Nov. 27, 1962 B. P. NUTTER 3,065,796

MULTIPLE PURPOSE WELL TOOLS

Filed Nov. 19, 1958

4 Sheets-Sheet 1

Fig. 1

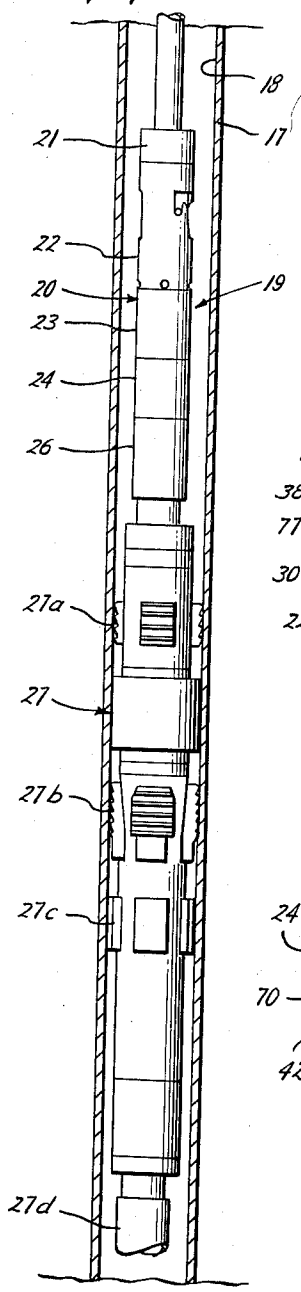


Fig. 9

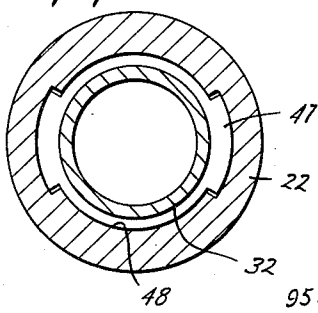


Fig. 10

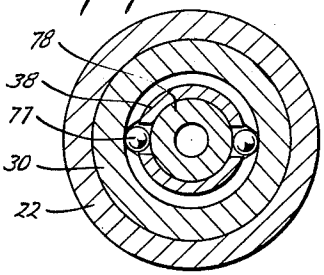


Fig. 11

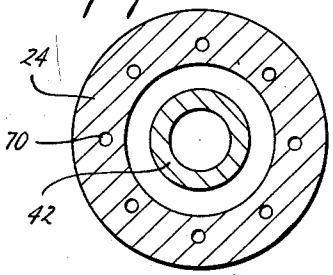
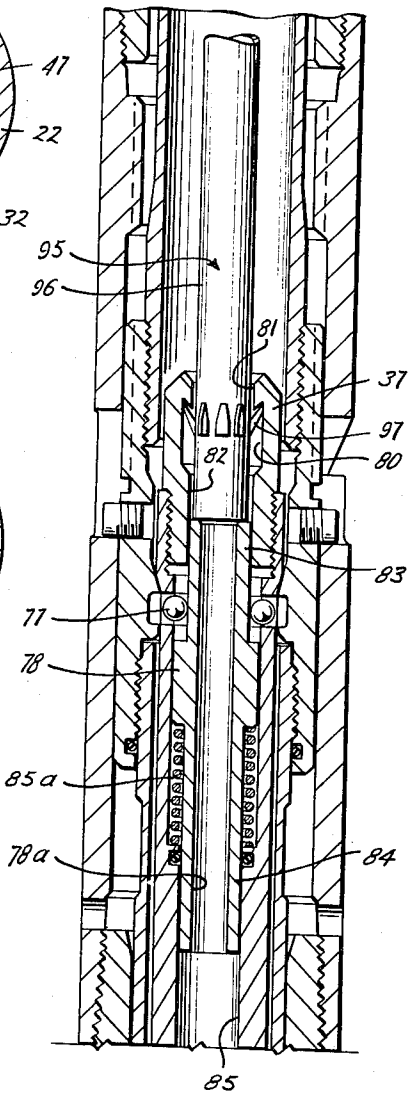


Fig. 12



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MULTIPLE PURPOSE WELL TOOLS

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Fig. 2A

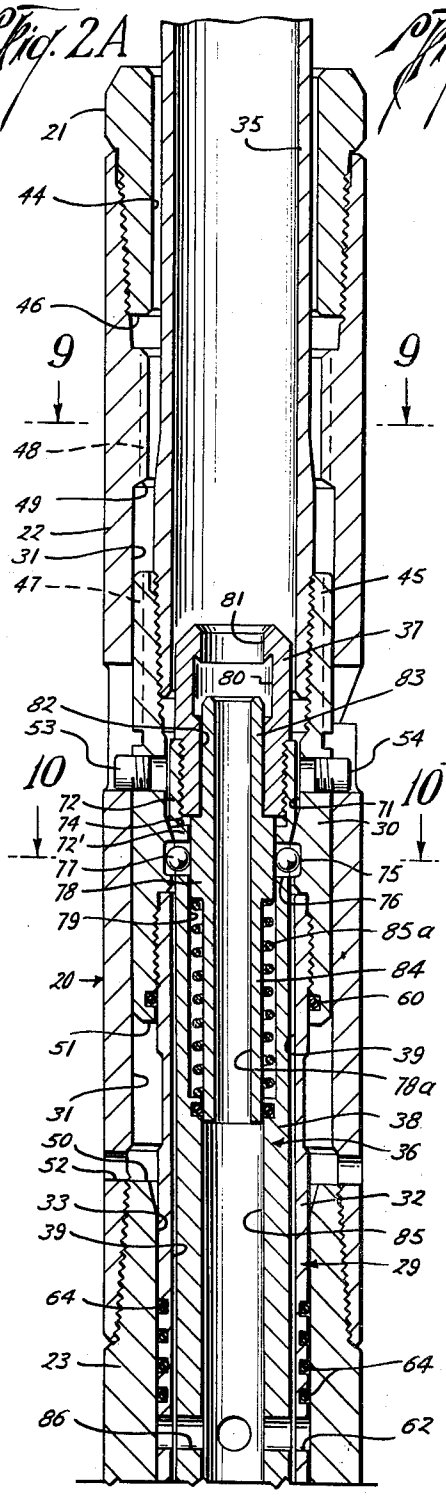
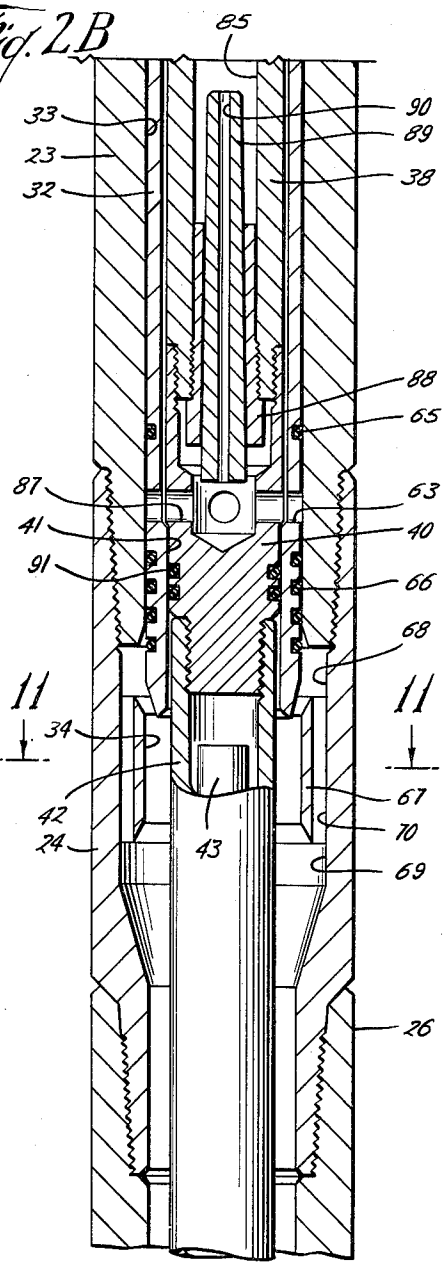


