

[54] **METHOD AND APPARATUS FOR TREATING WELLS**
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[52] U.S. Cl.**166/305, 166/311, 166/126**
[51] Int. Cl.**F21b 21/00, F21b 37/00**
[58] Field of Search.....166/299, 305, 311, 129, 130, 166/126, 163, 162, 164

[56] **References Cited**
UNITED STATES PATENTS
1,968,282 7/1934 Cavins.....166/311
3,240,273 3/1966 Solari et al.....166/299

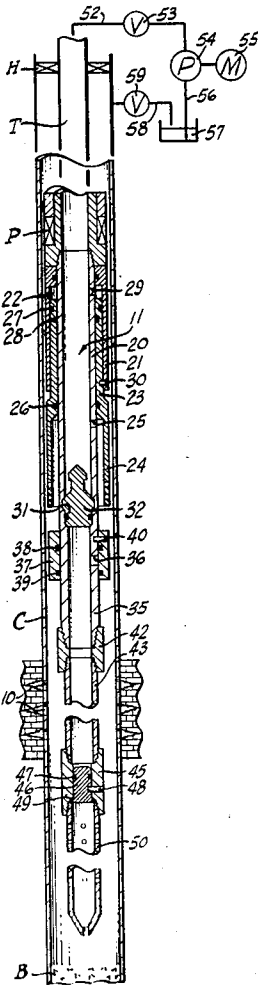
3,372,755 3/1968 Venghiattis.....166/299
3,589,442 6/1971 Kilgore.....166/299

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[57] **ABSTRACT**

Apparatus and method for producing an area or region of substantially reduced pressure in a well casing to suction purge perforations in the casing at the producing zone for clearing the perforations, removing detritus and the like. The apparatus is adapted for use with hydraulic set packers without causing premature setting thereof, and is designed to permit injection of treating fluids or the like into the well formation, if desired, prior to establishing production from the well. All operations are carried out with the flow conductor in place and without removing it from the well casing.

33 Claims, 35 Drawing Figures



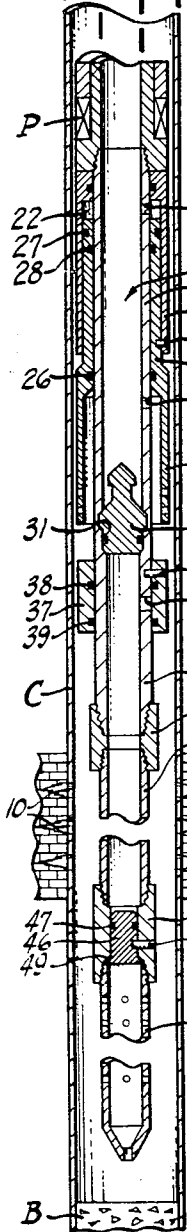
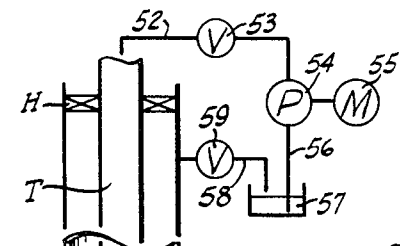


Fig. 1

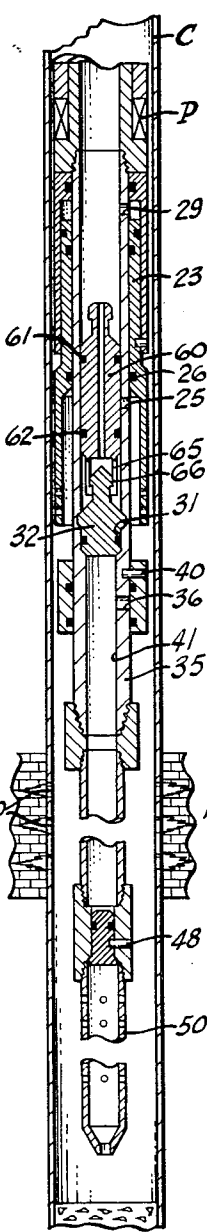


Fig. 2

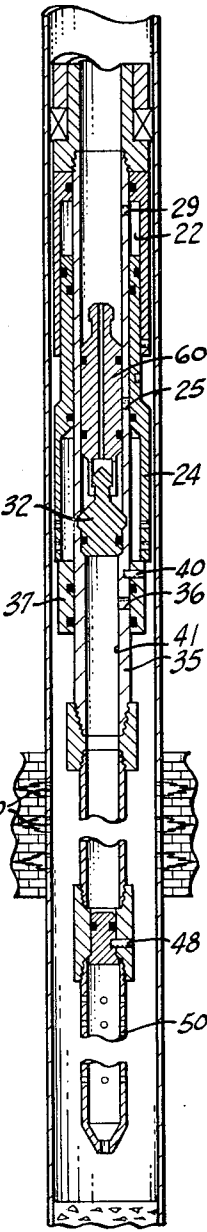


Fig. 3

Fig. 4

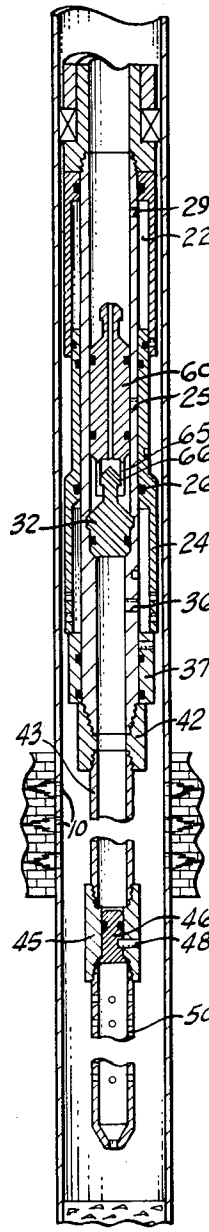
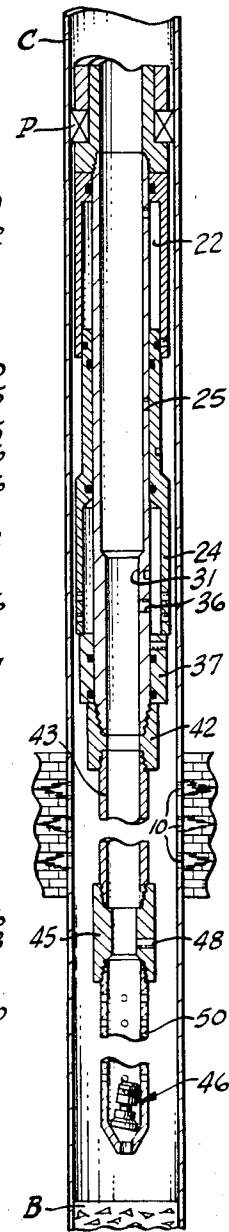


Fig. 5



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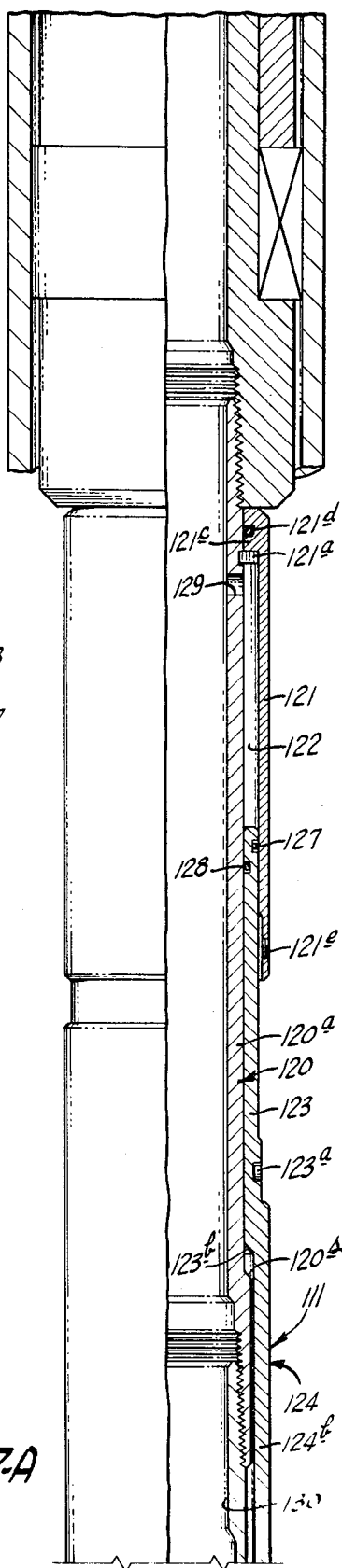
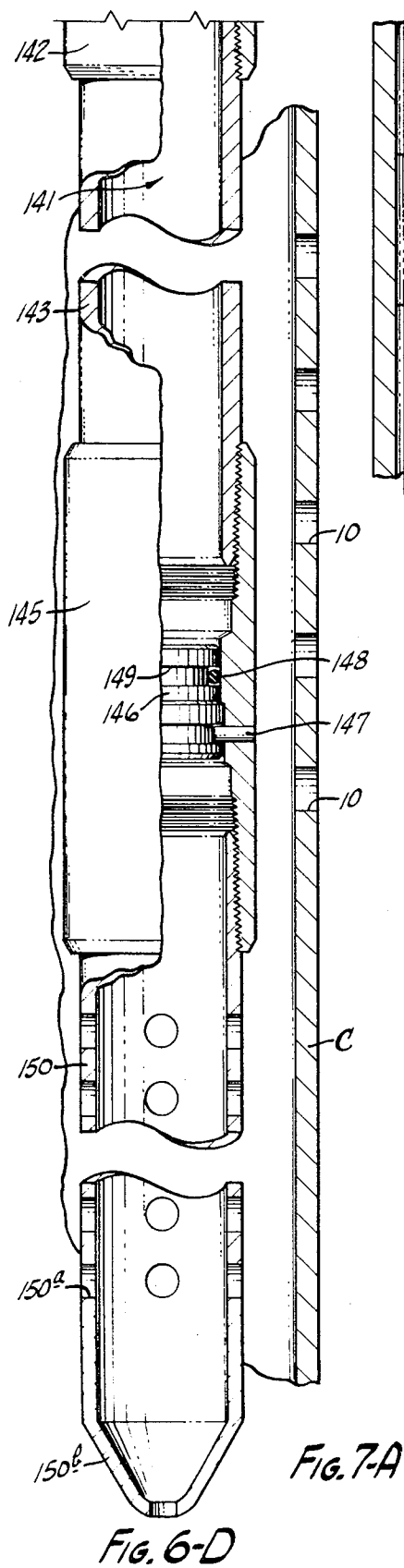


