

March 22, 1955

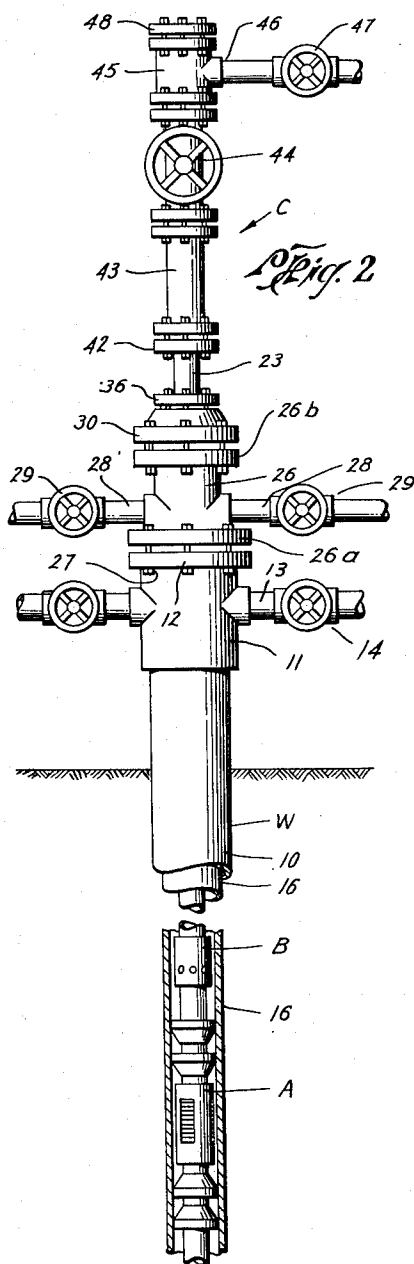
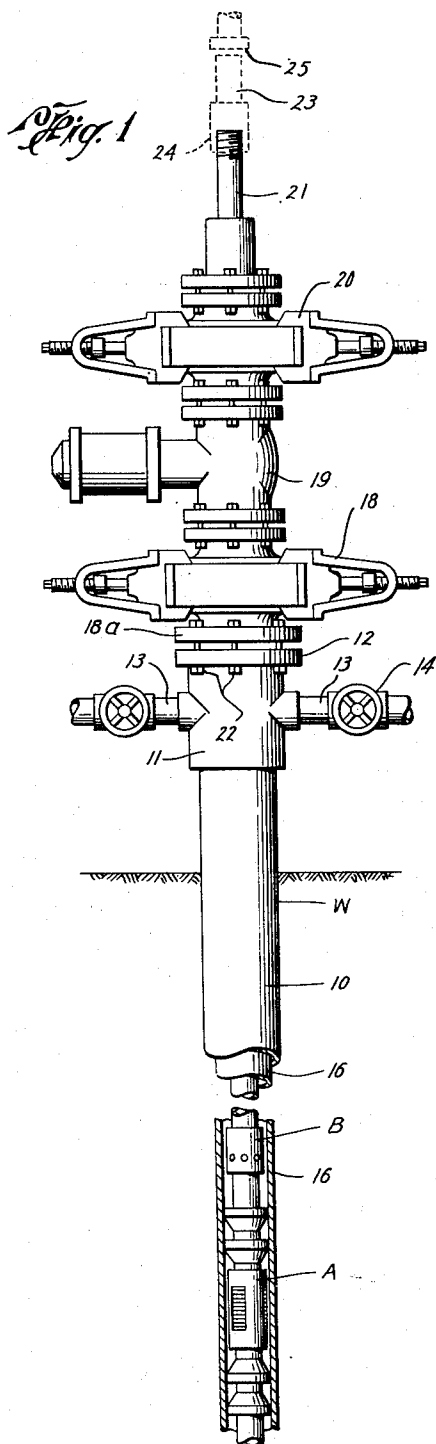
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2,704,579

WELL COMPLETION METHODS AND APPARATUS

Filed Dec. 22, 1950

5 Sheets-Sheet 1



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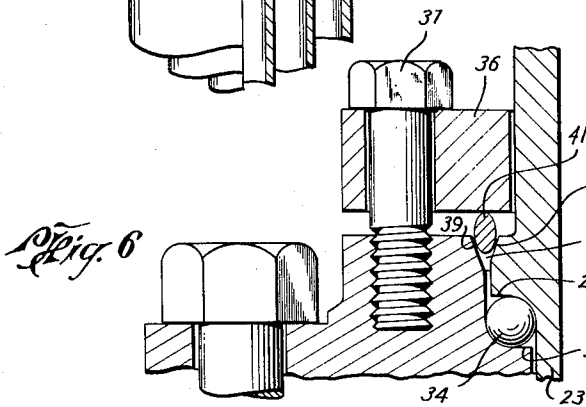
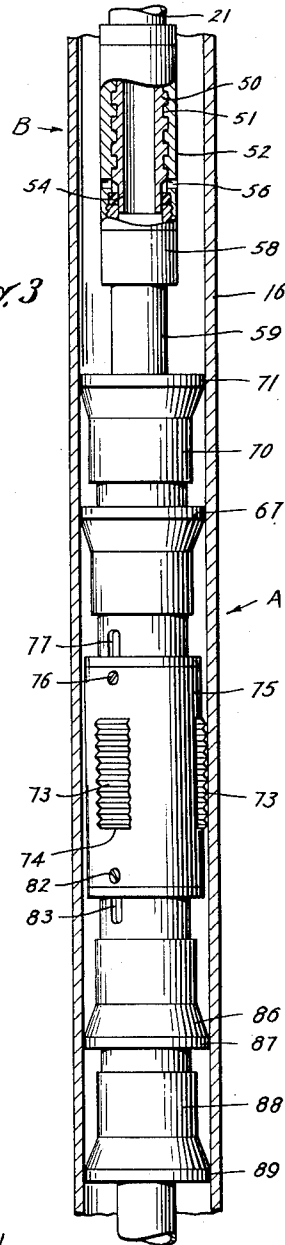
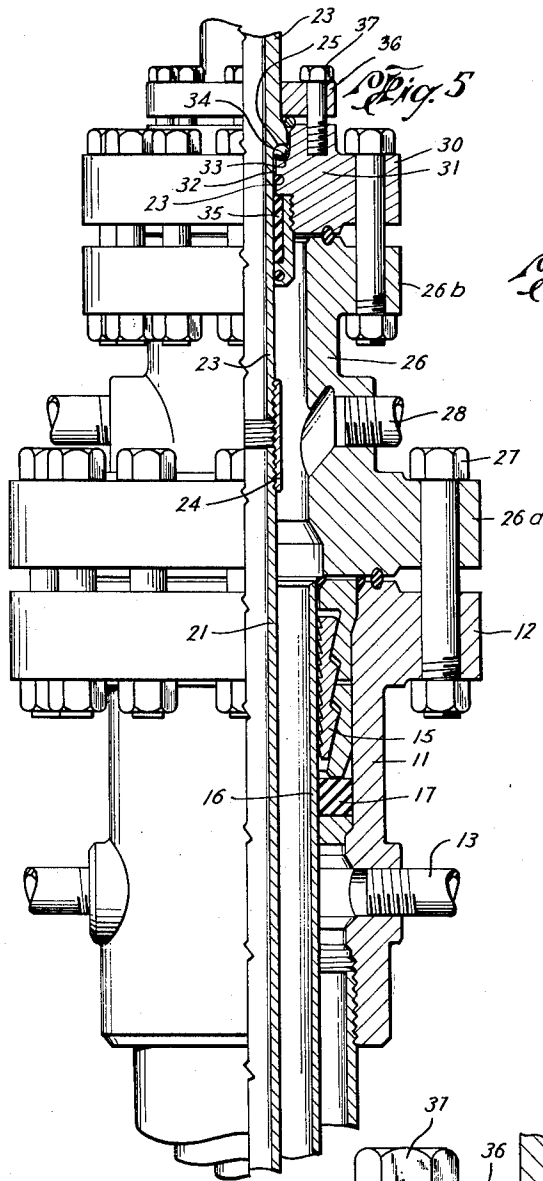
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WELL COMPLETION METHODS AND APPARATUS

