April 22, 1958 G. E. CONOVER 2,831,541

HYDRAULIC PACKER TOOL

Filed Aug. 13, 1953 4 Sheets-Sheet 1

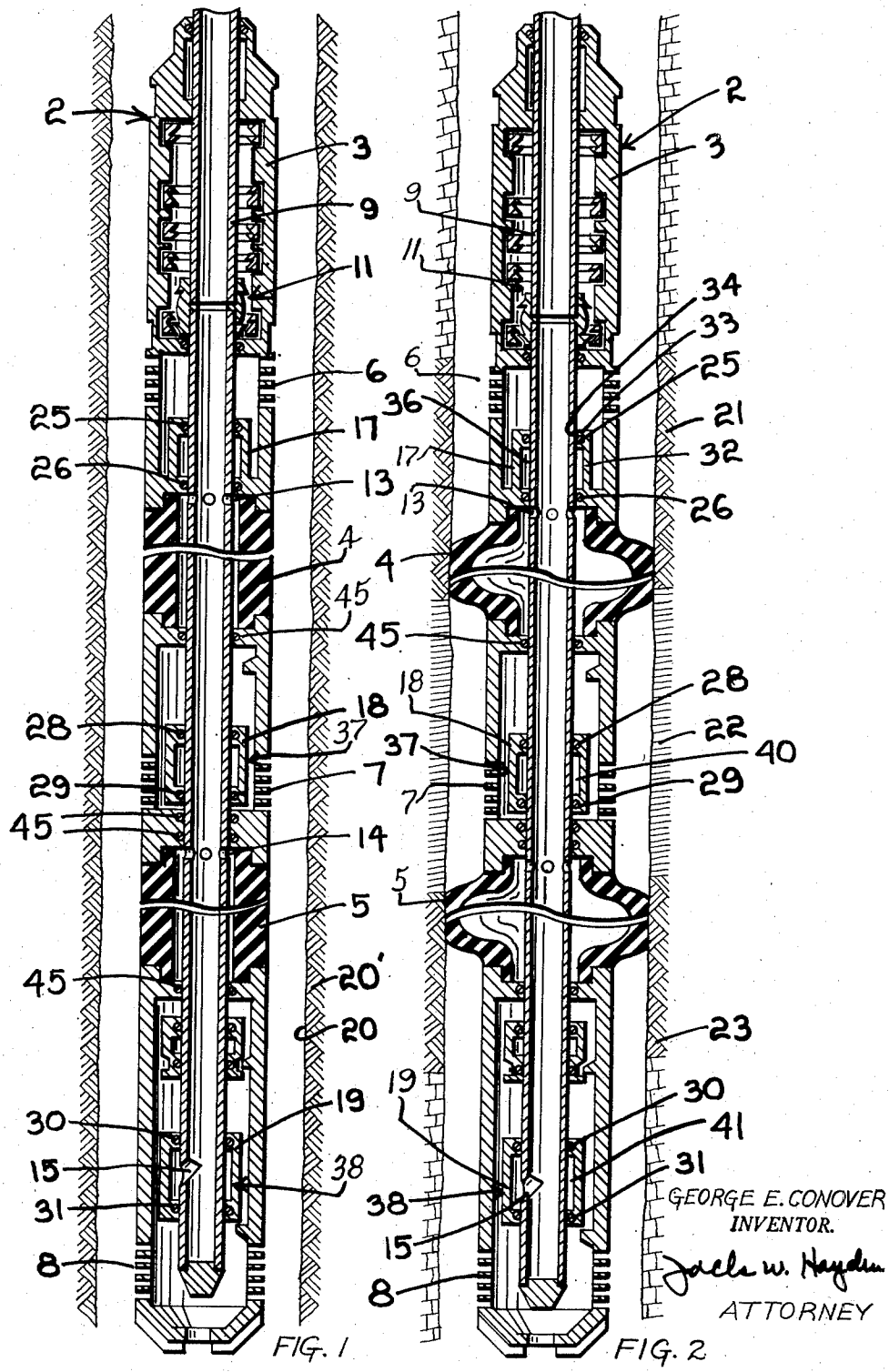

FIG. 1 FIG. 2

GEORGE E. CONOVER
INVENTOR.