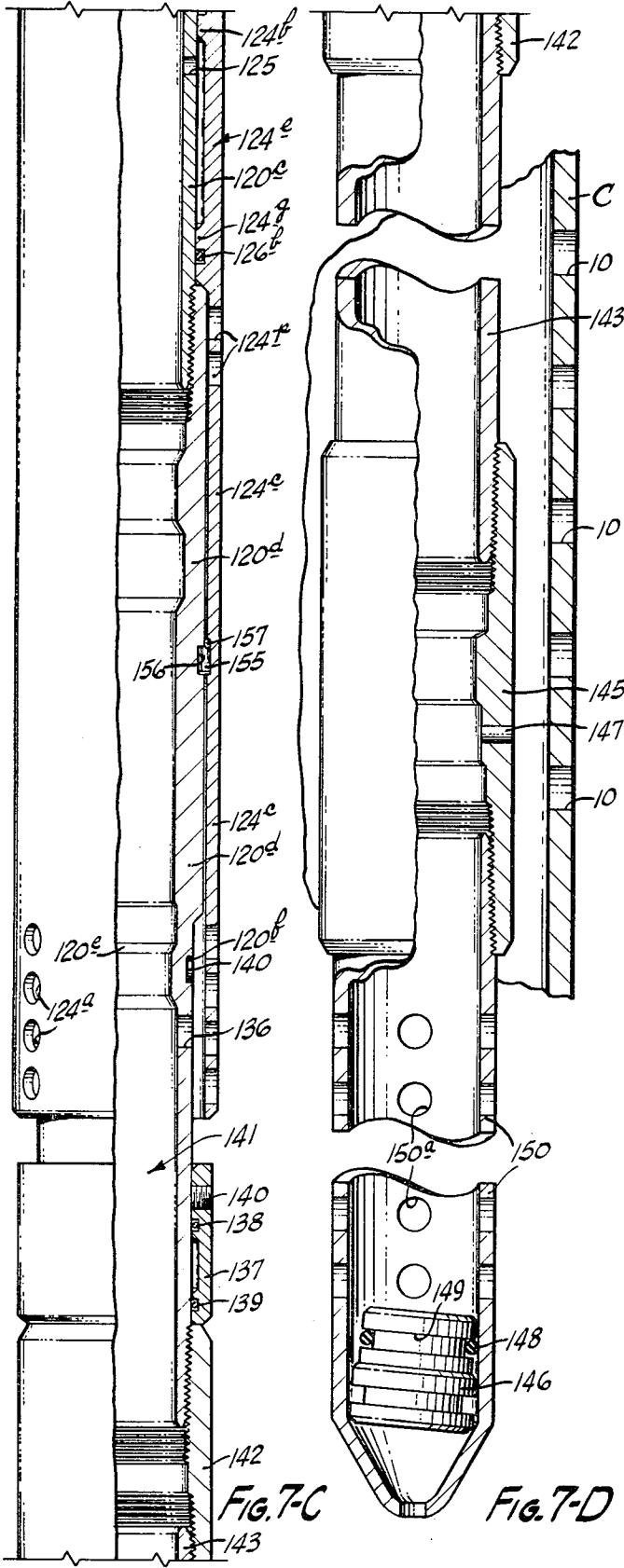
Fig. 7-B

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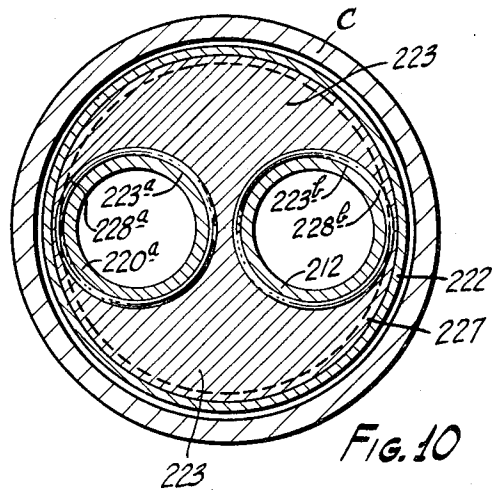
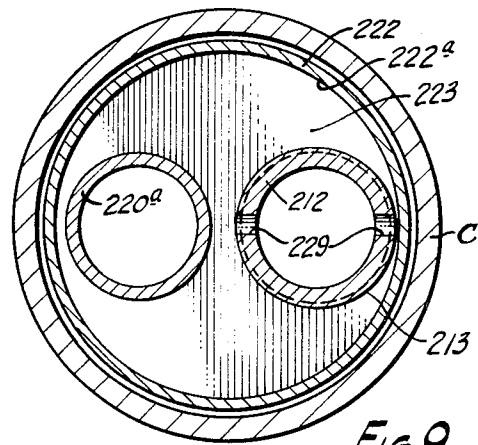
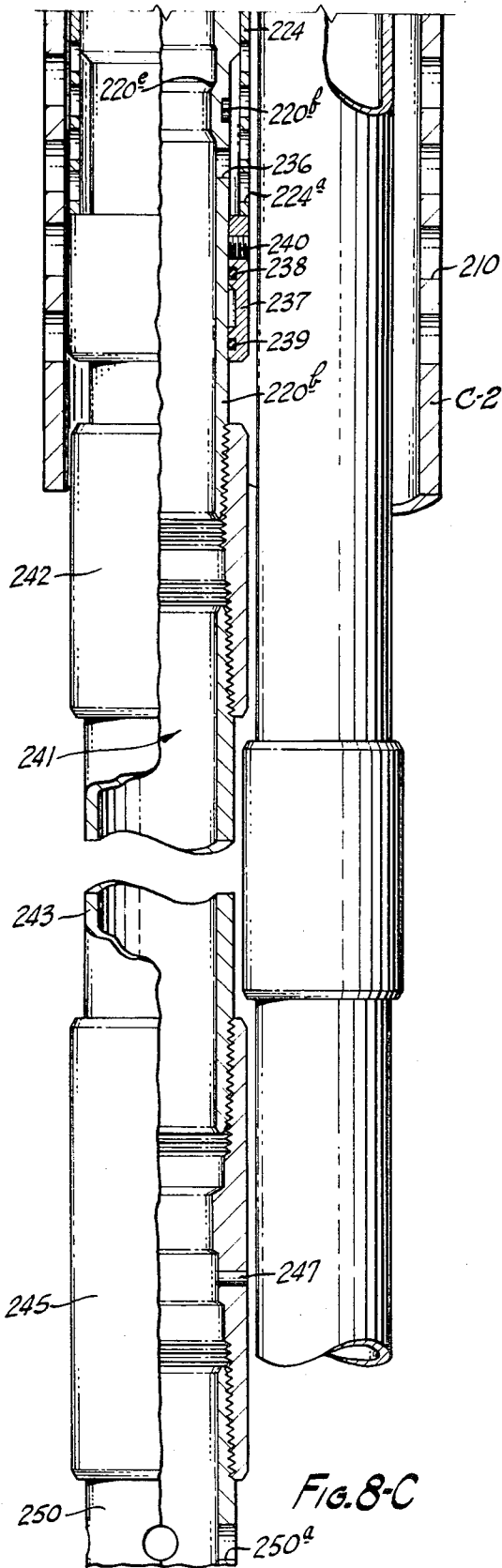
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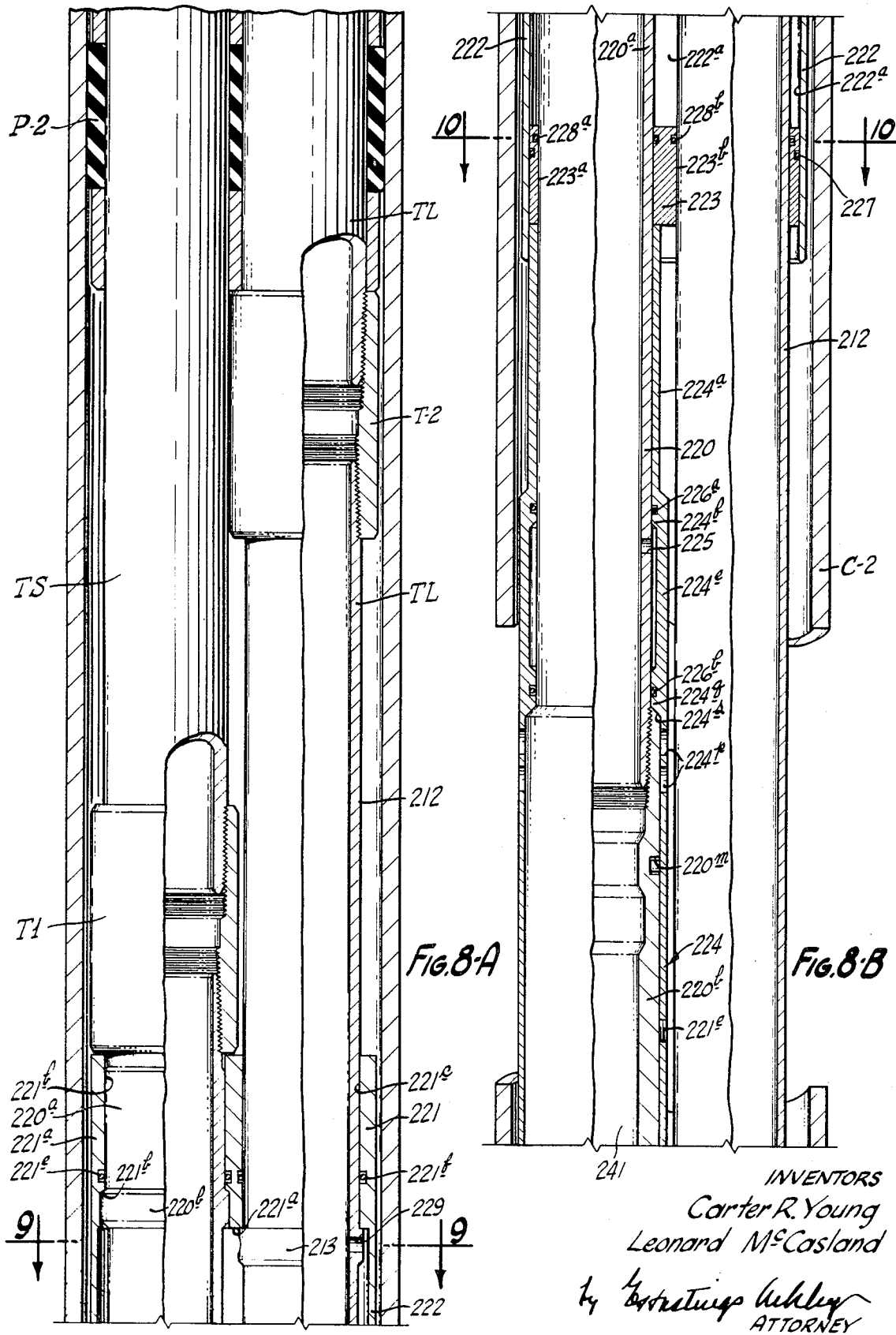
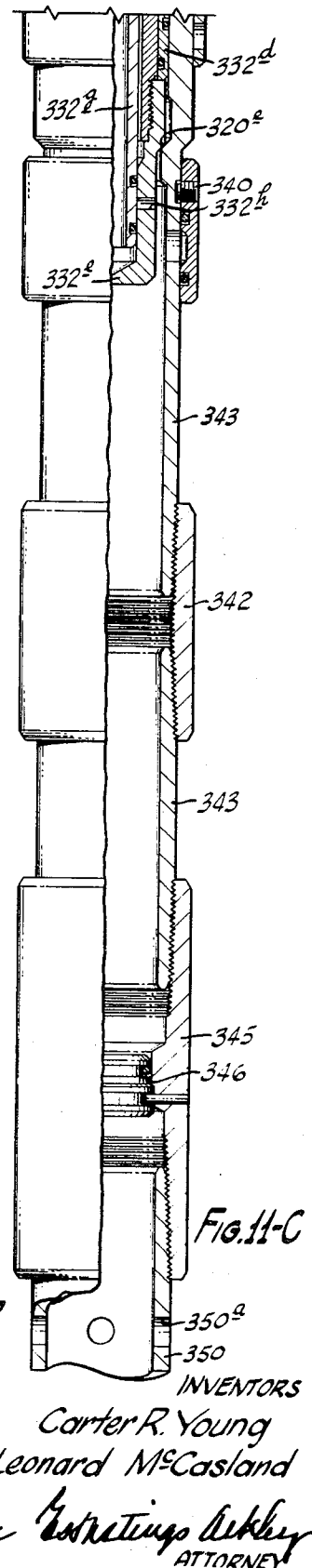
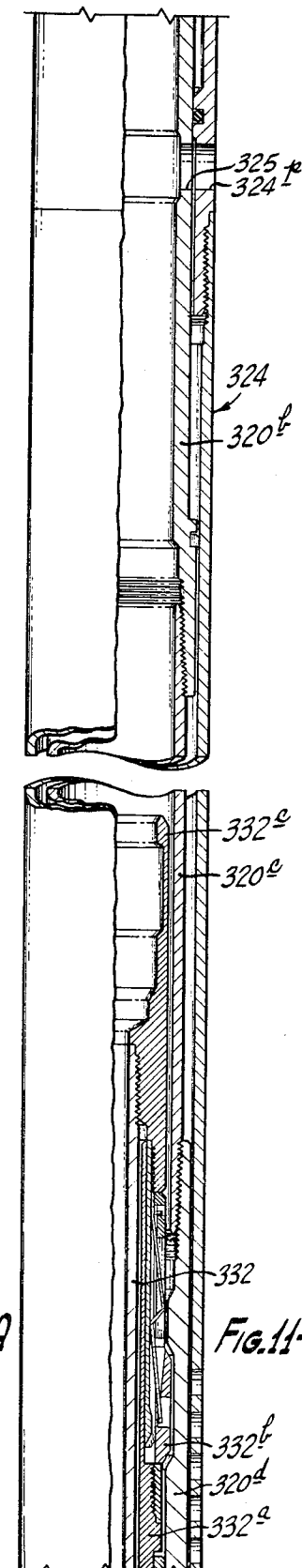
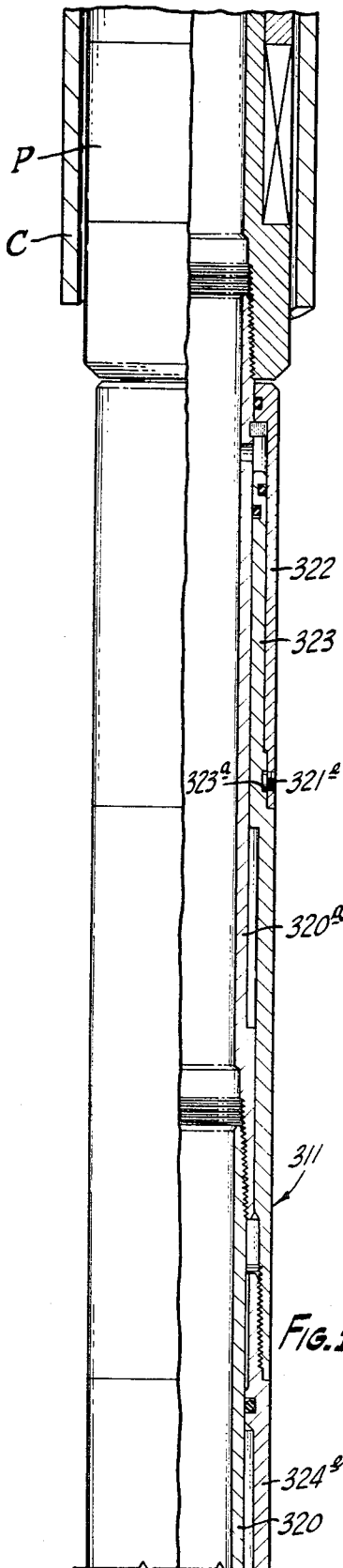


Fig. 8-A

Fig. 8-B

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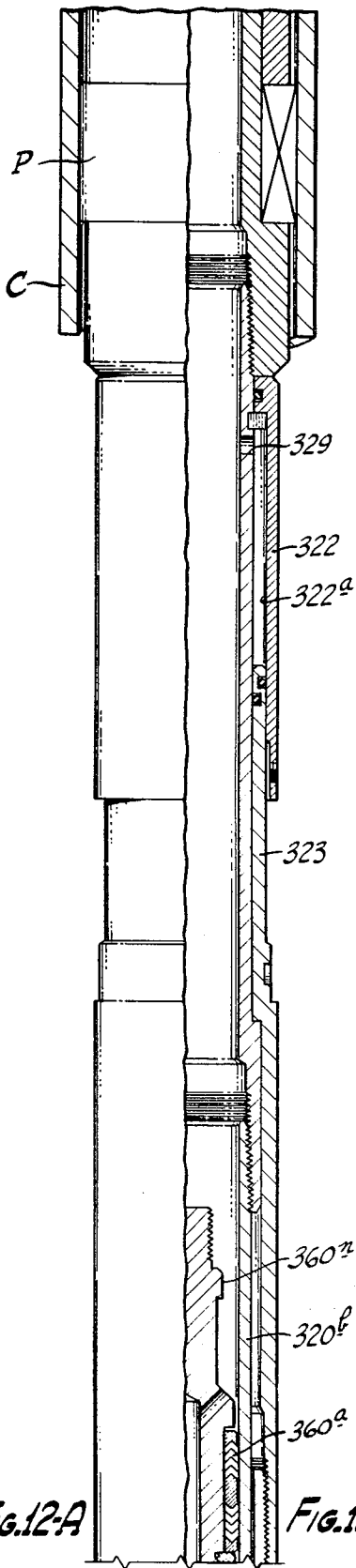