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*Fig. 9*

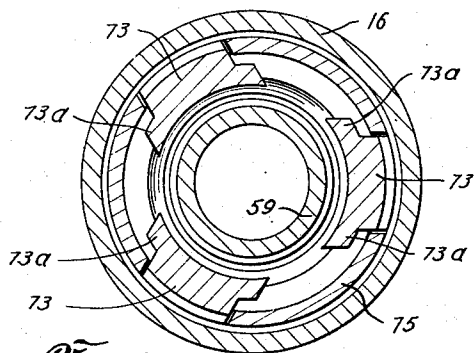
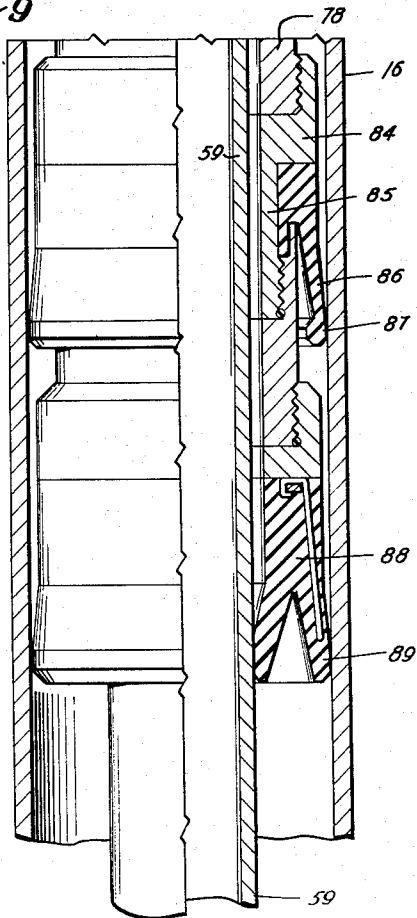


