Nov. 6, 1962 J. L. HUITT ET AL 3,062,294

APPARATUS FOR FRACTURING A FORMATION

Filed Nov. 13, 1959 2 Sheets-Sheet 1

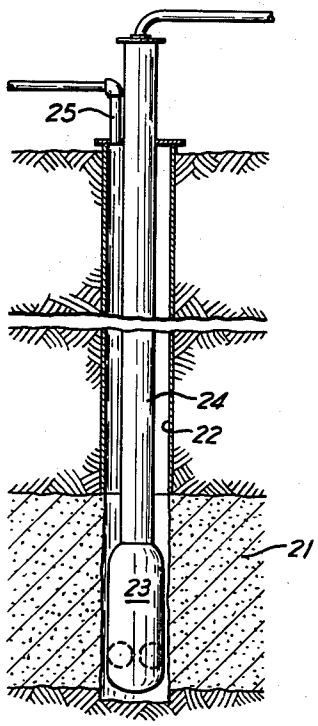


Fig. 1

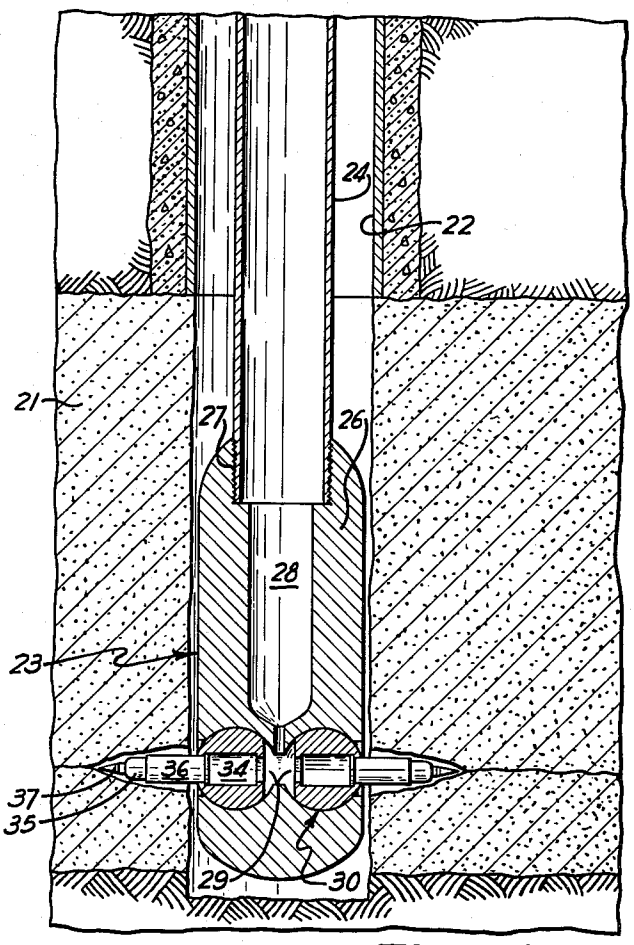


Fig. 2

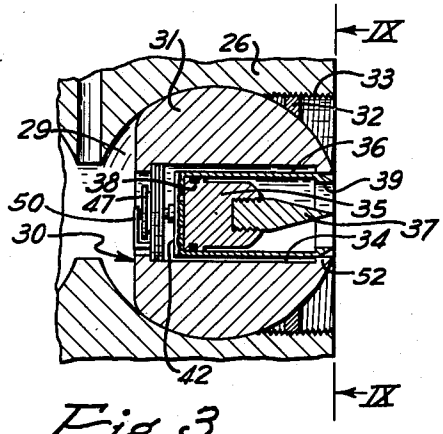


Fig. 3

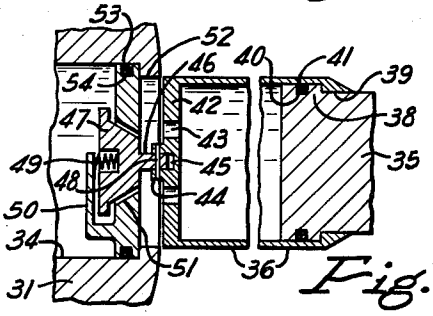


Fig. 4

INVENTORS
JIMMIE L. HUITT
JOSEPH L. PEKAREK
BY ABRAHAM J. TEPLITZ

ATTORNEY

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APPARATUS FOR FRACTURING A FORMATION