Fig. 12-A

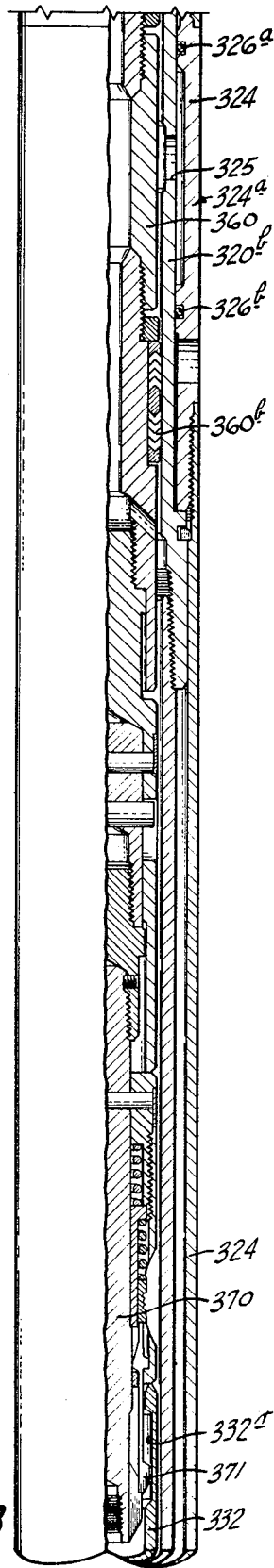


Fig. 12-B

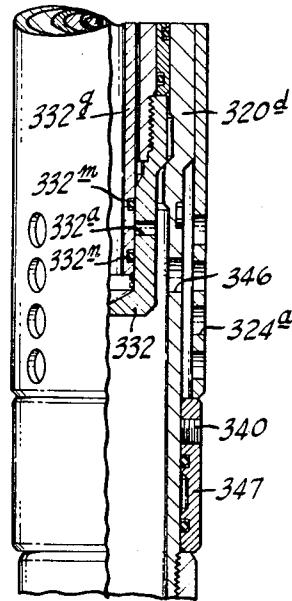


Fig. 12-C

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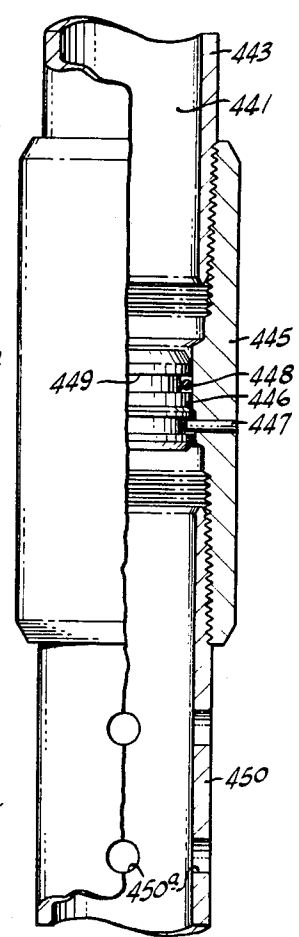
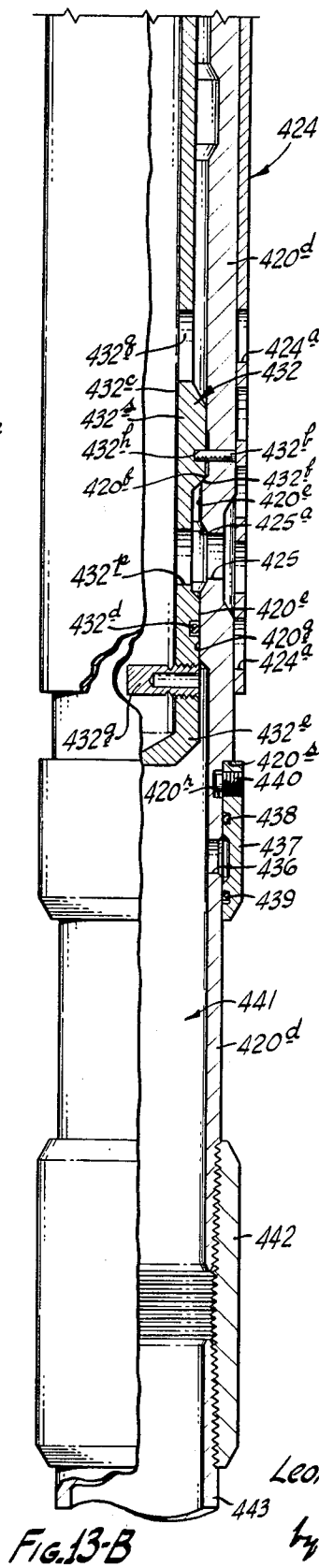
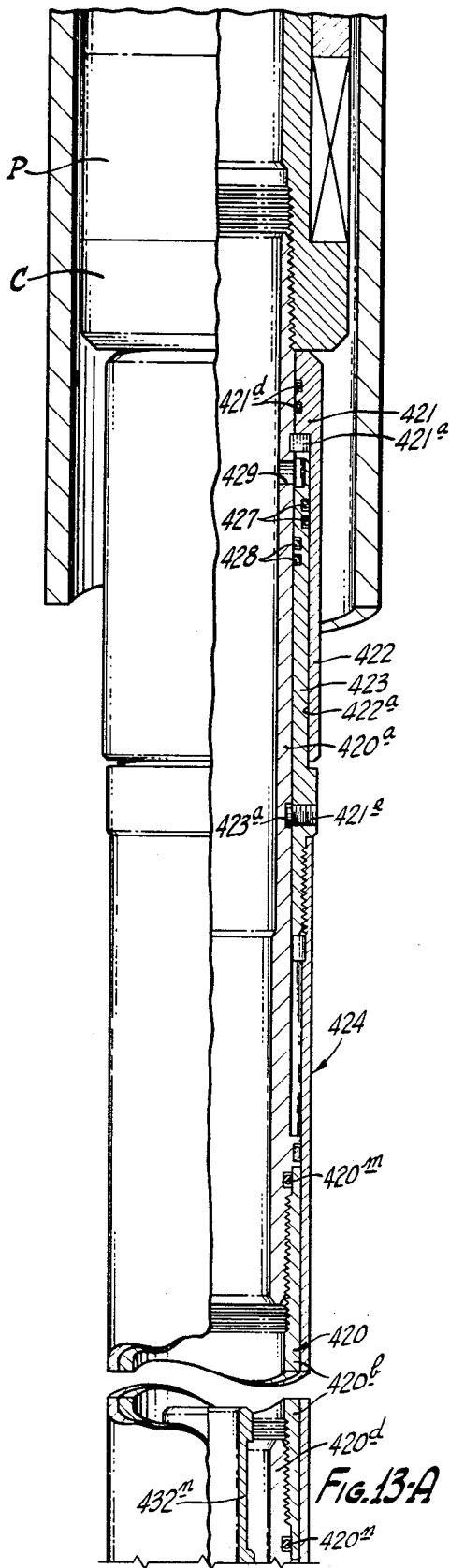


Fig. 13-C

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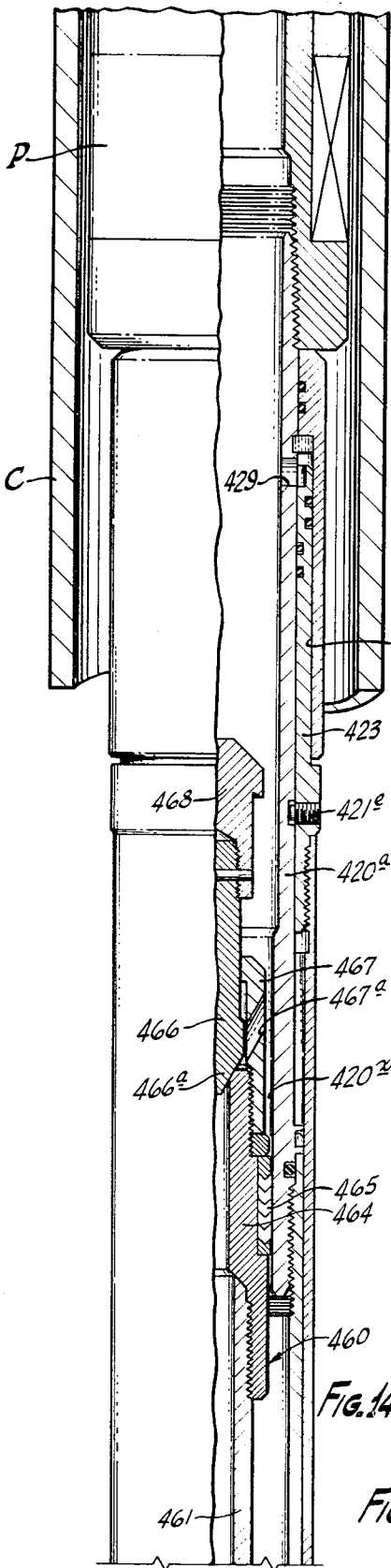
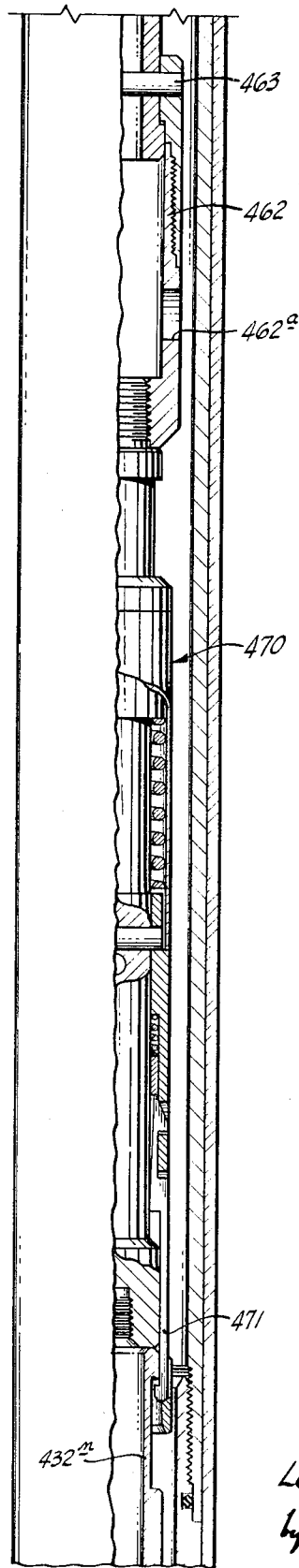


Fig. 14-A

Fig. 14-B



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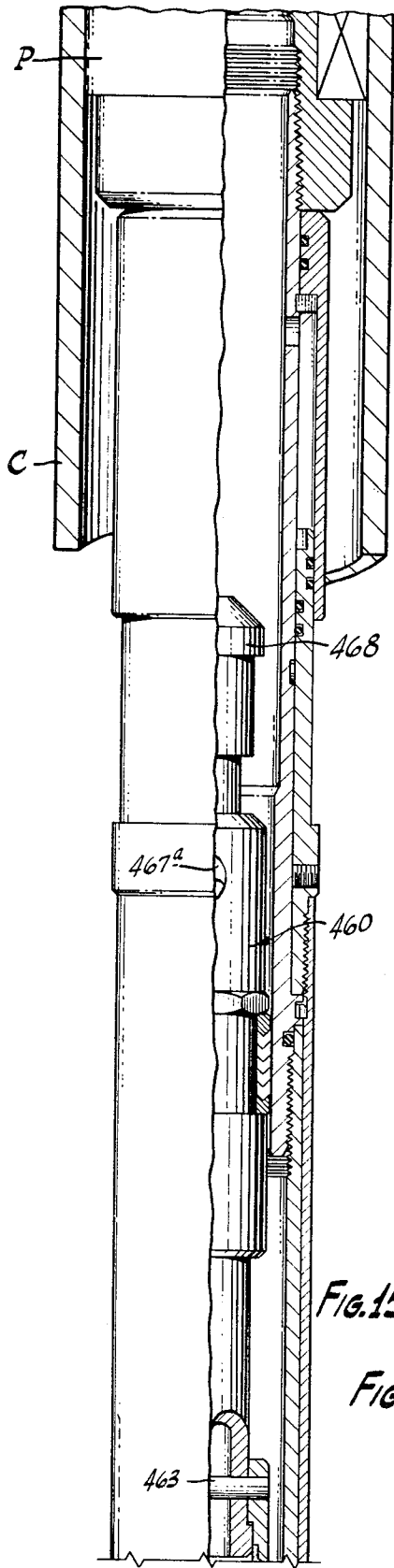


Fig. 15-A

Fig. 15-B

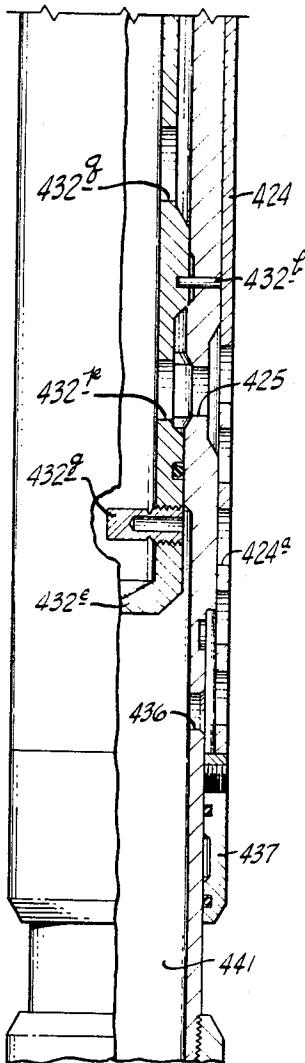
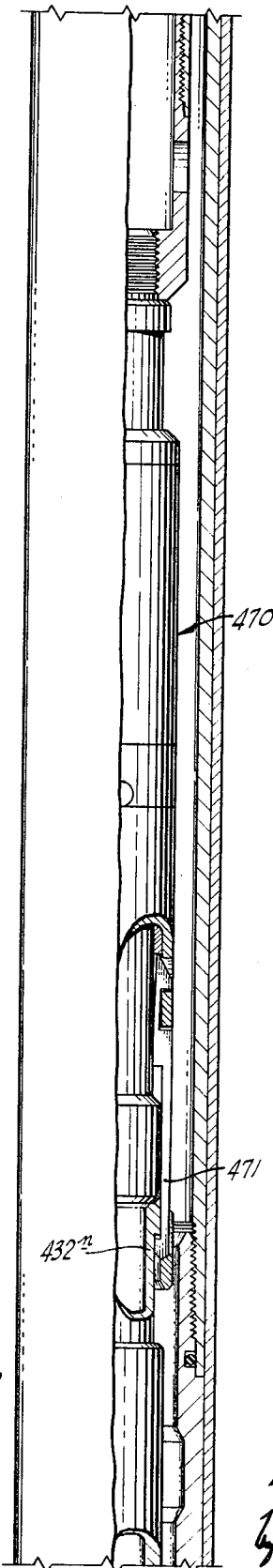