*Fig. 10*

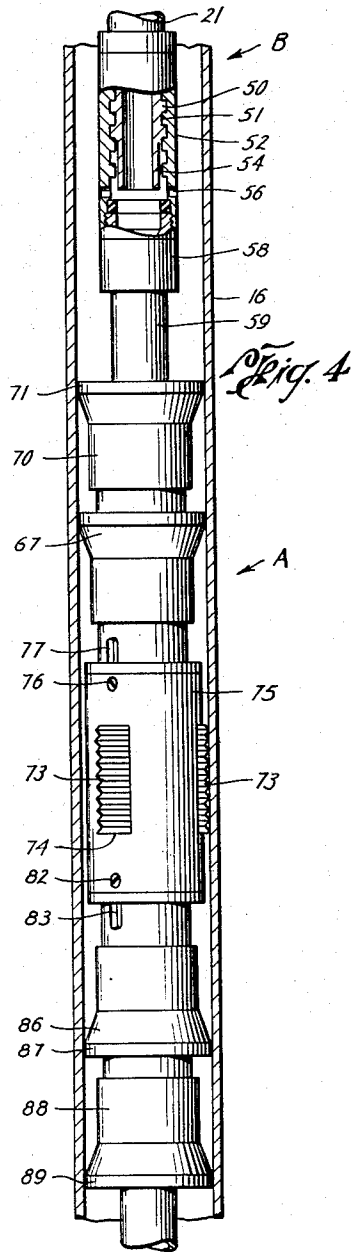


*Fig. 4*

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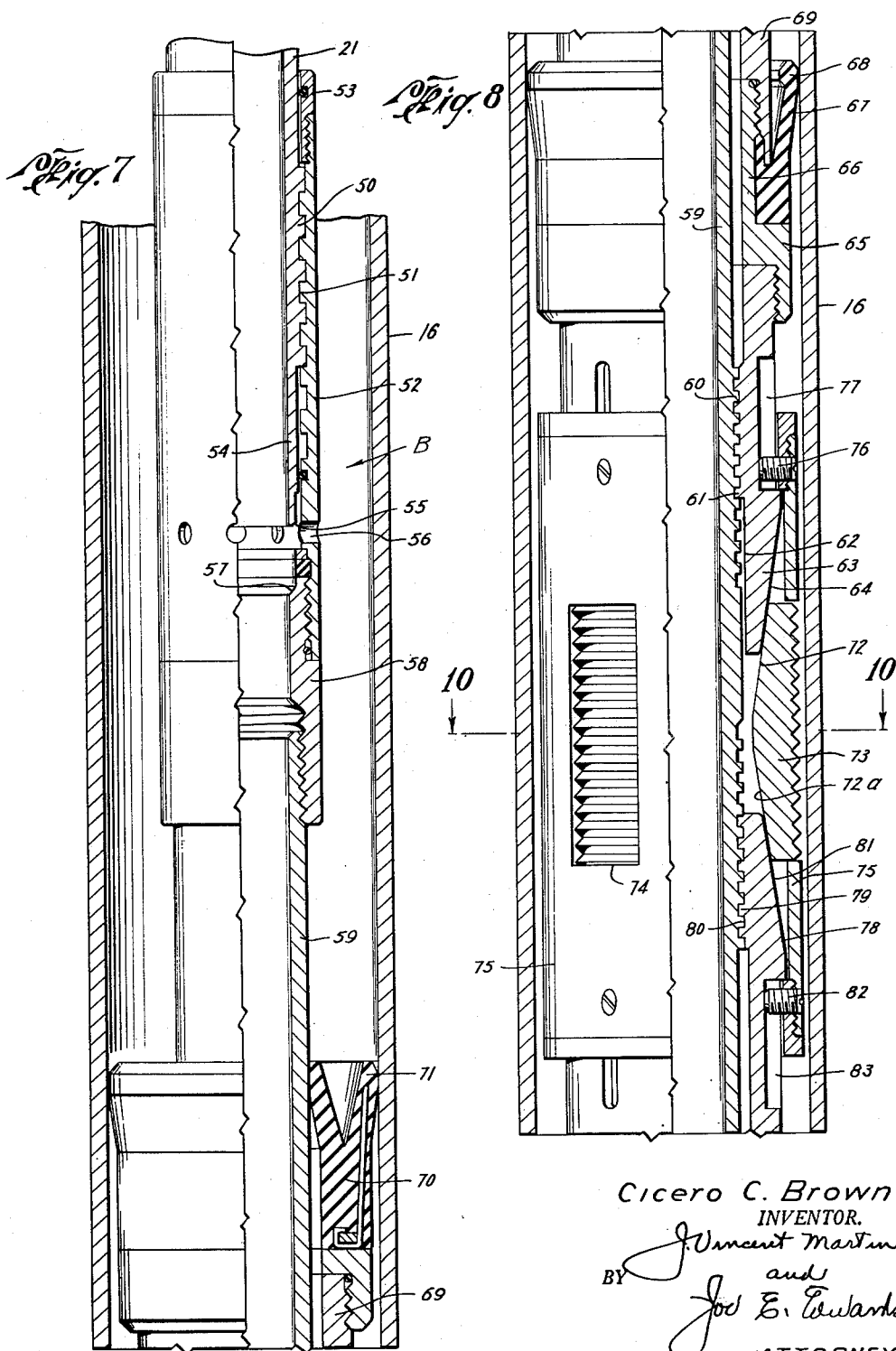
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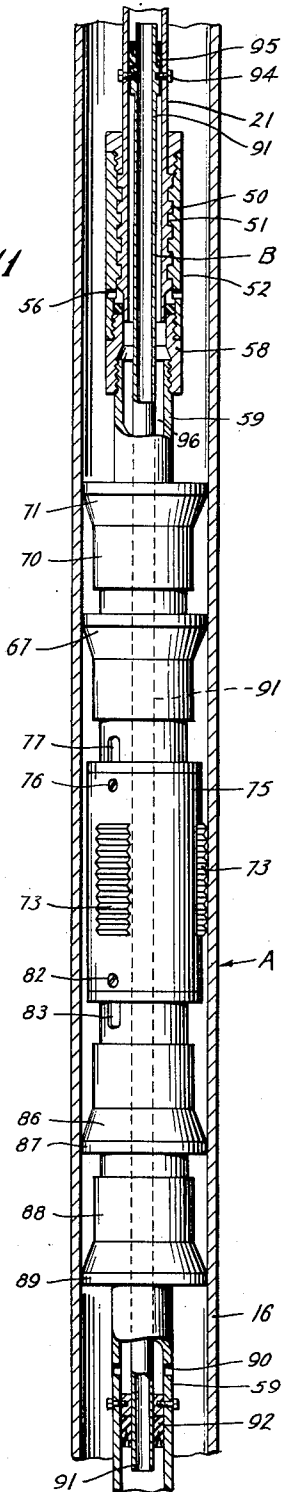
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*Fig. 11*



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## WELL COMPLETION METHODS AND APPARATUS

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Application December 22, 1950, Serial No. 202,174

12 Claims. (Cl. 166—44)

This invention relates to new and useful improvements in well completion methods and apparatus.

In the usual well completion method and apparatus, the production string or well tubing through which the well will ultimately produce is lowered through the drilling control equipment comprising a master gate and a blowout preventer or preventers and said control equipment maintains the well pressure under control during running in of the tubing. The tubing carries a production packer nearer its lower portion for sealing off the annulus around the tubing so that production of the well fluids may be effected through said tubing and the usual production packer has been of the hook-wall type which requires a longitudinal movement of the tubing to accomplish setting and which also requires the weight of the tubing to hold it in its set position.

While the tubing is being run the well is loaded with a column of mud which prevents normal flow of the well fluids and to initiate flow to "bring the well in," unloading of the mud column is necessary and this is the final well completion operation. This final operation may be a washing operation, which is merely a circulation of fresh water through the tubing and annulus to lighten the mud column, but obviously, with the usual hook-wall type of packer in the apparatus, the washing operation must be carried out before the packer is set because after setting of the packer all communication between the tubing and annulus is shut off. Therefore, if washing is employed as the final step, the well is "live" or capable of flowing when the drilling control equipment through which the tubing has been run is subsequently removed and replaced by the Christmas tree or production flow equipment, with the result that a danger of blowout is present. It might be noted that the drilling control equipment must be maintained in position during washing because longitudinal movement of the tubing is required to subsequently set the packer and such longitudinal movement cannot be effected after the Christmas tree is in position because the tubing is landed in final position when the packer is set.

