United States Patent

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[54] **APPARATUS AND METHOD FOR GRAVEL PACKING WELLS**
11 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **166/278,** 166/51
[51] **Int. Cl.** **E21b 43/04**
[50] **Field of Search** 166/278, 276, 208, 51, 158, 114, 227, 228

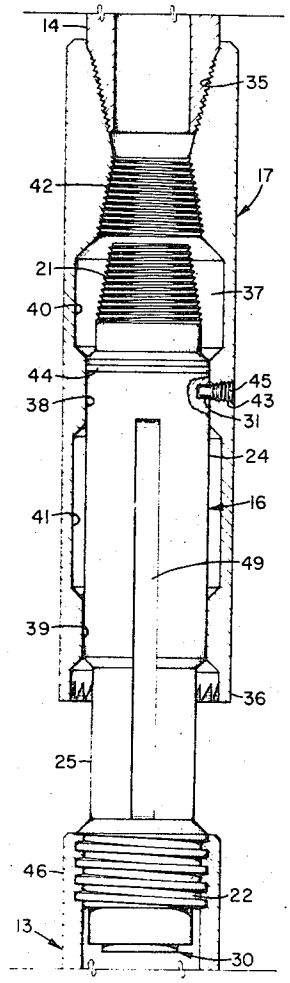
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ABSTRACT: A method and apparatus for placing and gravel packing a production liner in a well. The apparatus includes two interconnected parts: a plug member adapted to be retrievably connected to the liner and a retrieving member adapted to be connected to a tubing string. With the liner properly positioned in the well the two members are separated, the retrieving member remaining attached to the tubing string and the plug member providing a top closure for the liner. An aggregate suspended in a carrier fluid is pumped through the tubing and retrieving member assembly and pressure packed about the liner. Following the placement of the aggregate, the plug member and retrieving member are again joined permitting the plug member to be retrieved on the tubing string.