Fig. 15-C

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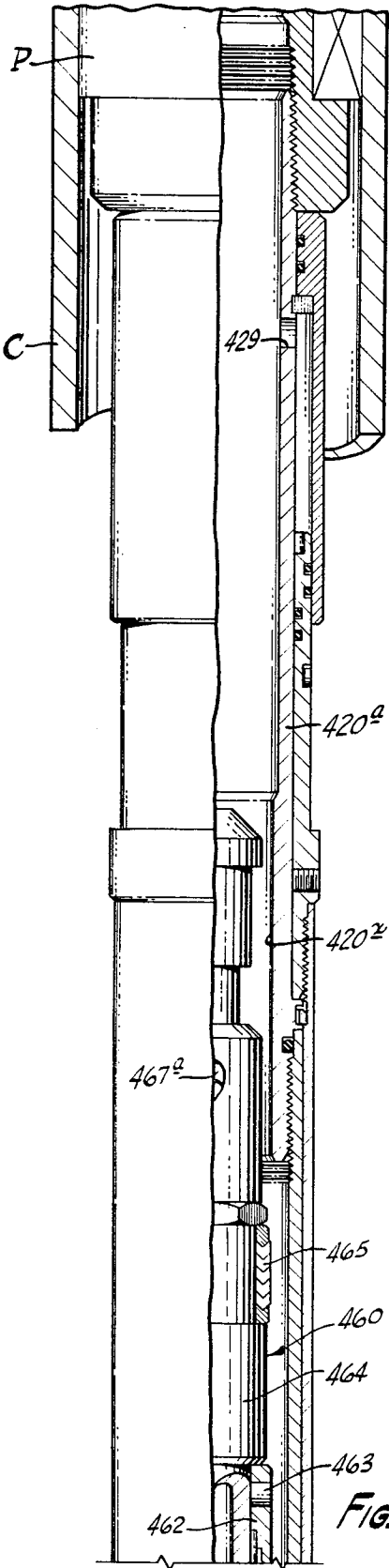


Fig. 16-A

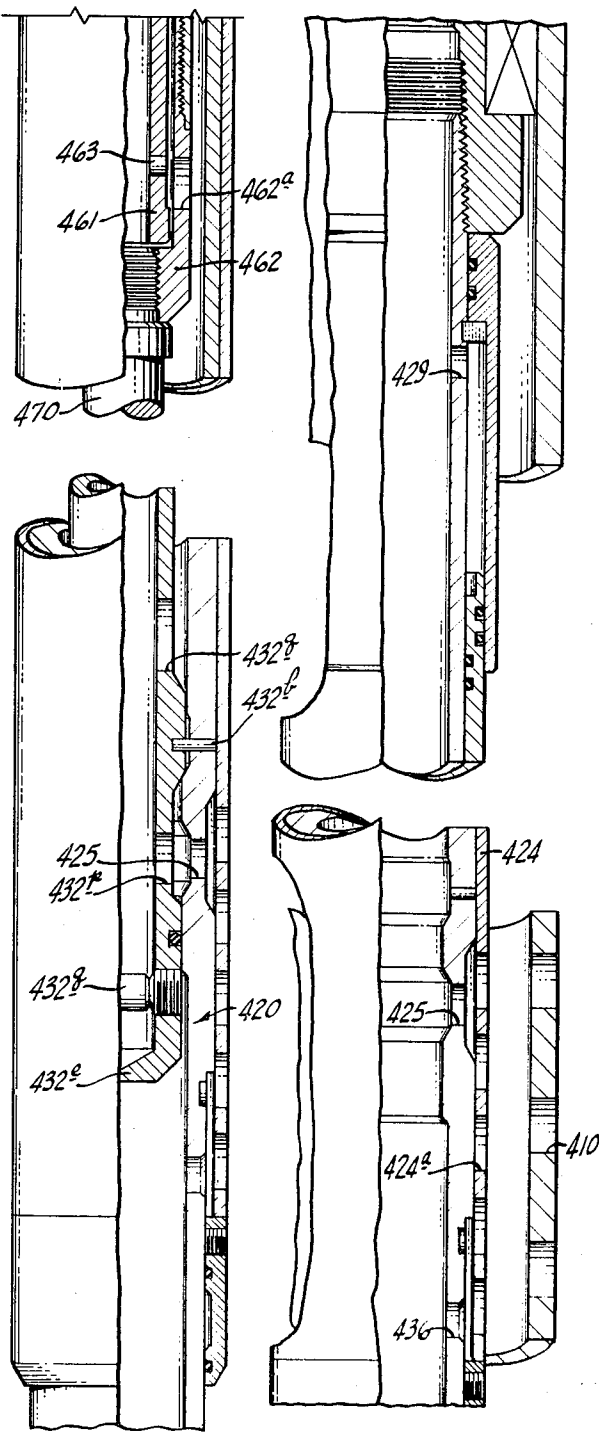


Fig. 16-B

Fig. 17

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METHOD AND APPARATUS FOR TREATING WELLS

This invention relates to new and improved methods and apparatus for treating wells.

Objects of the invention are to provide new and useful improvements in apparatus and methods for treating wells to clean perforations by producing an inward pressure surge through the perforations in the well casing; which is usable with single or multiple string flow conductors and packers; which permits circulation of lading fluids or the like from the well prior to setting the packer or packers; which permits injection of treating fluids into the well after setting the packer or packers and purging the perforations to clean the same, and before putting the well on production.

Further objects are to provide an improved method and apparatus of the character set forth, wherein actuation of the purging tool, setting of the packer, and opening of the flow passages may be accomplished by fluid pressure, after which the well bore may be opened by means of fluid flow operated retrieving tool or flexible line retrieving tools, as desired.

An important object of the invention is to provide a purging apparatus for use with well packers, either mechanically or hydraulically set, to produce an area or region of low pressure in a well bore adjacent the perforations in the casing opening to the well producing formation for cleaning the perforations after the packer has been set, and for treating the well after the perforations have been cleaned, if desired, then putting the well on production.

A particular object of the invention is to provide a purging tool structure which permits production of a region of low pressure of varied volume and various ranges below a packer adjacent the perforations in the well casing opening to the producing zone, and which is constructed to permit circulation of fluids in the well past the packer in both directions during movement of the packer into the well prior to setting the packer to prevent premature setting of the packer and to permit circulating fluid to clean the well bore, if desired, before setting the packer and performing the purging operation.

Still another object of the invention is to provide an apparatus and method of the character set forth which is designed to permit circulation of well fluids, such as loading fluids and the like, past the packer as it is moved into the well bore prior to setting the packer or packers to prevent premature setting of the packer and, if desired, to reduce the amount of cleaning necessary and to permit more efficient purging of the perforations with the tool.

Another object of the invention is to provide a purging tool and method of using the same of the character described providing means for and the step of injecting treating fluids into the well formation after the packer has been set and the purging operation carried out.

A still further object of the invention is to provide in a purging tool assembly of the character set forth means for removing all of the operating apparatus from the flow tubing string or flow conductor after the purging operation has been carried out.

Still another object of the invention is to provide a purging tool structure which may be used in connection with a multiple string packer for purging the producing zone in the well in the interval between the multiple

string packer above and the packer below such producing formation.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, wherein:

FIG. 1 is a schematic view of a well installation showing a system for carrying out the method of the invention and including a purging tool and packer apparatus shown in running in and fluid circulating position in the well casing;

FIG. 2 is a schematic view similar to FIG. 1 showing a pack-off tool in position for setting the packer and subsequent opening of the purge chamber port.

FIG. 3 is a similar schematic view showing the packer set preparatory to opening the purge chamber port;

FIG. 4 is a schematic view similar to FIG. 3 showing the purge chamber port open for cleaning the well perforations;

FIG. 5 is a schematic view of the well installation showing the packer and purging tool with the plugging and pack-off devices moved to permit the well to be produced through the tubing and the packer to the well surface;

FIG. 6A is an enlarged view, partly in elevation and partly in section, showing the lower portion of a packer and the upper portion of a purging tool similar to the structure shown schematically in FIGS. 1 through 5;

FIG. 6B is a continuation of FIG. 6A showing the mid-portion of the purging tool with the pack-off tool in place closing the circulating port;

FIG. 6C is a continuation of the lower portion of the purging tool and plug tool of FIG. 6B showing the purge chamber ports in the closed position;

FIG. 6D is a continuation of FIG. 6C showing the lower portion of the purge chamber of the purge tool and the perforated flow nipple at the lower end of the tubing string;

FIG. 7A, 7B, 7C and 7D are views similar to FIGS. 6A through 6D showing the packer in the set position and the purging tool open for flow of well fluids therethrough;

FIG. 8A, 8B and 8C are views similar to FIGS. 6A through 6D showing a multiple string packer and purging tool therefor;

FIG. 9 is a horizontal cross-sectional view taken on the line 9—9 of FIG. 8A,

FIG. 10 is a horizontal cross-sectional view taken on the line 10—10 of FIG. 8B.

FIGS. 11A, 11B and 11C are views similar to FIGS. 6A through 6D showing the upper portion of a modified form of purging tool connected to the lower end of a well packer;

FIGS. 12A, 12B and 12C are views similar to FIGS. 11A through 11C showing the packer set and the pack-off tool in place closing the circulating port and the purge chamber port open;

FIGS. 13A, 13B and 13C are views, partly in elevation and partly in section of a modified form of the purging tool assembly showing the same connected to a packer in the position in which they are run into the well casing showing the circulating port open and the purge chamber port closed;

FIGS. 14A and 14B are views similar to FIGS. 13A and 13B showing the pack-off tool in place to close the circulating by-pass passage and actuate the packer;

FIGS. 15A, 15B and 15C are views similar to FIGS. 13A, 13B and 13C showing the packer set and the circulating passage closed and the purge chamber port open;

FIGS. 16A and 16B are views similar to FIGS. 15A and 15B showing the pack-off tool moved to a position reopening the circulating by-pass passage for permitting injection of fluids through the tubing string into the well for treating the well formation; and,

FIG. 17 is a view of the upper and lower portions of the purging tool and packer showing the pack-off tool and plug tool removed from the bore of the purging tool and the tool in position for producing well fluids from the well formation.

In the drawings, FIGS. 1 through 5, a typical well installation is illustrated wherein a well casing C is located in a well bore and has its lower end closed by a cement plug B or the like. Perforations or flow inlet openings 10 are formed in the walls of the casing C adjacent a producing formation in the usual manner. The upper end of the casing is closed by a well head closure H and the usual tubing string T is suspended in the casing from the well head. Mounted on the tubing string T is a well packer P having connected to it at its lower end the purge chamber assembly 11 of the invention.

The purge chamber assembly includes an elongate tubular mandrel 20 having a circumferentially spaced tubular cylinder sleeve 21 secured at its upper end to the mandrel adjacent the lower end of the packer P and to provide an annular cylinder 22 in which a piston member 23 is slidable. The piston member has a depending annular skirt 24 which is spaced circumferentially from the mandrel 20 and extends downwardly from the piston around the mandrel below a lateral bypass or circulating port 25 formed in the wall of the mandrel below a lower seal member 26 in the internal bore at the lower end of the piston 23. External and internal upper seal rings 27 and 28, respectively, are mounted in suitable annular recesses in the piston near its upper end and seal between the upper end of the piston and the exterior of the mandrel 20 and the bore wall of the cylinder 21, whereby the piston 23 is movable in the cylinder by fluid pressure entering the cylinder bore 22 through a lateral port 29 communicating with the upper end of the cylinder above the upper end of the piston 23 slidable therein. The piston is releasably held against longitudinal sliding movement in the cylinder by means of a shear pin 30 extending through the cylinder into the piston holding the same against longitudinal movement.

The mandrel 20 has an internal annular locking and sealing surface 31 formed in the lower portion thereof spaced below the circulating port 25 and a plug 32 is releasably secured in anchored sealing position in such locking and sealing surface to close the upper end of a purge chamber cylinder 35 defining a purge chamber 41 formed in the bore of the mandrel below the locking and sealing surface 31. Lateral purge port openings 36 are formed in the wall of the purge chamber cylinder 35, and a closure sleeve 37 having upper and lower seal member 38 and 39, respectively, in its bore sealing between the sleeve and the external wall of the purge

chamber cylinder 35 closes the lateral port 36. The sleeve 37 is releasably held against movement on the purge chamber cylinder 35 by means of a shear pin 40 extending through the sleeve and into a suitable aperture in the exterior of the cylinder.

A coupling 42 is threaded onto the lower end of the purge cylinder 35 and connects one or more joints of tubing or other suitable pipe 43 to the lower end of the purge chamber cylinder 35. At the lower end of the pipe is a landing nipple 45 in which is mounted a removable or displaceable closing tool or closure plug 46 having a seal member 47 on its exterior sealing between the plug and the bore wall of the landing nipple 45. The plug is held in place in the landing nipple by shear pin 48 and has an upwardly facing shoulder 49 at its lower end preventing upper displacement of the plug in the nipple 45 to provide a positive closure for the lower end of the purge chamber 41 formed in the bore of the purge chamber cylinder 35 and the tubing or pipe joints 43 connected thereto.

The plug 32 at the upper end of the purge chamber cylinder 35 and the closure plug 46 in the landing nipple at the lower end of the pipe 43 define the upper and lower end closures of the purge cylinder chamber 41, and the sliding sleeve 37 closes the lateral port or ports into the chamber so that the purge chamber 41 is maintained under atmospheric conditions from the time the assembly is lowered into the well at the surface until the device is actuated, as will be hereinafter more fully set forth.

