June 13, 1939. R. A. MUELLER 2,162,179

OIL WELL COMPLETION EQUIPMENT

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Fig. 1.

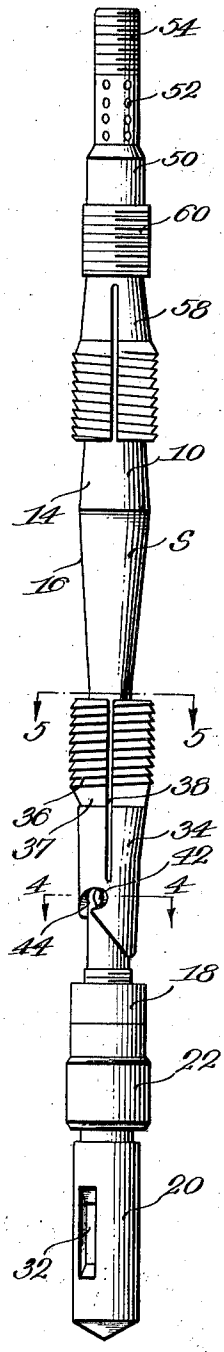



Fig. 2.

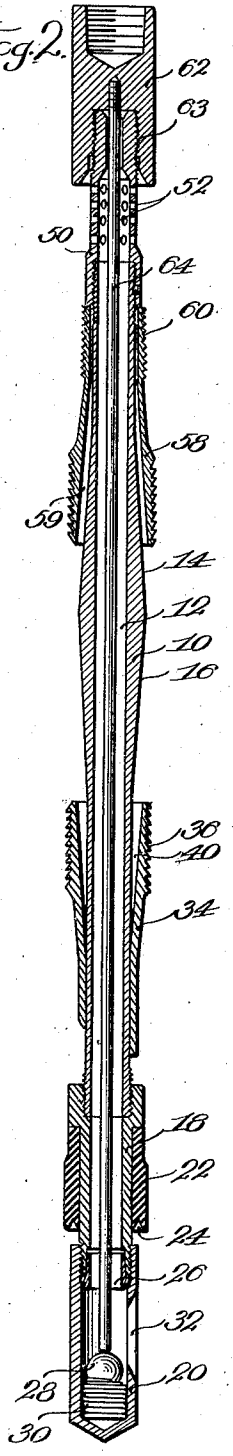



Fig. 3.

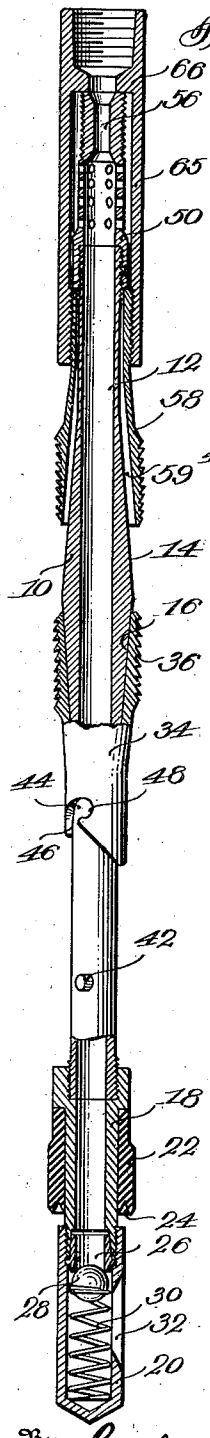



Fig. 4.

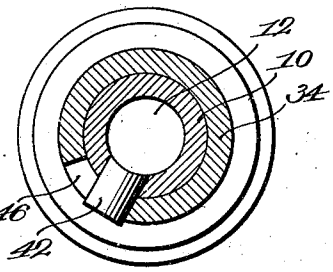
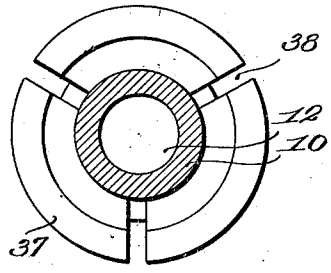



Fig. 5.

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OIL WELL COMPLETION EQUIPMENT

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Fig. 6.

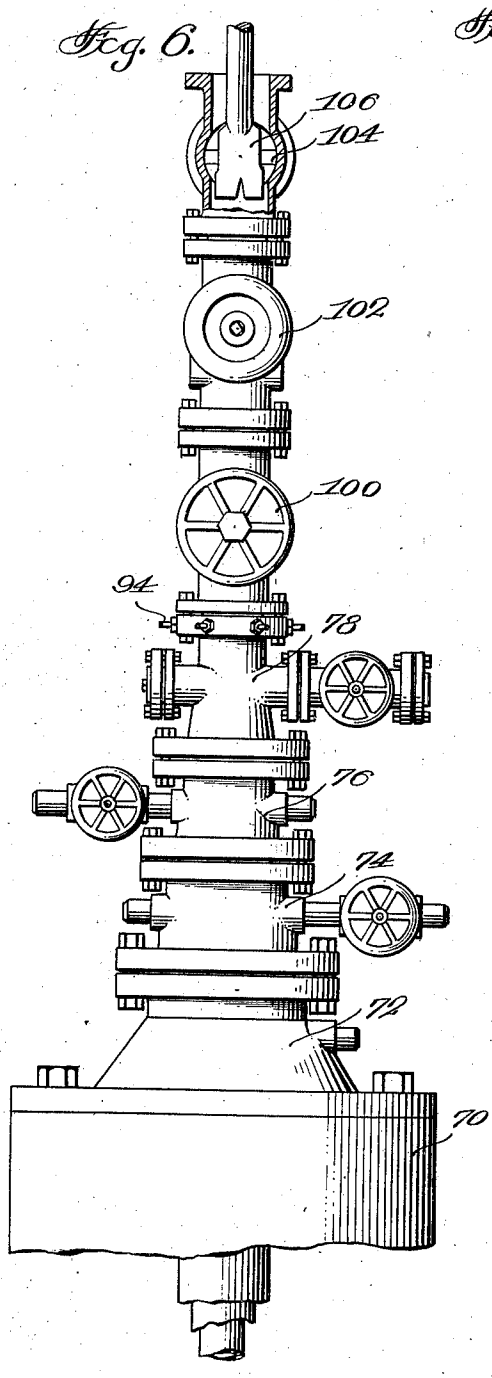



Fig. 7.