Fig. 2B



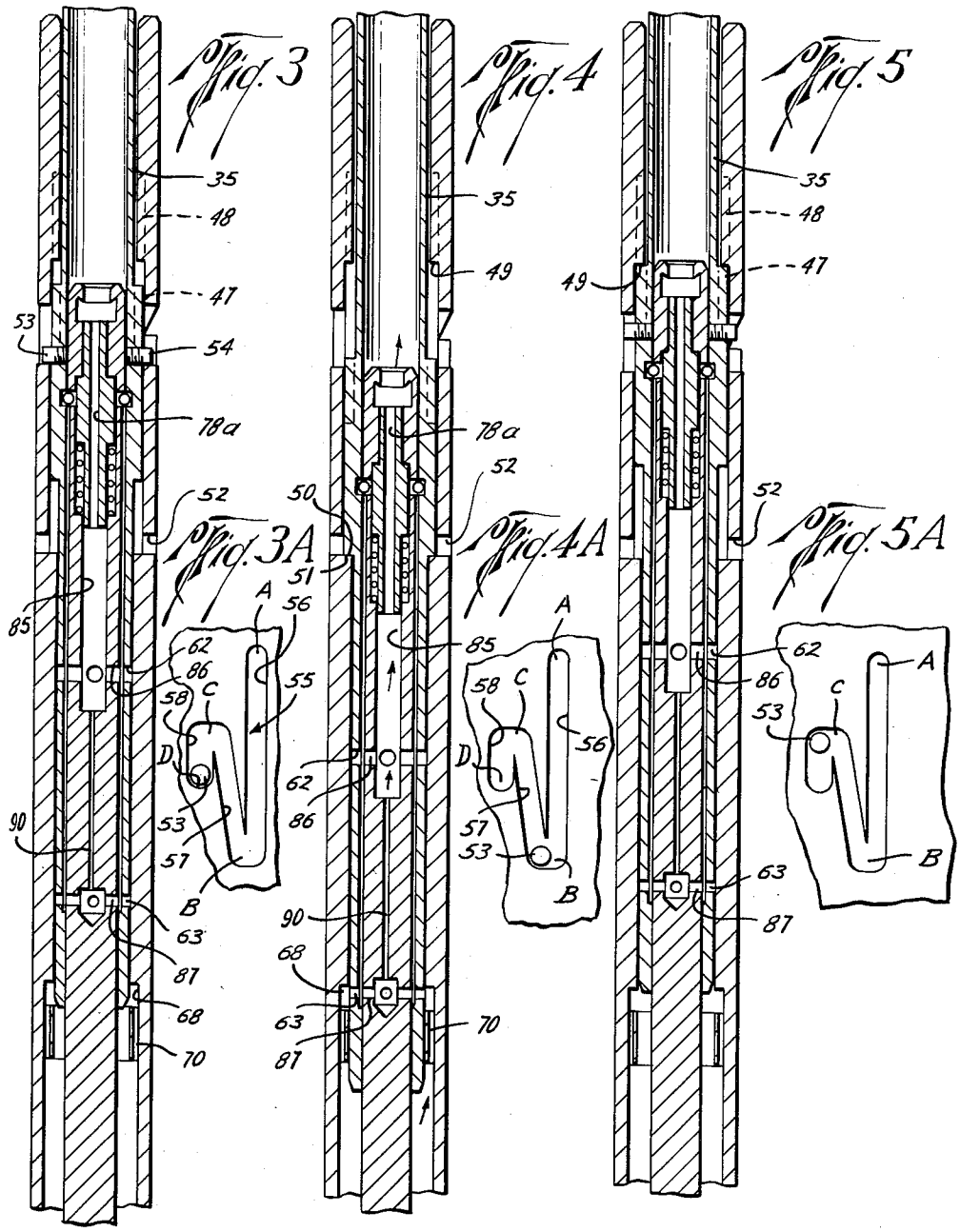
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MULTIPLE PURPOSE WELL TOOLS