Jacob W. Hayden
ATTORNEY

April 22, 1958 G. E. CONOVER 2,831,541

HYDRAULIC PACKER TOOL

Filed Aug. 13, 1953 4 Sheets-Sheet 2

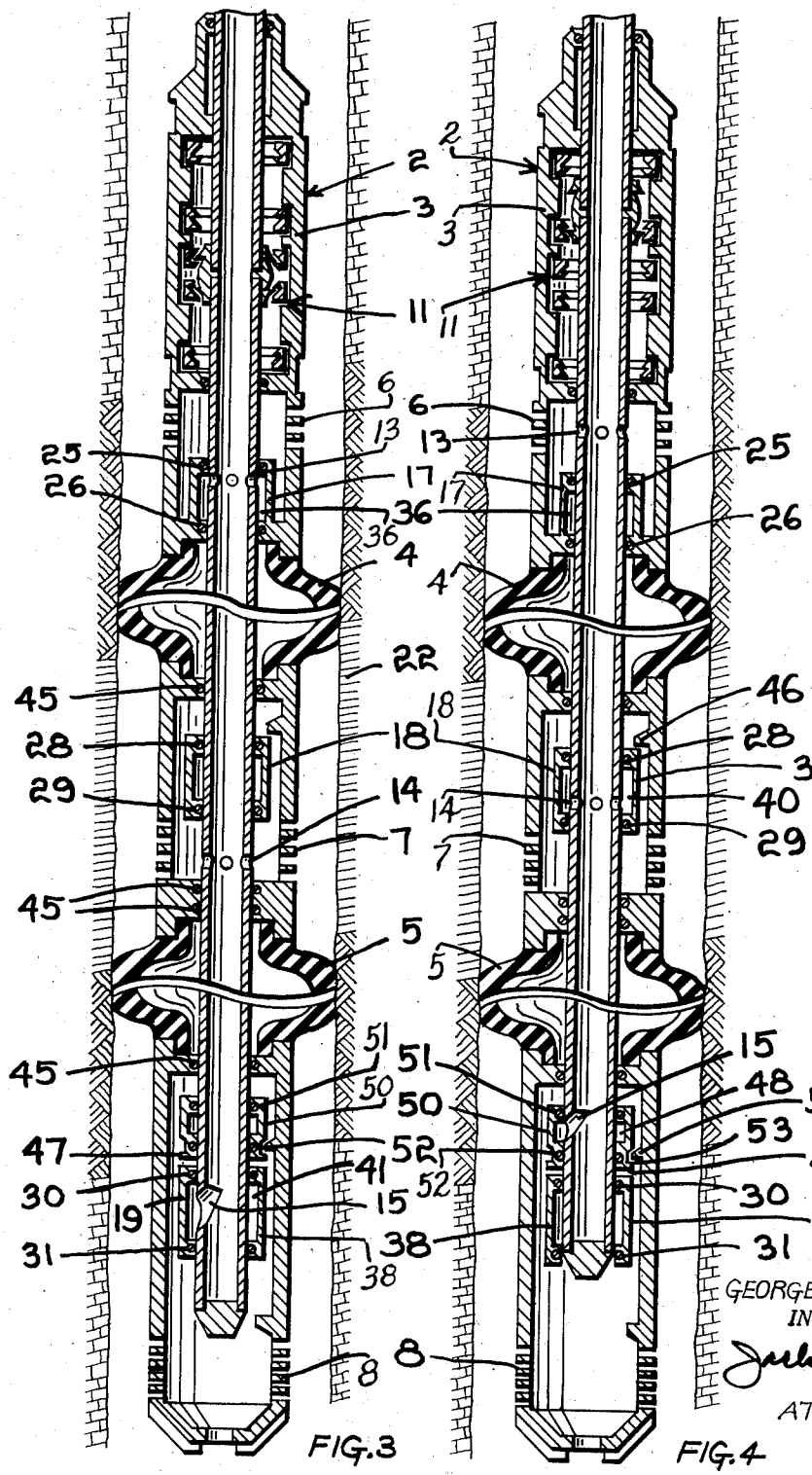

FIG. 3

FIG. 4

GEORGE E. CONOVER
INVENTOR.