In some instances, swabbing may be the final well completion operation and this can be accomplished after setting of the packer and connection of the Christmas tree, but a swabbing operation is not as desirable as washing because it has the disadvantages of possibly overloading the packer or of collapsing the tubing due to pressure reduction within the string.

It is, therefore, one object of this invention to provide an improved well completion method and apparatus wherein the Christmas tree control equipment may be located in its final position before setting of the production packer whereby the final well completion operations, either washing or swabbing, may be carried out with the control equipment in place to eliminate any possible danger of blow-out.

An important object is to provide an improved well completion method which includes running the production tubing into the well through the usual blowout equipment, then replacing the blowout equipment with the Christmas tree control assembly, then setting the packer, and thereafter performing the final well completion operations to bring the well in and cause it to flow through the tubing.

A particular object is to provide a method and apparatus, of the character described, wherein a washing operation may be carried out prior to setting of the production packer and with the Christmas tree flow control equipment in its final position on the well head.

Another object is to provide an improved well completion apparatus having a well packer which is adapted

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to be set by a rotation of the tubing string and without the necessity of imparting a longitudinal movement to the string, together with a Christmas tree control assembly within which the tubing string is rotatable, whereby said assembly may be positioned prior to setting of the packer to permit the final well completion operations to be effected with maintenance of complete control over the well pressure at all times.

A further object is to provide a well completion apparatus, of the character described, wherein a circulating valve is located above the well packer, with operation of the valve as well as setting of the packer being controlled by rotation of the tubing string; said valve permitting a washing operation to be carried out by circulating through the tubing and the annulus above the packer subsequent to setting of said packer, whereby the tubing string may be unloaded to initiate well flow; said valve also functioning as an equalizing valve to balance pressures across the packer when the latter is to be removed.

A particular object is to provide a swivel head assembly which is adapted to be incorporated in the Christmas tree control equipment and which has means for permitting rotation of the tubing or production string while maintaining a seal therearound, whereby various operations such as the setting of a packer or control of a circulating valve may be carried out after the control equipment is in its final position on the well head.

A still further object is to provide an improved well head assembly adapted to be mounted on a well head and including a swivel head through which the production pipe string extends, together with co-acting means on the string and head for rotatably mounting the string with respect to the swivel head; said swivel head having a locking means which when actuated locks the string against rotation, whereby said production string is non-rotatable within the assembly after it has effected the various necessary operations, such as setting of the well packer and control of the circulating valve, and functions in the usual manner to conduct well fluids there-through.

The construction designed to carry out the invention will be hereinafter described together with other features thereof.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings forming a part thereof, wherein an example of the invention is shown, and wherein:

Figure 1 is an elevation illustrating the usual well head hook-up which is employed in running tubing into the well,

Figure 2 is a similar view illustrating the Christmas tree assembly and well completion apparatus, constructed in accordance with the invention, with the Christmas tree assembly mounted on the well head in place of the usual hook-up shown in Figure 1,

Figure 3 is a view partly in section and partly in elevation showing the well packer which is employed with the apparatus, with the anchoring means in set position and the circulating valve closed,

Figure 4 is a similar view with the circulating valve open,

Figure 5 is an enlarged view partly in section and partly in elevation and clearly showing the swivel head of the Christmas tree assembly,

Figure 6 is an enlarged detail of the swivel head locking ring,

Figure 7 to Figure 9 are enlarged views, partly in section and partly in elevations of the circulating valve and well packer structure, with Figure 8 being a continuation of Figure 7 and Figure 9 being a continuation of Figure 8,

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

Figure 11 is a transverse vertical sectional view of a modification of the invention.

In the drawings, the numeral 10 designates an outer well casing which extends within a well bore W in the usual manner. A casing head 11 is mounted on the upper end of the outer casing and is formed of an annular body having a connecting flange 12 at its upper end. Side outlets 13 project radially from the casing

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body and have control valves 14 mounted therein. The casing head 11 is provided with the usual supporting slips 15 (Figure 5) which suspend or support an inner casing string 16 which extends downwardly within the well bore. A suitable packing 17 around the upper portion of the inner casing string seals off the annulus between the inner and outer strings. The foregoing is usual construction and forms no particular part of the present invention.

In completing a well to initiate the flow of well fluids, the entire well bore is loaded with a mud column which maintains the well shut in, since the relatively heavy column is in excess of the well pressure. To initiate flow a well tubing or production string is lowered into the well and said production string has heretofore been provided with the usual hook wall type of packer. Such a packer requires longitudinal movement for setting and this means that the packer must be moved into a set position at the time that the tubing is landed in final position. If it is desired to carry out a washing operation this must be done before the packer is set because after setting of the packer, communication between the tubing and the inner string of casing is shut off. Thus, with the present type of apparatus and methods a washing operation cannot be carried out within the well after the tubing is landed in final position.

The usual type of equipment which is employed in running the tubing or production string into the well is illustrated in Figure 1, and this assembly ordinarily includes a lower blowout preventer 18, a master gate valve 19 and an upper blowout preventer 20. As the well tubing or production string 21 is lowered within the inner casing string 16 the blowout preventers 18 and 20 function to close the annular space between the well tubing 21 and the inner casing 16. The use of the two blowout preventers permit the passage of couplings without losing the control and the master gate is provided as a means for completely shutting off the bore of the inner casing string. It is usual practice to mount the blowout preventer assembly directly on the connecting flange 12 of the casing head 11, such connection being made through bolts 22 which connect the flange 12 to a base flange 18a provided on the lower blowout preventer.

Where the usual production packer which requires longitudinal movement of the tubing 21 in order to set the same is employed, it is necessary to provide a tubing head (not shown) between the casing head 11 and the lower blowout preventer. Thus, when the tubing has been run into position it has been usual practice to set the packer by the final longitudinal movement of the tubing which lands said tubing in position within the tubing head. A washing operation is not possible and usually at this time the blowout preventers are removed and a Christmas tree control assembly is substituted therefor. Through the use of the usual lubricator at the upper end of the Christmas tree assembly, the tubing may be swabbed out to unload the tubing and initiate flow.