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Fig. 6

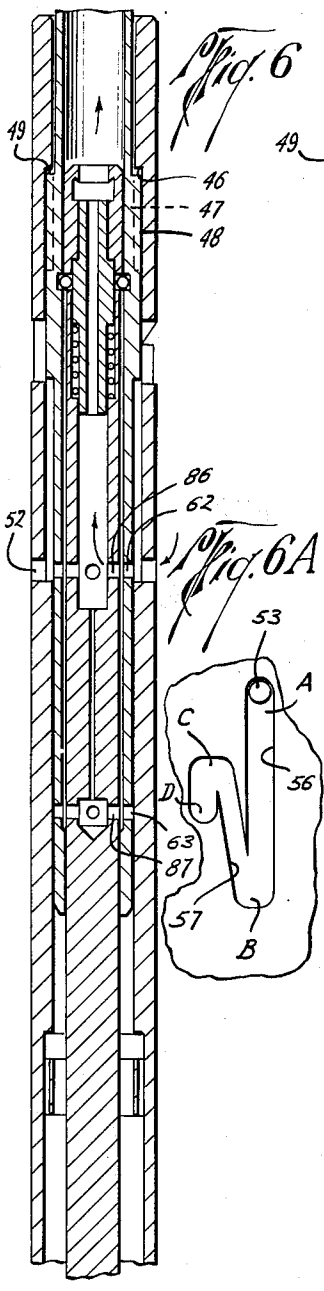


Fig. 6A

Fig. 7

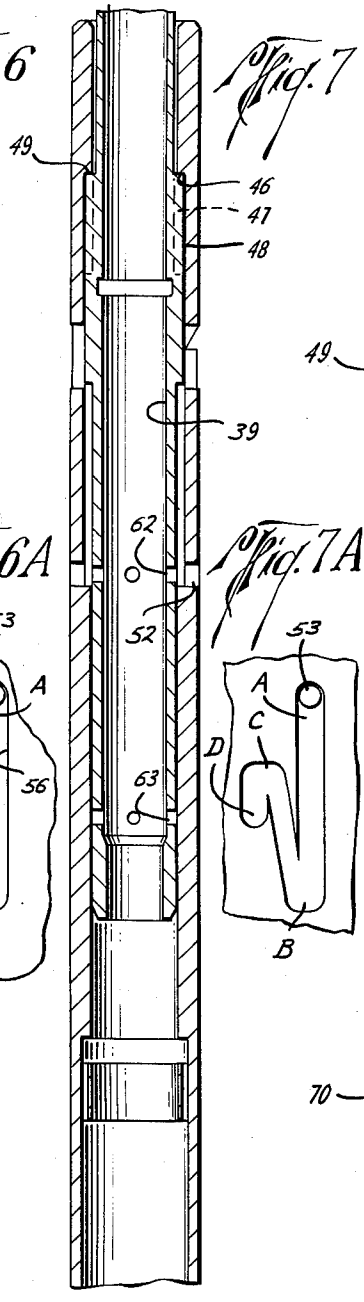


Fig. 7A

Fig. 8

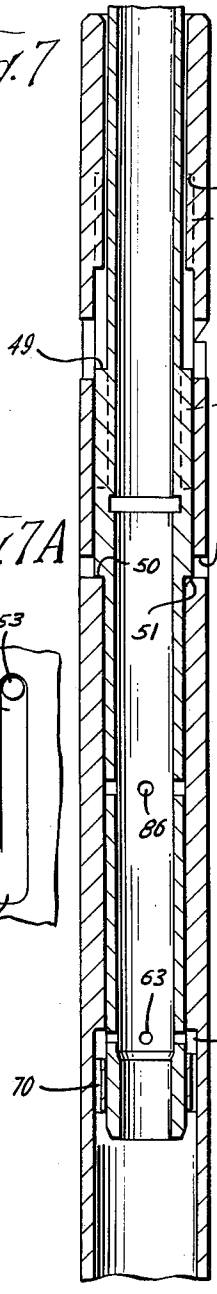
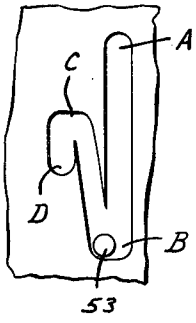


Fig. 8A



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United States Patent Office 3,065,796 Patented Nov. 27, 1962

3,065,796

MULTIPLE PURPOSE WELL TOOLS

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Filed Nov. 19, 1958, Ser. No. 775,023
16 Claims. (Cl. 166—226)

The present invention relates to well tools and, more particularly, to a multiple purpose drill stem well tool for performing a plurality of operations with only one trip of the drill stem into the well or borehole and wherein the tool can remain in the borehole for permanent-type completion.

It has heretofore been customary in various operation to employ different tools for perforating, testing a formation under flowing or static conditions, squeeze cementing, acidizing, fluid fracturing, or changing a bottom hole choke or bean. To use a different tool, the drill stem or tubing string must be removed from the well to permit the change of tools, and then reinserted in the well. As the depth of drilled boreholes is increased, the number of round trips, that is, the number of times a well string is removed and reinserted in a borehole, becomes significant by virtue of the increased time required for making round trips. Hence, various individual operations necessary in completion and remedial work result in increased costs.

It has therefore become increasingly desirable to perform multiple operations, where applicable, with a minimum number of round trips and preferably with only one trip into the borehole.

A multiple purpose well tool has been disclosed by J. L. Johnston et al. in Patent No. 2,760,581, issued Auguse 28, 1956. While the tool therein disclosed is quite satisfactory for many applications, it is often desirable to provide a variety of services and operations not heretofore available. The services and operations which may be desired are as follows: In a drill stem test the tool may be inserted in a borehole containing fluid or one without fluid; a packer below the tool is set and a pressure recorder in the tool obtains the initial shut-in pressure; the tool may then be opened to permit the well to produce and thereby to obtain a flow test; the tool may then be closed to obtain a final shut-in pressure recording and reverse circulation of well fluid may be accomplished either simultaneously with the obtaining of shut-in pressure or following the obtaining of shut-in pressure.

It will be seen from the above summary that all bottom hole pressures may be recorded. That is, the pressure chart will show the initial mud pressure, the initial shut-in pressure, flowing pressures, the final shut-in pressure and the final mud pressure.

After the drill stem testing operation, the pressure recorders, the bottom hole choke and central mandrel may be removed from the tool by wire line equipment providing a full opening through the tool and the tool can remain in the well as a production tube.

A perforating gun may then be lowered through the tool to perforate the casing. After perforation, hydraulic fracturing or acidizing may be accomplished through the full opening tool. If it is desired, cement may be squeezed into the formation via the full opening tool.

It will be apparent from the foregoing that a single tool allows testing, treating and squeezing operations.

Accordingly, an object of this invention is to provide a well tool whereby any or all of the above-enumerated operations may be carried out with only one trip of the tubing string into the well.

Another object of this invention is to provide a multiple purpose well tool having a broader range of operations than heretofore possible.

Yet another object of this invention is to provide an improved multiple purpose tool in which circulation ports are included in a tool.

A further object of this invention is to provide an improved multiple purpose tool which is full opening to permit lowering a gun perforator or other operational devices through the tool.

A still further object of this invention is to provide a multiple purpose well tool particularly suited for a sequence of test-treat-squeeze operations with only one trip of the tubing string into the well.

These and other objects are obtained by a well tool including a tubular housing adapted to be connected to a packer which is set in a desired location in the well. A first, outer tubular mandrel assembly is slidably received within the housing for limited longitudinal movement therealong and is adapted to be connected to the lower end of a tubing string for movement therewith. A second, inner mandrel assembly including a fluid-tight plug portion is releasably locked within the outer mandrel assembly and is sealingly engaged therewith. In a first position of the locked mandrel assemblies relative to said housing, a fluid passage is provided to permit flow of connate test fluid from the formation through the interior of the housing below the inner mandrel assembly plug portion and through the mandrel assemblies to the tubing string thus permitting the well to flow. In a second position of the locked mandrel assemblies relative to said housing, the fluid passage is closed preventing the flow of test fluid to the tubing string thus shutting off the well. In a third position of the locked mandrel assembiles relative to said housing, a fluid passage is provided between the exterior of said housing above the inner mandrel assembly plug portion to the tubing string permitting reverse circulation.

The inner mandrel assembly may be removed by a wire line and the remaining housing and outer mandrel manipulated so that a fluid passage therebetween provides a circulating valve to facilitate the handling of treating substances and, when the circulating valve is closed, to provide a fluid-tight passage for applying pressure to the substances. With the inner mandrel assembly removed, other tools, for example, a gun perforator may be passed through the body of the tool.