Jack W. Hayden

ATTORNEY

April 22, 1958 G. E. CONOVER 2,831,541

HYDRAULIC PACKER TOOL

Filed Aug. 13, 1953 4 Sheets-Sheet 3

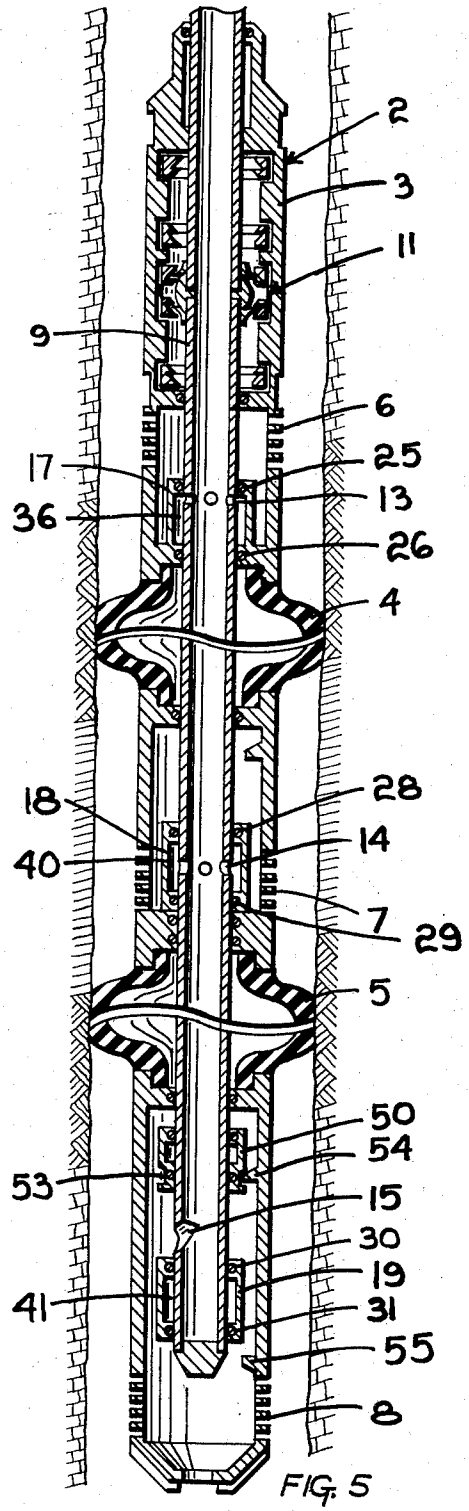

FIG. 5

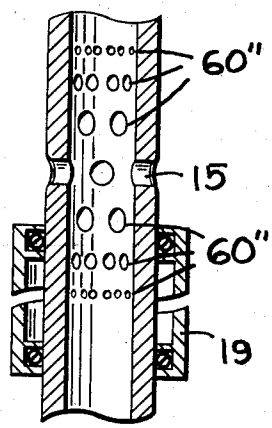

FIG. 9

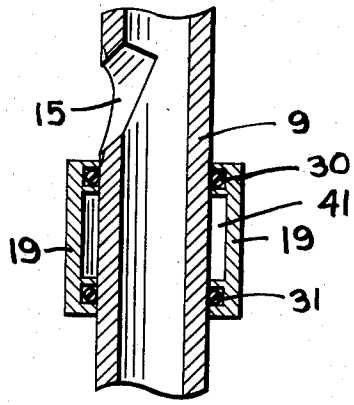

FIG. 6

GEORGE E. CONOVER
INVENTOR.

BY Jacob W. Hayden
ATTORNEY

April 22, 1958 G. E. CONOVER 2,831,541

HYDRAULIC PACKER TOOL

Filed Aug. 13, 1953 4 Sheets-Sheet 4

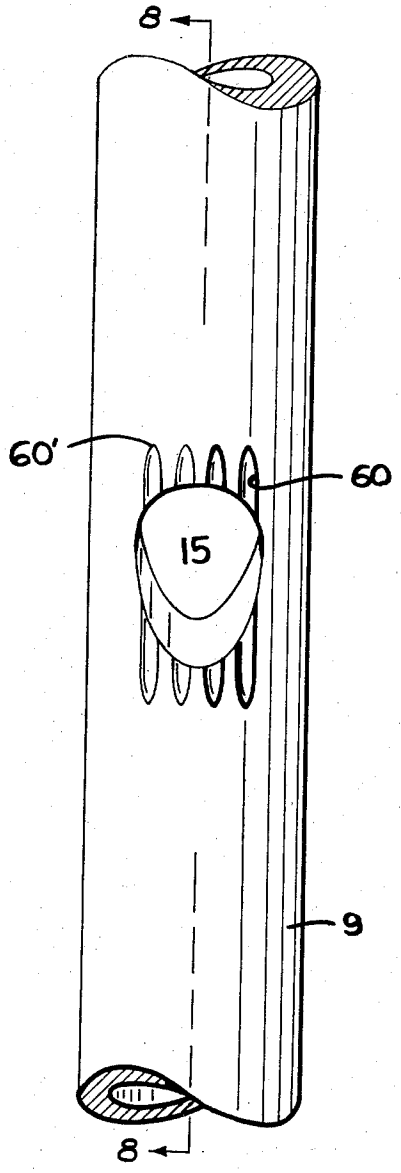

FIG. 7

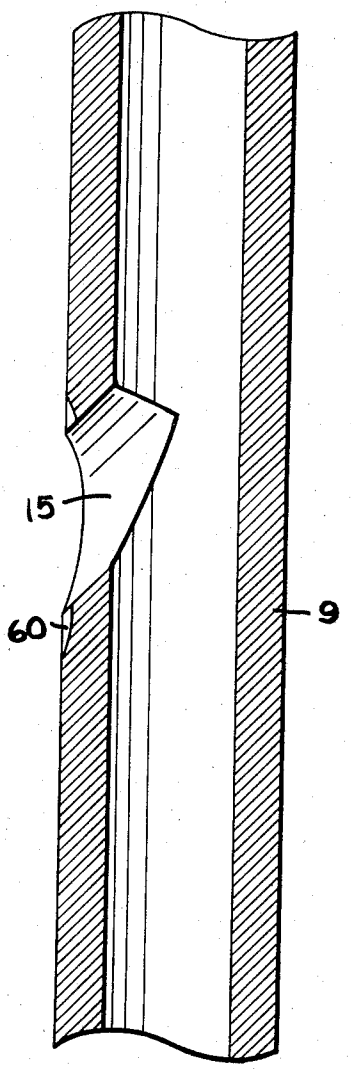

FIG. 8

GEORGE E. CONOVER
INVENTOR.