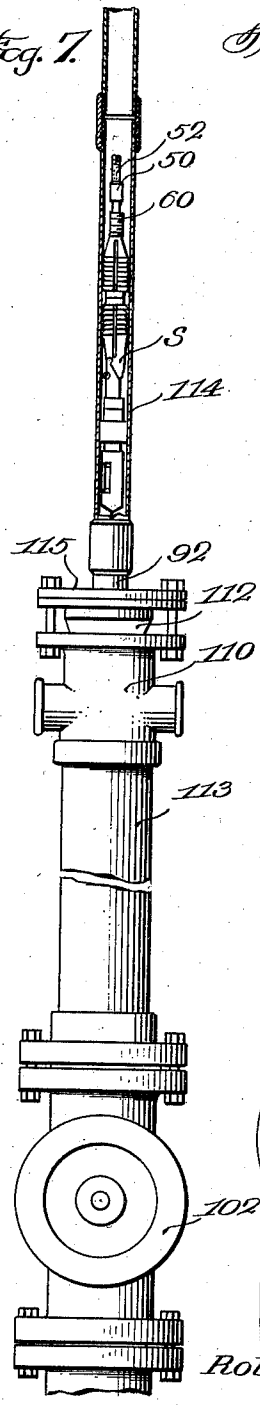
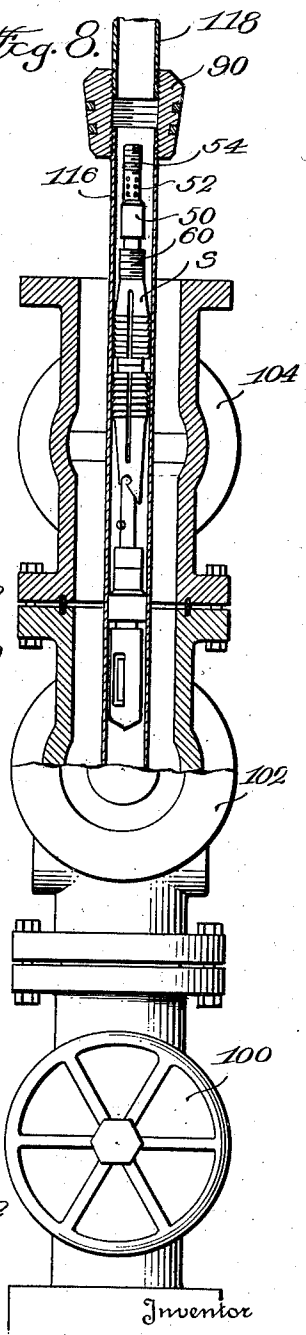



Fig. 8.

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OIL WELL COMPLETION EQUIPMENT

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Fig. 9.

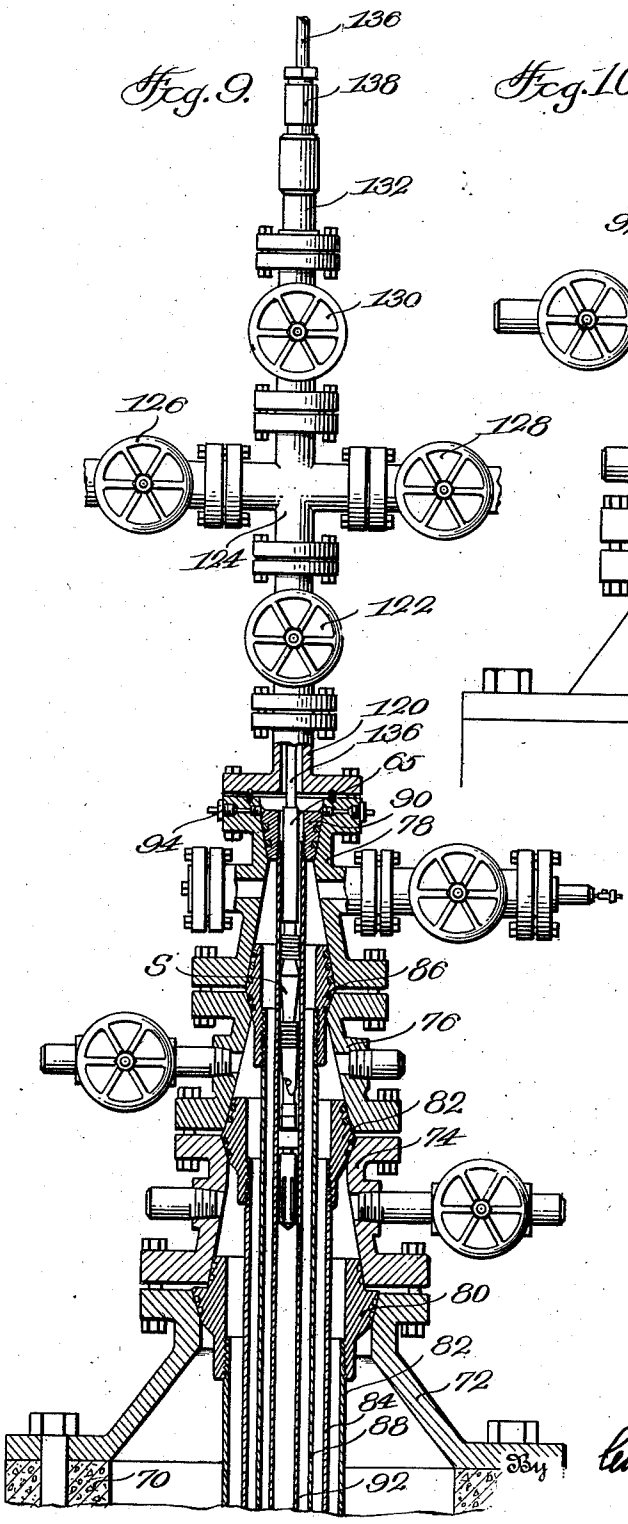
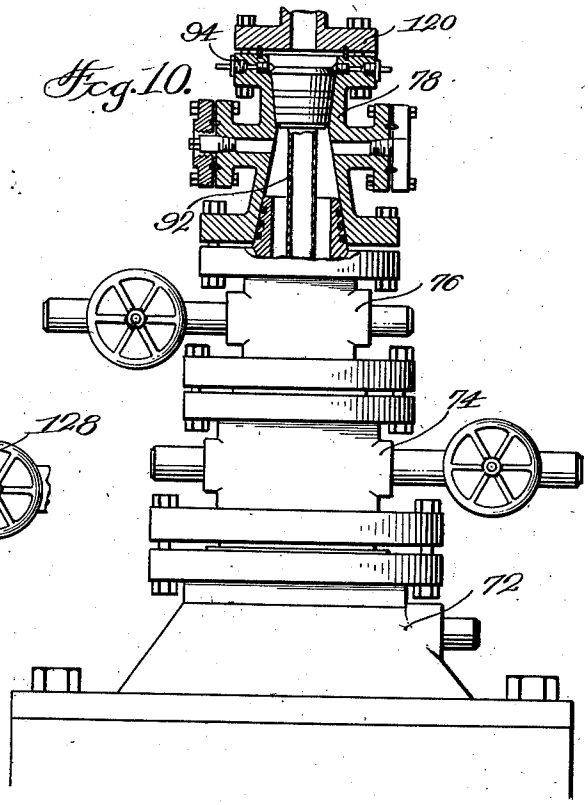