These and other features of the invention and others of its objects and advantages may be perceived from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic representation of the multiple purpose tool and packer in a borehole;

FIGS. 2A and 2B are views in longitudinal cross section of the upper and lower portions, respectively, of a well tool constructed in accordance with the principles of the present invention and shown in position for insertion in a well bore;

FIG. 3 is a simplified representation similar to the illustration of FIGS. 2A and 2B but drawn to a reduced scale and showing the well tool in position to obtain a shut-in pressure reading;

FIG. 3A is a side elevational view of a portion of the apparatus of FIG. 3 showing the position of an index pin in an index slot for the operating condition of FIG. 3;

FIG. 4 is a view similar to FIG. 3 showing the tool in its testing position to permit fluid flow to the tubing;

FIG. 4A is a side elevational view of a portion of the apparatus of FIG. 4 showing the position of the index pin in the index slot for the operating condition of FIG. 4;

FIG. 5 is a view similar to FIG. 3 showing another position of the tool in an intermediate operating position;

FIG. 5A is a side elevational view of the apparatus

of FIG. 5 showing the position of the index pin in the slot for the operating condition of FIG. 5;

FIG. 6 is a view similar to FIG. 3 showing the tool in position for reverse circulation;

FIG. 6A is a side elevational view showing the position of the index pin in the index slot for the operating condition of FIG. 6;

FIG. 7 is a view of the tool with the inner mandrel assembly removed and the reverse circulation ports open;

FIG. 7A is a side elevational view showing the position of the index pin in the index slot for the operating condition of FIG. 7;

FIG. 8 is a view of the tool with the inner mandrel assembly removed and the reverse circulation ports closed;

FIG. 8A is a side elevational view of the position of the index pin in the index slot for the operating condition of FIG. 8;

FIG. 9 is a cross-sectional view taken along lines 9—9 of FIG. 2A;

FIG. 10 is a cross-sectional view taken along lines 10—10 of FIG. 2A;

FIG. 11 is a cross-sectional view taken along lines 11—11 of FIG. 2B; and

FIG. 12 illustrates, in partial longitudinal cross section, apparatus for removing the center mandrel assembly.

In FIG. 1 is shown a multiple purpose well tool 19 disposed in a portion of a borehole 18, having a casing 17. Tool 19 has tubular housing 20 which includes a top sub 21, an index sub 22, an intermediate sub 23 and a bottom sub 24 threadedly connected together in end-to-end relation in the order recited. The bottom sub 24 has a lower threaded pin end received in the upper end of a tubular pressure recorder housing 26. The recorder housing 26 is adapted to be secured at its lower end to a packer assembly 27. The packer may be of suitable full opening construction, or of the type described in the patent application of B. P. Nutter, Serial No. 774,910, filed November 19, 1958, and assigned to the same assignee as the present invention. Packer 27, in general, is provided with a fluid passage for the passage of connate test fluid therethrough to the tool and preferably has conventional bypass valve means (not shown) to facilitate insertion in a well by passage of drilling fluid therethrough. The packer further has upper and lower slips 27*a*, 27*b* which when set against the casing will hold the packer against pressure above and below. Friction means 27*c* enables setting of the packer in sealing relation to the casing. The lower end of the packer may be connected to tubing 27*d* which extends to the formation to be tested. As shown in FIG. 1, packer 27 is expanded and the slips 27*a*, 27*b* engage the casing 17 to secure the packer in the casing and therefore the tubular housing 20 is secured against movement when the packer is set.

In the general arrangement of the tool as shown in FIGS. 2A, 2B, the tubular housing 20 receives a first, outer tubular mandrel assembly 29. Outer mandrel assembly 29 includes a tubular seating nipple 30 and a lower, tubular valve mandrel 32 which are threadedly secured in end-to-end relationship to the lower end of a section of pipe 35. Nipple 30 is slidably received in a central bore 31 of index sub 22 while mandrel section 32 is sized to be slidably and sealingly received within bores 33, 34 of housing subs 23, 24, respectively. Longitudinal and rotative manipulation of the pipe string 35 therefore may be imparted to the outer mandrel assembly 29.

A removable inner mandrel assembly 36 is releasably locked within the outer tubular mandrel assembly 29 by means of a latch structure hereafter to be described in greater detail. Generally, the inner mandrel assembly 36 includes an upper fishing head 37 disposed within the nipple 30, an intermediate tubular section 38 disposed loosely in bore 39 of the lower mandrel section 32, and a lower plug section 40 sealingly received in a smaller central bore 41 of lower mandrel section 32 (FIG. 2B). The above members of the inner mandrel assembly 36 are suitably secured together as by threaded connections and the lower section 40 is arranged to be threadedly connected to a pressure bomb housing 42 containing a conventional pressure bomb 43. The threaded connection between the lower box end of nipple 30 and the upper pin end of outer mandrel section 32 is fluidly sealed by sealing means, such as an O ring 60, disposed in a groove between the threaded connection.

Turning now to the specific details of the housing 20 and mandrel assemblies 29, 36, the lower end of a secton of pipe string 35 is loosely received in the central bore 44 of top sub 21 and central bore 31 of index sub 22, and is threadedly received in box end 45 of nipple 30. Nipple 30 is guided longitudinally and rotatively between various positions by index means (FIG. 3A) which will hereinafter be more fully explained.

In an uppermost position of the nipple relative to the index sub 22, the upper end surfaces of the nipple are adapted to engage the lower, downwardly facing shoulder 46 of sub 21 thereby limiting the upward movement of the nipple relative to the housing. In this position, external splines 47 on nipple 30 mesh with internal splines 48 on the sub 22 which extend inwardly of the bore 31.

In an intermediate position of the nipple 30 in the sub 22, the upper end surfaces of the nipple are adapted to engage the lower shoulder surfaces of splines 48. In this position the splines 47 and 48 are rotatively displaced so that their respective end surfaces are in abutment.

In a lowermost position of the nipple 30 in the sub 22, the lower end surface 51 of the nipple is adapted to engage the upwardly facing shoulder 50 of the pin end of sub 23 which is received in the lower box end of index sub 22. Circulation ports 52 are provided near the lower end of index sub 22 which permit reversal of fluid in the well as will hereinafter become more apparent.

Nipple 30 has a central bore 71 having a diameter similar to that of the interior of the pipe string 35 which is connected by an inwardly beveled transition portion 74 to a reduced diameter bore 39 in nipple 30 and mandrel section 32.

An enlarged head portion 72 of mandrel assembly 36 is connected by a tapered portion 72' to a reduced diameter portion of the inner mandrel section 38 to thereby be received within bores 71, 39 of mandrel assembly 29 with the beveled portion 74 of nipple 30 receiving the tapered portion of assembly 36.

To releasably secure the mandrel assemblies 29, 36 together, a plurality of recesses 75 are provided in the smaller bore portion of the nipple 31 just below the beveled portion 74. Mandrel section 38 is provided with lateral openings 76 corresponding in location to the recessed portions of the nipple. Ball members 77 are disposed in the openings and a tubular latching member 78 having an enlarged portion is slidably received in counterbore 79 of the mandrel section 38 to retain the balls in the recessed portions 75 thus securing the assemblies together.