BY Jacks W. Hayden
ATTORNEY

United States Patent Office 2,831,541 Patented Apr. 22, 1958

2,831,541

HYDRAULIC PACKER TOOL

George Edgar Conover, Midland, Tex., assignor to Lynes, Inc., Houston, Tex., a corporation of Texas

Application August 13, 1953, Serial No. 373,992

15 Claims. (Cl. 166—147)

The present invention relates to a hydraulic packer treating and testing tool for wells and more particularly to a valve arrangement in such tool.

It is desirable in various drilling operations to treat or test certain portions of the well bore for reasons well known in the art. The present invention relates in general to that class of well tool such as illustrated in the drawings and described in the patent issued to John Lynes, No. 2,611,437, dated September 23, 1952. As pointed out in the above noted patent, such tools are provided with hydraulic inflatable elements, whereby such elements may be expanded to isolate portions of a well bore.

In the operation of such packer tools, it is not uncommon to encounter pressure differentials up to several thousand pounds per square inch, and it is therefore desirable to provide a valve arrangement for use with such tool which, under such conditions, inhibits cutting out the seals in such valve arrangement. Additionally, great difficulty is encountered in clogging of the tool by foreign matter and debris and it is desirable to provide a valve opening so constructed and arranged which eliminates this difficulty. Also, the valve arrangement should be such so that it can be moved to a full closed or full opened position with as little relative movement between the parts of the operating mechanism as possible.

The present invention deals in particular with a valve arrangement in such tool, whereby communication either above, below or between the packers may be effected and controlled, and which overcomes the above difficulties.

A further object is to provide a valve arrangement including a hollow tubular support member, a sleeve on said support, seal means sealing between said support and said sleeve, and an opening in said valve support adapted to be covered and uncovered by said sleeve, said opening including leak passage means for equalizing pressure on said seal means to inhibit cutting thereof as said seals move over said opening.

A still further object is to provide a valve arrangement in a well packer tool whereby the valve may be moved to a full opened or full closed position with as little relative movement as possible between the valve parts.

Other objects and advantages of the invention will become more readily apparent from a description of the following drawing wherein:

Fig. 1 illustrates the well tool in position for lowering in the well bore with the inflatable elements being deflated and shows a form of the slide valve mechanism which controls communication between said mandrel and body;

Fig. 2 shows the tool with the inflatable elements expanded to isolate a section of the well bore;

Fig. 3 shows the tool with the mandrel moved relative to the body so that the mandrel openings and body openings which are located between the packers are open to each other whereby the well formation located between the packers may be treated or tested;

Fig. 4 illustrates the position of the mandrel with respect to the tool when communication is established between the mandrel openings and body openings above the packers for treating or testing the well formation above the packer;

Fig. 5 illustrates the position of the mandrel in the tool when the mandrel openings and body openings below the lower inflatable element are open to each other whereby treating or testing of the well formation below such lower element may be effected;

Fig. 6 is a vertical sectional view illustrating the valve arrangement, including an opening in the lower end of the mandrel;

Fig. 7 is an enlarged elevational view of the opening in the lower end of the mandrel with bleed grooves, or leak passages, shown thereon;

Fig. 8 is a vertical sectional view on the line 8—8 of Fig. 7; and

Fig. 9 is a vertical sectional view of an alternate embodiment of the valve arrangement and mandrel openings including the leak passage.

As shown in Fig. 1 of the drawings the tool is lowered into the well bore with the inflatable elements deflated. The well tool is denoted generally at 2 and comprises a body 3 including the spaced inflatable elements 4 and 5. It is to be noted that the body is a unitary structure and is provided with openings 6, 7 and 8 which are respectively, above the inflatable element 4, between the elements 4 and 5 and below the element 5. A hollow mandrel 9 is slidably mounted in the well tool 2 and extends through the inflatable elements as illustrated in the drawings. The hollow mandrel or pipe 9 extends to the surface of the well bore and affords a means of lowering the tool in the well bore, as well as affording a means for manipulating the tool in the well bore, and also serves as a means for conducting fluid to inflate the packers and to conduct fluid to treat the well formation or to receive well fluids from the formation for test purposes.

A suitable locking arrangement, as illustrated generally at 11 in Fig. 1, is provided for maintaining the mandrel at a plurality of predetermined relative positions with respect to body 3, whereby any of the various operations may be conducted as desired. This locking mechanism is of the type whereby the pipe or mandrel 9 may be fixed at a plurality of predetermined positions and can be released from such predetermined positions by relative manipulation between the mandrel or well pipe and the body 3. The mandrel 9 has openings 13 and 14 therein for communication with the interior of the inflatable elements 4 and 5 whereby such elements may be inflated and deflated. The openings 13 and 14 also serve for communication with the openings 6 and 7 respectively, while opening 15 in the lower end of the mandrel is provided for communication with the opening 8 in the body 3 of the tool as described more fully hereinafter.