Fig. 10.

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Patented June 13, 1939

2,162,179

# UNITED STATES PATENT OFFICE

2,162,179

## OIL WELL COMPLETION EQUIPMENT

Robert A. Mueller, Houston, Tex., assignor to Gray Tool Company, Houston, Tex., a corporation of Texas

Application September 29, 1937, Serial No. 166,438

13 Claims. (Cl. 166—20)

The present invention relates to oil well completion equipment including a tubing spear, which may be operated to provide control of the well at all times prior to, during and after completion, and without killing the well.

A further object of the invention is to provide a tubing spear and associated equipment which will permit the practice of a series of coordinated operations in the completion of an oil well, which will give the operator a wide choice of operations desirable or necessary to be performed, at any time prior to, during or after the completion of the well, with the well under control at all times and without killing the well.

In the drawings, which are illustrative of a preferred form of the spear, and preferred apparatus to be associated therewith, which drawings are in no sense restrictive,

Figure 1 is a side elevational view of the spear.

Figure 2 is a vertical sectional view of the spear, and associated mechanism for inserting the same into a tubing when the latter has been run into a well.

Figure 3 is a similar vertical sectional view of the spear, having associated therewith an implement for removing the same from the tubing.

Figures 4 and 5 are horizontal sectional views taken along the respective lines 4—4 and 5—5 of Figure 1.

Figures 6 through 9 are views of now well-known oil well completion equipment, showing the manner in which the spear of the present invention cooperates with said equipment in the performance of a coordinated sequence of oil well completion operations, and

Figure 10 is a partial view of the top of the well after the completion operations have been completed, with the well ready for flowing, and the spear removed. Only the lower nipple 120 of the Christmas tree is shown in this view, but it will be understood that the remainder of the Christmas tree shown in Figure 9 will be mounted above said nipple.

The spear of the present invention is intended for and capable of use under numerous situations, the present application disclosing the capability of the spear and associated mechanism in performing a sequence of usual operations in the completion of an oil well, while maintaining control of the well at all times and without killing the same. However, it will be understood that the spear of this invention and the completion equipment associated therewith provide a flexibility of control making possible the performance of numerous unusual operations which may have to be performed with safety to meet a particular situation. By unusual operations I mean those not normally carried out in the completion of a well, as well as operations perhaps not now known, but which will be evolved to meet particular situations in unusual or advanced producing fields.

The spear of the present invention is adapted to be inserted into flow tubing and the like, either as said tubing is being built up and run into the well, or after the tubing has been lowered into the well to position for flowing, or to position for performing any of the numerous operations for which flow tubing is utilized.

The principal element of the spear S is a hollow mandrel 10 having an interior bore 12 and an outside tapered surface sloping from the ends of the mandrel to a greatest diameter adjacent the center of the mandrel, providing an upper slip engaging surface 14 and a lower slip engaging surface 16. The lower end of the mandrel is secured as by means of threads to a hollow nipple 18, to the lower end of which is threaded a valve cage 20. The nipple 18 is surrounded by a suitable packer 22 shown as a rubber sleeve having a circular groove 24 in its lower end, this packer functioning as hereinafter described.

Suitably secured within the lower end of the nipple 18 is a valve seat 26, which is normally closed by a one way ball valve 28, the latter being normally biased to its seat by a spring 30 housed within the valve cage 20. The valve cage is equipped with one or more ports 32 to permit passage of fluid therethrough.

Surrounding the lower end of the mandrel and above the nipple 18 is a slip member 34, comprising a sleeve having pipe engaging teeth 36 on the exterior of its upper end, said teeth being carried by spring finger portions 37 of the slip member, the latter being formed by slots 38 extending longitudinally through a portion of the length of the slip member from the inner end thereof. The slip member is hollow, and its bore 40 flares outwardly as the inner end of the member is approached, this flared portion being adapted to engage the lower tapered portion 16 of the mandrel to expand the slip and prevent the spear from moving downwardly in the tubing in which it is positioned.

While the spear is being inserted into a string of tubing, the slip section 34 is retained in its inactive or outermost position as shown in Figures 1 and 2 by a pin 42 carried on the outer wall of the mandrel which engages within an inverted J slot 44 in the lower end of the slip

section, said slot having a vertical passage 46 and a horizontal ledge 48, the latter engaging the mandrel lug 42 and retaining the slip in its outermost and inactive position as shown in Figure 1. While the slip finger teeth 36 are in contact with the inner wall of the tubing during insertion, they do not exert sufficient pressure thereagainst to prevent insertion, when the spear is forced downwardly in the tubing. After the spear has been inserted to the desired position in the tubing, the mandrel may be rotated relative to the slip section to move the lug 42 off of the step 48 and into the longitudinal opening 46. At this time, the weight of the spear causes the mandrel to move downwardly with respect to the slip section to the position shown in Figure 3, thus permitting the lower mandrel section 16 to expand the slip fingers 37 against the inner wall of the tubing string, preventing downward movement of the spear with respect to the same.

The upper end of the mandrel 10 is secured as by means of threads to a hollow top nipple 50, the latter being provided with a plurality of perforations 52, and with an external threaded portion 54. The upper end of the top nipple is open through a restricted counterbore 56.