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SHEET 1 OF 2

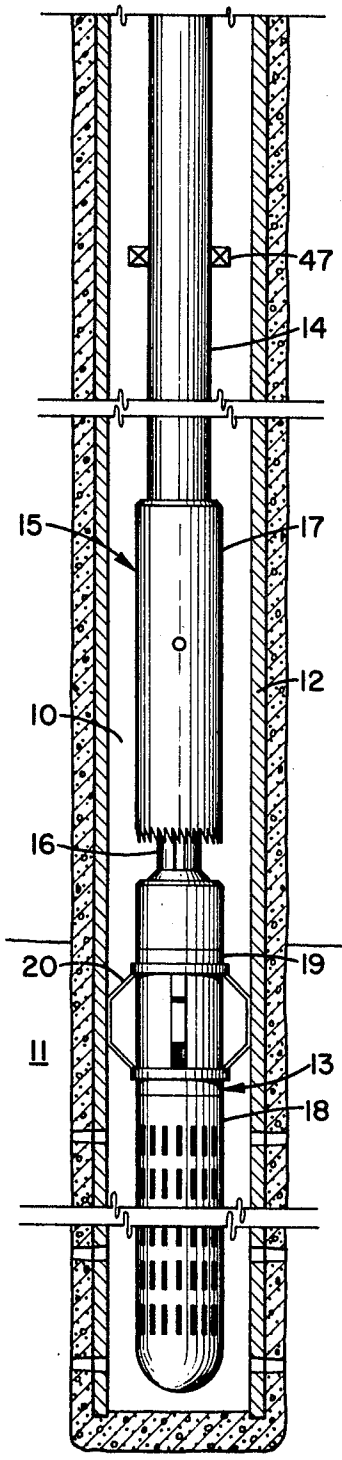


FIG. 1

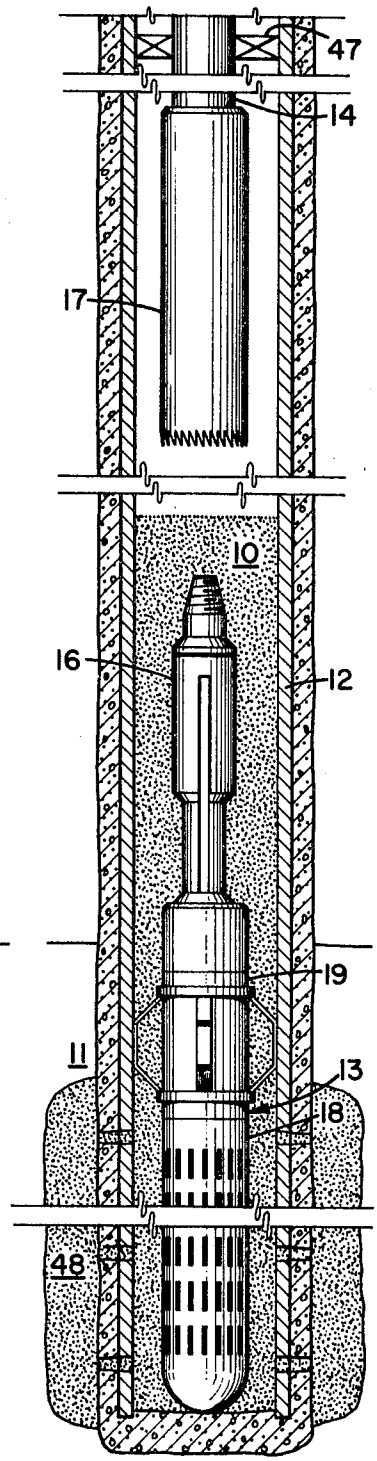


FIG. 2

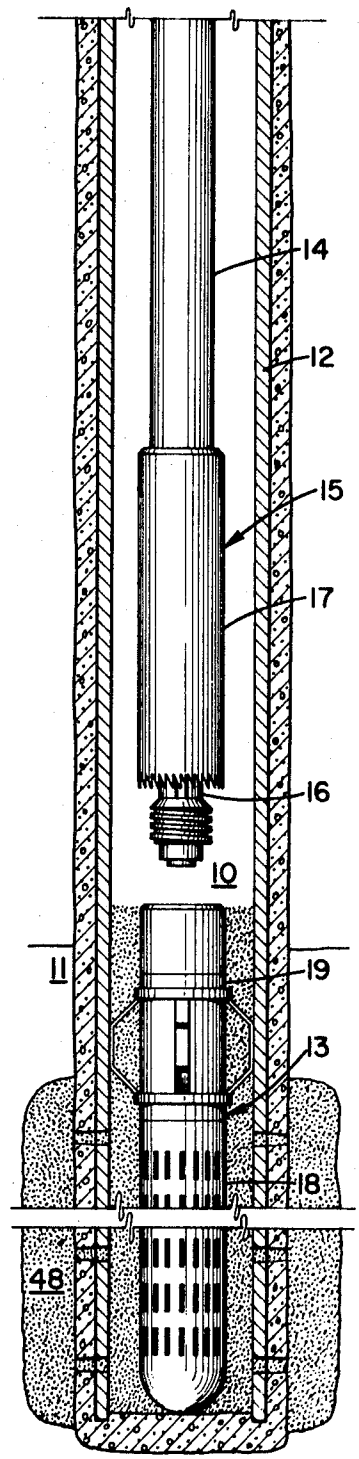


FIG. 3

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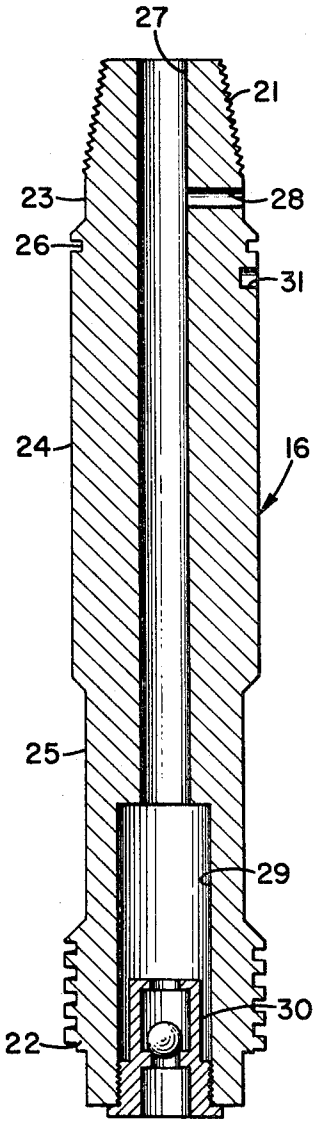


FIG. 4

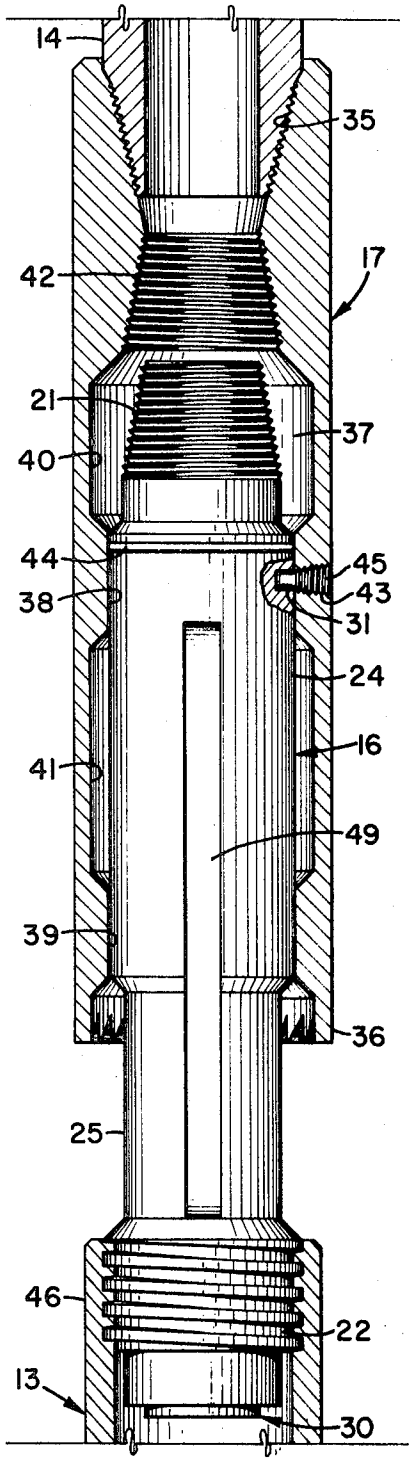


FIG. 5

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APPARATUS AND METHOD FOR GRAVEL PACKING WELLS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for gravel packing wells. In one aspect it relates to the pressure packing of an aggregate around a production liner located in a wellbore.

2. Description of the Prior Art

In completing wells in unconsolidated or poorly consolidated formations, the problem of sand control must be considered. The erosion and plugging effects of formation sand entrained in produced fluids are well known and if not arrested can result in a nonproductive well. A widely used sand control technique is the gravel pack installation, which operates on the principle of forming a sand exclusion zone through which the produced fluids must pass en route to the wellbore. The sand exclusion zone composed of particularly graded aggregate filters or bridges out the formation sand entrained in the produced fluid. The type of aggregate commonly used in gravel pack installations can include such particulate materials as sand, gravel, glass beads, walnut shells, and the like.