Valve means 17, 18 and 19 surrounds the mandrel 9 and provides a means for selectively controlling communication between the mandrel openings 13 and body openings 6 above the sealing elements, for controlling communication between the mandrel openings 14 and body openings 7 between the inflatable elements and for controlling communication between mandrel openings 15 and body openings 8 below the inflatable elements.

After the tool has been lowered to the desired elevation in the well bore, fluid may be injected into the mandrel 9 where it flows down and out through openings 13 and 14 therein so as to expand the elements 4 and 5 against the wall 20 of the well bore 20' as shown in Fig. 2. This isolates the portion 21 of the well above the packers, from that portion 22 between the packers and

isolates the portion 23 below the packers from the portions 21 and 22.

After the inflatable elements have been so expanded it may be desirable to selectively treat or test any or all of the portions 21 or 22 or 23 of the well bore. It is, of course, necessary to direct the fluid in a predetermined manner so that the proper or desired portion is treated. This necessitates an arrangement whereby certain of the mandrel openings and body openings can be communicated while simultaneously maintaining the packers inflated and the remaining mandrel openings closed relative to the body openings.

The valve means 17, 18 and 19 are provided to accomplish this purpose. It should be noted at this time that the valve means 17 is provided with seal means 25 and 26 which completely surround the mandrel 9 and form a seal therewith. Similarly, packing means 28 and 29 is provided in valve means 18 and packing 30 and 31 is provided in valve means 19.

The valve 17 is illustrated as being formed integrally with the body 3 by means of the longitudinally upwardly extending annular wall 32 that surrounds the mandrel 9. The wall 32 is provided with a cover 33 having an opening 34 therein to accommodate passage of the mandrel through the valve. This arrangement provides a chamber 36 between the seal rings 25 and 26 whereby the opening 13 in the mandrel may be moved thereinto and thereby prevent passage of fluid from such mandrel opening, as illustrated in Fig. 3. The valves 18 and 19 are mounted on the mandrel 9, such valves being in the form of cylinders as shown at 37 and 38 with the top and bottom of each cylinder having the seals 28, 29, 30 and 31, respectively in sliding, but sealing contact with said mandrel.

It is to be noted that the valves 18 and 19, being supported on the mandrel 9, are movable therewith upon relative longitudinal movement of the mandrel 9 in the packer tool. However, the valves 18 and 19 are slidable along such mandrel, and a chamber 40 and 41, respectively, is formed in each valve whereby a mandrel opening may be moved into such chamber between the seals at each end of the valve to effect a seal off of such opening and prevent communication of such opening and adjacent body opening.

In Fig. 2, for example, the opening 15 in the lower end of the mandrel 9 is disposed within the chamber 41 of valve 19. Openings 13 and 14 are disposed within the inflatable elements 4 and 5 and, therefore, communication between mandrel opening 15 and body opening 8 below the sealing elements is prevented.

After the packers have been inflated against the wall of the well bore, any desired operation either above, between or below the packers may be effected, and it is to be particularly noted in this respect that such operation is selective. That is to say, the tool may be used for treating or testing any one of the three isolated portions of the well bore entirely independent of the other two portions not being treated or tested.

For example, as illustrated in Fig. 3, the inflatable packer elements are sealed against the well bore and the mandrel move relative to the body 3 so as to communicate the openings 14 therein with the body openings 7 between the inflatable elements 4 and 5. It is to be noted that the body 3 of the tool is provided with a plurality of seals 45, whereby the fluid in the inflatable elements is sealed therein upon longitudinal movement of the mandrel relative to the tool body. As also shown in Fig. 3, the opening 13 is moved into the chamber 36 of valve 17 while valve 18, having moved with the mandrel, exposes mandrel opening 14 whereby it is in communication with body opening 7. Valve 19 has also moved with the mandrel and mandrel opening 15 is still maintained within chamber 41 so that the only portion of the well bore which may be treated or tested through the tool is that portion 22 between the inflated elements 4 and 5.

Fig. 4 illustrates the position of the valves 17, 18 and 19 when the mandrel 9 has been moved relative to the body 3 so as to communicate openings 13 therein with body openings 6 above inflatable element 4 so as to treat or test the portion 21 of the formation above the inflatable element 4. It is to be noted that the mandrel 9 has been moved to a new position relative to the body and is maintained in such position relative to the body 3 by the locking mechanism 11. However, the slide valves 18 and 19, having been engaged by stops 46 and 47, respectively, are held in engagement with such stops while the mandrel continues to move upwardly through the tool to its position in the locking assembly as shown in Fig. 4. This causes the openings 14 in the mandrel to move within the chamber 40 of slide valve 18.