It has been found that swabbing has certain disadvantages, such as overloading the packer or possibly collapsing the tubing, so that a washing operation is more desirable to bring the well in. However, with the usual well completion apparatus the washing must be done before the tubing is landed and before the packer is set, which would be at the time that the blowout preventers are still in position on the well head. Thus, if a washing operation is carried out with the usual apparatus the well is "live" or subject to flow at the time that the blowout preventers are removed and the Christmas tree control assembly substituted therefor. For this reason, if a washing operation is carried out in the usual type of apparatus, danger of blowout is constantly present.

In carrying out the present invention the tubing 21 has the well packer A connected to its lower portion and immediately above the well packer is a circulating valve B. The anchoring mechanism of the well packer, as will be explained, is arranged to be set and released by rotation of the tubing without any longitudinal movement thereof and the circulating valve B is also adapted to be opened and closed by tubing rotation. The tubing 21 may therefore be run into the inner well casing 16 through the blowout preventer assembly shown in Figure 1 in the usual manner with the circulating valve B being

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in an open position to permit by-pass of fluid through and around the packer A. Upon reaching the position at which the packer is to be set, the blowout preventer assembly may be removed from the casing head 11 and a supporting mandrel 23 connected to the upper end of the tubing. This mandrel has its lower end coupled to the tubing by an ordinary coupling 24 and said mandrel is formed with an external supporting shoulder 25 (Figures 1 and 5). In place of the blowout preventer equipment a Christmas tree control assembly generally indicated at C in Figure 2 is mounted on the tubing head, and it is pointed out that the location of the Christmas tree assembly is at a time prior to setting of the packer A. Replacement of the blowout preventer assembly by the Christmas tree assembly B is possible because at this time the well is not unloaded but is maintained under control by the usual mud column. As is clearly shown in Figures 2 and 5, the Christmas tree assembly includes a tubing head 26 which is adapted to have its base flange 26a connected with the flange 12 by bolts 27. The tubing head has the usual side outlets 28 provided with control valves 29. Bolted to the upper connecting flange 26b of the tubing head is a swivel head 30 which comprises an annular body 31 having an axial bore 32. An internal shoulder 33 is formed within the bore of the swivel head and supports a plurality of ball bearings 34. The mandrel 23 which is connected to the upper end of the tubing 21 extends through the bore 32 of the swivel head (Figure 5) and the external shoulder 25 of the mandrel is adapted to engage the ball bearings 34 (Figure 6). It will thus be evident that the tubing 21 is in effect suspended from the supporting shoulder 33 within the swivel head and the tubing is freely rotatable on the ball bearings 34. A suitable packing 35 is mounted in the lower end of the bore 32 of the swivel head 30 and seals off around the mandrel.

For retaining the tubing against upward movement and also for locking the tubing against rotation with respect to the swivel head 30, a locking ring 36 surrounds the mandrel 23 above the shoulder 25 and is attached to the top of the swivel head by stud bolts 37. An annular beveled surface 38 is formed on the mandrel above the shoulder 25 and coacts with an inclined beveled surface 39 (Figure 6) of the swivel head body to form a packing groove 40 between the mandrel and the swivel head above the supporting shoulder 33. It will be obvious that so long as the stud bolts 37 are relatively loose the locking ring 36 will be more or less free with respect to the annular packing ring 41 which is disposed within the groove 40. Therefore, the mandrel 23 and the tubing 21 which is connected thereto may be freely rotated with respect to the swivel head and also with respect to the tubing head, casing head and casing strings. When the stud bolts 37 are tightened down a frictional pressure is applied through the packing ring 41 to the inclined surface 38 of the mandrel, and thus the locking ring will function to frictionally lock the mandrel and tubing against rotation.

The upper portion of the mandrel 23 extends upwardly above the swivel head 30 (Figure 2) and is provided with a connecting flange 42 whereby a connecting sleeve 43 may be bolted thereto. The sleeve 43 supports a master gate valve 44 above which is a T 45. The T 45 has a lateral outlet line 46 controlled by a suitable hand valve 47. A closure 48 is bolted to the upper end of the T 45 and when removed permits connection of a swivel to the T, whereby fluid may be pumped downwardly through the tubing or permits the connection of the usual lubricator whereby a swabbing operation may be carried out.

In employing the apparatus and practicing the method the tubing 21 has the well packer A and circulating valve B mounted thereon and said tubing is run into the inner casing 16 through the blowout preventer assembly shown in Figure 1. The lower blowout preventer 18 of the assembly is bolted to the casing head 11 and thus it might be said that the tubing is run into the inner casing string in the usual manner.

After the tubing has reached its final position and before setting of the packer A or operation of the valve B, the blowout preventers 18 and 20 and gate valve 19 are removed and in place thereof the Christmas tree assembly C which is the final production control equipment is positioned on the casing head in the manner shown in Figure 2. The upper end of the tubing string has the

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supporting mandrel 23 connected thereto and the supporting shoulder 25 of this mandrel is disposed within the swivel head 30. At this time the lock ring 36 at the upper end of the swivel head is not tightened down, with the result that the mandrel and well tubing may be freely rotated. However, with this one exception the Christmas tree assembly C is the final production hook-up and thus is in place before the final well completion operations are carried out.

If it is desired to wash the entire well, this step may be carried out by holding the circulating valve B in an open position and thus circulation above and below the packer A may be accomplished. After this operation has been completed the tubing 21 may be rotated and such rotation, as will be hereinafter described, will set the anchoring means of the well packer A to lock the packer within the inner string. Rotation of the tubing may also close the circulating valve B or may permit the circulating valve B to remain open after setting of the packing, in which event a washing operation above the well packer may be accomplished. During such washing operation, a suitable swivel connection will be attached to the upper T 45 of the Christmas tree assembly, the valve 47 being closed at this time. In the event that a swabbing operation is desirable the well packer A is set and the circulating valve B closed, this being accomplished by rotation of the tubing. The locking ring 36 will then be tightened down to prevent subsequent accidental rotation of the tubing and a suitable lubricator will be connected to the upper T 45 of the Christmas tree assembly to allow the swabbing line to be lowered within the tubing.