Surrounding the upper end of the mandrel and mounted for vertical sliding movement thereon is an upper slip member 58 having tubing wall engaging fingers carrying appropriate serrations as described in connection with the member 34. This slip member is equipped with an outside threaded portion 60 adjacent its outer end for a purpose hereinafter apparent.

The spear of this invention may be put into use by being lowered into a tubing already in place in the well or may be positioned in a section of tubing which is being assembled into a tubing string above control equipment as the string is being lowered into the well.

If the spear is to be lowered into a tubing string already in the well, a lowering rod or pipe may terminate in a collar 62 having interior threads 63 in engagement with the external threads 54 of the top member of the spear. If fluid is to be encountered in the well, which must necessarily be by-passed as the spear is lowered away, the lowering collar 62 has secured to its lower end and extending throughout the bore 12 of the mandrel a valve opening rod 64, the latter retaining the one way valve 28 off of its seat as shown in Figure 2, thus permitting fluid in the well to pass upwardly through the mandrel, and outwardly through the perforations 52 in the top member 50.

When the spear is being lowered into the well, the lug 42 is set in the slot 44 in the lower slip member, with said lug engaging above the step 48, so that the slip is retained in the position of Figures 1 and 2, providing only minimum resistance to the insertion of the spear into the tubing. The upper slip 58, being freely mounted on the exterior of the mandrel, will by reason of the light drag of its fingers on the interior of the tubing string, be moved to its uppermost and inactive position as shown in Figures 1 and 2 during the insertion of the spear.

When the spear has been lowered to the desired depth in the tubing, the mandrel may be rotated with respect to the lower slip member 34 until the lug 44 is in aligment with the vertical channel 46, at which time the weight of the mandrel causes the entire tool to move downwardly under gravity with respect to the lower slip 34, the lower surface 16 of the mandrel then serving to expand the fingers of the lower slip member into intimate engagement with the interior wall of the tubing.

After the spear has thus been set, the lowering device including the engaging collar 62 may be backed off of the upper end of the spear, and removed from the well, it being obvious that the removal of the rod 64 permits the valve 28 to engage its seat, and close off any upward flow of fluid through the interior of the spear under influence of the spring 30.

If pressure exists in the well, it tends not only to expand the rubber packer 22, acting upon the lower end of the same in the slot 24, but it also influences the entire tool upwardly if of sufficient force. Upward movement of the tool under well pressure causes expansion of the upper slip member 58, which resists upward movement by engagement of its spring fingers with the interior wall of the tubing, and any upward movement of the tool under pressure will terminate when the upper surface 14 of the mandrel engages within the interior flared surface 59 of the upper slip member 58, and expands the fingers thereof into intimate engagement with the inner wall of the tubing.

The spear of the present invention provides self-operating means for locking the spear in the desired position in the well, against both upward and downward movement. The upper and lower slips 34 and 58 will rigidly engage the plain inner wall of the tubing at any point in the latter to prevent upward and downward movements of the spear in the tubing.

While the spear may be lowered away under certain conditions into tubing which is already positioned in the well as discussed above, it may be first inserted into a section of tubing which section is then built up into the tubing string as the latter is lowered into the well.

In this case, the lowering device including the collar 62 and the rod 64 may not be necessary, and the spear is inserted into a section of tubing at a site near the surface of the well in the condition shown in Figure 1 with the lower slip member 34 in retracted position. After insertion, the mandrel may be rotated with respect to the lower slip member, removing the lug 42 from the J slot so that when the tubing is positioned vertically, the weight of the mandrel drops into the lower slip member, thus expanding the same and securing the spear in place. Obviously, when this section of tubing is incorporated into the tubing string and lowered into the well, any pressure therein will only serve to move the mandrel upwardly with respect to the upper slip member 58, thus expanding the same and preventing further upward movement of the spear.

The spear may be removed from the well by an appropriate removing tool, or may be removed in a section tubing as the latter is withdrawn and broken down at the surface of the well. If it is desired to remove the spear from the tubing with the latter remaining in the well, a removing device such as that shown at 65 in Figure 3 may be used. This device comprises a rod or pipe terminating in a hollow wrench adapted to encompass the upper end of the spear, and having threads to engage the threads 60 of the upper slip section 58. The removing wrench is also equipped at the upper end of its encompassing cylindrical portion with an interior collar or abutment 66, the latter being adapted to engage the top end of the spear a period of time after the interior threads in the lower end of the wrench have engaged

the thread 60 of the upper slip member. When this shoulder engages the top of the tool, continued rotation of the wrench with respect to the spear causes the upper slip section 58 to be moved upwardly along the mandrel, terminating the expanding effect of the mandrel section 14 on the slip fingers. When the upper slip member has thus been retracted, the spear may be elevated from the wall.

The force of the valve spring 30 is such that such well known operations as washing the well may be performed with the spear in place. That is, the spear may be assembled in the flow tubing as the latter is built up, or may be lowered into the well to any desired point, after which washing operations either inside or outside of the screen may be performed with the well under perfect control. As is well known, the washing operation is one of the most dangerous and delicate necessary to be performed in the completion of oil wells, and the spear of the present invention, while providing against upward flow of high pressure fluid from the well, will permit downward flow of washing fluid through the tubing, through the mandrel and past one way valve 28 to wash the well. The spear may be positioned at any position in the tubing, adjacent the lower end thereof, or near the surface of the well, and may be readily inserted or removed at any time. In general, it will be evident that this device is of pronounced advantage in performing any of the usual operations in well completion necessary to be performed, as well as unusual operations, while maintaining control of the well against a blowout at all times and without killing the well.

The spear described above is adapted to be used with any type of oil well completion equipment, but is of particular advantage when used in association with now well known types of control equipment, in order to carry out a planned sequence of control operations in completing a well.

Throughout Figures 6 through 10, a now well known type of completion apparatus is disclosed, only so much of this equipment being illustrated as is necessary to describe the above mentioned sequence of operations.

In Figures 6 and 10, casing head equipment of the type disclosed in Patent No. 2,082,413, Mueller et al., June 1, 1937, is shown, this equipment comprising a foundation 70 on which is mounted a plurality of successive casing heads 72, 74 and 76, surmounted by a tubing head 78 of the type disclosed in the patent to Mueller et al. No. 2,150,887, March 14, 1939.