Mandrel opening 15 is moved into chamber 48 which is formed within cylindrical valve member 50. This valve member is provided with seals 51 and 52 so as to form a seal with the mandrel which passes therethrough. A groove 53 is the surface of such valve is engaged with projection 54 on the body so as to maintain such valve in a fixed position relative to the body 3.

Since mandrel openings 14 and 15 are closed off relative to body openings 7 and 8, the only communication established between the mandrel and the body openings is above the sealing element 4 as shown in Fig. 4.

By disengaging the mandrel 9 from the body 3 at the locking arrangement 11, and by moving the mandrel 9 downwardly through the well tool, communication between the body openings 8 and mandrel opening 15 below the lower inflatable element 15 is effected. As shown in Fig. 5 of the drawings, valve member 18 and its chamber 40 moves downwardly with the mandrel and continues to cover mandrel opening 14, also mandrel opening 13 is moved downwardly into the chamber 36 of valve 17. Since opening 15 has been previously moved out of valve 19, lowering of the mandrel relative to the body of the tool moves opening 15 out of valve 50 and exposes such opening and communicates opening 15 and body openings 8.

After the desired treating or testing operations below the lower inflatable element 5 have been conducted it may be desirable to close off communication between mandrel opening 15 and body opening 8 and this may be effected by lowering the mandrel so that valve 19 engages projection 55 in the lower end of the tool body 3. This arrests movement of the valve member 19 while allowing the mandrel to slide downwardly so as to move the mandrel opening 15 into the chamber 41 between the seals 30 and 31.

From the foregoing discussion, it can be seen that any one of a plurality of zones in a well bore may be selectively treated, or if desired, all zones adjacent the tool may be stepwise treated. The valve arrangement including the sleeve valves, openings, and cooperating stops on the body allows the tool to have one less position in the locking arrangement 11 than the number of functions performed by the tool. Also, the arrangement of the mandrel openings, sleeve valve and cooperating stop means on the body is such that a full opened or full closed position of the mandrel openings may be obtained with a minimum of relative movement between the mandrel and valve means.

Of course, the inflatable elements can be deflated and the tool reset at any other desired elevation so that a great number of treating or testing operations can be conducted while the tool is in the well bore.

If desired, the tool could be used as previously described to stepwise treat a plurality of formations or could be used to selectively treat any one of such formations. The tool could then be allowed to set for awhile and testing operation carried out to determine the success of the treating operations.

A great deal of difficulty is encountered because well tools tend to become clogged with debris or foreign matter. For example, dust or debris may collect in well tubing while it is stacked on the ground at the top of the well and, therefore, as successive joints are connected together and lowered into the well bore, the dirt therein settles into the tool which is connected to the bottom of the tubing.

Debris and foreign matter also arises from numerous other sources such as, for example, broken bits of swab cup rubbers may find their way into the tool from the well tubing so as to stop or plug the tool. Paraffin from the inside of the well tubing may fall off into the tool connected on the lower end thereof and formation cuttings from the well may pass into the tool during treating or testing operations so as to tend to clog the tool.

When the tool is being used for treating or testing operations, solid material in the mandrel **9** tends to settle so as to fill the mandrel below the point at which the mandrel and body openings are in communication for conducting treating or testing operations. In some situations, the settling may be to such an extent that the tool may become completely clogged in the lower end thereof while mandrel openings and body openings between the packer elements are communicated for testing or treating operations. In such situations, it would then be impossible to circulate through the mandrel port or valve opening at the lower end of the tool.

To overcome this difficulty, the opening **15** in the mandrel **9** at the lower end thereof is constructed so as to inhibit clogging of the tubular member **9**, and attention is directed to Figs. 7 and 8 of the drawings which show a preferred configuration and arrangement of the lower mandrel opening or valve opening **15**. As shown, the opening **15** is approximately the same size as the internal diameter of mandrel **9** or is substantially the same area as the internal transverse area of the hollow mandrel **9** and the opening **15** may be inclined with respect to the longitudinal axis of the mandrel **9**, as shown in the drawings.

Another difficulty encountered with operating well tools is in providing a sealing arrangement between relative movable members which will withstand pressure differentials up to several thousand pounds per square inch. As shown in the drawings, seal means **30** and **31** are provided on the sleeve valve **19** arranged on the hollow mandrel or tubular member **9**. As previously discussed, such sleeve valve is adapted to cover and uncover the mandrel opening or valve opening **15** upon predetermined relative movement between the mandrel and the body. As the seals move over opening **15**, such seals may be cut out by reason of the pressure differential on each side of the seal. It is therefore necessary to provide suitable leak passage means on each side of the opening **15** so that pressure on each side of the seals **30** or **31** is equalized prior to passing such seals over the valve opening **15**.

As illustrated in Figs. 7 and 8, one form of such leak passage means is shown as including a plurality of longitudinally extending grooves **60** which intersect the valve opening **15** on each side thereof so that the pressure on the seals in the sleeve valves may be equalized before passing such seals over the main opening. The grooves **60** bleed the pressure by the seal rings as such seal rings move thereover and the cross-sectional area of such grooves, being relatively small, will not permit enough force to be exerted against the seal ring so as to cut the exposed portion of the seal ring out.