Filed Nov. 13, 1959 2 Sheets-Sheet 2

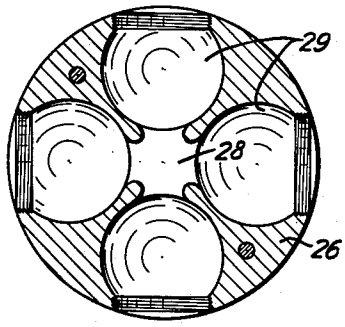


Fig. 5

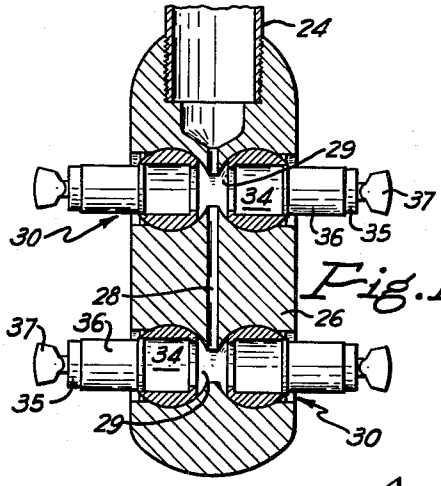


Fig. 12

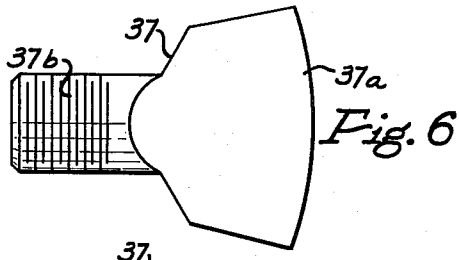


Fig. 6

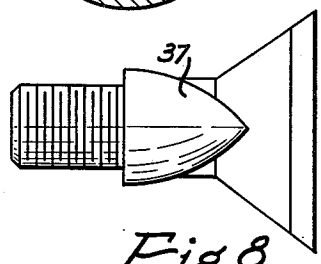


Fig. 8

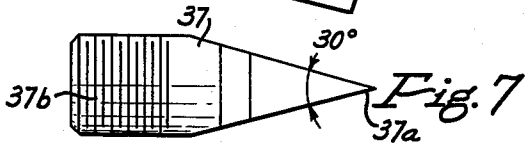


Fig. 7

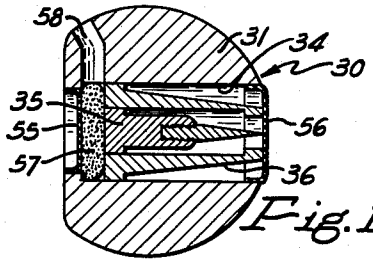


Fig. 10

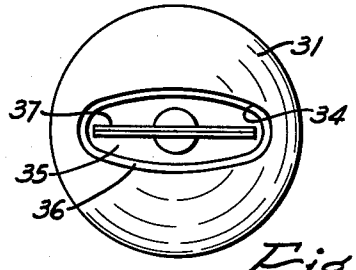


Fig. 9

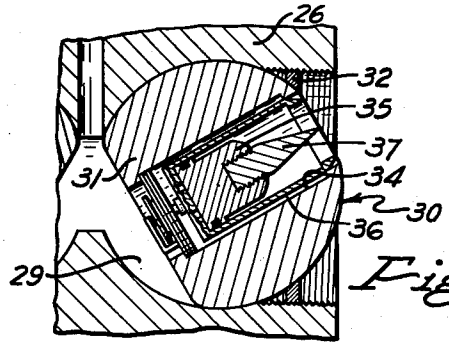


Fig. 11

INVENTORS
JIMMIE L. HUITT
JOSEPH L. PEKAREK
BY ABRAHAM J. TEPLITZ

ATTORNEY

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APPARATUS FOR FRACTURING A FORMATION

Jimmie L. Huitt, Glenshaw, and Joseph L. Pekarek and Abraham J. Teplitz, Penn Hills, Pa., assignors to Gulf Research & Development Company, Pittsburgh, Pa., a corporation of Delaware

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4 Claims. (Cl. 166—177)

This invention relates to apparatus for use in treating wells and more particularly to apparatus which is adapted to initiate fractures in subterranean formations.