A perforated nipple 50 is connected to the lower end of the landing nipple 45 and provides a strainer for admitting well fluids into the lower end of the tubing joints 43 and through the purge chamber cylinder 35 and mandrel 20 to the tubing string T above the packer P.

The packer and purge tool assembly 11 are lowered into the well in the usual manner on the tubing string T until the device is located at the desired elevation in the well bore with the packer P above and adjacent the perforations 10 in the casing. The assembly is then in the condition illustrated in FIG. 1. The upper end of the tubing string is then connected by means of a pressure supply pipe 52 having a valve 53 connected therein with a pump 54 driven by a motor 55 for drawing pressure fluid from a tank 57 through a pick-up conduit 56 and pumping the fluid from the tank 57 into the bore of the tubing string T. Return flow to the tank is permitted from the well through a lateral flow wing conduit 58 having a valve 59 connected therein. The flow conduit 58 communicates with the tank 57 and returns fluid into the tank. Fluids pumped into the tubing string T will pass downwardly therein through the bore of the packer P and through the bore of the mandrel 20 to the circulating port 25, then outwardly through such circulating port into the annular space between the purge tool assembly 11 and the casing wall. The fluids so entering the annular space will then flow back upwardly in the annular space between the tubing and casing to the lateral flow conduit 58, and be conducted into the tank 57. This enables the operator of the well to circulate loading fluids, mud or the like from within the bore of the casing after the packer and purge tool assembly have been lowered into position in the casing adjacent the formation to remove foreign matter prior to setting

the packer. This structure also permits the operation of the device in connection with a hydraulic fluid pressure set packer, since fluid may flow in either direction past the packer through the circulating or bypass port 25, as the packer is lowered into the well to prevent premature setting of the packer.

When it is desired to set the packer P, if it is a manually set packer or wire line set packer, the packer is operated in the usual manner to expand the locking and sealing means thereof into sealing engagement with the well casing. However, if the packer is hydraulically operated, wherein the locking elements and sealing means are expanded into locked sealing position by hydraulic fluid pressure, a pack-off tool 60 is lowered through the tubing string into the bore of the mandrel 20 to engage the upper end of the plug 32, as shown in FIGS. 2 through 4. The pack-off tool has longitudinally spaced upper and lower external packing means 61 and 62, respectively, which seal on opposite sides of the circulating port 25 when the pack-off tool is lowered into the bore of the mandrel and engages the plug 32 as shown in FIG. 2. When this occurs, the fluid pumped into the tubing string T by the pump at the surface will act in the usual manner to set the packer P. After the packer has been set, further fluid pressure directed into the tubing string will act through the lateral port 29 on the piston 23 to move the piston downwardly, after shearing the pin 30. Such downward movement of the piston will move the lower packing 26 in the bore of the piston below the lateral circulating port 25, as shown in FIG. 3, and close off flow through the lateral circulating port in either direction. Further fluid pressure applied to the piston 23 will move the piston and the skirt 24 carried thereby downwardly to shear the pin 40 connecting the closure sleeve 37 to the purge tool cylinder 35, and so displace the closure sleeve downwardly below the port 36 to rest on the upper end of the coupling 42. The purge tool port 36 is then open, and the reduced pressure or atmospheric pressure present in the bore of the cylinder 35 and the tubing sections 43 will create a region of low pressure in the annular space below the packer and above the closure cement plug B at the bottom of the well to draw or form a suction purge action on the perforations 10 to draw any foreign matter from within the perforations into the annular space in the well bore or into the bore of the chamber 41. The size of the chamber 41 may be controlled by selecting the number of joints of pipe 43 to be connected to the lower end of the cylinder 35. Since this type tool is used in deep wells where pressures are rather high, of the order of several thousand pounds, it will be seen that a sudden rush of fluid from the producing formation entering through the perforations 10 will take place when the purge chamber opening or port 36 is opened by moving the closure sleeve 37 downwardly as just described. This will cause a suction on the formation which helps remove debris, detritus or other foreign matter from the perforations and so open up the flow course from the formation into the bore of the well through the perforations.

After the purge chamber has been opened, as shown in FIG. 4, the pack-off tool 60, which is connected by means of resilient hook members 65 to the fishing neck 66 of the plug 32, is withdrawn from the purge tool assembly mandrel 20 by means of suitable wire line tools

or by fluid pressure operated devices, where such tools may be used in the well, and the pack-off tool 60 and plug 32 are moved upwardly through the tubing string to the surface and removed from the tubing string to open the well to the surface.

The lower plug 46 is then displaced by a suitable weight member or jarring device which shears the pin 48 and moves the plug downwardly from the landing nipple 45 into the lower end of the perforated nipple or strainer 50 at the lower end of the tubing string. When this closing tool or plug has been moved to the open position shown in FIG. 5, the well fluids flowing inwardly through the perforations 10 in the casing may enter through the perforated nipple and flow upwardly through the pipe 43 into the bore of the purge chamber cylinder 35, then upwardly through the mandrel 20 and through the bore of the packer and the tubing string T to the surface of the well in the usual manner. Fluids may also enter through the purge port 36, passing through the perforations 24a in the lower wall of the skirt 24 carried by the piston 23. Since the packer P is expanded into sealing engagement with the well casing, all fluids entering the well bore through the casing perforations will flow upwardly through the tubing string to the surface.

FIGS. 6A through 6D, and FIGS. 7A through 7D, inclusive, illustrate a commercial form of the purging tool assembly shown schematically in FIGS. 1 through 5. FIGS. 6A through 6D show the tool in the run-in position ready for operation in the well, while FIGS. 7A through 7D show it in producing condition.

The well packer P is connected to the upper end of the mandrel 120 of the purging tool assembly 111, which includes an upper section 120a, a pack-off tool landing nipple section 120b, a bypass circulating port sleeve 120c, and a closure plug landing nipple 120d forming the upper end of the purge cylinder or chamber 141, formed by one or more sections of pipe 143 jointed by couplings 142 to the lower end of the closure plug landing nipple 120d, and having at their lower end a closing tool nipple 145 threaded at its upper end onto the lower end of the pipe 143 and having a perforated strainer nipple 150 threaded into the lower end of its bore and provided with a plurality of perforations 150a for admitting well fluids into the bore of the tubing. The lower end 150b of the perforated nipple is swaged inwardly or tapered downwardly to provide a restriction in the bore for receiving and supporting a closing tool plug 146 which is releasably supported in the closing tool nipple 145 by means of a shear pin 147. A seal ring 148 disposed in an external annular groove 149 in the plug seals between the plug and the bore wall of the nipple 145 above the shear pin 147.

The purge chamber 141 extends downwardly from the closure plug landing nipple 120d forming the lower portion of the mandrel through the bores of the pipe section or sections 143 connected thereto and to the closing tool nipple 145. The closing tool plug 146 closes the lower portion of the purging tool chamber 141, while the removable closure plug 132 closes the upper end of the chamber. The closure plug tool 132, which is landed on an upwardly facing shoulder 120e in the plug nipple 120d at the lower end of the mandrel, comprises a mandrel 132a having a plurality of longitudi-

dinally movable laterally expansible locking dogs 132b carried by a dog carrier 132c slidable on the mandrel. An external annular seal assembly 132d on the mandrel 132a seals between the mandrel and the bore wall of the plug landing nipple 120d when the closure plug tool 132 is seated in the nipple. A closure cap 132e is threaded onto the lower end of the mandrel and has a shoulder 132f which engages the upwardly facing shoulder 120e in the bore of the landing nipple 120d. A frangible plug 132g mounted in a threaded lateral port in the side wall of the cap 132e closes the lateral port until the plug is broken in the well known manner to open the port to flow therethrough. With the closure plug tool 132 removably anchored in sealing position in the landing nipple 12d, the upper end of the purge chamber 141 is closed by the closure plug tool.

A plurality of lateral purging ports 136 are formed in the upper portion of the purge chamber 141 below the shoulder 120e in the closure plug landing nipple 12d. While only one port is shown, any desired number of any desired size may be provided. A closure sleeve 137 is slidable on the exterior of the lower portion of the closure plug landing nipple 12d and is provided with upper and lower seal rings 138 and 139, respectively, which seal between the sleeve and the exterior of the landing nipple to close the purging port or ports 136 when the sleeve is in the position shown in FIG. 6C. A shear screw 140 is threaded through the wall of the closure sleeve into an external recess 120f in the wall of the landing nipple 120d and releasably holds the sleeve in position closing the purge post ports 136 until it is desired to open the same in the manner which has been previously described. The size of the purge chamber 141 provided in the purging tool assembly may be varied by varying the length of the chamber formed by the pipe section or sections 143. More sections will give a longer and larger chamber, whereas fewer sections and shorter sections will reduce the size of the purge chamber; and in this manner the volume and force of the surge of fluid through the perforations 10 may be controlled.

The elongate tubular cylinder 121 secured to the upper end of the upper section 120a of the mandrel 120 is held in place thereon by a retaining lock ring 121a fitting in an external annular groove in the mandrel and engaging an internal annular downwardly facing shoulder 121b at the lower end of an internal annular flange 121c at the upper end of the cylinder. An O-ring seal 121d disposed in an internal annular groove in internal flange 121c at the upper end of the cylinder sleeve 121 seals between the cylinder sleeve and the exterior of the mandrel 120 to close the upper end of the cylinder bore 122 formed between the cylinder sleeve 121 and the mandrel 120. A pressure inlet port 129 is formed in the wall of the mandrel communicating with the cylinder bore 122 above a cylindrical piston 123 slidable on the mandrel and at its upper end within the bore of the cylinder sleeve 121. A shear screw 121e threaded through the lower end wall of the cylinder sleeve 121 engages in an external annular groove 123a formed in the exterior surface of the piston 123 and holds the piston in the upper position until the shear screw is sheared. External and internal seal rings 127 and 128, respectively, are positioned in external and internal grooves formed in the upper end of the piston

123, and the internal seal ring 128 seals between the piston and the exterior of the mandrel while the external seal ring 127 seals between the piston and the bore wall of the cylinder sleeve 121. Fluid pressure entering through the port 129 into the cylinder 121 will thus move the piston 123 downwardly when sufficient force of pressure has been applied to the piston to shear the shear screw 121e, as has been described.

A depending annular skirt 124 formed integral with the lower end of the piston 123 extends downwardly externally around the mandrel 120, around the exterior of the landing nipple 120b, around the exterior of the circulating nipple 120c, and to a point at approximately the mid-portion of the closure plug landing nipple 120d, where fluid flow openings or ports 124a are formed therein. The skirt 124 is shown as formed in two sections, and upper section 124b and a lower sleeve section 124e, for assembly purposes. The lower end of the lower section 124c extends downwardly around the closure plug landing nipple 120d to a point just above the upper end of the closure sleeve 137 closing the lateral purge port or ports 136. The flow openings or apertures 124a are formed in this lower section 124c of the skirt and are arranged to be disposed adjacent the purge port or ports 136 when the closure sleeve 137 is displaced from position closing the purge ports.

Circulating by-pass port or ports 125 is formed in the wall of the mandrel circulating sleeve section 120c and communicates with the enlarged lower bore 124d of the bore of the lower skirt section 124c below a closure sleeve valve section 124e formed in the upper portion of such lower section of the skirt and comprising a pair of upper and lower internal annular flanges 124f and 124g which fit closely around the exterior of the mandrel circulating sleeve section 120c. Seal members in the form of upper and lower O-ring seals 126a and 126b seal between the flanges 124f and 124g, respectively, and the exterior of the mandrel circulating sleeve section 120c. A plurality of bypass ports 124p may be provided through the wall of the lower skirt section 124c to facilitate circulation or bypassing of fluid through the port or ports 125.

When the packer P and the purging tool assembly 111 are connected together and lowered into the well casing C prior to setting the packer and actuating the purging tool assembly, the pack-off tool 160 is not in place in the purging tool, and fluids may be circulated through the bore of the tubing string above the packer P through the bore of the mandrel 120 to the circulating port or ports 125 and outwardly through the ports and through the bypass ports 124p, as well as downwardly through the bore 124d of the lower skirt member 124c and the apertures 124a, outwardly into the annular space between the purging tool and the casing and vice versa. The circulating port 125 also permits bypassing of fluids through the bore of the purging tool above the purge chamber and through the bore of the packer P to prevent premature setting of the packer, particularly when it is a hydraulically actuated packer. When it is desired to actuate the packer P, and to close the circulation ports and operate the purging tool assembly, the pack-off tool 160 is lowered through the tubing string and through the upper mandrel section 120a to anchored sealing position in the pack-off

tool landing nipple section 120b of the mandrel, as shown in FIGS. 6A through 6C.

The pack-off tool 160 is very similar to the locking and sealing device shown in the patent to Miller, U.S. Pat. No. 2,673,614, having an elongate mandrel 160a with a plurality of locking dogs 160b thereon supported by a dog carrier 160c slidable on the mandrel. A plurality of locator keys 160d are mounted on the mandrel below an upper sealing assembly 161, and the locator keys engage in a suitable locating recess section 130a in the internal locating and sealing surface 130 in the bore of the landing nipple 120d. An elongate mandrel extension 160f made up on the lower end of the mandrel 160a carries a spacer and stop shoe and lower seal assembly 162 on its lower end having an enlarged bore providing a skirt 162a which telescopes over the upper end of the removable plug tool 132, as shown in FIGS. 6B and 6C. An external annular packing ring assembly 162b carried by the stop shoe and lower seal assembly seals between the pack-off tool 160 and the bore wall of the circulating port sleeve 120c below the lateral circulating bypass port 125. Thus, the upper sealing assembly 161 and the stop shoe and lower seal assembly of the pack-off tool 160 close off the bypass port 125 to prevent flow therethrough when it is desired to actuate the packer P and to later open the purge chamber purging ports 136.

When the piston 123 of the purging tool assembly is held in the upper position shown in FIG. 6A by the shear screw 121e the closure sleeve valve section 124e is disposed above the bypass circulating port 125 in the mandrel circulating sleeve section 120c as shown in FIG. 6B. However, when the piston 123 is moved downwardly by fluid pressure after the packer P has been set, as shown in FIG. 7A, the sleeve valve section 124e of the lower skirt section 124c is moved to the position shown in FIGS. 7B and 7C, wherein the upper and lower sealing rings 126a and 126b, respectively, are disposed above and below the circulating port or ports 125 to also close off flow through such port or ports. The pack-off tool 160 may then be removed without opening the tubing string to flow through the circulating ports.