The fishing head 37 has a threaded pin end received in a box end of the enlarged mandrel section 38 and has an upper enlarged diameter bore portion 80 extending between reduced diameter bores 81, 82 with the section formed between bores 80, 81 providing an internal fishing recess. Bore 82 slidably receives an upper stem portion 83 of the latching member 78. A lower, stem portion 84 extends downwardly from member 78 and is slidably received in the bore 85 of the mandrel 38. Central bore 78*a* in member 78 provides for fluid communication through the member. A stepped surface formed between bore 85 and bore 79 provides a seating surface for a

spring 85*a* to resiliently bias the latching member 78 upwardly in the position shown.

In a central portion of mandrel sections 32 and 38 are lateral circulation ports 62, 86, respectively, which permit fluid flow to the interior bore 85 of mandrel section 38. The ports 82, 86 are shown to be equally spaced about the mandrel sections and four in number. Sealing means 64 such as O rings suitably seal the outer surface of mandrel 32 with respect to the bore 31 above the ports 62.

In the lower portion of mandrel section 32 and sealing section 40 (FIG. 2B) are lateral test ports 63, 87 which open into the interior of section 40. Sealing means such as O rings 65 and 66 suitably seal the outer surface of mandrel 32 with respect to the bore 31 above and below the ports 63. Sealing means (O rings) 91 suitably seal the outer surface of section 40 with respect to the inner bore 41 of mandrel section 32.

Threadedly connected in the lower end of bore 85 is an internally tapered choke liner 88 which receives an outwardly tapered choke 89 having a central bore 90 providing a fluid passage therethrough. The bore 90 places the test ports 63, 87 in fluid communication with bore 85 of the inner mandrel section.

The sub 24 has an upper box end which is threadedly coupled to the lower pin end of sub 23 and a lower pin end which is threadedly received by the box end of recorder housing 26. An intermediate portion 67 of sub 24 has a central bore 34 which is similar in diameter to bore 33 of sub 23 to slidably and sealingly receive the lower portion of mandrel section 32. Disposed above and below the intermediate portion 67 are enlarged bore portions 68, 69 which are fluidly connected by means of longitudinal passages 70 extending between the bore portions. The upper and lower end portions of sub 23 and the ends of intermediate portion 67 of sub 24 are chamfered to facilitate entrance of the various O rings contained in the mandrel section 32. The passages 70 in the intermediate section together with the enlarged bore portion 68 constitute the housing test ports which permit fluid communication between the sub 24 and the mandrel 32 when the ports 63 of the mandrel assembly 29 are aligned with the enlarged bore portion 68.

To obtain the rotative and longitudinal positions of the mandrel assembly 29 relative to the housing 20, the nipple 30 has a pair of indexing pins 53, 54 disposed in diametrically opposed threaded holes (FIG. 2A). The pins are received in indexing slot systems on either side of the index sub 22. For convenience only one will be described since the systems are similar.

As shown in FIG. 3A, pin 53 extends into an index slot system 55 in the index sub 22. Index slot system 55 is generally shaped in an N type configuration having a first longitudinally extending slot 56, with upper and lower end portions terminating in pockets "A" and "B," respectively. A transfer slot 57 is inclined relative to the longitudinal slot 56 and has its lower end portion disposed adjacent to the lower end portion of slot 56 so as to form a dwell portion in the pocket "B." The upper end portion of inclined slot 57 is terminated at a pocket "C" which is at a point intermediate the upper and lower extremities of slot 56. A second longitudinal slot 58 is disposed adjacent to and extends downwardly from pocket "C" with the adjacent portions of slots 57, 58 forming a second dwell portion. Slot 58 is terminated at a lower pocket "D" which is at a point intermediate the upper and lower extremities of slot 56. As will hereinafter become more apparent, manipulation of the pipe string causes mandrel assembly 29 to assume various rotative and longitudinal positions relative to the housing 20 provide various control operations.

The operation of the well tool 19 will now be explained with reference to FIGS. 3 through 8 and FIGS. 3A through 8A which show the basic arrangement of the tools in a simplified manner.

The tool 19 is assembled and the mandrel assemblies 29, 36 are locked together and disposed in the housing as shown in FIGS. 2A—2B. The tool and a suitable packer are then lowered to the zone to be teste dand the packer set. As shown in FIGS. 3 and 3A, the pin 53 is in pocket "D" and the testing ports 63, 87 and the circulation ports 62, 86 are closed so that no fluid enters the interior of the tool. After the packer is set, the initial shut-in pressure is recorded.

Next the well may be permitted to flow by raising, rotating and lowering the pipe string 35. Since the mandrel assemblies 29, 36 are locked together, they move as a unit and pin 53 is moved up slot 58 to pocket "C" and down slot 57 to pocket "B" (FIGS. 4, 4A). In this position the bore 68 and passages 70 are placed in fluid communication with test ports 63, 87 and fluid may flow as shown by the arrows through passages 70, bore 68 and ports 63, 87 to the central bores 90, 85 and 78*a* and the pipe string 35. In this position also, the circulation ports 62, 86 remain closed. Further, the abutment surfaces 50, 51 of the sub 22 and nipple 30, respectively, provide a solid support for the weight of the pipe string 35.

After the flow test the pipe string 35 is rotated and raised so that pin 53 travels from pocket "B" to pocket "C" and the testing ports 63, 87 are again closed to take a final shut-in pressure (FIGS. 5, 5A). When the pin 53 is in pocket "C" the splines 47, 48 have their lower and upper surfaces, respectively, in abutment.

After taking the final shut-in pressure, the pipe string is rotated, lowered and raised so that the pin 53 travels from pocket "C," slot 57 to pocket "B" and then through slot 56 to pocket "A" as shown in FIGS. 6, 6A. This effectively places the circulation ports 62, 86 of the mandrel assemblies in fluid communication with circulation port 52 of the housing 20 permitting well fluid to flow into the bore 85, 78*a* to the pipe string 35 as shown by the arrows. Hence, the fluid in the pipe string flows to the surface for recovery. In this position, testing ports 63, 87 remain closed and splines 47, 48 are meshed in the uppermost position of nipple 30 in the index sub 22.

Referring back to the tool position shown in FIGS. 4, 4A, it will be appreciated that from the test flow position shown, the pipe string 35 alternatively may be raised so that pin 53 travels in slot 56 from pocket "B" to pocket "A" closing the test ports 63, 87 and opening the circulation ports 62, 86 so that reverse circulation may be accomplished at the same time the final shut-in pressure is taken.

From the foregoing it will be appreciated that whenever pin 53 is in pocket "C" or "D" both the circulation ports 62, 86 and the testing ports 63, 87 are closed. This is accomplished by the sealing means 64, 65, 66 disposed above, intermediate and below ports 62, respectively, sealing the mandrel section 32 in bore 33 of the housing and the sealing means 91 which fluidly seals the lower section 40 in the bore 41 of mandrel section 32.

Whenever the pin 53 is in pocket "B" the test ports 63, 87 are opened to the passages 70 and bore 68 permitting fluid flow to the interior of the pipe string while the circulation ports are closed. This is accomplished by the the sealing means 66 sealing mandrel section 32 in bore 34 of sub 24 and sealing means 65 sealing mandrel section 32 in bore 33 of sub 23.