The gavel pack installation involves the separate but related operations of placing the aggregate opposite the unconsolidated formation and the location of a liner or screen to maintain the aggregate in place. The installation can be performed by first locating the liner at the proper setting depth and then depositing the aggregate about the liner by circulation techniques. However, the preferred placement method has bee a two-stage operation involving first pressure packing the aggregate into the formation leaving an excess aggregate in the wellbore and then washing the liner into place. The two-stage technique ensures that aggregate is tightly packed against the formation and that a sand exclusion zone of some radial extent is obtained. In perforated completions, e.g. cased wellbore provided with perforations in the productive interval, the pressure packing step is particularly important because of the difficulty in placing the aggregate outside the casing. The two-stage gravel pack installation, however, is attended with risks and disadvantages which are well recognized. It requires two trips to perform and is therefore time consuming and expensive. Washing the liner into place involves a certain amount of risk because of the possibility of sticking the pipe before the liner reaches the proper setting depth. Moreover, there is no positive control to ensure that the aggregate is properly placed about the liner at the conclusion of the installation.

SUMMARY OF THE INVENTION

The apparatus and method of the present invention permits setting the liner and the pressure packing of the aggregate in a single operation thereby avoiding many of the problems associated with the two-stage technique referred to above.

An assembly referred to herein as a liner setting tool permits the liner to be lowered into the wellbore on the tubing. The liner setting tool comprises two main parts: a retrieving member adapted to be connected to the tubing and a plug member adapted to be retrievably connected to the top of the liner. The two members are joined together by a frangible connector such that they can be separated by the application of a shear force. With the liner properly located in the wellbore, the frangible connector can be ruptured permitting the movement of the tubing independent of the liner. The tubing then can be raised to an elevation substantially above the liner for the aggregate placement step of the operation. The aggregate suspended in a carrier fluid is pumped through the tubing at such rates and pressures to form a tightly packed sand exclusion zone which completely surrounds the liner and extends outwardly from the wellbore. The plug member closes the top of the liner preventing the aggregate from entering the interior thereof. Following the placement of the aggregate, the plug member can be retrieved on the tubing, completing the gravel pack installations. Optionally, an anchor packer can be run and located to pressure seal the annulus between the liner and the casing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1, 2, and 3 are longitudinal sectional views showing the sequence of the gravel pack installation preformed according to the present invention.

FIG. 4 is a longitudinal sectional view of the plug member.

FIG. 5 is a view shown partly in section illustrating the assemblage of the plug member and the retrieving member.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be described in connection with the gravel packing of a cased wellbore **10** as illustrated in FIG. **1**. The wellbore **10** has been drilled into an unconsolidated formation **11** by conventional techniques. A casing **12** has been set and cemented in place and the pay interval perforated. It should be observed, however, that the present invention can also be applied in open hole gravel packs.

In performing the gravel pack according to the present invention, a production liner **13** is lowered down the wellbore **10** on the tubing **14**, a liner setting tool **15** providing the connection between the liner **13** and the tubing **14**.

The production liner **13** as defined herein embraces the variety of devices commonly used in gravel pack installations such as perforated or slotted liners, and screens. As shown in FIG. **1**, the liner **13** includes a lower perforated section **18** and an upper blank section **19**. Centralizers, one shown as **20**, attached to the outer periphery of the liner **13** maintain the liner concentrically in the casing **12**.

The setting tool **15** constructed according to the present invention comprises an inner plug member **16** adapted to be connected to the liner **13**, and an outer retrieving member **17** adapted to be connected to the tubing **14**. The two members **16** and **17** are maintained in assembled relation during running-in operations by a first connection means which in one preferred form is provided by a frangible connector described below. Release of the fist connection means separates the plug member **16** and the retrieving member **17**, the latter remaining attached to the tubing **14**, and the former providing a top closure for the liner **13**.

With the liner **13** located the bottom of the wellbore **10**, the retrieving member **16** is separated from the plug member **17** permitting the independent movement of the tubing **14**. The tubing **14** is raised several feet above the liner **13** provided with the top closure plug member **17** and positioned for commencing the aggregate placement operations. After the aggregate has been pressure packed outside the casing **12** and around the liner **13**, the tubing **14** is lowered to retrieve the plug member **16** by operations of the retrieving member **17**.