Downward movement of the piston 123 and the lower section 124c of the skirt member 124 then causes the lower end of the skirt member 124 to engage the upper end of the purge port closure sleeve 137 and move the same downwardly to open the purge port or ports 136, to create a surge of pressure into the chamber 141 through the purge ports. The plug tool 132 remains in place closing the upper end of the purge chamber and the closing tool plug 146 remains in place closing the lower end of the chamber, and when the purge ports are opened a sudden surge of fluids into the purge chamber will occur to open or clear the perforations 10 in the casing.

Downward movement of the piston 123 and the skirt member 124 is limited by engagement of the internal annular downwardly facing shoulder 123b at the lower end of the piston with the upwardly facing external annular stop shoulder 12s on the lower portion of the upper mandrel section 120a (FIG. 7A). The skirt member is positively held down in its lower position by a snap ring 155 carried in an external annular recess 156 in the exterior wall of the closing plug landing nip-

ple 120d which engages in an internal annular recess 157 formed in the bore of the lower skirt section 124c (FIG. 7C).

After the purge ports have been opened and the purging surge of fluids has taken place, the pack-off tool 160 may be removed from the assembly in the usual manner. Since the closure sleeve valve section 124e is disposed with the packing rings 126a and 126b disposed on opposite sides of the circulating or bypass port or ports 125, as shown in FIG. 7C, and since the plug tool 132 remains anchored in place in the landing nipple 120d, no flow of fluids will take place into the bore of the purging tool assembly. At this point, the shear plug 132g in the lower end of the bore of the plug tool may be fractured in the usual manner, as by dropping a weight or prong or the like, and the lateral port through the shear plug into the bore of the plug tool will then be opened to equalize the pressures above and below the plug tool, whereupon it may be likewise removed from the well in the usual manner by flexible line lowering operating mechanism or by other means.

When the plug tool 132 has been removed, fluid flow may take place into the bore of the purging tool assembly through the purge ports 136 and then flow upwardly therethrough into the tubing string above the packer. Now, the closing tool plug 146 may be moved out of the closing tool nipple 145 by shearing the pin 147 and moving the plug downwardly from the nipple into the lower portion of the perforated strainer 150 on the lower end of the assembly. This step opens the ports 150a in the strainer or perforated nipple and permits flow of fluids from the well bore upwardly through the purging tool assembly to the tubing string above the packer and thence to the surface.

When the pack-off tool 160 and the plug tool 132 have been removed from the purging tool assembly in the manner already described, and the closing tool plug 146 has been moved downwardly from the closing tool nipple 145 to the lower end of the perforated nipple of strainer 150, as shown in FIGS. 7A through 7D, inclusive, the assembly is in position for production of well fluids from the well. The packer is expanded into sealing position and the perforated nipple 150 is open to flow, as are the purge tool port or ports 136.

The lower skirt section 124c, being held in its lower position by the snap ring 155, prevents the purge port closure sleeve 137 from moving upwardly to close the purge port or ports 136 and likewise holds the circulating port closure sleeve valve 124e in position closing the circulating port 125.

It will therefore be seen that this commercial form of the purging tool assembly functions in the same manner as the form illustrated and described in connection with FIGS. 1 through 5 to accomplish the results set forth in connection therewith.

An adaptation of the purging tool assembly for use with dual or multiple string packers is shown in FIGS. 8A through 10, inclusive. In this form of the device, the purging tool valve and purge chamber assembly structure, which is identical with that just described in connection with FIGS. 6A through 7D, all parts of the valve, purge chamber and like parts, will be given corresponding numbers to those of the form already described.

The operating piston for moving the skirt member and the related parts of the purge tool assembly into position for operation are shown in FIGS. 8A and 8B and 9 and 10. The packer, shown to be a dual string packer P-2, has a pair of side-by-side tubing strings extending therethrough, a long tubing string TL which extends downwardly through the packer P-2 to a lower packer (not shown) below the purging tool assembly in the well bore, which seals around the lower end of the long string tubing string TL in the usual manner. The short string of tubing TS also extends through the packer P-2, but terminates below the packer P-2 and above the lower packer (not shown) in the well with which the long string is connected.

The purging tool assembly 111 is connected to the short string of tubing TS below the packer P-2, the upper mandrel section 220a of the elongate mandrel 220 has an external flange 220b at its upper end which engages a downwardly facing shoulder 221b at the lower end of one of a pair of side by side bores 221b and 221c in the head 221 at the upper end of the cylinder 222. A coupling member T-1 is connected to the upper end of the upper mandrel section 220a and to the lower end of the short string of tubing TS extending downwardly through the packer P-2. The lower end of the coupling engages the upper end of the cylinder head 221; as shown in FIG. 8A, and, with the external annular flange 220b, positively holds the cylinder in place against longitudinal movement with respect to the upper mandrel section 220a of the mandrel 220. Thus, the operating piston and cylinder mechanism of the purge tool assembly 111 is connected to the short string of tubing TS and is movable therewith.

The packer P-2 is supported by a coupling T-2 connected to the upper end of the mandrel section 212 of the long string of tubing TL, and is connected at its upper end to the upper end of the short sting TS and the long string TL in the usual manner.

The mandrel 212 of the long string TL extends downwardly through the other bore 221c of the side by side bores in the cylinder head 221, and has an external annular flange 213 thereon, the upper end of which engages the under side 221a of the cylinder head 221 as shown in FIG. 8A, and this flange limits upward movement of the piston 223 in the cylinder 222.

The packer may be set by movement of the long string of tubing TL or the short string TS, or hydraulically, in the usual well known manner, as was the packer P previously described, the operation of the packer being unaffected by the operation of the purging tool assembly 111. Within the elongate operating cylinder 222 is the piston 223 having a pair of side-by-side bores 223a and 223b and the upper mandrel section 220a of the mandrel 220 connected to the short string of tubing extends through the bore 223a, while the mandrel 212 of the long string of tubing TL extends through the bore 223b. An O-ring or seal member 221e is disposed in an internal annular groove in the bore 221b in the cylinder head 221 and seals between the cylinder head and the upper mandrel section 220a. An O-ring or sealing member 221f disposed in an internal annular groove in the bore 221c in the cylinder head seals between the cylinder head and the mandrel 212 of the long tubing string TL.

The piston 223 is slidable in the bore 222a of the cylinder 222 depending from the cylinder head 221. Internal upper annular sealing rings 228a and 228b are disposed in internal annular grooves in the bores 223a and 223b, respectively, and seal between the piston 223 and the exterior of the mandrel sections 220a and 212, while an external annular seal ring 227 is disposed in an external annular groove in the piston 223 and seals between the piston and the wall of the bore 222a of the cylinder.

An operating fluid inlet port 229 extends through the wall of the long string mandrel 212 and provides for entry of operating fluid pressure into the bore 222a of the cylinder 222 for moving the piston 223 downwardly in the cylinder for closing the bypass ports 225 and opening the purge ports 236, as will be described.

The piston 223 is disposed when moved downwardly to engage the upper reduced portion 224a of the skirt member 224 which extends downwardly around the lower portion of the upper mandrel section 220a which has the circulating bypass port or ports 225 formed therein and the upper portion of the plug tool landing nipple 220b, which has the purge port or ports 236 formed in the lower portion of its wall and closed by the purge port closure valve sleeve 237.

The tubing sections or pipe sections 243 forming the purge chamber 241 are connected to the lower end of the plug tool landing nipple 220b by the coupling 242, and the closing tool landing nipple 245 is connected to the lower end of the joint or joints of pipe 243 defining the purge chamber. A plug identical to the plug 146 of the form just described is adapted to seat in the landing nipple 245 and to be held in place therein by means of the shear pin 247 for closing the lower end of the purge chamber 241. A strainer or perforated nipple 250 is connected to the lower end of the closing tool landing nipple and has lateral ports or inlet openings 250a formed therein for admitting fluids from the well producing zone to the bore of the nipple to flow upwardly through the purging tool assembly when the tool is in condition for production in the same manner as the form just described.

When the purging tool and packer are run into the well, the piston 223 is in its upper position in the cylinder 222, engaging the lower end of the flange 213. With the piston in this upper position, the skirt member 224 may also be secured in its upper position, with the upper end of the reduced upper portion 224 engaging the underside of the piston 223, by the shear screw 221e threaded through the wall of the skirt and having its inner end engaged in an external recess 220m in the exterior wall of the plug tool landing nipple 220b. Circulating bypass ports 224p are formed in the wall of the skirt below the lower internal annular flange 224g of the closure sleeve section 224e which carries the O-ring seal member 226b in an internal annular groove in its bore. The upper internal annular flange 224f carries the upper seal member or O-ring 226a in an internal annular groove in its bore and these seal rings seal between the sleeve valve section 224e and the exterior wall of the lower portion of the upper mandrel section 220. When the skirt is in its upper position, the closure sleeve section 224e is disposed above the circulating bypass ports 225 and the ports 224p in the skirt are disposed in registry with such circulating ports 225 to

permit fluids to be circulated or to bypass through the ports between the interior and exterior of the mandrel below the packer P-2. The lower end of the skirt member 224 is also then disposed above the purge port closure sleeve or valve 237 having the internal annular O-ring seal members 238 and 239 disposed in internal annular grooves formed in its bore and sealing on opposite sides of the purge port or ports 236. The sleeve valve is held in its upper purge port closing position by the shear screw 240 which has its inner end engaged in an external annular recess 220f formed in the exterior of the plug tool landing nipple 220b.

A closure plug tool such as the plug tool 132 of the form illustrated and described in FIGS. 6A through 7D, is disposed in the bore of the plug tool landing nipple 220b supported on the upwardly facing shoulder 220e therein just above the purge ports 236 and locked in the locking recesses in the landing nipple in the manner already described. This plug tool closes the upper end of the purge chamber 241 and the lower end of the purge chamber is closed by the closing tool in the closing tool landing nipple 245 in the manner already described and the purge ports 236 are closed by the closure sleeve valve 237 in the manner already described.

As the assembly is lowered into the well, fluids may enter through the lateral ports or bypass ports 224p in the skirt member and the bypass or circulating ports 225 in the upper mandrel section 220a and flow upwardly in the bore of the mandrel to facilitate entry of the packer through fluid. When the tool has been lowered to the desired depth the long string TL is engaged in the lower packer (not shown) and the upper packer P-2 is set in the usual manner sealing off the annular space between the tubing strings and the casing above the lower packer to isolate the perforations 210 between the lower packer and the upper packer in the usual manner.

To actuate the skirt member 224 to close the bypass circulation ports 225, fluid pressure is pumped down the long string TL and passes out through the ports 229 into the bore 222a of the cylinder 222 above the piston 223 to move the piston downwardly. When the piston moves downwardly, the skirt member 224 is moved downwardly to move the closure sleeve section 224e downwardly and so close the circulating bypass port or ports 225. Downward movement of the sleeve member is then continued until the purge port sleeve valve 237 is moved downwardly after the shear screw 240 has been sheared. This opens the purge ports 236 to permit flow inwardly through the lateral inlet ports 224a in the skirt member 224 and through the purge port or ports 236 into the purge chamber 241 in the manner already described. The surge of fluids into the surge chamber clears the perforations 21 in the casing wall and removes foreign matter therefrom to improve flow into the bore of the casing. Downward movement of the skirt member on the upper mandrel section 220a is limited by the engagement of the downwardly facing shoulder 224s at the lower end of the internal annular flange 224g of the closure section 224c with the upwardly facing end 220s of the plug tool landing nipple 220b, as shown in FIG. 8B.

After the purging step has been performed, the plug tool (not shown) is removed in the manner already

described and the closing tool plug is displaced downwardly from the closing tool landing nipple 245 to the lower end of the perforated nipple or strainer 250 to permit production of well fluids through the short tubing string TS. Well fluids will be produced through the long string TL in the usual manner. The lateral port 229 will communicate with the bore 222a of the cylinder 222, but such fluids will be confined in such cylinder between the piston 223 and the cylinder head 221.

Obviously, more than two strings of pipe may be installed in a well casing and more than one purging tool assembly may be connected in the several strings. It is believed obvious that a purging tool assembly may be connected to the lower portion of each string of tubing in the well to communicate with the producing areas or strata isolated by the packers in the well bore, in the same manner as were the two zones illustrated in FIGS. 8A through 10.

A slightly modified form of the purging tool assembly is illustrated in FIGS. 11A through 12C, inclusive. In this form of the device, a slightly modified type of plug tool is shown and a large bypass circulation port arrangement is provided. Also, the pack-off tool and plug tool utilize a common locking mechanism and are removed simultaneously from within the mandrel of the assembly.

The packer P is mounted in the casing C in the usual manner and the operating piston for the purge tool assembly 311 is secured to the lower end of the packer. The cylinder 322 has the piston 323 slidably disposed therein and initially held in its upper position by a shear screw 321e engaged in an external annular recess 323a in the exterior of the piston. The skirt member 324 extends downwardly from the piston in the manner already described and is provided with the closure sleeve section 324e which is adapted to close the lateral bypass circulation ports 325 formed in the wall of the mid-section 320b of the mandrel which is secured to the lower end of the upper section 320a. The lower section 320c of the mandrel is connected at its upper end to the lower end of the mid-section 320b and extends downwardly therefrom and is connected at its lower end to the upper end of the plug tool landing nipple 320d.

The plug tool 332 is releasably anchored in the landing nipple 320d in the same manner as the form first described, being supported upon an upwardly facing shoulder 320e at the lower end of the landing nipple 320d, and releasably locked in place by expansible and retractable locking dogs 332b of the locking device 332a, which may be of the type shown in the patent to Tamplen, U.S. Pat. No. 3,208,531, dated Sept. 28, 1965. The closure cap 332e of the lower end of the plug tool has a sliding sleeve closure member 332g therein having a pair of O-rings mounted in external annular grooves opposite thereon and sealing on opposite sides of the lateral port 332h in the cap 332e. The upper end of the slidable sleeve closure member is connected to the fishing connection 332c at the upper end of the locking device. The external seal assembly 332d seals between the plug tool and the bore wall of the landing nipple 330d.