The foundation casing head 72 is provided with an inside seat in which is hung and sealed a hanger 80 attached to and suspending an outside string of casing 82, said hanger having an upper sealing surface to receive the interior of a second casing head 74, the latter also having an upper interior seat for sealing engagement with the hanger 82 which suspends a second string of casing 84.

The third casing head 76 is adapted to seal with the upper portion of the hanger 82, and likewise seal with a hanger 86 of a third string of casing 88. The tubing head 78 is also provided with a lower interior seat to seal with the upper portion of the hanger 86, and is equipped with an upper interior seat to receive a tubing hanger 90 which is secured to and suspends a flow tubing 92.

As described in the aforementioned Mueller et al. patent, the tubing hanger is provided with locking bolts 94 operable from the exterior of the casing head when control equipment is mounted thereabove to lock the tubing hanger 90 in sealing engagement in the seat of the tubing head 78, and prevent the hanger 90 and tubing from being blown from the well.

Each of the casing heads is provided with suitable outlets, as shown in the aforementioned patent, which may be plugged, or connected with outlet lines under the control of suitable valves, as shown, in order to permit venting of pressure from the interior of the various casing strings, or to provide for the discharge of fluid through these outlets during operations necessary in seating the various strings of casing, for instance during drilling operations through a previously set string of casing, to permit discharge of the drilling fluid.

The casing heads and the tubing head are equipped with flange and bolt connections of like size, of dimensions designed to result in a sturdy casing head assembly, and are arranged one upon another, the overall dimension or diameter of the equipment decreasing as the equipment progresses upwardly to provide a solid structure unlikely to be carried away by the well pressure or to weaken due to vibration as the well flows.

Referring to Figure 6, the tubing head serves as a foundation for control equipment mounted directly thereon, said equipment comprising first a drilling master valve 100, surmounted successively by blow out preventers 102 and 104. The drilling master valve is connected with the tubing head by bolt and flange connections of like size. This is necessary, as it is desirable to use control equipment having the lowest possible number of square inches of area exposed to the pressure within the well. The minimizing of the area subject to well pressure of any of the control devices, such as master valves and blow out preventers is a primary requisite in their design, and must take precedence over any advantage which would result from using equipment having an increased pressure subject area. It is quite undesirable to mount one control device above another, with the device so mounted having a greater area subject to the pressure in the well than the device or devices below it.

The drilling master valve, by reason of its bolt and flange connection with the tubing head may be removed and relegated to the position of an accessory when its function has been performed, and likewise it may be replaced on the tubing head when its performance is again desired.

Similarly, the blow out preventers 102 and 104 are connected to one another and to the master valve by bolt and flange connections of like size so that the area exposed to the well pressure may be kept at a minimum. The blow out preventers may likewise be removed to the position of accessories after they are no longer needed, and replaced as a part of the control equipment when they are again needed.

The bores of the drilling master valve 100, the blowout preventers 102 and 104 and the tubing head 78 are at least as large as the interior diameter of the last string of casing 88, so that a drill 106, shown in Figure 6, having a diameter substantially as large as that of the interior diameter of said last string of casing may be lowered through the control equipment to drill through and below said string of casing as desired, while maintaining control of the well around the drill stem by means of the blow out preventers 102 and 104 in the well-known manner. The drill stem is hollow to permit passage of drilling fluid

downwardly therethrough, to be discharged through the side outlets in the tubing head 78, and is equipped preferably adjacent its lower end with a one way valve to permit a downward flow of drilling fluid through the stem, while preventing upward flow of fluid under pressure from the formation. Any well-known type of one way valve employed in drill strings may be used for this purpose.

In order to keep the well closed off at all times to guard against a blow out, the master drilling valve 100 may be kept closed until the drill bit is inserted to a point below the blow out preventer 102, and when one or both of the blow out preventers engages and seals with the outside of the drill stem, the master drilling valve may be opened, and the drill stem lowered therethrough. It will be understood that the blow out preventers 102 and 104 are so positioned that they may be used alternately to pass the connecting collars of the drill string without opening up the well. When the drilling bit reaches working position, the drill stem may be rotated and manipulated as desired through the blow out preventers, without losing control of the well. Following completion of the drilling operation, the drill stem and bit may be removed for the insertion of other tools, or for the insertion of the tubing without losing control of the well at any time, and without killing the well. The drill bit is removed through the master valve and blow out preventers in a manner the reverse of that related with respect to its insertion.

As is well known in the art, many operations may have to be performed at this stage of completion, particularly operations to determine if the well is drilled to the proper depth for running the flow tubing. Such operations performed at this dangerous stage of completion usually involve removal of the drill stem, application thereto of other tools and reinsertion of the same into the well. It may be necessary at this time to remove and reinsert the drill string many times. Such operations may include: running the Schlumberger, drilling the rat hole, running the drill stem testing tool, reaming out the rat hole, and setting a perforated liner or strainer and packer. It will be understood that the bore through the master drilling valve 100, blow out preventers 102 and 104 and tubing head 78 is sufficient to permit passage of all devices necessary to perform the above operations, such as the screen liner or packer, and it is obvious that the control equipment disclosed may be manipulated to accomplish the perhaps usual operations above, as well as unusual operations, without losing control of the well.

When the above type of operations have been completed, the time will have arrived when it is desirable to lower the flow tubing into the well. Before the well is ready to flow through this tubing it may be necessary to utilize the same in performing other operations involving manipulating the tubing, such as setting of the packer, etc.

If the well is mudded up sufficiently, the flow tubing may be lowered into the same in sections assembled above the upper blow out preventer, and the spear S assembled into the flow tubing adjacent the upper end thereof. However, if the well gives indication of danger of a blow out, the spear S may be inserted into the lower end of the flow tubing and run into the well past the blow out preventers with the master valve in closed condition, and with said preventers engaging the tubing, the master valve may be then opened for running the tubing.