The apparatus of our invention is particularly adapted for initiating fractures in subterranean formations in accordance with the newly developed method for completing wells which is disclosed and claimed in the patent application of Malcolm R. J. Wyllie, Serial No. 852,847, filed November 13, 1959. In the Wyllie method, fractures are produced in an earth formation by driving a tool having a sharp penetrating edge surface into the formation in a given radial direction with sufficient force to effect cleavage of the formation and to develop a surface or plane of weakness in the formation so oriented that it permits a fracture to be extended in the formation in a desired plane and direction. Thereafter, a fracture is extended in the formation by the application of hydraulic pressure. With the application of hydraulic pressure the fracture propagates along the plane of weakness which has been developed artificially in the formation and can be extended for a desired distance into the formation utilizing much lower hydraulic pressure than is normally required to initiate the fracture. The Wyllie method provides a convenient method of creating a fracture at a single point of predetermined depth in the earth and in a predetermined orientation with respect to the borehole. The present invention provides an apparatus which is particularly advantageous for use in initiating fractures in accordance with the Wyllie method.

The apparatus of the invention, in general, comprises a generally cylindrical body member or mandrel adapted to be connected to the lower end of a drill pipe. The mandrel is provided with an interior longitudinal chamber and a plurality of chambers having a generally globular configuration disposed around the periphery of said mandrel in fluid communication with said interior chamber. Conforming in shape and mounted within the said peripherally disposed chambers are bodies having a central bore formed therein in which there is slidably mounted in telescopic arrangement bit members having sharp penetrating edge surfaces which are adapted to be forced into the walls of the borehole to cleave the formation and to develop oriented planes of weakness in the formation. The interior longitudinal chamber in the mandrel registers with the string of the drill pipe through which a hydraulic fluid may be supplied to force the penetrating bit members into the formation.

The invention can best be described in detail with reference to the drawings in which:

FIGURE 1 is a diagrammatic view in vertical section of a bore hole showing the apparatus of the invention positioned therein opposite a producing formation in which a fracture is desired.

FIGURE 2 is a view partially in cross-section of the apparatus of the invention showing the formation penetrated by the apparatus of the invention.

FIGURE 3 is a vertical view in cross-section of one of the bit-projecting units of the apparatus of the invention.

FIGURE 4 is a detailed cross-sectional view of valve means for shutting off fluid flow through the bit-projecting unit of FIGURE 3.

FIGURE 5 is a plan view in cross-section of one embodiment of the apparatus in which four bits may be employed to penetrate the formation at 90° angles.

FIGURE 6 is a plan view of a bit member having an arcuate penetrating edge surface which is employed in the apparatus of the invention.

FIGURE 7 is a side view of the bit of FIGURE 6.

FIGURE 8 is a plan view of a bit having a straight penetrating edge surface which is employed in the apparatus of the invention.

FIGURE 9 is a frontal view taken on the line IX—IX of FIGURE 3.

FIGURE 10 is a modified form of the apparatus of the invention.

FIGURE 11 is a view partially in cross-section of a further modification of the apparatus of the invention.

FIGURE 12 is a view partially in cross-section of still another form of the apparatus of the invention.

Referring particularly to the drawings, FIGURE 1 shows a vertical section of an underground earth formation 21 penetrated by a wellbore and casing 22. Disposed within the wellbore at the depth at which a horizontal fracture is desired in the formation is the fracturing apparatus of the invention designated generally by the numeral 23. Drill string 24 extends downwardly through the casing head and connects the fracturing apparatus 23 with a source of fluid supply (not shown). Tubing 25 is provided for injection of a conventional fracturing fluid.