The plug tool 332 closes the upper end of the purge tool chamber 341 and the closure plug 346 closes the

bore of the closing tool nipple 345 to close the lower end of the purging tool chamber formed by the joints of pipe or the like 343 connected by the couplings 342 to provide a purging chamber of any desired size. The perforated nipple or strainer 350 having the ports 350a therein is secured to the lower end of the closing tool nipple 345.

A bypass port 324p is formed in the wall of the skirt member below the closure sleeve section 324e and is arranged to communicate with the circulating port 325 to permit fluids to bypass the packer by entering the tubing through the ports 324p and circulation port 325.

The packer and purging tool assembly are run into the well in the manner already described and are positioned at the desired elevation therein as shown in FIGS. 11A through 11C. When the tool is in this position, a pack-off tool assembly 360 is run into the well through the tubing T and positioned in the mid-section 320b of the mandrel having the circulating port 325 therein. The lower end of the pack-off tool is secured to the upper end of the locking mechanism of the plug tool 332 by means of a pulling tool 370 having a plurality of radially movable dogs or catchers 371 thereon which engage in the internal annular recess 332r in the fishing connection 332c at the upper end of the closure plug 332 for connecting the pack-off tool with the closure plug. The pack-off tool has an upper packing assembly 360a sealing with the bore wall of the midsection 320b of the mandrel above the lateral port 325 and a lower packing assembly 360b sealing with the bore wall of the mid-section 320b below the lateral port 325 to close the lateral circulating port 325 in the manner first described.

With the tool assembly in this position, fluid pressure introduced into the tubing string will enter through the inlet port 329 into the cylinder bore 322a and act on the upper end of the piston 323 to move the piston and the skirt member 324 downwardly so that the closure sleeve section 324a of the skirt member is disposed with the upper and lower sealing rings 326a and 326b, respectively, engaging the exterior of the section 320b of the mandrel above and below the circulating port 325 to positively close the same. The lower end of the skirt member 324 is then moved downwardly to engage the purge port closure valve sleeve 347 to move the same downwardly to open the purge port 346 for the purpose of permitting the entry of fluids into the purge chamber 341.

After the purging operation has been performed, as has been described previously, the pack-off tool 360 is lifted upwardly through the mandrel of the purging tool assembly by means of a retrieving tool engaging the fishing neck 360n at the upper end of a pack-off tool. As the pack-off tool is moved upwardly, the pulling tool 370 is likewise moved upwardly, and upward movement of the pulling tool moves the fishing neck 332a of the plug tool 332 upwardly to move the sliding sleeve closure member 332g upwardly with respect to the cap member 332e. Upward movement of the sleeve closure member 332g moves the seals on the exterior thereof upwardly with respect to the lateral port 332h in the cap and opens the same to permit equalization of pressures on opposite sides of the plug, and therefore permits the closure plug to be moved upwardly out of the landing nipple 320d.

When the pack-off tool and closure plug have been removed from the bore of the tubing, the closing tool plug 346 is displaced downwardly in the manner already described from the landing nipple 345 to open the strainer or perforated nipple 350 to flow inwardly through the ports 350a and upwardly through the purging tool and the tubing string to the surface.

A further modified form of the purging tool assembly is shown in FIGS. 13A through 17, inclusive, in which the upper end of the elongate mandrel 420 of the purging tool is also connected to the lower end of the packer P in the manner previously described. The mandrel consists of an upper mandrel section 420a, a medial or intermediate mandrel section 420b threaded onto the lower end of the upper mandrel section and forming a continuation thereof, and a plug tool landing nipple 420d threaded into the lower end of the intermediate mandrel section 420b. An O-ring seal member 420m disposed in external annular groove in the lower end of the upper mandrel section 420a seals between that section and the upper end of the intermediate mandrel section 420b, while a similar O-ring seal member 420n is disposed in an external annular groove in the upper end of the plug tool landing nipple and seals between the landing nipple and the lower end of the intermediate mandrel section 420b, whereby the mandrel forms a continuous fluid conductor to the packer bore.

The plug tool landing nipple 420d has an elongate internal annular flange 420e providing the upwardly facing stop shoulder 420f at its upper end against which the plug tool 432 is adapted to be supported by the engagement of a shoulder 432f at its lower end of an external annular stop flange 432s thereon with the upwardly facing shoulder 420f. The plug tool has an O-ring or seal member 432d disposed in an external annular groove in the lower portion of the body thereof disposed to engage the inner wall of the lower sealing surface 420g in the bore of the internal annular flange 420e below the lateral circulating port 425 formed in the wall of the landing nipple and communicating with an internal annular recess 425a in the bore wall of the flange. The recess provides for circulation of fluids to the one or more bypass or circulating ports 425 to facilitate flow therethrough. The plug tool 432 has an axial bore 432c which extends downwardly to the closure cap 432e at the lower end of the plug tool, and the closure cap has a lateral threaded port into which a shear plug 432g is screwed to close the port until the shear plug is sheared to open the port in the same manner as the form previously described.

The plug tool is held in place with its downwardly facing shoulder 432f engaging the upwardly facing seat 420f in the plug landing nipple by means of a shear pin 432b which extends through a lateral opening in the wall of the landing nipple and into an external recess or annular groove 432h, whereby the plug tool is securely held in place in the landing nipple. Additional lateral circulating ports 432q are formed in the wall of the plug tool above the stop flange 432s having the shoulder 432f on the lower end thereof for a purpose to be described later. A fishing neck 432n is provided on the upper end of the tubular body of the plug tool.

The skirt member 424 of this form of the device is connected by threads to the lower end of the piston 423

which is slidable in the cylinder in the bore 422a of the cylinder 422. The cylinder head 421 is connected by means of a split retaining ring 421a to the upper end of the upper mandrel section 420a in the same manner as that of the device of FIG. 6A, and is confined between the lower end of the packer and the retainer ring 421a against movement on the mandrel. The cylinder head has a pair of O-ring seal members 421d disposed in internal annular grooves in its bore sealing between the cylinder head and the exterior of the upper mandrel section. Upper external O-ring seal members 427 and lower internal O-ring seal members 428 are provided in suitable external and internal annular grooves in the upper end of the piston 423 and seal between the piston and the wall of the cylinder bore 422a and the exterior of the upper mandrel section 420a, whereby operating fluid pressure entering through the inlet opening 429 into the bore of the cylinder may act on the piston to move the same downwardly.

The piston and the skirt member connected thereto are held in the upper position shown in FIGS. 13A and 13B by means of a shear screw 421e threaded through the lower end of the piston into an external recess 423a formed in the exterior wall of the upper mandrel section 420a. The skirt member extends downwardly around the lower end of the upper mandrel section, around the intermediate mandrel section 420b and around the major portion of the plug tool landing nipple 420d to a position below the lateral circulating port 425 in the wall of the landing nipple. A plurality of flow ports 424a formed in the lower end wall of the skirt member are disposed to register and communicate with the lateral flow port 425 in the mandrel to permit circulation of fluids through the flow port and through the circulating passage 432p in the side wall of the plug tool in registry with the circulating port. Thus, when the piston and the skirt member are in the upper position shown in FIGS. 13A and 13B, fluids may circulate freely through the openings or apertures 424 in the skirt member, through the circulation port or ports 425, and through the circulation port or ports 432p into the bore of the plug tool and upwardly through the bore of the mandrel 420 and through the bore of the packer P thereabove, then upwardly through the tubing string (not shown) to the surface.

The plug tool landing nipple 420d has the lower portion of its bore slightly enlarged, and the purge tool port or ports 436 are formed in the wall of such lower portion of the landing nipple for communicating with the purge chamber 441 formed by the lower portion of the landing nipple and one or more joints of pipe 443 connected to each other by couplings 442 in the manner already described. The lower end of the lower pipe section 443 forming the purge chamber 441 is threaded into the upper end of a closing tool landing nipple 445 having a closing tool plug 446 secured therein by a shear pin 447. An O-ring seal 448 disposed in an internal annular groove 449 in the exterior of the closing tool plug for sealing between the plug and the closing tool landing nipple until the shear pin 447 is sheared to permit the plug to move downwardly out of the landing nipple into the perforated nipple or strainer 450 having the lateral openings or ports 450a formed therein for permitting well fluids from the producing formation into the bore of the nipple for flowing up-

wardly through the purging tool assembly to the surface.

The purge tool ports 436 are closed in the same manner as heretofore by the purge tool closure valve sleeve 437, which has seal rings 438 and 439 disposed in internal annular recesses in the bore wall of the closure valve sleeve sealing between the valve sleeve 437 and the exterior of the lower reduced portion of the landing nipple 420d below a downwardly facing shoulder 420s which limits upward movement of the valve sleeve on the mandrel. The valve sleeve is held in the upper position by a shear screw 440 threaded through the sleeve into an internal annular recess 420r in the exterior of the mandrel above the purge ports. The closure valve sleeve thus closes the purge port or ports 436 in the same manner as in the forms previously described.

When it is desired to set the packer P in the casing and to actuate the purging tool assembly, after the packer with the purging tool assembly connected therewith has been lowered into the well casing to the desired position, a pack-off tool assembly 460 having a pulling tool 470, similar to that shown in the patent to Marshall et al., U.S. Pat. No. 2,605,131, issued July 29, 1952, secured to its lower end is lowered through the bore of the packer into the bore of the mandrel 420 of the purging tool assembly until the inwardly facing dog hooks 471 at the lower end of the pulling tool engage under the undercut flange at the upper end of the fishing neck 432n of the plug tool, as shown in FIG. 14B. The pulling tool is thus positively connected to the plug tool and at the same time connects the pack-off tool to the plug tool.

The pack-off tool includes an elongate tubular mandrel 461 which is slidable in the upper end of a connector sub 462 connected to the upper end of the pulling tool 470. A shear pin 463 releasably holds the mandrel in its upper extended position with respect to the sub 462, as shown in FIG. 14B. On the upper end of the mandrel 461 is a packing mandrel 464 having a sealing assembly 465 on the exterior thereof for sealing between the pack-off tool and the reduced internal bore 420x in the lower portion of the upper mandrel section 420a. A drop valve or check valve 466 is slidably connected to the upper end of the packing mandrel 464 and has a head 466a which engages the upper end of the bore of the mandrel 464 to close the same to prevent flow downwardly therethrough. A retainer bushing and valve housing 467 is threaded onto the upper end of the packer mandrel 464 and supports and guides the check valve closure member 466 in its vertical movement. The upper end of the valve body member 466 has a fishing neck connected thereto which may be utilized to lift the valve to open the bypass passage through the ports 467a in the housing and guide bushing 467.

When the pack-off tool 460 and pulling tool 470, connected together in the manner shown in FIGS. 14A and 14B, are lowered into the purging tool assembly mandrel and the dogs 471 of the pulling tool are engaged with the fishing neck 432n of the plug tool, fluids cannot pass downwardly through the bore of the mandrel of the purging tool assembly to the lateral circulating ports 425 therebelow.

The connector sub or bushing 462 has a lateral port or ports 462a formed therein intermediate its ends which, if the valve closure is held open, as by wire line tools (not shown), will permit fluids to flow into and through the bore of the mandrel 461 and the connector sub 462 and then outwardly through the ports 462a and exteriorly of the pulling tool downwardly to the inlet ports 432q into the plug tool and then through the bore of the plug tool to the lateral circulating port 432p in the plug tool and the circulating bypass port or ports 425 in the plug tool landing nipple.

With the pack-off tool in the position shown in FIGS. 14A and 14B and the packer P expanded to packing position, as shown in FIG. 15A, fluid pressure introduced through the bore of the packer into the upper end of the bore of the mandrel 420 will pass outwardly through the port 429 into the cylinder bore 422a where it acts on the upper end of the piston 423 to move the same downwardly to shear the pin 421e and so move the skirt member 424a downwardly as shown in FIGS. 15A through 15C. The lower end of the skirt member moves the purge port closure valve sleeve 437 downwardly to open the purge ports 436 to cause a purging action by the flow of fluids into the purging chamber 441 in the purge tool assembly in the manner already described. The pack-off tool 460 closes the bore of the purge tool mandrel 420 against downward flow therethrough from above to the bypass ports 425, and the packer closes off the annular space thereabove. Therefore, the perforations into the well bore from the producing zone will be freed of foreign matter, and the production of fluids through the perforations increased.

Under some circumstances, it may be desired to inject a treating fluid into the formation after the purging operation has taken place. In many such cases it may also be desired to permit any solid matter or detritus drawn into the well bore during the purging operation to settle, either to the bottom of the well bore or to the bottom of the purge chamber, prior to introducing the treating fluid into the well so that such foreign matter will not be carried back into the perforations or into the producing formation. In either event, to introduce the treating fluid, the packing mandrel 464 of the pack-off tool 460 is moved downwardly by fluid pressure introduced through the same downwardly by tubing string and packer bore to act on the upper end of the parking mandrel 464 and the valve closure 466 to shear the shear pin 463 connecting the mandrel 461 to the upper end of the bushing or sub 462. When the pin 463 is sheared, the mandrel 461 may move downwardly until the lower end of the packing mandrel 464 engages the q end of the bushing 462, as shown in FIG. 16A. Any fluid in the sub 462 will be displaced therefrom through the ports 462a. When this movement has taken place, the packing assembly 465 has been moved downwardly below the sealing surface 420x in the bore of the upper mandrel section 420a, and fluids may flow downwardly through the annular space between the upper end of the pack-off tool and the upper mandrel section and downwardly past the exterior of the pack-off tool and the pulling tool 470 to the circulating ports 432i in the plug tool above the external annular flange 432s. The fluids then flow inwardly through the circulating port 432q and downwardly in the bore of the plug

tool and outwardly through the lateral ports 432p below the flange and outwardly through the circulating bypass port or ports 425 in the plug tool landing nipple and the openings 424a in the skirt member into the annular space therebelow, from whence they may be pumped into the producing formation through the perforations 410 in the well casing below the packer. After the circulation of treating fluids has been accomplished in the usual desired manner, the pack-off tool 460, the pulling tool 470 and the plug tool 432 may be removed from the bore of the purging tool mandrel 420 by pulling upwardly on the fishing neck 468 at the upper end of the valve closure member 466 to lift the valve member and the pack-off tool 460 connected therewith to lift the pulling tool 470 and the plug tool engaged by the hook dogs 471 of the pulling tool, until the shear pin 432b is sheared to free the plug tool for removal from the well. Prior to doing so, the shear plug 432g may be sheared to equalize pressures above and below the cap member 432e of the plug tool.