In Figure 7, the flow tubing 92 is shown being run into the well with the spear S inserted therein. It will be understood that when the spear is inserted into a section of tubing before the latter is built up into the flow string the spear will comprise that arrangement of parts shown in Figure 1, and will not include the lowering collar 62 nor the valve opening rod 64. While I prefer to use blow out preventers of the ram type, diagrammatically indicated in Figure 6, the upper blow out preventer may be replaced by a bowl 110 and "wrap around" device 112 as shown in Figure 7. This arrangement is generally similar to that disclosed in the patent to Minor, No. 1,812,358, June 30, 1931, the "wrap around" comprising a pair of semi-circular plug segments which can be quickly wrapped around the tubing to seal within the bowl 110 to close off the space between the tubing and casing. These segments may be hinged together at one side, and may be equipped with a latching device at their other side, so that they form a plug around the tubing, which plug is received in the bowl to form a seal between the tubing and casing. The bowl may be carried at the upper end of a spacing nipple 113 and may be flanged and equipped with bolts to engage a hold down plate or the like 115 to hold the "wrap around" in place.

By proper and well-known manipulation of the blow out preventers, the tubing may be lowered into position in the well, the connecting collars thereof being alternately passed by each blow out preventer to maintain a seal around the tubing at all times.

The spear may be inserted into a special short length of tubing 114 as shown in Figure 7, which length is built up into the regular flow tubing string above the upper blow out preventer, or said spear may be inserted into any of the conventional length sections of the flow tubing string before said sections are assembled to said string above the upper blow out preventer.

If the well is sufficiently mudded up, it may be more convenient to delay inserting the spear until one of the final or uppermost sections of the flow tubing is built into the tubing string, but if dangerous pressures are indicated, the spear should be inserted in the lowermost section of flow tubing, which section is inserted past and sealed with the blow out preventers with the master drilling valve 100 closed, after which the latter may be opened and the tubing snubbed on down into the well with the blow out preventers maintaining control around the tubing at all times.

With the spear of Figure 1 in position in the flow tubing, but with the lug 42 removed from above the step 48 so that the slip section 34 is in operative position, flow through the tubing may be controlled at any depth therein by means of this independent device not connected except through the walls of the tubing with the surface of the well. As hereinbefore stated, the weight of the mandrel prevents the spear from dropping through the tubing, whereas if any pressure is encountered of sufficient intensity to raise the spear, it automatically locks itself in fixed position against the inner wall of the tubing. Furthermore, the valve 28 prevents upward flow of fluid past the spear.

With the blow out preventers engaged with the tubing, various operations may be performed, and the tubing may be manipulated up and down, or rotated, without at any time losing control of

the well. Such operations may include outside washing of the well. During this operation the tubing may be lowered to sealing engagement with the bottom of a screen or strainer positioned at the lower end of the inside string of casing 88, and the well washed by downward flow of washing fluid pumped through the tubing past the one way valve 28, this fluid moving up around the outside of the screen and discharging through the appropriate side outlets in the casing head. After outside washing, the tubing may be elevated, after which inside washing may be performed. During inside washing, the lower end of the tubing may be positioned or adjusted at any desired point in the casing, or with relation to the screen, and the washing fluid is pumped downwardly as before through the tubing past the one way valve 28, rising within the casing and discharging through the appropriate side outlets at the surface of the well, in this instance through the side outlets in the tubing head 78. During these operations, the washing fluid is forced downwardly through the tubing by a pump unit located adjacent the well and connected with the upper end of the flow tubing, usually through flexible hose connections. If a packer is to be set, the tubing may be elevated, depressed or rotated as desired, with control against blow out maintained, in order to effect the desired operation.

After the washing and similar operations, the tubing may be elevated substantially to hanging position, with the upper end of the string 116 thereof which is to be located at the point of hanging above the upper blow out preventer 104. With the spear S still in place within the tubing, and preventing upward flow of fluid therethrough from the well, and with the blow out preventers 102 and 104 preventing upward flow around the tubing, the tubing string is broken and tubing hanger 90 is connected to the same as shown. Thereafter, the tubing, by means of a lowering nipple 118, connected into the upper end of the hanger, is lowered to hanging position, the bores of the blow out preventers 102 and 104 and the master drilling valve being sufficient to pass the hanger 90. The hanger is lowered to position below the upper blow out preventer 104, with the preventer 102 closed, after which the preventer 104 is engaged with the lowering nippel 118, and the lower preventer 102 opened to pass the hanger to its seat through the master drilling valve 100, thus maintaining control at all times.

After the hanger 90 is seated in the tubing head 78 and the locking screws 94 are moved inwardly to lock the hanger in sealed position, all of the control equipment comprising the master valve, blow out preventers, etc. may be removed and relegated to the position of accessories, to be later used on other wells, or until it is desired that they again be positioned on the same well. It will be understood that the seal around the tubing is at that time provided at the hanger 90 while the spear S maintains the tubing seal whether it is located adjacent the upper end of the tubing as shown, or further down in the well.

The well is then ready for flowing, and the flow control equipment shown in Figure 9 is then positioned on the tubing head 78 as a foundation. The flow control equipment comprises an adaptor 120 mounted upon the tubing head as a foundation, the adaptor and tubing head having bolt and flange connections of like size. Positioned on the adaptor is a master manifold valve 122, in vertical alignment with the tubing and having a materially smaller pressure subject area than the master drilling valve 100. The flow control equipment comprising the adaptor, master manifold valve and other regulating devices is known as a Christmas tree, and it will be apparent that this Christmas tree equipment may be moved to position as a unit and stabbed onto the tubing head as a foundation. I have shown the Christmas tree as further including a T 124 having dual side passages controlled by the flow valves 126 and 128, there being a vertical extension from the T controlled by the valve 130. The Christmas tree equipment is connected together by bolt and flange connections of like size for a reason previously explained. These connections are such that the parts of the Christmas tree may be removed for repair or replacement without danger of leakage. That is, with this type of connection, any valve or fitting of the Christmas tree may be removed and repaired, and then again replaced, or the valve or fitting may be removed and a new valve or fitting substituted therefor, without the possibility of the connections being damaged to thus result in leakage.

With the Christmas tree in position, the well is ready for flowing as soon as the spear is removed. A nipple 132 of suitable length is fitted above the valve 130, and a spear removing device such as the wrench 65 carried on a solid rod 136 is lowered through the valve 130 with the valve 122 in closed condition. A stuffing box 138 carried at the upper end of the nipple 132 is then packed around the solid rod 136 to provide a seal. When this is done, valve 122 may be opened, and the rod lowered through the stuffing box while maintaining a seal until the tool 65 engages the threads 60 of the upper slip member 58 of the spear. The tool 65 will release the spear from engagement with the walls of the tubing, after which the spear may be elevated to position above the valve 122, and then the latter is closed. The interior of the fittings from the valve 122 to the stuffing box 138 constitute a conduit to receive the spear, this conduit being of greater length than that of the spear. With the valve 122 closed, the stuffing box 138 may be taken off and the lifting rod 136 together with the spear entirely removed from the well head equipment. The nipple 132 may be removed and replaced with a flow line, or plugged at its upper end with a pressure gauge plug as desired. The well is then in condition for flowing, as shown in Figure 10, with the Christmas tree mounted on the casing head as a foundation. It will be apparent that not at any time during the sequence of operations described, is it necessary to open up the well either through the casing or tubing to flow of dangerous pressures from the well.

The present invention provides a marked flexibility of control, and gives the operator not only a wide choice of operations which can be safely performed, but also a wide choice of the manner in which these operations may be carried out. For instance, when the completion of the well has arrived at the stage where the Christmas tree has been attached to the casing head with the spear still in place in the tubing, if desired, washing of the well may be performed through the Christmas tree. At this stage, the apparatus is in the condition shown in Figure 9, except that the removing rod 136 with its wrench 65 and stuffing box 138 would not be in place. When in this condition, a connection may be

made to the upper end of the Christmas tree from the pumps, and washing fluid could be forced downwardly through the tubing past the spear, and out through the bottom of the tubing, passing upwardly through the casing and discharging from the side outlets in the tubing head 78. Thus, the well could be washed with the Christmas tree in place, rather than washing the same with the control equipment of Figure 1 and before the Christmas tree is attached.

That is to say, some operators may prefer, or it may be necessary, to wash the well both outside the screen or strainer and inside using the control equipment of the type shown in Figure 6. On the other hand, other operators may prefer, or it may be desirable, to only perform inside washing and through the Christmas tree as described above. Obviously, the flexibility of the apparatus of this invention provides a wide choice of operations. If desired, outside washing of the screen or strainer could be performed with the control equipment of Figure 1 in place, leaving inside washing, if found to be necessary, to be done at the more secure time when the Christmas tree is in position on the casing head and the well practically ready to flow.

Not only does the present invention provide for a wide choice of usual as well as unusual operations prior to and during completion, but it also provides for any operations desired to be performed subsequent to completion and at any time during the flow life of the well. After the Christmas tree is attached, and the spear S removed, the equipment is in the condition shown in Figure 10. The well may now be flowed with the equipment in this condition, and it will be observed that the removal of the spear leaves the tubing open for free flow, without any obstructions therein. If during the flow life of the well, or at any time subsequent to completion, it is desirable to open up the well to perform any subsequent operations, the spear S may be reinserted into the tubing and positioned therein by reversing the operations described in connection with Figure 9, after which the Christmas tree may be safely removed with the well under control and the control equipment including the master drilling valve 100 and blow out preventers 102 and 104 may replace the same, in order that additional operations in the well may be carried out. For instance, after the spear is inserted into the tubing and the control equipment is reapplied to the casing head, the tubing may be lifted from the well by reversing the operations described in connection with its insertion for the attachment to the tubing of any type of packer, or the like, for any desired use; for instance, for use to isolate particular sands, as desired.

If some change in the position of the tubing is necessary in order to effect a better oil gas ratio, the tubing may be then raised or lowered, by removing sections therefrom, or attaching sections thereto, without losing control of the well either through casing or tubing, by manipulation of the tubing and control equipment obvious from the description given hereinabove. Such lengthening or shortening of the tubing will, of course, include elevating the hanger 90 through the control equipment as previously described, removing the hanger for changes in length of the tubing, and then reapplying the hanger after the changes in length are effected, and lowering the hanger through the control equipment to its seat in order to continue the flowing of the well.

After these operations subsequent to completion are effected, the Christmas tree may again be stabbed on while maintaining control of the well, in the manner previously described.

It will be apparent that many operations not described may be safely carried out with the apparatus disclosed by following the teachings of this application.

I claim:

1. In apparatus for completing a well in formation having high pressure, a casing, a casing head, flow tubing in said casing, control equipment on said casing head including a blowout preventer providing a seal between said casing and said tubing, said casing head having a side outlet below said control equipment and a valve controlling said outlet, a removable spear in sealing engagement with the inner wall of said tubing in a portion thereof below the casing head, said spear having releasable means for rigidly maintaining it against downward movement in said tubing and against upward movement therein under well pressure, and being unconnected with the surface of the well except through the walls of the tubing, means connected with the upper end of said tubing for forcing washing fluid downwardly therethrough to wash the well, and means included in said spear adapted for passage of said downwardly flowing washing fluid therethrough while preventing upward flow of fluid under well pressure therethrough, the washing fluid discharging through said side outlet from the casing.

2. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a releasable slip on the outer wall of said mandrel for rigidly engaging the inner wall of the tubing to prevent downward movement of the spear therethrough, a second releasable slip on the outer wall of said mandrel for rigidly engaging the inner wall of the tubing to prevent upward movement of the spear therethrough, and a one way valve controlling said passage adapted for flow of fluid downwardly through the tubing and said passage and having means to prevent upward flow of fluid from the well therethrough, said spear having means to cooperate with a removing tool to release said second named slip to permit removal of said spear from the tubing in order to flow the well therethrough

3. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a releasable slip on the outer wall of said mandrel actuated by the weight of said spear for rigidly engaging the inner wall of the tubing to prevent downward movement of the spear therethrough, a second releasable slip on the outer wall of said mandrel actuated by the well pressure in the tubing below the spear for rigidly engaging the inner wall of the tubing to prevent upward movement of the spear therethrough, and a one way valve controlling said passage adapted for flow of fluid downwardly through the tubing and said passage and having means to prevent upward flow of fluid from the well therethrough, said spear having means to cooperate with a removing tool to release said second named slip to permit removal of said spear from the tubing in order to flow the well therethrough.