Whenever the pin 53 is in pocket "A" the test ports 63, 87 are closed and the circulation ports 62, 86 are opened. Sealing means 64, 65 seal the mandrel section 32 to bore 33 while sealing means 66 provides a lower seal.

It will therefore be apparent that the well tool 19 can obtain initial mud pressure, initial shut-in pressure, flowing pressure, final shut-in pressure and the final mud pressure with only one trip in the well and that reverse circulation of collected fluid may be accomplished.

Referring now to FIG. 12, a fishing tool 95, which may

be suitably lowered in the tubing **35** by means of a wire line, is shown in position to release the inner mandrel assembly **36** from the tool. The fishing tool **95** has a cylindrical body **96** which is loosely received in bores **81**, **82** of the fishing head **37**. The lower portion of body **96** has resilient fingers **97** which extend outwardly and upwardly from body **99**. Fingers **97** hence will pass through bore **81** and expand to engage the section of wall between bores **80**, **81**. The bottom surface of body **96** is lowered to engage the upper stem **83** and push the latch member **78** downward compressing spring **85***a* and permitting ball members **77** to be released thus uniocking mandrel assembly **36** from assembly **29**. When the body **95** is subsequently raised, fingers **97** engage the surface between bores **80**, **81** to remove the entire assembly **36** from the tool as shown in FIG. 7.

With the assembly **36** removed, a perforating gun may then be lowered through the tool body to perforate the casing.

In FIGS. 7 and 7A, the mandrel assembly **29** is shown after the inner mandrel assembly **36** has been shown removed. Assembly **29** is illustrated in an operating condition similar to that illustrated in FIGS. 6, 6A, i.e., the reverse circulation ports **62** are opened to the housing ports **52** with the pin **53** in position "A."

In FIGS. 8 and 8A, the mandrel assembly **29** is shown in an operating position similar to that of FIGS. 4 and 4A; the reverse circulation ports **62** are closed.

With the tool operable between the operating conditions shown in FIGS. 7 and 8, the tool can remain in the well bore and features a valve which permits hydraulic fracturing or acidizing operations. Also, if it is desired, cement may be squeezed. These operations are made feasible by the reverse circulation port **62** remaining in the tool which permits reverse circulation of the various fluids as desired.

From the foregoing it will be seen that a single trip with one tool allows testing, treating and squeezing operations and that the tool is full opening to permit a perforating gun to pass therethrough. Further that no matter what sequence of operations is carried out, the tubing string has but one round trip in the well. The removable inner mandrel assembly **36** opens the tool to permit the use of a circulating valve in the pipe string as desired. Also the mandrel assembly **36** may be changed to provide a different size flow choke if desired.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and therefore the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit of this invention.

What is claimed is:

1. In a well tool: a tubular housing having a central bore portion, and an enlarged bore portion therebelow and a circulation port located above said enlarged bore portion; a tubular outer mandrel slidably received within said central bore portion and adapted to be connected to a pipe string for movement therewith relative to said housing; an inner tubular mandrel assembly releasably locked within said outer mandrel assembly and including a plug portion; sealing means for sealing said plug portion and said outer mandrel assembly against fluid flow therebetween; said outer mandrel assembly having a plurality of ports located above said sealing means and arranged to open to the interior of a pipe string; sealing means between said outer mandrel assembly and said housing above and below said mandrel ports; and means carried by said outer mandrel assembly for interconnecting with said housing and guiding the movement of said mandrel assemblies relative to said housing between positions including a lowermost position placing at least one of said outer mandrel ports in fluid communication with said enlarged bore portion, an intermediate position sealing off said outer mandrel ports within said central bore portion and an uppermost position placing at least one of said outer mandrel ports in fluid communication with said housing circulation port.

2. In a well tool: a tubular housing having a central bore portion of uniform diameter and an enlarged bore portion therebelow and having a lateral circulation port disposed above said enlarged bore portion; a tubular outer mandrel assembly slidably received within said central bore portion including means arranged to connect said assembly to a tubing string for longitudinal and rotational movement therewith relative to said housing, said outer mandrel assembly further having lateral circulation ports and test ports longitudinally spaced from each other and arranged for fluid communication with the interior of a tubing string; sealing means between said outer mandrel assembly and said housing for sealing said ports against fluid flow therebetween; an inner mandrel assembly releasably locked within said outer mandrel assembly and including a plug portion disposed below said mandrel test ports; means between said outer mandrel assembly and said inner mandrel assembly for sealing said plug portion within said outer mandrel assembly; said mandrel assemblies being movable between a first position placing said mandrel test ports in fluid communication with said enlarged bore portion while sealing off said mandrel circulation port within said central bore portion, a second position sealing off said mandrel test ports and circulation ports within said central bore portion, and a third position placing said mandrel circulation ports and housing circulation ports in fluid communication while sealing off said mandrel test ports within said central bore portion; and means carried by said outer mandrel assembly and interconnected to said housing for guiding the movement of said outer mandrel assembly relative to said housing between said positions.

3. In a well tool: a tubular housing; a tubular outer mandrel assembly slidably received within said housing and adapted to be connected to a tubing string for longitudinal and rotational movement therewith relative to said housing; an inner tubular mandrel assembly releasably locked within said outer mandrel assembly and having a bore therethrough closed at its lower end and arranged to be in fluid communication with a tubing string at the upper end thereof; said inner and outer mandrel assemblies each having aligned lateral circulation ports and test ports longitudinally spaced from each other, said circulation ports and said test ports permitting fluid communication between the outer surfaces of said mandrel assemblies to said inner mandrel bore; sealing means disposed between said inner and outer mandrel assemblies below the lowermost port in said inner mandrel for preventing fluid flow therebetween; sealing means between said outer mandrel assembly and housing located above and below said outer mandrel circulation and test ports; means in said housing forming a test port; means carried by said outer mandrel assembly and interconnected to said housing for guiding the motion of said assemblies within said housing between longitudinally spaced positions, said housing circulation ports and mandrel assembly circulation ports being in fluid communication in one of said positions, said test ports being sealed off within said housing in said one position, said mandrel test ports being in fluid communication with said housing test ports in another position, second mandrel assembly circulation ports being sealed off within said housing in said other position, and said mandrel test ports and circulation ports in still another position being sealed off from one another within said housing.

4. In a well tool: a tubular housing having a uniform central bore portion and an enlarged bore portion therebelow and circulation ports disposed above said enlarged portion; an outer mandrel assembly slidably received within said central bore portion, said outer mandrel assembly having circulation ports and test ports spaced longitudinally of one another; sealing means between said outer

mandrel assembly and said housing for said ports; means for connecting said outer mandrel assembly to a tubing string for longitudinal and rotational movement therewith relative to said housing between a first position placing said outer mandrel test ports in fluid communication with said enlarged bore and sealing off said mandrel circulation ports within said central bore portion, a second position sealing off said mandrel test ports and said circulating ports within said central bore portion, and a third position placing said housing circulation ports and mandrel circulation ports in fluid communication while sealing off said test ports within said central bore portion; said outer mandrel assembly having a pair of oppositely facing shoulders, said housing having a pair of oppositely facing shoulders, said outer mandrel assembly shoulders being respectively engageable with said housing shoulders at said first and third longitudinal positions; and an index slot and pin means operatively connected between said housing and said outer mandrel assembly for guiding the motion of said outer mandrel assembly between said first and third positions to bring the respective pair of shoulders into engagement in said position and including portions for locking said outer mandrel assembly and said housing in said second position.