However, it can be appreciated that in the absence of such provision for equalizing the pressure on each side of the seals before passing such seals over opening **15**, the exposed area of the seal rings under operating pressures encountered, will cause such seal rings to quickly cut out.

The ends of the grooves, as illustrated at **60'**, have a very small cross-sectional area so that as the seal means

contacts such grooves, a very small portion thereof is subjected to pressure action.

An alternate arrangement of the valve opening **15** and leak passage means **60** is illustrated in Fig. 9. The valve opening **15** is located centrally with respect to a plurality of graduated ports or mandrel openings **60''** on each side thereof. The graduated ports serve the same purpose as the longitudinally extending grooves or leak passage grooves, or leak passage means **60** and equalize pressure on the seals in the valves without exposing too large an area of such seals, whereby cutting action of the seals by the high pressures normally encountered in using the tool are eliminated.

The slide valve illustrated at **19** is of sufficient length so as to span the graduated mandrel openings **60''** when the valve is in covering position over opening **15**.

Broadly, the invention relates to a well packer tool including a mandrel and body with inflatable elements thereon, and more particularly the invention relates to a valve arrangement in such tool for controlling communication between the mandrel and body either above, between, or below the inflatable elements.

What is claimed is:

1. In an inflatable packer tool, a body including spaced inflatable elements thereon, a mandrel slidably mounted in said body and extending through said elements, there being openings in said mandrel and in said body, and valve means mounted on said mandrel and movable therewith for closing off communication between said mandrel openings and said body openings, and stop means for engaging said valve whereby movement of said mandrel relative to said valve slides said valve along said mandrel so as to uncover said mandrel openings to establish communication between said mandrel and body openings.

2. In an inflatable packer tool, a body including spaced inflatable elements thereon, a mandrel slidably mounted in said body and extending through said elements, there being openings in said mandrel and in said body, valve means slidably mounted on said mandrel for closing off communication between said mandrel openings and said body openings, and additional means for engaging said valves whereby movement of said mandrel relative to said body slides said valves along said mandrel so as to uncover said mandrel openings to establish communication between said mandrel and body openings.

3. In an inflatable packer tool having a body with spaced inflatable elements thereon, and a mandrel slidably mounted in said body and extending through said elements, and there being openings in said mandrel and body for communication, cylindrical valve means in said body and on said mandrel for closing off communication between said mandrel and body openings, stop means associated with said tool for engaging said valve means whereby movement of said mandrel relative to said valve slides said valve along said mandrel so as to uncover said mandrel openings to establish communication between said mandrel and body openings.

4. In an inflatable packer tool having a body with spaced inflatable elements thereon, and a mandrel slidably mounted in said body and extending through said elements, there being openings in said mandrel and body for communication, cylindrical valve means slidable relative to said mandrel for closing off communication between said mandrel and body openings, and stop means associated with said tool for engaging said valve whereby movement of said mandrel relative to said valve slides said valve along said mandrel so as to uncover said mandrel openings to establish communication between said mandrel and body openings.

5. In a well tool, a body, there being openings in said body, a hollow mandrel slidably mounted in said body, there being opening means in said mandrel for communicating with said body openings, sleeve valve means surrounding said mandrel and slidable thereon, means in said body for engaging said valve whereby said mandrel

may be moved relative thereto to open or close said mandrel openings, said mandrel opening means being inclined relative to the longitudinal axis of said mandrel and of substantially the same area as the internal transverse area of said hollow mandrel to inhibit clogging thereof.

6. In a well tool, a body, there being openings in said body, a hollow mandrel slidably mounted in said body, there being opening means in said mandrel for communicating with said body openings, sleeve valve means surrounding said mandrel and slidable thereon, means in said body for engaging said valve whereby said mandrel may be moved relative thereto to open or close said mandrel openings, said mandrel opening means being inclined relative to the longitudinal axis of said mandrel and of substantially the same size as the internal diameter of said hollow mandrel to inhibit clogging thereof, said valve means including seal means sealably engaging said mandrel, and said mandrel port means including leak passage means for equalizing pressure on said seal means to inhibit cutting thereof by movement across said port means.

7. In a well tool, a body, there being openings in said body, a hollow mandrel slidably mounted in said body, there being opening means in said mandrel for communicating with said body openings, valve means surrounding said mandrel and slidable thereon, means in said body for engaging said valve whereby said mandrel may be moved relative thereto to open and close said mandrel openings, said valve means including seal means sealably engaging said mandrel, and said mandrel port means including leak passage means for equalizing pressure on said seal means to inhibit cutting thereof by movement across said port means.