After the well has been unloaded either by swabbing or washing, flow of well fluids is initiated upwardly through the tubing 21. Of course, when such flow is occurring the closure 43 closes the upper end of the T 45 of the Christmas tree assembly and the valve 47 is opened so that flow from the well is through the outlet line 46.

It will be evident that the apparatus and method permits a sub-surface control of the well packer A and the circulating valve B without any longitudinal movement of the tubing 21. This makes it possible to locate the Christmas tree assembly C in its final position before the packer is set which means that any desirable washing operation may be effected without losing control over the well.

The apparatus contemplates any suitable well packer and circulating valve which may be operated and controlled by a rotation of the tubing without longitudinal movement thereof, but in Figures 3, 4 and 7 to 9 a packer and circulating valve arrangement suitable for the purpose is illustrated. The details of this packer and valve are clearly shown and described in my co-pending application, Serial No. 202,467. Referring to Figure 7 the lower end of the tubing 21 is provided with relatively coarse external threads 50 which are adapted to engage internal threads 51 formed within the bore of an elongate tubular housing 52. A collar 53 threaded into the upper end of the bore of the housing limits downward movement of the housing with respect to the tubing. Below the threads 50 the tubing is formed with a valve sleeve section 54, the lower reduced end of which has an annular seating surface 55. The lower portion of the sleeve coats with a series of radial inlet ports 56 extending through the wall of the housing 52 and said seating surface is adapted to engage an internal annular seat 57 provided at the upper end of a coupling 58. When the parts are in the position shown in Figure 7 the ports 56 will open but upon a rotation of the tubing 21 with respect to the housing the coarse threads will move the valve sleeve section 54 downwardly to engage the seating surface 55 with the annular seat 57 and, therefore, close flow through said ports.

The threads 50 and 51 are preferably left hand threads and are relatively coarse with a fast lead. The coupling 58 functions to connect the housing 52 with the upper end of a tubular mandrel or support 59 which forms the main supporting structure of the well packer A. The mandrel extends entirely through the packer A and may have its lower end connected to a tail pipe section (not shown).

The intermediate portion of the mandrel 59 (Figure 8) is formed with a series 60 of external screw threads which are relatively coarse but which are somewhat finer than the threads 50 and 51 which operate the circulating

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valve B. This series of threads 60 are preferably right hand threads and are in constant engagement with internal threads 61 which are formed within the bore 62 of an upper annular slip expander member 63. The member 63 has its lower external surface conical or tapered to form a slip expander surface 64 while the upper end of the member is connected with a collar 65. The collar 65 has a tubular extension 66 and a packing element in the form of an annular packing cup 67 surrounds said sleeve and is supported by the collar 65. The sealing lip 68 of the packing cup is directed upwardly and engages the bore of the inner casing 16. A spacer sleeve 69 is connected with the upper end of the tubular extension 66 and has its upper end supporting the uppermost packing element 70. As is clearly shown in Figure 7 the uppermost packing element comprises an annular packing cup having flared sealing lips 71, one of which engages the wall of the well pipe 16, while the other engages the external surface of the mandrel 59. Both of the packing elements 67 and 70 are directed upwardly so that the pressure in the annular space thereabove acts downwardly on said elements. Since said elements are directly connected with the upper slip expander 63 it will be evident that pressure acting on said packing elements will urge the upper expander member downwardly.

The slip expanding surface 64 of the upper expander member 63 is adapted to coact with the inclined inner surfaces 72 of a plurality of gripping elements or slips 73. Each slip 73 is mounted for radial movement within a slot or opening 74 formed in a tubular carrier sleeve or casing 75, with outward movement of the slip being limited by projections 73a (Figure 10) formed on the slip; the projections 73a are adapted to abut the internal wall of the carrier or casing 75 to limit complete outward displacement of the slips from said carrier. The upper portion of the carrier 75 is coupled to the upper expander member 63 through a plurality of pins 76 which project radially inwardly into keyways or grooves 77 formed in the external surface of said expander member. The provision of the connecting pins 76 and keyways 77 permits a limited independent movement of the expander member longitudinally of the carrier sleeve or casing 75, whereby the expander member may move downwardly between the slips 73 to expand the same.

A lower expander member 78 which is similar to the upper expander member has a threaded connection through internal threads 79 on said member and external threads 80 on the mandrel with said mandrel, and these threads are preferably left hand threads. The upper portion of the lower expander member 78 is provided with an inclined expanding surface 81 which is adapted to coact with an inclined surface 72a formed at the lower portion of each gripping slip 73. The lower expander member is also coupled through a plurality of pins 82 and keyways or grooves 83 to the lower end of the carrier sleeve or casing 75. Thus, the lower expander member 78 is capable of a limited movement longitudinally of the carrier sleeve or casing 75 and therefore, with respect to the gripping slips 73, whereby said lower expander may be utilized to expand the slips radially.

The lower end of the expander member 78 is connected with a collar 84 having a tubular extension 85, this element being similar to the collar 65 which couples the upper expander to the packing elements. One of the packing elements 86 surrounds the tubular extension and is in the form of an annular cup which is identical in construction to the upper cup 67; the sealing lip 87 of the cup 86 is directed downwardly. Below the cup 86 is a second packing element 88 which comprises an annular packing cup which is identical in construction to the packing cup 70. The sealing lips 89 of the lowermost cup 88 are directed downwardly and thus the pressure in the annular space between the mandrel 59 and the well pipe 16 acts against the cups 86 and 88 to move their respective sealing lips into engagement with the wall of the well pipe. Since the packing elements 86 and 88 have a direct connection with the lower expander member 78, the pressure acting on these cups urges the lower expander upwardly with respect to the slip carrier 75 and gripping slips 73.

In the operation of the packer and circulating valve these elements are lowered by means of the well tubing with the parts in the position shown in Figures 7 to 9. In such position the circulating valve is open and the slips 73

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of the packer A are retracted. When the packer is to be set the lowering pipe or conductor is rotated in a direction to the right. The threads 50 and 51 of the circulating valve are coarser and have a faster lead than the threads 60, 61 and the threads 79, 80 and therefore, initial rotation will result in downward movement of the sleeve valve to close the circulating valve and therefore close the circulating ports 56. At this time the housing 52 is maintained stationary by the frictional engagement of the packing cups with the wall of the pipe.