5. In a well tool: a tubular housing having a longitudinally extending bore including a central bore portion and an enlarged bore portion therebelow, said portions defining an upper shoulder, said tubular housing further having inwardly extending splines in said enlarged bore portion which are disposed adjacent said upper shoulder, said splines having lower surfaces defining lower shoulders; a tubular mandrel slidably received within said central bore portion; a tubular seating nipple connected to said mandrel and arranged to be connected to a tubing string and movable therewith relative to said housing, said nipple being slidably received within said enlarged bore portion for longitudinal movement between said upper and lower shoulders; interengageable, outwardly extending splines on said seating nipple for engagement with said housing splines; said housing and said mandrel respectively having at least one port; an index slot and pin means connected between said housing and mandrel to guide the longitudinal and rotative movement of said mandrel relative to said housing between a position wherein said outwardly extending splines engage said lower shoulders to a position wherein said outwardly extending splines mesh with said inwardly extending splines.

6. In a well tool: a tubular housing having a longitudinal extending central bore portion and an enlarged bore portion therebelow defining an upper shoulder, inwardly extending splines in said enlarged portion having lower surfaces defining lower shoulders; a tubular mandrel slidably received within said central bore portion; a seating nipple connected to said mandrel and to a tubing string and movable relative to said housing, said nipple being slidably received within said enlarged bore portion for longitudinal movement between said upper and lower shoulders; interengageable, outwardly extending splines on the upper end of said seating nipple for engagement with said housing splines; said housing having a circulation port; said mandrel having a circulation port; pressure sealing means above and below said mandrel circulation port and between said seating nipple and said mandrel; said circulation ports and associated pressure sealing means being arranged to provide a fluid passage therebetween when the upper shoulders of said seating nipple splines contact said upper housing shoulder; said mandrel circulation port being sealed off within said housing when the upper shoulder of said seating nipple splines abut the lower end of said housing splines; an index slot in said housing including at least a diagonal leg and a longitudinally extending leg, and an index pin on said seating nipple received within said index slot to guide the longitudinal and rotational movement of said outer mandrel and facilitate engagement of said splines.

7. In a well tool: a tubular housing; a tubular outer mandrel assembly adapted to be connected to a tubing string for movement therewith relative to said tubular housing; said outer mandrel assembly being slidably received within said tubular housing for longitudinal movement relative thereto between a plurality of longitudinally spaced positions; an inner mandrel assembly releasably locked within said outer mandrel assembly and including a plug portion; annular seal means between said plug portion and said outer mandrel assembly to close the lower end of said outer mandrel assembly; said tubular housing and said inner and outer mandrel assemblies having portions cooperating to define test valve means, said test valve means being open in one of said positions, between the interior of said tubular housing below said plug portion and the interior bores of said assemblies above said plug portion; said tubular housing and outer mandrel assembly each having ports which cooperate, in a second position, to define circulating valve means for permitting fluid flow through the said ports between the exterior of said tubular housing and the interior bore of said outer tubular mandrel assembly above said plug portion; and sealing means arranged between said outer mandrel assembly and said tubular housing, in a third position, to prevent fluid flow through said ports and said test valve means.

8. In a well tool: a tubular housing adapted to be connected to a packer; a tubular outer mandrel assembly slidably received within said tubular housing for longitudinal movement relative thereto among first, second and third positions, said assembly being adapted for connection with a tubing string for manipulation therewith to said positions relative to said housing; an inner tubular mandrel assembly releasably locked within said outer mandrel assembly and including a fluid-tight plug portion sealingly disposed within said outer mandrel assembly; test valve means including ports in said outer mandrel assembly arranged for cooperation with said housing, in a first position of said mandrel assemblies relative to said housing, to define a passageway for fluid between the interior of said tubular housing below said inner mandrel plug portion and the interior of said outer mandrel assembly above said plug portion; circulating valve means including ports in said housing and said outer mandrel assembly above said plug portion said ports being arranged, in the second position of said mandrel assemblies, for communication with one another to provide a fluid passage between the exterior of said tubular housing and the interior of said outer mandrel assembly; and sealing means arranged, in the third position of said mandrel assemblies, between said outer mandrel assembly and said tubular housing to prevent fluid flow through said ports.

9. In a well tool: a tubular housing adapted to be connected to a packer; an outer tubular mandrel assembly slidably received within said tubular housing for longitudinal movement relative thereto between a plurality of longitudinally spaced positions, said outer mandrel assembly being adapted for connection to a tubing string for movement therewith; a tubular inner mandrel assembly releasably locked within said outer mandrel assembly, said inner mandrel assembly having a longitudinally extending bore which is closed at a lower end and open at an upper end for communication with a tubing string, said inner mandrel assembly further having ports intermediate of said ends; said tubular housing and said inner and outer assembles having portions cooperating to define test valve means, said test valve means in a first of said positions being open for fluid flow between the interior of said tubular housing below said closed end and the ports of said inner mandrel assembly; said outer mandrel assembly and said tubular housing each having ports which cooperate, in a second of said positions, to define circulating valve means for permitting fluid flow through the ports between the exterior of said tubular housing and said inner mandrel ports above said closed bore end; and sealing

means arranged between said outer mandrel assembly and said tubular housing to prevent fluid flow through said ports and said test valve means in a third of said positions.

10. In a well tool: a tubular housing adapted to be connected at its lower end to a packer; a tubular outer mandrel assembly slidably received within said tubular housing for longitudinal movement relative thereto between positions including a lowermost, an intermediate and an uppermost position, said outer mandrel assembly being adapted for connection with a tubing string; a tubular inner mandrel assembly releasably locked within said outer mandrel assembly, said inner mandrel assembly having a longitudinally extending bore which is closed at a lower end and open at an upper end for communication with a tubing string; said inner mandrel assembly further having ports intermediate of said ends; means in said inner mandrel assembly to releasably lock said inner mandrel assembly to said outer mandrel assembly; sealing means between the lower end of said inner mandrel assembly and said outer mandrel assembly; said tubular housing and said inner and outer mandrel assemblies, in said lowermost position, having portions cooperating to define test valve means, said test valve means being open in said lowermost position for fluid flow between the interior of said tubular housing below said closed end and the ports of said inner mandrel assembly; said tubular housing and said tubular outer mandrel assembly each having ports which cooperate, in the uppermost position, to define circulating valve means for permitting fluid flow through the ports between the exterior of said tubular housing and said outer mandrel assembly ports above said closed end; and sealing means arranged between said outer mandrel assembly and said tubular housing to prevent fluid flow through said circulating valve means and said test valve means in said intermediate position.