4. A removable spear for use in washing wells adapted for engaging and sealing with the inner

wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a releasable slip movably mounted on the outer wall of said mandrel, said slip having an active position in rigid engagement with the inner wall of the tubing to prevent downward movement of the spear therethrough, and an inactive position, a second releasable slip on the outer wall of said mandrel for rigidly engaging the inner wall of the tubing to prevent upward movement of the spear therethrough, a one way valve controlling said passage adapted for flow of fluid downwardly through the tubing and said passage and having means to prevent upward flow of fluid from the well therethrough, and means carried by said spear for retaining said first named slip in its inactive position when the spear is being inserted into the tubing, said spear having means to cooperate with a removing tool to release said second named slip to permit removal of said spear from the tubing in order to flow the well therethrough.

5. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a releasable slip on the outer wall of said mandrel for rigidly engaging the inner wall of the tubing to prevent downward movement of the spear therethrough, a second releasable slip movably mounted on the outer wall of said mandrel, having an active position in rigid engagement with the inner wall of the tubing to prevent upward movement of the spear therethrough, and an inactive position, a one way valve controlling said passage adapted for flow of fluid downwardly through the tubing and said passage and having means to prevent upward flow of fluid from the well therethrough, and a spear removing device adapted to engage said second named slip and move it from its active to its inactive position in order to lift the spear from the tubing.

6. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, releasable means on said mandrel for rigidly engaging the plain inner wall of the tubing at any point in the latter to prevent downward movement of the spear therethrough, a second releasable means on said mandrel for rigidly engaging the plain inner wall of the tubing at any point in the latter to prevent upward movement of the spear therethrough, and a one-way valve controlling said passage which opens for flow of fluid downwardly through the tubing and said passage and closes to prevent upward flow of fluid from the well therethrough, said spear having means to cooperate with a removing tool to release said second named means to permit removal of said spear from the tubing in order to flow the well therethrough.

7. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, releasable means on said mandrel for rigidly engaging the plain inner wall of the tubing at any point in the latter to prevent downward movement of the spear therethrough, a second releasable means on said mandrel actuated by the well pressure in the tubing below the spear for rigidly engaging the plain inner wall of the tubing at any point in the latter to prevent upward movement of the spear therethrough, and a one-way valve controlling said passage which opens for flow of fluid downwardly through the tubing and said passage and closes to prevent upward flow of fluid from the well therethrough, said spear having means to cooperate with a removing tool to release said second named means to permit removal of said spear from the tubing in order to flow the well therethrough.

8. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, releasable tubing engaging means mounted for movement on the exterior of said mandrel, said means having an active position wherein it rigidly engages the plain inner wall of the tubing at any point in the latter to prevent downward movement of the spear therethrough, and an inactive position, a second releasable tubing engaging means on the exterior of said mandrel for rigidly engaging the plain inner wall of the tubing at any point in the latter to prevent upward movement of the spear therethrough, a one-way valve controlling said passage which opens for flow of fluid downwardly through the tubing and said passage and closes to prevent upward flow of fluid from the well therethrough, and means carried by said mandrel for retaining said first-named means in its inactive position when the spear is being inserted into the tubing, said spear having means to cooperate with a removing tool to release said second named tubing engaging means to permit removal of said spear from the tubing in order to flow the well therethrough.

9. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, releasable tubing engaging means on said mandrel for rigidly engaging the plain inner wall of the tubing at any point in the latter to prevent downward movement of the spear therethrough, a second releasable tubing engaging means mounted for movement on said mandrel having an active position wherein it rigidly engages the plain inner wall of the tubing at any point in the latter to prevent upward movement of the spear therethrough, and an inactive position, a one-way valve controlling said passage which opens for flow of fluid downwardly through the tubing and said passage and closes to prevent upward flow of fluid from the well therethrough, and a spear removing device adapted to engage said second-named tubing engaging means and move it from its active to its inactive position to permit lifting of the spear from the tubing.

10. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a releasable slip on the outer wall of said mandrel adjacent the lower end of the spear for engaging the inner wall of the tubing to prevent downward movement of the spear therethrough, a second releasable slip movably mounted on the outer wall of the mandrel adjacent to and below the upper end of the spear, having an active position in engagement with the inner wall of the tubing to prevent upward movement therethrough, and an inactive position, a one-way valve controlling said passage which opens for flow of fluid downwardly through the tubing and said passage and closes to prevent upward flow of fluid from the well therethrough, and a spear removing device comprising a hollow body adapted to be moved down-

wardly in encompassing relation over the upper end of said spear to engage said second named slip and move it from its active to its inactive position to permit lifting of the spear from the tubing.

11. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a releasable slip on the outer wall of said mandrel for engaging the inner wall of the tubing to prevent downward movement of the spear therethrough, a second releasable slip on the outer wall of said mandrel for engaging the inner wall of the tubing to prevent upward movement of the spear therethrough, a one-way valve controlling said passage which opens for flow of fluid downwardly through the tubing and said passage and closes to prevent upward flow of fluid from the well therethrough, and a packer mounted on the outer wall of the spear adapted to be expanded by well pressure below the same, said packer forming a seal between the outside of the spear and the inner surface of the tubing, said spear having means to cooperate with a removing tool to release said second named slip to permit removal of said spear from the tubing in order to flow the well therethrough.

12. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a slip on the outer wall of said mandrel for engaging the inner wall of the tubing to prevent downward movement of the spear therethrough, a second slip on the outer wall of said mandrel for engaging the inner wall of the tubing to prevent upward movement of the spear therethrough, a one-way valve controlling said passage adapted for flow of fluid downwardly through the tubing and said passage and having means to prevent upward flow of well fluid therethrough, and an inserting tool secured to said spear having means for maintaining said valve in condition to permit upward flow of well fluid therethrough when the spear is being inserted down into the tubing.

13. A removable spear for use in washing wells adapted for engaging and sealing with the inner wall of a tubing or the like comprising a mandrel having a longitudinal passage therethrough, a slip on the outer wall of said mandrel adjacent the lower end thereof for engaging the inner wall of the tubing to prevent downward movement of the spear therethrough, a second slip on the outer wall of said mandrel adjacent the upper end thereof for engaging the inner wall of the tubing to prevent upward movement of the spear therethrough, a one-way valve at the lower end of said spear for controlling said passage and adapted for flow of fluid downwardly through the tubing and said passage and having means to prevent upward flow of well fluid therethrough, and an inserting tool secured to the upper end of said mandrel having a rod extending through said passage to maintain said valve in condition to permit upward flow of well fluid therethrough when the spear is being inserted down into the tubing.

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