After the circulating valve closes, continued rotation of the tubing will result in a longitudinal movement of the expander members 63 and 78 to expand the slips. The pressure above and below the packer will act upon the packing cups and thus the differential in pressure across the packer will maintain the slips in a tightly set position.

If it is desired to reopen the circulating valve after setting of the packer the tubing is rotated to the left and the coarser fast lead threads 50 and 51 will cause upward movement of the valve sleeve 54 to uncover the valve 56. Thus, after the packer is set it is possible to open the circulating ports 56 as shown in Figure 4 and to carry out a washing operation in the annulus above the packer A.

From the foregoing it will be evident that control of the well packer A and control of the circulating valve B is accomplished solely through the rotation of the tubing and without any longitudinal movement of the pipe. The apparatus permits the final well completion operations to be carried out with the Christmas tree assembly C in its final position. As has been explained, rotation of the tubing as it is suspended in the Christmas tree assembly is possible when the locking ring is loosened, and tightening of said locking ring will lock the tubing against rotation after well production beings.

In some instances, it may be desirable to carry out a washing operation below the packer A after the same is in its set position and in Figure 11 a modification of the apparatus is illustrated. In this modification the lower portion of the mandrel 59 is provided with circulating ports 90 which are disposed at a point below the lowermost packing cup 89. An elongate wash tube 91 is disposed axially within the mandrel and has its lower end extending below the ports 90. An annular seal 92 surrounds the wash tube and seals the annular space between said tube and the mandrel below the ports 90. The tube is rotatable within the packing 92. The upper end of the wash tube is connected by suitable screws 94 directly to the tubing 21 and above the connection an annular packing or seal 95 is provided.

It will be evident that where the wash tube is used the assembly is lowered into the well pipe with the parts in the position shown in Figure 11. In such position a by-pass of fluid through the ports 90, then through the annular space 96 between the wash tube and the mandrel and then through the open circulating valve is possible. This allows a by-pass of fluid through the packer during lowering.

When the packer is to be set, the operation is identical to that of the first form which has been heretofore described. The packer is lowered into position and the tubing is rotated, which results in first closing the circulating valve B and then effecting a setting of the packer slips. If it is desired to thereafter circulate, the tubing is rotated in a direction to the left and the threads of the circulating valve which have a faster lead than the threads of the packer unit will result in opening the circulating valve while the packer remains in its set position. Washing or other fluid to be circulated into the area below the packer is then directed downwardly through the wash tube and escapes from the lower end thereof as well as from the lower end of the tubing string and then passes upwardly through the annulus to enter ports 90; from this point the flow is upwardly through the mandrel 59 and outwardly through the openings of the circulating valve. It is thus apparent that a circulation may be carried out below the packer after said packer is in its set position. Of course, when such circulation is complete, the circulating valve is again closed and subsequent production may be upwardly through the wash tube and tubing string.

Having described the invention, I claim:

1. The method of completing a well wherein a well head is mounted on the upper end of a well casing and also wherein blowout equipment is mounted on said well

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head, said method including, running a production string having a well packer thereon through the blowout equipment into the well casing, thereafter removing the blowout equipment and mounting a Christmas tree assembly on the well head, then rotating the production string without longitudinal movement to set the well packer to seal off the annular space between the production string and the well casing, establishing communication between the production string and the well casing above the set packer, circulating a washing fluid through the well casing above the packer and through the tubing to initiate well flow, thereafter rotating the production string without longitudinal movement to effect a closing off of the communication between the production string and the well casing above the packer, and producing well fluids through said production string.

2. The method of completing a well wherein a well head is mounted on the upper end of a well casing and also wherein blowout equipment is mounted on said well head, said method including, running a production string having a well packer thereon through the blowout equipment into the well casing, thereafter removing the blowout equipment and mounting a Christmas tree assembly on the well head, thereafter carrying out a washing operation within the well above and below the packer while the Christmas tree assembly is in position on the well head, then rotating the production string to set the packer, then carrying out a second washing operation through the production string and through the annulus between the production string and casing above the set packer, then rotating the production string to shut off communication between the production string and annulus and finally producing well fluids through said production string.

3. A well completion apparatus including, a well casing, a well head on the upper end of the well casing and adapted to have a blowout preventer assembly mounted thereon, a well tubing, a well packer mounted on the tubing, coating threaded means between the packer and the tubing for effecting a setting and release of the packer upon a rotation of the tubing, said tubing and packer being adapted to be lowered into the well casing through the blowout preventer assembly, a Christmas tree assembly having means for mounting the same on the well head, whereby after tubing has been lowered into the well casing said Christmas tree assembly may be substituted for the blowout preventer assembly, means for rotatably supporting the tubing within the Christmas tree assembly, a circulating valve in the well tubing above the well packer for controlling the establishment of communication between the tubing and the area exteriorly thereof above the well packer, coating threaded means between the tubing and the valve for operating said valve by a rotation of the tubing, whereby said valve and packer may be operated when the tubing is rotated and while said assembly is in position on the well head, the coating threaded means between the packer and tubing being of a different pitch than the pitch of the coating threaded means between the tubing and the valve, whereby the valve may be actuated to be opened or closed when the packer is in its set position.

4. A well completion apparatus including, a well casing, a well head on the upper end of the well casing and adapted to have a blowout preventer assembly mounted thereon, a well tubing, a well packer mounted on the tubing, coating threaded means between the packer and the tubing for effecting a setting and release of the packer upon a rotation of the tubing, said tubing and packer being adapted to be lowered in the well casing through the blowout preventer assembly, a Christmas tree assembly having means for mounting the same on the well head, whereby after the tubing has been lowered into the well casing said Christmas tree assembly may be substituted for the blowout preventer assembly, means for rotatably supporting the tubing within the Christmas tree assembly, a circulating valve in the well tubing above the well packer for controlling the establishment of communication between the tubing and the area exteriorly thereof above the well packer, coating threaded means between the tubing and the valve for operating said valve by a rotation of the tubing, whereby said valve and packer may be operated when the tubing is rotated and while said assembly is in position on the well head, the coating threaded means between the tubing and the valve being

coarser and of a faster lead than the coacting threaded means between the packer and the tubing, whereby upon initial rotation of the tube the valve will be operated prior to operation of the packer.