11. In a well tool: a tubular housing adapted to be connected at its lower end to a packer; an outer mandrel assembly including a tubular outer mandrel slidably received within said housing and a tubular sleeve coupled to the upper end of said outer mandrel and adapted for connection with a tubing string for longitudinal and rotational movement therewith relative to said housing; means on said housing and said outer mandrel assembly for limiting movement of said outer mandrel assembly relative to said housing in first, second and third positions, said means including spline portions on said housing and said outer mandrel assembly in one rotational relationship arranged to limit movement of said outer mandrel assembly in said first position and, in another rotational relationship, permit said mandrel assemblies to by-pass said first position to move between said second and third positions; cooperating index means operably connected between said housing and said tubular sleeve for guiding relative longitudinal and rotational movement of said housing and said outer mandrel assembly to selectively position said outer mandrel assembly at said first, second or third positions; an inner mandrel assembly releasably locked within said outer mandrel assembly and including a plug portion sealingly disposed within said outer mandrel assembly; test value means including portions of said tubular housing and said outer mandrel assembly, when opened, providing a fluid passage for fluid between the interior of said tubular housing below said plug portion and the interior of said outer mandrel assembly, said test valve means being opened in said first position of said mandrel assemblies relative to said tubular housing; circulating valve means including portions of said outer mandrel assembly and said tubular housing, when opened, providing a fluid passage between the exterior of said tubular housing and the interior of said outer mandrel assembly above said plug portion, said circulating valve means being opened in said second position of said mandrel assemblies relative to said housing; and means between said outer mandrel assembly and said tubular housing for sealing said test valve means and said circulating valve means from fluid flow in said third position of said mandrel assemblies relative to said tubular housing.

12. In a well tool: a tubular housing having a circulation port; an outer tubular mandrel assembly adapted to be connected to a tubing string for movement therewith longitudinally relative to said tubular housing, said outer mandrel assembly being slidably mounted within said tubular housing for longitudinal movement relative thereto; said outer mandrel assembly further having circulation ports and test ports spaced longitudinally from one another, said ports arranged to be in fluid communication with the interior of a tubing string; an inner mandrel assembly releasably locked within said outer mandrel assembly and including a plug portion disposed below said outer mandrel assembly test ports; means sealing said plug portion with respect to said outer mandrel assembly to prevent fluid flow therebetween; said tubular housing having a portion cooperating with said outer mandrel assembly test ports to permit fluid communication from points below said inner mandrel assembly plug portion to the interior of a tubing string when said assemblies are in a lowermost position relative to said tubular housing; annular sealing means between said outer mandrel assembly and said tubular housing for preventing fluid flow to said outer mandrel assembly circulation ports and said test ports when said assemblies are in a second position longitudinally displaced relative to said tubular housing from said lowermost position; said housing circulation ports and outer mandrel assembly circulation ports being arranged to be placed in fluid communication when said assemblies are in a third position relative to said tubular housing and longitudinally displaced from said other positions.

13. In a well tool: a tubular housing having a central bore portion and an enlarged bore portion therebelow and having a circulation port located above said enlarged bore portion; a tubular outer mandrel assembly slidably mounted within said central bore portion and having means for connecting said outer mandrel assembly to a tubing string to thereby permit longitudinal and rotational movement therewith relative to said tubular housing, said outer mandrel assembly further having circulation ports and test ports spaced longitudinally of each other to permit fluid communication with the interior of a tubing string; sealing means arranged along said outer mandrel assembly above and below said ports for sealing with said tubular housing; an inner mandrel assembly releasably locked to said outer mandrel assembly and including a plug portion disposed below said mandrel assembly test ports; means for sealing said plug portion with respect to said outer mandrel assembly to prevent fluid flow therebetween; said mandrel assemblies being moveable between a first position placing said mandrel assembly test ports in fluid communication with said enlarged housing bore, a second position sealing said outer mandrel assembly circulation ports and test ports within said central bore portion of said housing, and a third position placing said outer mandrel assembly circulation ports and housing circulation ports in fluid communication with one another; and means carried by said tubular housing and interconnected to said outer mandrel assembly for guiding the movement of said outer mandrel assembly relative to said housing between said positions.

14. In a well tool: a tubular housing adapted to be connected to a packer; a tubular outer mandrel assembly slidably received within said tubular housing and adapted to be connected to a tubing string for longitudinal and rotational movement therewith relative to said tubular housing between first, second and third positions; an inner mandrel assembly releasably locked within said outer mandrel assembly and including a plug portion; means for sealing said plug portion with respect to said

inner mandrel assembly to prevent fluid flow therebetween; said outer mandrel assembly having a pair of oppositely facing shoulders, said tubular housing having a pair of oppositely facing shoulders, said outer mandrel assembly shoulders being respectively engageable with said tubular housing shoulders when said outer mandrel assembly is in said first and third positions; index slot and pin means operatively connected between said tubular housing and said outer mandrel assembly for guiding the motion of said outer mandrel assembly between said positions and including portions for releasably retaining said outer mandrel assembly and said housing in the second position; said outer mandrel assembly having test ports and circulation ports located above said plug portion which ports are spaced from one another along the length of said outer mandrel assembly, said test ports being arranged to cooperate with said tubular housing in the first position to define a fluid passage longitudinally through the tool; packing means between said outer mandrel assembly and said tubular housing arranged to prevent fluid flow through said test ports and said circulation ports when said outer mandrel assembly is in said second position; said housing having circulation ports arranged to cooperate with said outer mandrel assembly circulation ports to provide a fluid passage from the exterior of said housing to a tubing string above said plug portion when said outer mandrel assembly is in said third position.

15. In a well tool as defined in claim 14, wherein one shoulder on said housing has a longitudinally extending groove therein and a shoulder on said mandrel assembly is on a spline arranged to fit in said groove, said spline being arranged to selectively abut said one shoulder or to fit in said groove; said index slot and pin means being arranged to permit relative rotation between said outer mandrel assembly and housing to facilitate positioning of said spline relative to said one shoulder and said groove.

16. In a well tool: a tubular housing having a uniform

central bore portion and an enlarged bore portion therebelow; said tubular housing further having circulation ports above said enlarged bore portion; an outer mandrel assembly adapted to be connected to a tubing string, said outer mandrel assembly being slidably received within said central bore portion for longitudinal and rotational movement therewith relative to said tubular housing; said outer mandrel assembly having circulation ports and test ports spaced longitudinally of one another; sealing means for said mandrel assembly ports located between said outer mandrel assembly and said tubular housing; a pair of oppositely facing shoulders respectively formed on said tubular housing and outer mandrel assembly and arranged to co-engage when the outer mandrel assembly is moved to position said test ports in fluid communication with said enlarged bore portion; a second pair of oppositely facing shoulders respectively formed on said tubular housing and outer mandrel assembly and arranged to co-engage when the outer mandrel assembly is moved to position said housing circulation test ports and said mandrel assembly circulation ports in fluid communication; and index slot and pin means operably connected between said outer mandrel assembly and said housing for selectively positioning said pairs of shoulders in engagement and for locating said outer mandrel assembly in yet another position wherein said test ports and circulation ports are within said central bore portion and said sealing means prevent fluid communication through said ports.

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