As shown more particularly in FIGURES 2 and 3, the device of the invention comprises a body member or mandrel 26 having a threaded portion 27 at its upper end which is adapted to receive the threaded lower end of drill string 24 and in this manner the fracturing apparatus is connected to, supported from and receives pressure fluid from the drill string. The mandrel 26 is provided with an interior longitudinal chamber 28 which is in fluid communication with chambers 29 which are disposed around the periphery of the mandrel. The chambers 29 have a generally globular configuration and are illustrated in the drawings as being spheroidal in shape. However, the chambers can also be spherical in shape and can be varied in number as will be explained hereinafter.

Located within the spheroidal chambers 29 are the bit-projecting units designated generally by the numeral 30. The bit-projecting units 30 consist of a barrel 31 which conforms in shape to chambers 29 and fits snugly therein. The globular shape of chambers 29 and barrels 31 is important since this configuration enables the barrels 31 to be mounted within the chambers 29 in any desired position so as to initiate substantially horizontal fractures or fractures sloping at a desired angle from the horizon. Lock ring 32 threadably engages the threaded portion 33 of mandrel 26 and serves to maintain the barrel 31 in fixed position within the chamber 29. Barrel 31 is formed with an elongated non-cylindrical central bore 34 in which is located piston 35. As shown more clearly in FIGURE 9, bore 34 within barrel 31 is non-cyclindrical or non-circular in cross-section. This configuration effectively prevents rotation of the piston 35 relative to the barrel 31 thereby insuring that the penetrating bit members attached to piston 35 enter the formation in the desired plane. Bore 34 within barrel 31 can have any configuration which will prevent rotation of the piston 35 relative to barrel 31. Piston 35 fits slidably within the sleeve member 36 and has attached to its outer end the penetrating bit members 37 which are adapted to penetrate and cleave the earth formation. The rear portion 38 of piston 35 abuts against inwardly projecting flange 39 on sleeve 36 to limit the extent of the forward movement of piston 35 relative to sleeve 36. The rear portion 38 of piston 35 is provided with a circumferential groove 40 within which is disposed suitable packing material 41 for providing a fluid tight seal.

As shown in FIGURE 4, the rear wall 42 of sleeve

member 36 is provided with a number of openings 43 which allow passage of a pressure fluid to act upon piston 35 and thereby drive the bit members 37 into the formation. The enlarged center portion 44 of wall 42 is provided with a recess 45 which receives in loose fit extension or lug 46 of valve 47. Valve 47 is attached to the rear wall 42 of sleeve 36 by means of shear pin 48 so that the valve 47 moves in conjunction with sleeve 36. Spring 49 attached to valve 47 and arm 50 of valve seat 51, in cooperation with shear pin 48 maintains valve 47 in the open position as shown in FIGURE 4. Valve seat 51 is dimensioned to fit slidably within bore 34 and to form a fluid-tight seal when abutting against the inwardly projecting flange 52 on barrel 31. O-rings 53 of suitably deformable material are disposed in outer circumferential grooves 54 in the valve seat 51 to form a fluid-tight seal between the valve seat 51 and bore 34.

As shown in FIGURE 5, the apparatus of the invention can be provided with four peripherally disposed spheroidal chambers 29 when it is desired to create simultaneously horizontal fractures in the walls of the borehole spaced at 90° angles. The apparatus can be constructed with as few as two peripherally disposed chambers 29. However, it is ordinarily desired to create a plurality of radially extending horizontal fractures in the walls of the borehole which when extended by known hydraulic fracturing techniques may meet to form a single fracture radiating in all directions 360° around the borehole. For this reason, it is preferred to provide in the apparatus a greater number such as for example, four or more, of the peripherally disposed chambers 29 and bit projecting units 30. By employing a series of horizontally spaced bits around the periphery of the fracturing apparatus, the space between the individual fractures is reduced, thus facilitating the creation of a single 360° fracture.

The apparatus of the invention can be employed to create or initiate generally horizontal fractures in earth formations, that is, fractures in a plane more or less parallel with the horizon or in planes sloping from the horizon. By virtue of their matching, generally globular configuration, the bit-projecting units 30 can be mounted within the chambers 29 in any desired position so that the pistons 35 and the bit members 37 are disposed at any desired angle from the horizon. Thus, for example, the bit-projecting units 30 can be mounted within chambers 29 as shown in FIGURE 11 to create a fracture sloping at an angle of about 30° from the horizon. This feature is particularly advantageous when the apparatus is to be used in a borehole which deviates from the vertical, since by simply adjusting the relative position of the bit-projecting unit 30 within chambers 29, compensation can be made for the deviation of the borehole.

In FIGURE 12 there is shown a modified form of the apparatus which is adapted to create vertical fractures in the earth formations. As seen in FIGURE 12, a plurality of spheroidal chambers 29 and bit-projecting units 30 are arranged in vertically spaced relationship within the body 26 of the fracturing apparatus. In this embodiment of the invention, the bit members 37 are attached to piston 35 in such manner that the sharp forward earth penetrating edges of the bits are disposed in a vertical plane. This arrangement results in the formation of a vertical fracture in the formation when the bits are caused to penetrate the fracture. Obviously, the body or mandrel 26 may be made as long as practical and provided with any number of chambers 29 and bit-projecting units 30 for creating a desired vertical fracture. Moreover, a suitable number of chambers 29 and bit-projecting units 30 arranged in vertically spaced relationship can be provided around the periphery of the fracturing apparatus to create vertical fractures in the earth formation in any desired radial direction from the borehole.

The bit members 37 which are adapted to penetrate and fracture the earth formation can be of various design. The bit members 37 will, in general, be formed of hardened steel or the like and be provided with sharp penetrating edge surfaces which enable the bits to readily penetrate the earth formation. The opposed working surfaces leading back from the penetrating edges of the bits are preferably inclined so that the bits increase in thickness from the penetrating edge rearwardly. This structure enables the bits to readily cleave the formation. The sharp forward or penetrating edges of the bits develop a sufficient concentration of stress in the formation to establish a plane of weakness therein extending from the apex of the V-shaped fracture a substantial distance into the formation. The included angle at the forward or penetrating edge of the bit may thus range from about 10° to 60°.

When employing the fracturing apparatus of the invention to create substantially horizontal fractures or fractures sloping at an angle from the horizon, it is preferable to employ bits having arcuate or curved penetrating edge surfaces of substantially the same degree of curvature as the borehole to prevent point contact between the edge of the bit and the walls of the borehole. In FIGURE 6, there is shown a preferred bit 37 having an arcuate penetrating edge 37*a*. The rear portion 37*b* is threaded for attachment to piston 35. FIGURE 7 which is a side view of the preferred bit 37 shows that the included angle at the penetrating edge of the bit is 30°.

FIGURE 8 shows a bit 37 having a straight penetrating edge surface which is likewise suitable for use in the apparatus of the invention. As is apparent, bits having straight penetrating edge surfaces are preferred for use in creating vertical fractures.

The size of the fracturing apparatus and the elements thereof will vary depending upon the intended usage of the apparatus. In general, the diameter of the fracturing apparatus will be smaller than the diameter of the borehole in which it is employed and yet will not be so small as to preclude the bits from penetrating the walls of the borehole when at the extreme extent of their outward travel. The extent of the penetration of the bits into the formation will vary and may range from a small fraction of an inch up to several inches depending upon the properties of the formation, the fluid pressure applied to the pistons, and the size of the fracturing apparatus and the elements thereof in relation to the borehole.

In operation of one embodiment of the fracturing apparatus of the invention, the apparatus 23 is connected to a drill string 24 and run into a borehole to the desired depth. Fluid pressure is then applied to the apparatus through the drill string 24. The pressure fluid passes through the interior longitudinal chamber 28 into spheroidal chambers 29 and central bore 34 within the barrel 31. Valve 47 in its normally open position permits passage of pressure fluid through the valve and through openings 43 in rear wall 42 of sleeve element 36 to act upon the piston 35. The fluid pressure forces piston 35 outwardly thereby causing the bits 37 to penerate the walls of the borehole and produce a parting in the formation. Sufficient force is directed outwardly against piston 35 by the fluid pressure to insure that the bits 37 penetrate the formation a sufficient distance to cleave the formation and to develop an artificial plane of weakness therein in the desired plane and direction.

As piston 35 continues its outward travel under the action of the fluid pressure, the rear portion 38 of the piston engages flange 39 on sleeve 36 causing the sleeve together with valve 47 to which it is attached to move outwardly through the bore 34. By continuing the application of fluid pressure, the piston 35 and sleeve 36 eventually emerge from barrel 31. The emergence of sleeve 36 from the barrel 31 permits the pressure fluid to flow freely into the borehole thereby creating a substantial pressure differential across the valve 47. The pressure differential across valve 47 is sufficient to shear pin 48

and to seat valve 47 in valve seat 51 against the resisting force of spring 49. The seating of valve 47 in valve seat 51 prevents further fluid flow through the bore 34, and causes a significant build up in pump pressure which indicates to the operator that the earth penetrating bits have separated from the apparatus. The fluid pressure in drill string 24 is released to allow valve 47 to open and withdraw lug 46 from recess 45. The fracturing apparatus can then be withdrawn from the wellbore leaving the bits within the formation to maintain open the induced fracture.

Liquids or gases such as air may comprise the fluid pressure working medium. The fluid pressure required to force the bits into the formation will depend upon various factors and particularly the area of the piston 35, the extent of overburden and geological characteristics of the formation such as the tensile strength of the formation, plasticity of the formation, that is, the amount of distortion the formation exhibits between the yield point and the point of rupture and so forth. Another factor which influences the fluid pressure required to force the bit into the formation is the sharpness of the penetrating edge of the bit. Generally, bits having sharp penetrating edges will penetrate and cleave the formation under lower fluid pressure than bits having more blunt edges. The fluid pressure required to fracture a particular formation can readily be determined experimentally by those skilled in the art. The fluid pressure applied through the drill string to force the bits into the formation may be applied continuously or intermittently to drive the bit into the formation with an impulsive force. Thus, for example, the penetrating bits 37 can be forced into the formation by applying pressure to within 200 pounds per square inch of the determined fracture pressure, releasing the pressure and repeating this operation for a number of cycles.

Means other than hydraulic pressure can be employed to operate the fracturing apparatus of the invention. Thus, for example, propellant charges can be employed for driving the bits into the formation. In this respect the apparatus can be modified as illustrated in FIGURE 10 which is a cross-sectional view of one of the bit-projecting units 30. The barrel 31 is provided with a non-cylindrical bore 34 which is closed at its inner end as at 55. A frangible diaphragm 56 closes the outer end of bore 34. A propellant charge such as black powder or the like is provided in space 57 behind the tapered sleeve 36 and piston 35. A recess 58 is provided in barrel 31 to receive a suitable detonator for detonating the propellant charge. The detonator employed can be any of those commonly employed for this purpose such as for example, a conventional pressure-actuated type detonator.

From the foregoing, it will be seen that with apparatus constructed in accordance with this invention fractures can be created in earth formations at a predetermined depth and predetermined orientation with respect to the wellbore. The apparatus can be employed to initiate fractures in earth formations in any desired plane and radial direction. Thus, the purpose of the invention has been effectively accomplished.

Obviously the apparatus of the invention is susceptible to modification and variation in its construction. For example, when actuation of the device is accomplished by means other than fluid pressure, the interior longitudinal chamber can be eliminated from the apparatus. Moreover, the number of bit-projecting units employed in the apparatus can be varied. Therefore, those modifications and variations which fall within the spirit of the invention and the scope of the appended claims are to be considered part of the invention.