When the pack-off tool, the pulling tool and the plug tool have been removed from the bore of the mandrel, the assembly is left open as shown in FIG. 17, and the closing tool plug 446 is then moved downwardly out of the landing nipple 445 by shearing the pin 447. This opens the bore of the closing tool landing nipple 445 to permit entry of fluids through the ports 450a in the perforated nipple or strainer 450 for flow upwardly through the bore of the purging tool assembly to the surface. The fluids may likewise flow inwardly through the purge tool port or ports 436 and the circulating ports 425 as well, entering through the perforations 424a at the lower end of the skirt member.

From the foregoing it will be seen that this form of the purging tool assembly provides for means for accomplishing the additional step of circulating fluids for treating the well by injection of such fluids through the tubing string and the purge tool mandrel into the annulus below the packer for delivery to the perforations in the casing for treating the well, or for performing other operations thereon requiring circulation of fluids through the tool assembly into the annulus below the packer, or the injection of treating chemicals into the well producing formation.

In all forms of the device it will be seen that means have been provided for creating a surge of fluid pressure into the annulus between a flow conductor and the well casing through the perforations in the casing below a packer, for clearing the perforations of foreign matter, to stimulate flow through the perforations, and remove detritus therefrom. It will be seen that the volume of the surge or the intensity thereof may be controlled by varying the size of the surge chamber. This is accomplished by adding or subtracting lengths of tubing defining the surge chamber between the plug tool and the closing tool at the lower end of the surge chamber. Under the high pressures which are usually found in deep wells, a substantial surge will occur with a relatively small surge chamber. In other wells, where pressure is not so high, the chamber may be larger to assure a sufficient surge action. It will also be seen that the device is adapted to use with multiple string packers in multiple zone production type wells, and that means is provided for injection of fluids for treating the wells when desired. It will particularly be noted

that all forms of the purging tool assembly are provided with means for circulating fluids past the packer used in connection therewith, to prevent premature setting of the packer, but that the circulation ports may be closed readily when desired.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

We claim:

1. A method of treating a well to clear the entrance openings from a producing formation into the well bore, comprising: closing an area of the well bore adjacent the entrance openings from the producing formation to provide a closed chamber and in the well bore at such entrance openings; suddenly reducing the pressure in said closed chamber area of said well bore to draw well fluids inwardly through the entrance openings into the well bore to clear said openings for flow therethrough; introducing treating fluids from the surface through the well bore into the closed chamber area to treat the producing formation communicating therewith through such entrance openings; then flowing well fluids from the producing formation through the chamber area to the surface through the well bore thereabove.

2. A method of treating a cased well to clear entrance openings from a producing formation into the well casing, including: introducing a closed purge chamber containing substantially atmospheric pressure into the well casing; inserting a packer into the well casing connected to the closed purge chamber; maintaining a bypass flow path through the packer as the same is lowered through the well casing; setting the packer with the closed purge chamber therebelow at a point in the well casing above the entrance openings from the producing formation into the well casing to provide a closed chamber region in the well casing communicating with such entrance openings; closing the bypass flow path through the packer; opening the closed purge chamber in the closed chamber region in the casing below the packer to create a surge of fluid flow from the producing formation through the entrance openings into the casing; and flowing well fluids through the closed chamber region from the producing formation to the packer and upwardly through the well casing thereabove.

3. In the method of claim 2 the additional step of conducting treating fluid downwardly through the well casing and through the packer into the closed chamber region in the well casing below the packer for treating the producing formation communicating therewith through the entrance openings prior to flowing the well fluids upwardly through the well casing.

4. In the method of claim 3 the further step of producing the well fluids through the opened closed chamber and packer to the well surface without disturbing the setting of the packer.

5. In the method of claim 2 the additional step of permitting foreign matter in the well fluids drawn into the well casing through the entrance openings when the closed chamber is opened to settle in the well bore below the packer before introducing the treating fluid through the packer and closed chamber area to treat

the producing formation communicating therewith through the entrance openings.

6. In the method of the character set forth in claim 2 the step of setting the packer by hydraulic fluid pressure introduced through the well bore to the packer to actuate the same

7. In the method of the character set forth in claim 2 the step of closing the bypass flow path and opening the purge chamber by hydraulic fluid pressure applied thereto through the well bore thereabove.

8. Apparatus for cleaning the entrance openings from producing formation into a well bore which includes: an elongate tubular mandrel having a longitudinal bore therethrough and means thereon for connecting it to a well packer; means providing a bypass flow passage through the mandrel to the bore of the packer; means movable relative to the mandrel for closing said bypass flow passage; first closure means in the bore of said mandrel at longitudinally spaced points therein closing said bore to provide an elongate purge chamber in said mandrel spaced from said bypass flow passage of said mandrel; lateral inlet opening means in said mandrel communicating the interior of said purge chamber with the exterior of the mandrel; second closure means on said mandrel initially closing said inlet opening means and movable to a position opening said inlet opening means; and means on said mandrel engageable with said second closure means for moving said second closure means from position closing said inlet opening means to a position opening said inlet opening means to suddenly open said purge chamber.

9. Apparatus of the character set forth in claim 8 including: means releasably supporting said first closure means in said bore of said mandrel and releasable to permit said first closure means to be moved from such longitudinally spaced points in the mandrel to open the purge chamber to flow through the mandrel.

10. Apparatus of the character set forth in claim 8 wherein said first closure means comprises: a plug tool releasably locked in sealing position in said mandrel above said lateral inlet opening means and a closing tool landing nipple and a closing tool seated therein in sealing position connected to the mandrel below the lateral inlet opening means.

11. Apparatus of the character set forth in claim 10 wherein said plug tool is removable from locked sealing position in the mandrel and said closing tool is displaceable from the closing tool landing nipple to permit fluid flow longitudinally through the mandrel.

12. Apparatus of the character set forth in claim 8 wherein said means for moving said second closure means is operable by fluid pressure applied within the mandrel to said means.

13. Apparatus of the character set forth in claim 12 including: fluid pressure operated means for actuating said means for closing said bypass flow passage to close said passage.

14. Apparatus of the character set forth in claim 8 including: means providing a circulating flow passage in the mandrel opening to the exterior thereof at a point spaced from said purge chamber; and means movable in the mandrel initially closing said circulating flow passage and movable to a position opening said passage to flow therethrough.

15. Apparatus of the character set forth in claim 14 wherein said means closing said circulating flow passage is movable to open said passage in response to operating fluid applied thereto within the mandrel thereabove.

16. Apparatus of the character set forth in claim 8 wherein the plug tool is removable upwardly through the mandrel.

17. Apparatus of the character set forth in claim 16 wherein said means for closing said circulating flow passage is removable upwardly through the mandrel.

18. Apparatus of the character set forth in claim 17 including: means operatively connecting said means for closing said circulating flow passage with said plug tool whereby they may be moved together upwardly through the mandrel.

19. In combination with the apparatus of claim 8; a fluid operated well packer connected to the upper end of the mandrel and having means connecting it to a well tubing string.

20. A well treating system for a well having a string of casing therein with perforations in its wall providing entrance openings from a producing formation into the bore of the casing for production of well fluids from the producing formation into the well bore for flow to the surface of the well, said system including: a string of tubing having a packer connected thereto; a purge chamber connected in the string of tubing below the packer and comprising an elongate closed chamber having removable closures at its opposite ends and a lateral inlet opening with a movable closure initially closing said lateral opening; means providing a fluid bypass path through the bore of the packer for bypassing well fluids past the packer as the packer is lowered into the well casing; fluid operated means for closing the bypass passage in response to a predetermined operating fluid pressure; means for opening the lateral inlet opening of the closed purge chamber by a predetermined fluid pressure in excess of the pressure required to close the bypass flow passage through the packer bore; and means for removing said removable closures at the opposite ends of said purge chamber, after the lateral inlet opening has been opened, to permit well fluids to flow upwardly through the purge chamber and the packer and through the tubing string to the surface.

21. In a well system of the character set forth in claim 20, means for establishing an injection fluid flow path through the packer to the exterior of the purge chamber after the lateral inlet opening of the purge chamber has been opened and before the removable closures have been removed, whereby treating fluid may be introduced from the surface through the tubing string and the packer into the producing formation for treating the same before opening the purge chamber for flow of well fluids therethrough.

22. A method of treating a well to clear entrance openings from a producing formation into a well casing including: supporting a closed purge chamber containing substantially atmospheric pressure below a packer; supporting the packer on a string of well tubing; introducing the purge chamber and packer into the well casing by means of the string of well tubing; maintaining a bypass flow path through the packer as the same is lowered through the well casing; locating the packer at

a desired location in the well casing above the entrance openings with the closed purge chamber disposed therebelow; closing the bypass flow path through the packer; setting the packer to provide a closed chamber region in the well casing therebelow communicating with said entrance openings; opening the closed purge chamber by hydraulic fluid pressure to create a surge of fluid flow from the producing formation through the entrance openings into the casing; then, flowing well fluids from the producing formation through the chamber region in the casing into the opened surge chamber and through said surge chamber and said packer and said string of well tubing to the surface.

23. The method set forth in claim 22 including the step of introducing treating fluid through the string of well tubing and packer into the closed chamber region and through the entrance openings into the producing formation to treat such formation prior to flowing the well fluids from the well.

24. A method of the character set forth in claim 23 including the steps of opening a circulating flow passage from the packer to the closed chamber region exteriorly of the closed purge chamber; and introducing treating fluid through the string of well tubing and packer into the closed chamber region and through the entrance openings into the producing formation to treat such formation prior to flowing the well fluids from the well.

25. The method of the character of the claim 22 including the step of allowing the solid matter drawn into the closed chamber region by the surge of fluid flow through the entrance openings to settle prior to introducing the treating fluid into the closed chamber region and through the entrance openings into the producing formation.

26. The method of the character of the claim 23 including the step of allowing the solid matter drawn into the closed chamber region by the surge of fluid flow through the entrance openings to settle prior to introducing the treating fluid into the closed chamber region and through the entrance openings into the producing formation.

27. The method of the character of claim 22 wherein the steps of setting the packer and opening the closed purge chamber are accomplished by application of a first predetermined operating fluid pressure through the tubing string to the packer and the subsequent application of a second predetermined higher operating fluid pressure through the tubing string to the closed purged chamber.

28. The method of the claim 23 including the step of opening said circulating flow passage from the packer to the closed chamber region by fluid pressure applied from the surface through the tubing string to the packer.

29. The method set forth in claim 22 including the steps of setting the packer by application of hydraulic fluid pressure thereto before opening the closed purge chamber; establishing a circulating flow passage spaced from said purge chamber from the packer to the closed chamber region by application of hydraulic fluid pressure through the packer; and introducing treating fluid through the string of well tubing and packer and through the circulating flow passage into the closed chamber region and through the entrance openings

into the producing formation to treat such formation prior to flowing well fluids from the well.

30. The method set forth in claim 27 including the step of closing the bypass flow path through the packer by application through the tubing of a predetermined operating fluid pressure lower than said first predetermined operating fluid pressure and prior to setting the packer by application of said first predetermined operating fluid pressure thereto.

31. A method of treating a well to clear the entrance openings from a producing formation into the well bore, comprising: closing off a region of the well bore adjacent the entrance openings from the producing formation to provide a closed chamber in the well bore communicating with such openings; producing a suddenly reduced pressure in said closed chamber area of said well bore to draw well fluids inwardly through the inlet openings into the well bore to clear said openings for flow of well fluids therethrough; opening a flow path into said closed chamber in the well bore from the surface for introducing treating fluids therethrough to the closed chamber area of the well bore; introducing treating fluids from the surface through the well bore and said flow path into the closed chamber area to treat the producing formation at such entrance openings; then, opening the closed chamber to flow therefrom to the surface to produce well fluids from the producing formation through the closed chamber area through the well bore to the surface.

32. A method of treating a well to clear the entrance openings from a producing formation into the well bore, comprising: introducing a closed purge chamber containing substantially atmospheric pressure into the

well casing by lowering the same into the casing on a tubing string from the surface; simultaneously inserting a packer into the well casing connected in the tubing string above the closed chamber; maintaining a bypass flow pass through the packer as the same is lowered into the well bore through the well casing; hydraulically closing the bypass through the packer by fluid pressure introduced into the tubing string at the surface; setting the packer by a higher hydraulic pressure introduced into the tubing string at the surface to provide a closed chamber area in the well casing adjacent the perforations from the producing formation into the well bore; closing the bypass flow path through the packer; opening the closed purge chamber by an actuating fluid pressure introduced into the well casing at the surface of a value in excess of that required to set the packer and close the bypass flow path to produce a surge of well fluids from the producing formation through the perforations into the well bore; opening a circulation path through the packer and spaced from the closed chamber into the well casing adjacent the perforations by an operating fluid pressure of a value in excess of that required to open the purge chamber; then, opening the closed chamber area in the well bore to flow from the producing formation through the purge chamber and packer to the well surface.

33. In the method set forth in claim 32 the additional step of introducing treating fluids through said circulation path to treat the producing formation before producing the well through said purge chamber, packer and tubing string to the surface.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,687,202 Dated August 29, 1972

Inventor(s) Carter R. Young and Leonard McCasland

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 11, for "lading" read --loading--

Column 3, line 3, for "by3pass" read --by-pass--

line 63, before "nd" insert --a--

Column 4, line 50, after "t" insert --.---

Column 6, line 41, cancel "jointed" and insert --joined--

Column 9, line 18, for "Ax" read --An--

Column 11, line 39, for "sting" read --string--

Column 15, line 47, for "valVe" read --valve--

Column 19, line 17, for "4222a" read --422a--

line 55, for "q" read --upper--

Signed and sealed this 9th day of January 1973.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents