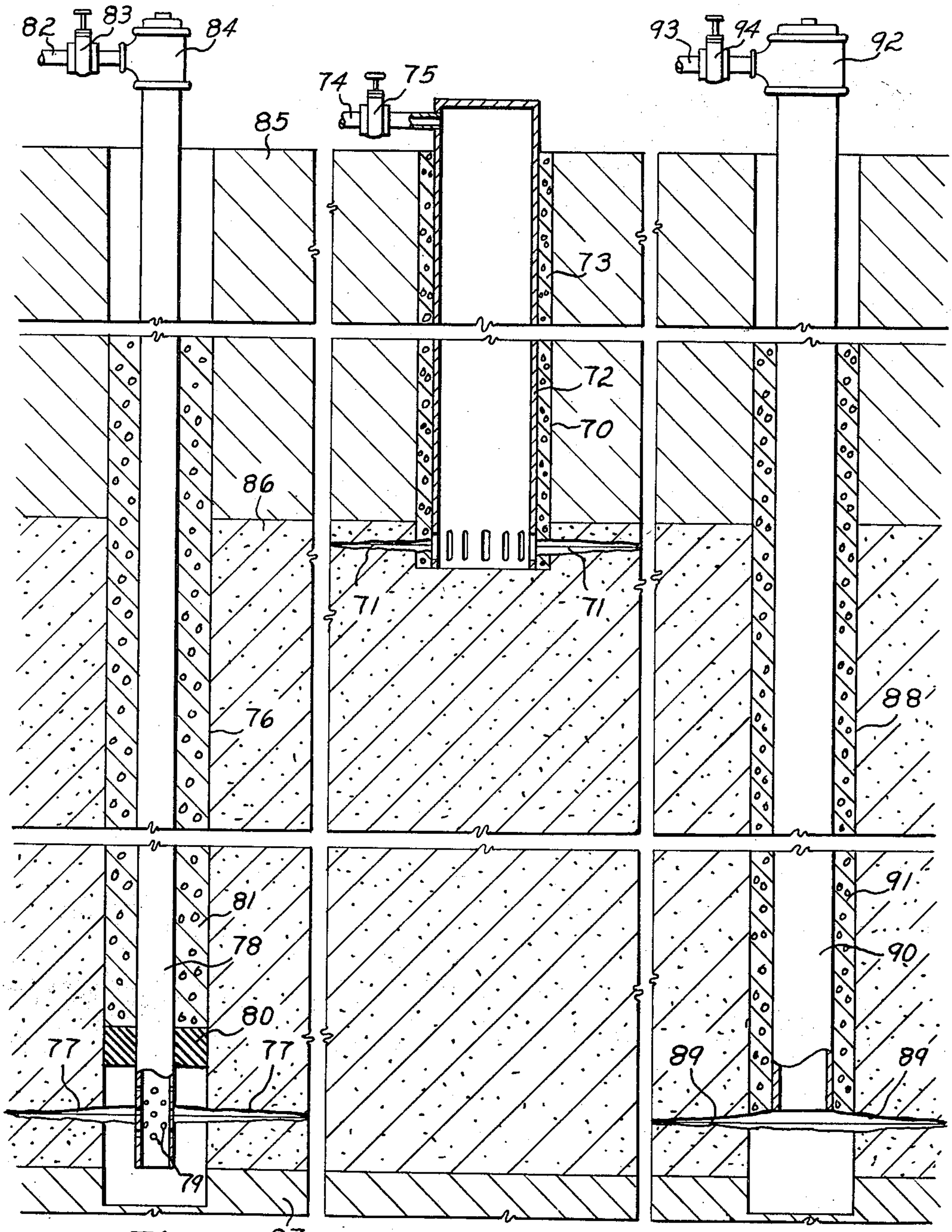

Fig. 6. Fig. 7. Fig. 8.

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United States Patent Office

2,851,109

Patented Sept. 9, 1958

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2,851,109

FRACTURING PACKER AND METHOD OF APPLICATION THEREOF

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Application February 2, 1956, Serial No. 563,089

11 Claims. (Cl. 166—177)

This invention relates to a packer for fracturing the borehole face of an oil well and a method of application thereof and refers more particularly to such a packer which isolates a predetermined cross-sectional area of the well bore face for the application of pressure thereto for fracturing purposes and a method of application of the fracturing process with said packer to permit employment thereof in a gaseous pressurization vertical oil production method.

This application is an improvement of my Patent No. 2,593,497, entitled "Method and Apparatus for Producing an Oil Well," filed May 26, 1947, and my Patent No. 2,725,106, entitled "Oil Production," filed December 20, 1951. It is a continuation-in-part of my co-pending application, Serial No. 439,521, entitled "Single Packer Oil Production Method and Apparatus," filed June 28, 1954, now Patent 2,785,753, and my application Serial No. 549,-280, entitled "Original Oil Production Method," filed November 28, 1955, now abandoned.

In the above listed patents and applications, I have set forth various modifications of a gaseous pressurization vertical oil production method wherein gaseous pressure is applied to the top portion of an oil sand and oil is produced from the lower portions thereof. In order for this type of method to be operable, as I have set forth in these cases, it is necessary to seal the gaseous pressurization input area above the oil horizon so that the pressurization media will not escape into the overlying formations. It is also necessary to seal the well bore face of the production well above the oil production area in the lower part of the oil horizon to prevent migration of gaseous pressurization media downwardly along the well bore face in the production well. Thus, it may be seen that for the efficient and, indeed, feasible operation of this method, it is necessary to provide a limited gas pressurization area at the top of the oil horizon and a limited oil production area at the bottom of the oil horizon, these areas being very completely sealed off one from the other and the surrounding formations to prevent leakage thereto and therefrom of the gaseous pressurization media.

A number of methods of well completion have been shown in the above listed applications and issued patents. The desired method of completion usually depends a good deal on the characteristics of the sand, its depth, its thickness, the regularity or irregularity of the well bore face through and above the oil horizon (which is determined somewhat by the drilling process), and the softness or hardness of the sand relative sloughing, etc. Thus, in some instances, a casing is run into the oil sand and cement is forced up around the outside surface of the casing between it and the well bore face. The casing and the surrounding annular seal of cement are then perforated as desired to produce the input and/or output areas. Another method of completion is to run a tubing to the desired level in the oil horizon and then pack off a volume between the outside surface of the tubing and the well bore face. An annular column of sealing substance or cement may then be filled in over the packer to any desired level. Still another method of completion contemplates completing a well bore having a shot hole cavern therein, gravel packing the desired lower portion of the oil horizon, laying a layer of sand or granular material on top of the gravel and then putting a sealing column of sealing substance or cement thereabove to any desired level, thus filling out the whole volume of the shot cavern.

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It is desirable in most, or at least some of the applications of this method to fracture the oil horizon to permit optimum pressurization input of gaseous pressurization media at the top portion of the oil horizon at a minimum of horsepower per unit of compression and also optimum oil recovery from the lower portion of the oil horizon. The drawbacks in the application of fracturing to such a method previously have been (1) that the area to be fractured should be either very close to the top or to the bottom of the oil horizon, (2) the area to be fractured should be very limited in cross-sectional area, especially in oil sands of relatively small total cross-sectional area and, finally (3) there has not been provided previously a fracturing packer operable to hold within the required fracturing pressures, adjustable to any desired pressurization cross-sectional area and applicable directly to the well bore face without necessarily being first enclosed in a casing against which it may seat while the fracturing pressure is being applied. All previous well bore packers to abut the well wall face have been designed to hold pressures coming out of the oil or gas reservoir and the pressures they hold are never above formation pressure. Fracturing pressures, of course, far exceed formation pressures.

Therefore, an object of the present invention is to provide a fracturing packer which is directly applicable to the open well bore without requiring enclosure in a casing set thereagainst.

Another object of the invention is to provide a fracturing packer directly applicable to the open well bore which has a variable cross-sectional area of pressurization application to be fixed as desired by the operator.

Another object of the present invention is to provide a fracturing packer which, due to its employability in the open well bore and also its controllable pressurization area, is adaptable to prepare both the crown and the base of an oil horizon for the application of a vertical pressurization gas-oil production method wherein any fracturing of the horizon must be severely limited vertically within the horizon.

Yet another object of the invention is to provide various modifications of a method of preparing well bores for oil production utilizing a gaseous pressurization vertical drive oil production method wherein certain desired sections of the oil horizon may be fractured and then sealed off for optimum operation of the method.

Other and further objects of the invention will appear in the course of the following description thereof.

In the drawings, which form a part of the instant specification and which are to be read in conjunction therewith, embodiments of the invention are shown and, in the various views, like numerals are employed to indicate like parts.

Fig. 1 is a cross-sectional view through an earth formation having the borehole of an oil well drilled therein, the inventive preferred modification of the fracturing packer assembly being shown positioned within the borehole of the well.

Fig. 2 is a cross-sectional view of an earth formation containing an oil horizon, the well bore of an oil well having been drilled to the vicinity of the bottom of the oil horizon, suitable casing and production tubing having been set within the oil horizon, the oil horizon having been fractured at the uppermost portion and the lowermost portions thereof to permit optimum operation of the production method.

Fig. 3 is a cross-sectional view through an earth formation having an oil horizon therein, the borehole of an oil well having been drilled below the bottom of the oil horizon, a modified form of the inventive fracturing packer being shown positioned within the borehole of the oil well within the oil horizon, suitable surface and pressurization tubing being connected to the fracturing packer assembly, the horizon face having been fractured with the assembly at a selected point.