We claim:

1. Apparatus for initiating fractures in subsurface formations penetrated by the borehole of a well, comprising a mandrel having a chamber of generally globular shape disposed therein intersecting the outer surface of the mandrel to form an outer port, a body member of generally globular shape fitting rotatably within said chamber, means engaging the mandrel and body member for locking the body member in a desired position in the chamber, said body members having an elongated non-cylindrical bore extending from the end of the body member adjacent the outer port inwardly into the body member, a non-cylindrical piston fitting slidably within said non-cylindrical bore, a bit member extending from the outer end of the piston, and means for applying fluid pressure to the end of the piston opposite the bit member to force the bit member outwardly to cleave the formation.

2. Apparatus for initiating fractures in subsurface formations penetrated by the borehole of a well, comprising a mandrel having a plurality of chambers of generally globular shape located around the periphery of the mandrel whereby the chambers intersect the outer surface of the mandrel to form a plurality of outer ports, a body member of generally globular shape fitting rotatably within each of said chambers, means engaging the mandrel and the body members to lock the body members in a desired position in the chambers, a passage through the mandrel communicating with each of the chambers near the center of the mandrel, each of said body members having a non-cylindrical bore extending therethrough in alignment with the outer ports, a non-cylindrical sleeve fitting snugly and slidably within each bore, a non-cylindrical piston slidable within each sleeve, means on the pistons adapted to engage the sleeves and limit outward movement of the pistons relative to the sleeves, a bit member on the outer end of each of the pistons, and means for applying fluid pressure to the passage whereby the pistons and sleeves are driven outwardly in the bores to cleave the formation.

3. Apparatus for initiating fractures in subsurface formations penetrated by the borehole of a well, comprising a mandrel having a plurality of chambers of generally globular shape located around the periphery of the mandrel whereby the chambers intersect the outer surface of the mandrel to form a plurality of outer ports; a body member of generally globular shape fitting rotatably within each of said chambers; means engaging the mandrel and the body members to lock the body members in a desired position in the chambers; each of said body members having a non-cylindrical bore extending therethrough in alignment with the outer ports; an inwardly extending lip at the outer end of each bore; a non-cylindrical sleeve within each bore adapted to slidably engage said lip; a non-cylindrical piston slidable within each sleeve; means on the pistons adapted to engage the sleeves and limit outward movement of the pistons relative to the sleeves; a bit member on the outer end of each of the pistons; a passage through the mandrel communicating with each of the chambers whereby fluid pressure applied in said passage is transmitted to the pistons to drive the bit members into the borehole wall; said sleeve having a rear wall across its inner end; said rear wall having openings therein; a valve element extending inwardly from the rear wall of the sleeve; said valve element comprising a disc slidable in said bore and adapted to engage the lip whereby outward movement of the disc is limited, sealing means engaging said disc and body member to prevent flow therebetween, a valve port extending through the disc, a valve plug adapted to close the disc, resilient means supporting the valve plug adjacent said valve port in a position allowing flow through the valve port, said resilient means allowing movement of the valve plug to close the valve port in response to an increase in pressure drop across the disc; and shearable means connecting the valve element and the sleeve.

4. Apparatus for initiating fractures in subsurface formations penetrated by the borehole of a well, comprising a mandrel adapted to be connected to the lower end of a string of pipe for positioning said mandrel at the desired location in the well, said mandrel having a plu-

rality of chambers of generally globular shape located around the periphery of the mandrel whereby the chambers intersect the outer surface of the mandrel to form a plurality of outer ports, a body member of generally globular shape fitting rotatably within each of said chambers, means engaging the mandrel and the body members to locate the body members in the desired position in the chamber, a passage through the mandrel extending from the opening in the pipe on which the mandrel is run into the well to each of the chambers, each of said body members having a non-cylindrical bore extending therethrough in alignment with the outer ports, a non-cylindrical sleeve fitting snugly and slidably within each bore, a non-cylindrical piston slidable within each sleeve, means on the pistons adapted to engage the sleeves and limit outward movement of the pistons relative to the sleeves, and a bit member on the outer end of each

of the pistons whereby on the application of fluid pressure on the pipe the pistons and sleeves move outwardly in the bore to drive the bit members into the borehole wall to cleave the formation.

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