8. In a well tool, a body, there being openings in said body, a hollow mandrel slidably mounted in said body, there being opening means in said mandrel for communicating with said body openings, a sleeve valve mounted on said mandrel, seal means between said valve and mandrel and maintaining said valve in position on said mandrel whereby they may be moved together, and stop means mounted on said body whereby said sleeve valve may be engaged thereagainst and upon relative movement between said mandrel and said sleeve valve, said mandrel opening may be covered or uncovered by said sleeve valve, said mandrel opening means being inclined relative to the longitudinal axis of said mandrel and of substantially the same size as the internal diameter of said hollow mandrel to inhibit clogging thereof.

9. In a well tool, a body, there being openings in said body, a hollow mandrel slidably mounted in said body, therebeing opening means in said mandrel for communicating with said body openings, a sleeve valve mounted on said mandrel, seal means between said valve and mandrel and maintaining said valve in position on said mandrel whereby they may be moved together, and stop means mounted on said body whereby said sleeve valve may be engaged thereagainst and upon relative movement between said mandrel and said sleeve valve, said mandrel opening may be covered or uncovered by said sleeve valve.

10. In an inflatable packer tool for a well bore, a body including a pair of spaced inflatable packer elements thereon, there being opening means in said body for communicating with the well bore located above, between and below said elements, a hollow mandrel slidably mounted in said body and extending through said elements, there being opening means in said mandrel for communicating with said body opening means, separate valve means within said body and surrounding said mandrel for selectively closing off said mandrel opening means relative to said body opening means, and co-engageable means on said mandrel and body cooperable to selectively position said mandrel relative to said valve means to selectively open and close said mandrel openings for communication with said body opening means.

11. In a well tool, a body, there being openings in said body, a hollow mandrel slidably mounted in said body, there being opening means in said mandrel for communicating with said body openings, a sleeve valve mounted on said mandrel, and stop means mounted on said body whereby said sleeve valve may be engaged thereagainst and upon relative movement between said mandrel and said sleeve valve, said mandrel opening may be covered or uncovered by said sleeve valve, said mandrel opening means being inclined relative to the longitudinal axis of and mandrel and of substantially the same size as the internal diameter of said hollow mandrel to inhibit clogging thereof, said valve means including seal means sealably engaging said mandrel, and there being leak passage means on each side of said mandrel opening means to leak fluid around said seal means for equalizing pressure on said seal means prior to moving it across said mandrel opening to inhibit cutting of said seal means.

12. In a well tool, a body, there being openings in said body, a hollow mandrel slidably mounted in said body, there being opening means in said mandrel for communicating with said body openings, a sleeve valve mounted on said mandrel, and stop means mounted on said body whereby said sleeve valve may be engaged thereagainst and upon relative movement between said mandrel and said sleeve valve, said mandrel opening may be covered or uncovered by said sleeve valve, said valve means including seal means sealably engaging said mandrel, and said mandrel opening means including leak passage means on each side of said mandrel opening to leak fluid around said seal means for equalizing pressure on said seal means prior to moving it across said mandrel opening to inhibit cutting of said seal means.

13. A valve arrangement including a tubular member, there being port means in the wall thereof of substantially the same area as the transverse area of said member, there being a plurality of longitudinal grooves in the outer wall of said member and intersecting said port on each side thereof, and slide valve means arranged on said member for covering and uncovering said port, seal means on said valve means for sealably engaging said member, stop means whereby said slide valve means may be engaged thereagainst and upon relative movement between said member and valve means said opening in said member may be covered or uncovered, said grooves forming leak passage means for leaking fluid around said seal means for equalizing pressure on said seal means prior to moving it across said opening in said member to inhibit cutting of said seal means.

14. A valve arrangement including a tubular member, there being a port in the wall thereof substantially the diameter of said member, and being inclined relative to the longitudinal axis of said member, there being a plurality of longitudinal grooves in the outer wall of said member and intersecting each side of said port, and slide valve means arranged on said member for covering and uncovering said port, seal means on said valve means for sealably engaging said member, stop means whereby said slide valve means may be engaged thereagainst and upon relative movement between said member and valve means said opening in said member may be covered or uncovered, said grooves forming leak passage means for leaking fluid around said seal means for equalizing pressure on said seal means prior to moving it across said opening in said member to inhibit cutting of said seal means.

15. A valve arrangement including a tubular member, there being port means in the wall thereof, said port means including leak passage means on each side thereof in the wall of said member, and slide valve means arranged on said member for covering and uncovering said port means, seal means on said valve means for sealably engaging said member, stop means whereby said slide valve means may be engaged thereagainst and upon relative

movement between said member and valve means said opening in said member may be covered or uncovered, said leak passage means leaking fluid around said seal means for equalizing pressure on said seal means prior to moving it across said opening in said member to inhibit cutting of said seal means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,227,731 Lynes ---------- Jan. 7, 1941
2,575,603 Taylor et al. ---------- Nov. 20, 1951
2,611,437 Lynes ---------- Sept. 23, 1952
2,633,200 Humason ---------- Mar. 31, 1953
2,643,723 Lynes ---------- June 30, 1953