Fig. 4 is a cross-sectional view through an earth formation having an oil horizon therein, the borehole of an oil well having been drilled to the vicinity of the bottom of the oil horizon, a second modification of the inventive fracturing packer shown positioned within the well bore within the oil horizon, suitable surface and pressurization tubing being attached to the fracturing packer assembly and the face of the oil horizon having been fractured with the assembly.

Fig. 5 is a cross-sectional view through an earth formation having an oil horizon positioned therein, two wells being shown drilled into the oil horizon, the left well being solely a production well with suitable casing and production tubing set within the well bore thereof, the oil horizon having been fractured at the lower portion thereof to permit optimum production from the horizon, the right well being solely a pressurization well, with suitable casing being set therein, the oil horizon being fractured at the very topmost portion thereof to permit optimum pressurization of the horizon to produce the oil therefrom.

Fig. 6 is a cross-sectional view through an earth formation containing an oil horizon, the left well therein being solely a production well with suitable production tubing set therein and the oil horizon having been fractured in the lowermost portion thereof.

Fig. 7 is also a cross-sectional view through an earth formation containing an oil sand, the well being solely a pressurization well designed for use in a vertical drive gaseous pressurization method, the pressurization casing having been run and set into the top of the oil horizon, and the oil horizon having been fractured at the topmost portion thereof.

Fig. 8 is a cross-sectional view through an earth formation containing an oil horizon, the well being solely a production well, suitable production casing being run to the vicinity of the bottom of the oil horizon, the casing set and cemented and perforated as shown, the oil horizon having been fractured at the lowermost portion thereof to provide optimum production from the horizon.

Referring first to Fig. 1, in which is shown an enlarged cross-sectional view of the inventive fracturing packer assembly, the numeral **10** designates a section of tubing having a central area **11** thereof of greater cross-sectional area. Center section **11** has tapered end portions **12** and perforations **13** positioned centrally thereof. Tubing **10** has relatively long, external threaded section **14** at the lower end thereof and relatively short threaded section **15** at the upper end thereof. The inventive fracturing packer assembly is assembled from both sides of the enlarged tubing portion **11**. Taking the assembly process from the top end of the tubing **10** first, expandable cup-shaped packer **16** having steel washer **17** fixed in the base thereof and wire reinforcement grid **18** embedded in the base thereof, is slid on the tubing **10** downwardly until the washer **17** wedges against the tapered portion **12** of the thicker section **11** of tubing **10**. Packer **16** has tapered outside portion **19** and an outer diameter at its greatest diameter preferably essentially equal to that of the hole bore which is to be fractured. The open end of the packer **16** is preferably of lesser outer diameter than its portion of greater diameter to permit ready insertion into the hole bore. Packer base support ring **20** having upwardly angled outer edges **21** is then slid on the pipe **10** and is wedged against the upper end of packer **16**. The inner diameters of steel ring **17** and wedge ring **20** are preferably just slightly greater than the outer diameter of the tubing **10** to permit sliding thereon. Steel collar washer **21** having right angled downward end and tapered upper end **22** is then slid on the tubing **10**. The inner diameter of washer **21** is the same as wedge ring **20** and the outer diameters of wedge ring **20** and washer **21** are equal to the outer diameter of the thickened portion **11** of the tubing **10**. Outer packer **23**, having steel base ring **24** and the same construction as the inner packer **16**, is then slid onto pipe **10** and wedged against the tapered edge **22** of steel collar washer **21**. A base wedge ring **25** exactly similar to wedge ring **20** is then slid onto the pipe to support and engage the base of outer packer **23**. A pair of lock nuts **26** and **27** threaded to engage the threaded upper portion **15** of the tubing **10** are preferably employed to fix both upper packers **16** and **23** and their supporting assemblies on the upper portion of the pipe. Should speedier operation be desired, a swedge nipple **28** of greater lower jaw depth than is shown in the drawing may be employed to wedge the upper assembly on the fracturing packer assembly. Swedge nipple **28** has threaded jaws to engage the upper threaded end **15** of the pipe and grooved portion **29** to permit engagement by oil well grappling tools should the fracturing packer assembly be left in the hole. Engaging nut **30** has lower left-hand threaded jaws **31** to engage the upper outside threads of the swedge nipple **28** and conventional right-hand thread portion **32** to engage pipe string **33**. The left-hand thread **31** permits disengagement of the fracturing packer assembly to leave it in the hole should such be desired. All other threaded portions of the fracturing packer assembly have conventional right-hand threads.

Referring now to the lower portion of the fracturing packer assembly, lower inner packer **16*a*** having fixedly attached base ring **17*a*** and wire reinforcement **18*a*** therein, is slid on the tubing **10** exactly as the inner packer **16** and wedged on the tapered portion **12** of the thickened portion **11** of tubing **10**. Base locking ring **20*a*** of the same form as rings **20** and **25** then engages the lower face of the packer **16*a***. Steel collar washer **21*a*** of the same form as washer **21** is slid on the tubing **10** to abut the base ring **20*a*** and provide a wedge means for secondary outer packer **23*a*** having base ring **25*a*** and a wire reinforcement therein. Base ring **25*a***, identical to base ring **20*a***, engages the base of the secondary packer and threaded lock nuts **26*a*** and **27*a*** engage the lower threaded portion **14** of the tubing **10**. Standing valve **34** having upper threaded portion **34*a*** to engage threaded portion **14** of the tubing **10** has opening **34*b*** in the lower end thereof and ball **34*c*** to permit fluid flow upwardly into tubing **10** but not outwardly therefrom. The outer diameters of the packers **16*a*** and **23*a*** are the same as packers **16** and **23** and the inner and outer diameters of base rings **20*a*** and **25*a***, washer **21*a*** and lock nuts **26*a*** and **27*a*** are identical to their comparable members at the upper end of the fracturing packer assembly.

The inventive fracturing packer assembly is shown positioned in a well bore in an earth formation.

The diameter of the packers **16**, **23**, **16*a*** and **23*a*** when fully expanded is greater than the diameter of the well bore to be fractured whereby to contain between the packers any fluid pressurization medium (preferably oil) forced between the packers from inside the tubing through the perforations **13**. The two pairs of packers serve to contain any pressurization media, the extra outer pair of packers retaining any pressurization media that might leak past the inner packers through fissures, scoring, or the like in the well bore. The packers are formed of a relatively resilient substance such as a special type of rubber designed to resist oil deterioration and extreme pressure. The resilient material permits the packers to set against the well wall under pressure and to fill the crevices and irregularities in the well wall by compaction of resilient material therein, thus preventing blow-by of pressure and concentrating the pressure in the area desired to be fractured. It should be noted that this form of fracturing packer is employed in the open well bore to fracture as at **13***a* the well wall. Additionally, it should be noted that the well bore may be fractured in a very limited area which permits control of the fracturing of the oil horizon in a vertical direction. This makes possible the employment of this fracturing method with a gaseous drive vertical pressurization method.

Referring to Fig. 3, a modified form of the invention is shown wherein it is desired to apply the fracturing pressure to a larger cross-sectional area of the well bore. The only difference in the structure of this modification from the structure of that previously described is that either the upper or lower inner packer is replaced by a substitute packer **16***b* of smaller diameter than those regularly employed. This packer is of lesser diameter when fully expanded than the diameter of the well bore to be fractured. Thus, the fluid pressurization media bypasses the smaller packer **16***b* and is retained by the outer packer. The structural parts of such a modification are the same as in the preferred modification with the exception of this one smaller packer **16***b* and, thus, the fracturing packer assembly is numbered with like numbers. In Fig. 3, however, the well bore is shown drilled below the bottom of the oil horizon to show that the packing element may be lowered very close to the bottom of the horizon so the lowermost portion of the horizon may be fractured.

In Fig. 4 is shown a second modification of the invention wherein it is desired to apply the fracturing pressure over an even larger cross-sectional area of the well bore than was contemplated in the modification shown in Fig. 3. The only difference in the constructions of Figs. 4 and 1 is that in Fig. 4 the two internal packers of Fig. 1 are replaced by two other substitute packers **16***c* and **16***d* of lesser diameter than the diameter of the well bore to be fractured when the packers **16***c* and **16***d* are fully expanded. This permits the by-passing of the pressurization media past the two inner packers to be held and stopped by the outer packers **23** and **23***a*. The selection for use of the modifications shown in Figs. 1, 3 and 4 depends largely upon what the purpose of the fracture of the oil horizon is, the condition of the well bore as to regularity, softness of sand, sloughing, etc., the depth of the oil horizon from its bottom level to its top level, the pressure required to fracture the sand and other like factors.

The purpose of the standing valve assembly in the bottom of the tubing is to permit insertion of the packing element or fracturing element into the hole bore through drilling mud or fluids present in the hole bore. Such fluids may enter the tubing as the tubing is moved downwardly through the fluids but when pressure is exerted from the interior of the tubing, the valve **22** seals.

In operation, the packing element or packing and fracturing element is positioned in the oil sand so the perforated center part thereof is opposite the area desired to be fractured of the oil horizon. Oil or other suitable pressurization media such as other liquids or air, other gases, etc., is then forced into the tubing under high pressure from whence it escapes through the perforations and exerts force equally on the two inner packers (in the Fig. 1 modification) and the face of the oil sand. The pressure applied expands the packers against the wall of the hole bore thereby sealing the pressure medium therebetween so that fracturing force is exerted on the oil sand. The outer packers operate to seal the two inner packers against any blow-by. When a larger pressurization area is desired, one or more inner packers may be replaced by smaller packers as shown in the modification in Fig. 4.

In a vertical drive gaseous pressurization method as set forth in my above entitled application and issued patents, wherein gaseous pressure is applied to the top portion of the oil horizon and liquid oil is recovered from the bottom of the horizon, it is often desirable to fracture both the top and bottom portions of the oil sand to provide greater access into the sand at the top thereof for the gaseous pressurization medium and greater outlet access at the bottom of the formation for liquid oil production therefrom. Previously this has been impossible due to the fact that it has not been feasible to closely limit the zone of fracturing when the face of an oil sand is fractured. The provision of the fracturing packer assembly previously described makes possible the application of fracturing now in such a vertical drive gaseous pressurization method for the production of oil. A series of applications of such a method coupled with fracturing of the horizon to amplify the pressurization and production access in an oil horizon is set forth below.

Referring now to Fig. 2, a cross-sectional view of an earth formation is shown with the overlying impermeable formations **35** above oil horizon **36**. Impermeable formations **37** below the horizon are also shown. The borehole **38** of an oil well is drilled to the top of the oil sand, pressurization casing **39** is set above the sand from the top thereof and cemented at **40** from the top of the sand to a level above the top thereof. Casing **39** has a pressure flow line **41** thereto with a valve **42** therein. Either before or immediately after the setting of casing **39** and cementing thereof the face of the borehole is fractured by a fracturing packer assembly such as is shown in Figs. 1, 3 or 4 at the bottom of the sand **41** and at the top of the sand **42**. It is desirable that the fractures **41** and **42** be as close as possible to the top and bottom portions of the sand for a number of reasons. In the first place, if the oil sand **36** is narrow it is desirable to avoid any vertical fissures or cracks which might run between the two fractures and permit migration of the gaseous pressurization medium therebetween. In the second place, the lower the bottom fracture is in the oil horizon, the longer time it will take before the gas-oil interface created by the input of gaseous pressurization medium into the top of the horizon will reach the fracture and thus end the usefulness of the production well. Production tubing **43** having flow line **44** at the upper end thereof and valve **45** therein is run to the vicinity of the bottom of the oil horizon (either above or below). Tubing **43** has inlet openings or perforations **46** in the lower end thereof. Tubing **43** is sealed to the well wall by packer **47** in the vicinity of the bottom of the oil horizon but above the bottom thereof and fracture **41**. Conventional **T 48** is positioned at the top of tubing **43** to permit the insertion of a pumping string therein.

The primary casing seal **40** above the top of the oil horizon is of such strength and extent as to confine within the oil formation such pressures as may be applied to the top of the horizon in the oil production method. The tubing sealing packer **47** is of such strength and cross-sectional area as to prevent leakage along the face thereof under such pressures as may be employed in the gaseous pressurization oil production method. The annulus **48** between the well wall and the tubing above the sealing packer **47** is filled with liquid (preferably slightly weathered oil of the same viscosity and gravity as the oil in the horizon) to a level above the top of the oil horizon **36**. This liquid is put into the annulus through flow line **41** in the casing **39**.

In operation gaseous pressure is then applied to the top of the fluid column in the annulus through the pressure flow line **41** whereby, when the pressure becomes sufficiently great, the top of the fluid column is forced below the top of the oil horizon and the gaseous pressure flows out into the topmost portion of the oil horizon. The fluid column in the annulus **48** is shown in Fig. 2 at three levels, A, B, and C. A represents the fluid level before the pressurization medium is applied into the casing annulus to force the column downwardly. B represents an intermediate level in the pressurization method when the gaseous pressure applied to the top of the liquid column has forced the liquid column below the top of the horizon, thus permitting the gaseous pressurization media to pass into the top of the horizon. The upper fracture **42** assists in the input of gaseous pressurization media. The gaseous pressurization input soon strikes an equilibrium between escape into the horizon and forcing downward of the fluid column and forming a gas cap whose gas-oil interface corresponds with the fluid column top. The level C represents a much later stage in the vertical gaseous pressurization method wherein the gas cap created by the input of gaseous pressurization media into the top of the formation has expanded both horizontally and vertically so that the oil in the formation has been driven downwardly below the level C. The pressurization may continue until the fluid column level in the annulus, which will correspond with the oil level in the oil horizon, migrates downwardly below the lower level of the packer **47** when the pressurization media would pass directly into the perforations **46** in the tubing **43** and no more oil would be produced from the well.

It is contemplated that oil may be pumped from the tubing if desired and T **48** is provided at the top of the tubing **43** for that purpose. If a gas pocket already exists in the top of the oil sand, it is preferable, of course, that the fracture be made in this zone so that increased pressurization input may be achieved. It is also contemplated that the permeability of various formations or levels in the oil horizon itself may differ. Thus, it may be necessary only to fracture the top portion of the horizon to increase pressurization input or, on the other hand, it may be necessary or desirable to fracture only the bottom portion to aid in the output of liquid oil. It is also contemplated to employ a plurality of wells such as are shown in Fig. 2 with either the top or bottom portions or both fractured positioned within an oil field.

Fig. 5 illustrates another application of the limited area fracturing applied in a vertical drive gaseous pressurization method. In the left well, the borehole **49** is drilled through earth formations **50** into oil horizon **51** and below the bottom thereof into formations **52**. To fracture as near to the bottom of the horizon as possible, the borehole is drilled preferably slightly below the lower level of the horizon. Surface casing **53** may be run to the top of the oil horizon and cemented **54** as shown. Either before or after this casing is run and cemented, a fracturing packer element as shown in Figs. 1, 3 or 4 is run to the vicinity of the bottom of the oil horizon and the oil horizon is fractured **55** as shown. The closer this fracture is to the bottom of the oil horizon, the more oil will be enabled to be produced from the horizon by the vertical drive gaseous pressurization method. Casing **53** having been run and cemented, as shown, and having flow line **56** with valve **57** therein, tubing **58** is run within the casing **53** to the vicinity of the bottom of the oil horizon and sealed to the casing **53** at the upper end thereof. Tubing **58** has inlet openings **59** at the lower end thereof and flow line **60** with valve **61** therein at the upper end thereof. Tubing **58** is sealed to the well wall in the vicinity of the bottom of the oil horizon but above the bottom thereof and above the fracture **55** therein by packer **62**. The primary casing cement seal **54** is of such strength and extent as to confine within the oil formation such pressures as may be applied to the top of the oil horizon during the operation of the method. The tubing seal (packer **62**) is of such strength and cross-sectional area as to prevent leakage across the face thereof at the pressures employed in the production method. The annulus **63** between the well wall and the tubing **58** above the sealing packer **62** is filled with liquid, preferably slightly weathered oil of the same viscosity and gravity as that in the oil horizon, to a level above the top of the oil horizon.

A separate pressurization well borehole **64** is then drilled into the top of the oil horizon. The top portion of the horizon is then fractured as at **65** by a fracturing packer assembly as in Figs. 1, etc., which is run into the borehole. The borehole must be drilled far enough below the top of the oil horizon **51** to permit the proper seating of the packers therebelow to be able to fracture at or just below the top face of the horizon. Casing **66** is then run to the top of the oil horizon or into the top of the oil horizon and sealed from the top of the oil horizon to a level above the top of the oil horizon. The seal **67** is of such strength and extent as to confine within the horizon any pressures which may be applied through the casing **66** thereto. Casing **66** has pressure flow line **68** with valve **69** therein attached the upper end thereof. Gaseous pressurization medium is then applied to the top portion of the oil horizon through flow line **68** on pressurization casing **66** in pressurization well borehole **64**. The pressurization media flows into the top portion of the oil horizon and forms a gas cap therein expanding both outwardly and downwardly driving the liquid oil therebefore and therebelow. A gas-oil interface appears at the boundary of the gas cap formed by the pressurization input. The gas cap expands outwardly and downwardly as previously described re Fig. 2 and, eventually, will reach the open borehole of the production well. In the meantime, of course, oil is being produced from the tubing **58** through the input openings **59**. Oil may also be pumped from tubing **58**, T **58***a* being provided for this purpose at the upper end thereof. When the gas cap reaches the well bore **49**, the pressurization media immediately will rise to the top of the liquid column at A and, exerting pressure on the top thereof, will force it downwardly as the pressurization becomes high enough below the top of the horizon and the casing **53**. The letters A, B and C represent successive levels of the liquid in the annular column as the gas cap expands downwardly. A represents the liquid column before the gas cap reaches the annulus. Eventually, all the oil will have been driven downwardly through the horizon and the gas-oil interface will pass below the packer **62** and the production well will be finished as a producer. It is also contemplated that in addition to the pressurization medium through the pressurization well casing additional gaseous pressurization media may be put into flow line **56** on casing **53** to aid in the pressurization process. Of course, if pressurization medium is not added to flow line **56**, while the pressure is being applied through the pressurization well casing **66** valve **57** on flow line **56** on the casing **53** must be closed.

In Figs. 6 and 7 is shown another modification of the vertical drive pressurization method employing fractured portions of the horizon with a pressurization well, the Fig. 7 well, essentially like that shown in the right well in Fig. 5 and the production well in Fig. 6 completed in a different manner. The pressurization well which also is of a type to be employed with the Fig. 8 production well will now be described once for both modifications. (Fig. 6 and Fig. 8.) The borehole **70** of an oil well or pressurization well is drilled through earth formations **85** into the top of an oil horizon **86**. The well bore is drilled below the top of the horizon a sufficient distance for a fracturing packer assembly as shown in Figs. 1, 3 or 4 to be set to fracture the face of the oil horizon either at or immediately below the top level thereof. After the top of the horizon is fractured as at **71**, casing **72** is run into the top of the oil horizon and cemented **73** from the top of the horizon to a level thereabove sufficient to prevent any escape of gaseous pressurization media thereabove. Casing **72** has pressure flow line **74** with valve **75** therein attached to the upper end thereof.

Referring now to the production well shown in Fig. 6, the borehole **76** of an oil well is drilled to the vicinity of the bottom of an oil horizon, preferably a little therebelow into formations **87** so that a fracturing packer assembly such as is shown in Fig. 1 may be set against the bottom of the oil horizon or very slightly thereabove and the oil horizon fractured as at **77**. After fracturing, a production tubing **78** having inlet openings **79** at the lower end thereof is run to the vicinity of the bottom of the oil horizon and packed off **80** at the vicinity of the bottom of the oil horizon but above the bottom thereof and above the fracture **77** therein. An annular column of sealing substance **81** such as cement is then poured in above the packer to a level above the top of the oil horizon. This sealing column **81** and the packer **80** are intended to prevent migration of gaseous pressurization media down the face of the well bore into the production area below the packer. Tubing **78** has flow line **82** and valve **83** therein at the upper end thereof. Conventional **T 84** at the upper end thereof permits insertion of a pumping string in the tubing **78**, should such be desired.

In operation, the Fig. 7 well is used only for pressurization and the Fig. 6 well is used only for production. Gaseous pressurization media, such as air, is forced in through flow line **74** into casing **72** and thence out into the top of oil horizon **86**. An expanding gas cap is formed which moves both outwardly and downwardly driving the liquid oil in the horizon downwardly to be recovered from the production area below the packing **80** through the perforations **79** in the tubing **78**. Should the gas cap expand to the well bore **76**, the sealing column **81** prevents any migration down the well bore face and the gas cap expansion continues in regular fashion until the gas-oil interface formed between the pressurization zone and the oil in the horizon passes below the packer **80**. At that point, most of the oil in the horizon has been exhausted therefrom and the production well is finished as a producing unit.

It is, of course, in the Fig. 6 modification as well as in the Fig. 5 modification, contemplated that the method be employed both in a plurality of production wells and/or a plurality of pressurization wells positioned relative one another in an oil horizon. Oil may be pumped from the tubing **78** with the aid of conventional **T 84**. Again, especially in an oil horizon of relatively small cross section, it is desirable that both fractures **71** and **77** be as close to the respective boundaries of the formation **86** as possible.

In Fig. 8 combined with Fig. 7 is shown another modification of the vertical drive gaseous pressurization method employed in conjunction with fracturing of the oil horizon. In this modification, the production well is in Fig. 8 and the pressurization well is in Fig. 7. The center well has already been described. In the production well, the borehole **88** is drilled to the vicinity of the bottom of the horizon **86** and preferably a little bit below so as to permit fracturing of the horizon as close to the bottom thereof as possible. After the borehole **88** has been drilled, a fracturing packer assembly such as is shown in Fig. 1 is run into the borehole of the well in the vicinity of the bottom of the horizon but above the bottom thereof and the horizon is cracked as shown at **89**. Casing **90** is then run within the oil horizon to the vicinity of the bottom of the oil horizon but above the bottom thereof and above the upper limit of the fracture **89**. The casing **90** is then cemented or sealed **91** from the bottom thereof to a level above the top of the oil horizon so as to seal the well wall and borehole against any migration of gaseous pressurization media therealong. Casing **90** has conventional **T 92** at the top thereof to permit pumping of fluid oil from the casing and also has flow line **93** with valve **94** therein attached to the top end thereof.

In operation, gaseous pressurization media is again put into the top of the oil horizon through the fracture **71** below the pressurization well borehole **70**. A gas cap and gas-oil interface is formed which expands outwardly and downwardly within the oil horizon driving the oil therebefore. When the gas cap reaches the well bore **88**, the sealing column **91** prevents any migration of gaseous pressure therealong. The gas cap must expand downwardly within the oil horizon until the gas-oil interface passes below the end of the casing **90** and sealing column **91** to end the usefulness of the production well as a producer. Again, the method in this modification may be employed in a plurality of pressurization and/or production wells. The seals along the casing **90** and the pressurization casing **72** must be of the character previously described to prevent any leakage or migration of the pressurization media therealong.

As the character, softness, permeability, etc., of an oil sand vary throughout its volume, it is also contemplated that a number of pressurization and/or production wells be provided within a given oil sand finished in a variety of ways, as shown in Figs. 2, 5, 6 and 7. In each instance, the horizon may be fractured at the top and/or at the bottom to improve either the pressurization characteristics at the top of the sand or the oil output characteristics at the bottom of the sand.

Generally speaking, the inventive method as applied to the production of oil from an oil horizon comprises the steps of (1) running a channel to the top portion of an oil horizon, (2) fracturing the oil horizon at or immediately below the top portion of the oil horizon, (3) running a channel to the bottom portion of the oil horizon, (4) fracturing the horizon at or immediately above the bottom portion of the oil horizon, (5) sealing a portion of the channel running to the top portion of the horizon to the well wall from the top of the horizon to a level above the top thereof, (6) sealing a portion of the channel running to the bottom of the oil horizon to the well wall from a level above the bottom of the horizon and above the lower fracture to a level adjacent the top of the horizon but below any fracture thereof, (7) applying gaseous pressure to the top of the oil horizon through the channel to the top thereof, and producing oil from the channel to the bottom of the oil horizon.

Again, generally considering the method, it consists of providing a limited gaseous pressurization zone in the top portion of an oil horizon sealed off from the earth formations above the oil horizon and communicating with the surface with a first pressure-tight channel, the pressurization zone being fractured before sealing near the top of the horizon, providing an oil production zone adjacent the bottom portion of the horizon sealed off from the oil horizon thereabove at least to the bottom of the gaseous pressurization zone and communicating with the surface through a second pressure-tight channel, the production zone being fractured near the bottom of the horizon before sealing, applying gaseous pressure to the top of the oil horizon in the gaseous pressurization zone through the first pressure-tight channel and producing oil from the bottom of the horizon at the oil production zone through the second pressure-tight channel.

From the foregoing, it will be seen that this invention is one well adapted to attain all of the objects and ends hereabove set forth together with other advantages which are obvious and which are inherent to the structure.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. Apparatus for fracturing limited zones in oil wells comprising a length of tubing attachable at its upper end to a pipe string leading to the surface, means for sealing the lower end of said tubing against fluid flow from within the tubing, a portion of said tubing intermediate the upper and lower ends thereof of greater outer diameter than the remainder of said tubing, at least one perforation in said greater outer diameter tubing por-

tion communicating between the interior and exterior thereof, upper and lower primary expandable cup-shaped packers each slidable on said tubing to a position each abutting the upper and lower extremities respectively of the greater outer diameter tubing portion, the concave portions of said primary packers adjacent said greater outer diameter tubing portion, upper and lower collars each slidable on said tubing above and below the upper and lower primary packers, respectively, to abut the primary packers on the sides thereof away from the greater outer diameter portion of the tubing, upper and lower secondary expandable cup-shaped packers each slidable on said tubing to a position each abutting the upper and lower extremities of said collars, the concave portions of said secondary packers adjacent said collars, means fixable to said tubing above and below said secondary packers for compacting said primary packers against the greater outer diameter tubing portion, the collars against said primary packers and the secondary packers against said collars, the outer diameter of the packers when fully expanded greater than the inner diameter of the well bore to be fractured.

2. Apparatus for fracturing limited zones in oil wells comprising a length of tubing having means at its upper end to attach it to a pipe string, means for sealing the lower end of said tubing against fluid flow from within the tubing, a portion of said tubing intermediate the upper and lower ends thereof of greater outer diameter than the remainder of said tubing, at least one perforation in said greater outer diameter tubing portion communicating between the interior and exterior thereof, upper and lower primary expandable cup-shaped packers each abutting the upper and lower extremities respectively of the greater outer diameter tubing portion, the concave portions of said primary packers adjacent said greater outer diameter tubing portion, upper and lower collars each positioned above and below the upper and lower primary packers, respectively, abutting the primary packers on the sides thereof away from the greater outer diameter portion of the tubing, upper and lower secondary expandable cup-shaped packers each above and below the upper and lower collar, respectively, abutting the upper and lower extremities thereof, the concave portions of said secondary packers adjacent said collars, means fixed to said tubing above and below said secondary packers compacting said primary packers against the greater outer diameter tubing portion, the collars against the primary packers, and the secondary packers against said collars, the outer diameter of the packers when fully expanded greater than the inner diameter of the well bore to be fractured.

3. Apparatus as in claim 2 wherein the means for sealing the lower end of the tubing against fluid flow from therewithin comprises a check valve sealing against internal pressure and opening against external pressure.

4. Apparatus as in claim 2 wherein the means for compacting the packers and collars relative the greater outer diameter portion of the tubing comprise upper and lower secondary collars threaded on the tubing and exerting force against the secondary packers.

5. Apparatus as in claim 2 including a metal cup retainer receiving the convex portions of each of said primary and secondary packers.

6. Apparatus as in claim 2 wherein the outer diameter of the collars between the packers is no greater than the greater outer diameter tubing portion.

7. Apparatus as in claim 4 wherein the outer diameter of the greater outer diameter tubing portion and the primary and secondary collars is substantially the same.

8. Apparatus as in claim 2 wherein the greater outer diameter portion of the tubing has an internal diameter substantially that of the rest of the tubing.

9. Apparatus as in claim 2 wherein the upper and lower portions of the greater outer diameter tubing portion are tapered.

10. Apparatus as in claim 2 wherein the upper and lower portions of said collars are tapered to receive the secondary packers.

11. Apparatus as in claim 2 wherein the greater outer diameter portion of the tubing is mounted substantially centrally thereof.

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