5. A well completion apparatus including, a well casing, a well tubing, a well packer mounted on the tubing, coacting threaded means between the packer and the tubing for effecting a setting and release of the packer upon rotation of the tubing, means for rotatably supporting the tubing within a well head assembly, a circulating valve in the well tubing above the well packer for controlling the establishment of communication between the tubing and the area exteriorly thereof above the well packer, coacting threaded means between the tubing and the valve for operating said valve by a rotation of the tubing, whereby said valve and packer may be operated when the tubing is rotated, the coacting threaded means between the valve and the tubing being faster acting than the coacting threaded means between the tubing and the packer, whereby the valve is actuated prior to the setting or release of the packer, depending upon direction of rotation.

6. A well completion apparatus including, a well casing, a well tubing, a well packer mounted on the tubing, coacting threaded means between the packer and the tubing for effecting a setting and release of the packer upon rotation of the tubing, means for rotatably supporting the tubing within a well head assembly, a circulating valve in the well tubing above the well packer for controlling the establishment of communication between the tubing and the area exteriorly thereof above the well packer, coacting threaded means between the tubing and the valve for operating said valve by a rotation of the tubing, whereby said valve and packer may be operated when the tubing is rotated, the coacting threaded means between the tubing and valve being coarser and having a faster lead than the coacting threaded means between the tubing and the packer, whereby the valve is actuated prior to the setting or release of the packer.

7. A well completion apparatus as set forth in claim 3, wherein the means for rotatably supporting the tubing comprises a swivel head including an annular body having a seat which is engaged by an annular enlargement on the tubing, and a locking ring surrounding the tubing above the enlargement and adapted to frictionally engage the same to lock the tubing against rotation, loosening of said ring allowing free rotation of the tubing relative to the swivel head.

8. A well completion apparatus as set forth in claim 5, together with pressure-responsive means on the well packer exposed to pressures in the annulus between the well tubing and the well casing above and below the packer for maintaining the packer in its set position within the well casing.

9. A well completion apparatus including, a well casing, a well head on the upper end of the well casing and adapted to have a blowout preventer assembly mounted thereon, a well tubing, a well packer mounted on the tubing and having means for setting said packer upon a rotation of the tubing, said tubing and packer being adapted to be lowered into the well casing through the blowout preventer assembly, a Christmas tree assembly having means for mounting the same on the well head, whereby after the tubing has been lowered into the well casing, said Christmas tree assembly may be substituted for the blowout preventer assembly, means for rotatably supporting the tubing within the Christmas tree assembly, whereby said tubing may be rotated to set the well packer subsequent to mounting of the Christmas tree assembly upon the well head, said means for rotatably supporting the tubing comprising a swivel head including an annular body having a seat which is engaged by an annular enlargement on the tubing, and a locking ring surrounding the tubing above the enlargement and adapted to frictionally engage the same to lock the tubing against rotation, loosening of said ring allowing free rotation of the tubing relative to the swivel head.

10. A well completion apparatus including, a well casing, a well head on the upper end of the well casing and adapted to have a blowout preventer assembly mounted thereon, a well tubing, a well packer mounted on the tubing and having means for setting said packer upon a rotation of the tubing, said tubing and packer being adapted to be lowered into the well casing through

the blowout preventer assembly, a Christmas tree assembly having means for mounting the same on the well head, whereby after the tubing has been lowered into the well casing, said Christmas tree assembly may be substituted for the blow out preventer assembly, means for rotatably supporting the tubing within the Christmas tree assembly, a circulating valve in the well tubing above the well packer for controlling the establishment of communication between the tubing and the area exteriorly thereof above the well packer, said valve including means for actuating the same upon rotation of the tubing, whereby said valve may be operated and the packer also operated when the tubing is rotated within the Christmas tree assembly and while said assembly is in position on the well head, said means for rotatably supporting the tubing comprising a swivel head including an annular body having a seat which is engaged by an annular enlargement on the tubing, and a locking ring surrounding the tubing above the enlargement and adapted to frictionally engage the same to lock the tubing against rotation, loosening of said ring allowing free rotation of the tubing relative to the swivel head.

11. A well completion apparatus including, a well casing, a well head on the upper end of the well casing and adapted to have a blowout preventer assembly mounted thereon, a well tubing, a well packer mounted on the tubing and having means for setting said packer upon a rotation of the tubing, said tubing and packer being adapted to be lowered into the well casing through the blowout preventer assembly, a Christmas tree assembly having means for mounting the same on the well head, whereby after the tubing has been lowered into the well casing, said Christmas tree assembly may be substituted for the blowout preventer assembly, means for rotatably supporting the tubing within the Christmas tree assembly, a circulating valve in the well tubing above the well packer for controlling the establishment of communication between the tubing and the area exteriorly thereof above the well packer, said valve including means for actuating the same upon rotation of the tubing, whereby said valve may be operated and the packer also operated when the tubing is rotated within the Christmas tree assembly and while said assembly is in position on the well head, a tubular wash pipe disposed axially within the tubing and having its upper end located above the circulating valve with its lower end disposed below the packer, means for sealing off the annular space between the tubing and wash pipe at the extremities of the pipe, and said tubing having a fluid inlet in its wall at a point below the packer but above the annular seal at the lower end of the wash pipe, whereby the circulating valve controls flow through said inlet, the wash pipe permitting a washing operation to be carried out below the set packer when the circulating valve is open.

12. The method of completing a well wherein a well head is mounted on the upper end of a well casing and also wherein blowout equipment is mounted on said well head, said method including, running a production string having a well packer thereon through the blowout equipment into the well casing, thereafter removing the blowout equipment and mounting a Christmas tree assembly on the well head, then actuating the well packer to set same in sealing engagement with the well casing to seal off the annular space between the production string and the well casing, establishing communication between the production string and the well casing above the packer and through the tubing to initiate well flow, thereafter closing off the communication between the production string and the well casing above the packer by rotating the production string without longitudinal movement thereof, and then producing well fluids through said production string.

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