As mentioned above, the plug member **16** is adapted to be retrievably attached to the top of the liner **13** and serves as a top closure means for the liner **13** during aggregate placement step. As shown in FIG. **4**, the plug member **16** is of unitary construction having an upper threaded pin **21**, a lower upset end **22**, and three intermediate cylindrical sections **23**, **24**, and **25**. The middle section **24** is slightly upset from the flanking sections **23** and **25** and is provided with an O-ring groove **26** in its upper end. The threads formed in the pin **21** are right-hand threads and can conform to API standards. The lower upset end **22** is provided with external left-hand threads which can also conform to API standards or can be Acme threads as illustrated. An axial bore **27** of relatively small diameter extends through the entire length of the plug member **16**, terminating at the lower end in counterbore **29**. The counterbore **29** is internally threaded for receiving a ball valve **30**. A port **28** extending radially through section **23** junctions with the axial bore **27**.

Formed in the cylindrical section 24 and immediately below the O-ring groove 26 are a plurality of circumferentially spaced recesses, one shown as 31. These recesses, as will be described later, receive shear bolts which maintain the plug member 16 and the retrieving member 17 in assembled relation. In this embodiment three recesses 31, spaced 120° apart, are provided. As shown in FIG. 5 the outer retrievable member 17 is constructed in the form of a unitary sleeve having an upper, internally threaded end 35 and a lower, serrated end 36. The upper end 35 is adapted to be threadedly connected to the tubing 14 by conventional right-hand threads as shown. An axial opening 37 extends through the member 17 and is defined, in part, by internally upset sections 38 and 39 and full-opening sections 40 and 41. The upset sections 38 and 39 are sized to receive the cylindrical section 24 of the inner plug member 16 in close conformity. A plurality of threaded apertures, one shown as 43, extend radially through the wall of section 38. The number and spacing of the apertures 43 correspond to the number and spacing of recesses 31 so that when the plug member 16 is inserted into the retrieving member 17 the recesses 31 register with the apertures 43.

Above the full-opening section 37 is an internally threaded section 42 for mating with the threaded pin 21 of the inner plug member 16. Although not apparent from the drawings the outer periphery of the member 17 in generally flush with the outer periphery of the tubing couplings (not shown). The axial opening 37 can have a flow area about equal to or greater than that of tubing 14. This large flow area presents very little resistance to flow of fluids.

The large flow area provided by the member 17 is particularly important in applications where the placement of the aggregate is performed at pressures and rates approaching those used in fracturing operations.

In preparing the assembly for running the liner 13, the plug member 16 provided with an O-ring 44 is inserted through the lower serrated end 36 of the outer retrieving member 17. With the recesses 31 of the plug member 16 aligned with the apertures 43 of the retrieving member 17, threaded shear bolts 45 are screwed into the apertures 43. The shear bolt connection provides a first means for interconnecting the members 16 and 17 and maintains them in assembled relation for lowering the liner 13 down the wellbore 10. In the assembled condition, the O-ring 44 sealingly engages the internally upset section 38, and the pin 21 of the plug member 16 is disposed in the full opening section 40 in axial alignment but spaced from the threaded section 42 of the retrieving member 17, A lower portion of the plug member 16 projects below the serrated end 36 of the retrieving member 17 permitting the left-hand threaded end 22 to be connected to the liner 13. A thread crossover sub 46 defining the upper extremity of the liner 13 provides the internal left-hand threads for mating with the external threads of the plug member 16. The upper threaded end 35 of the retrieving member 17 is connected to the tubing 14 preparatory to lowering the assembly into the wellbore 10.

Thus the assembly comprising the liner 13 and the plug member 16 is suspended on the assembly comprising the tubing 14 and the retrieving member 17 by means of the shear bolts 45. As the entire assembly is lowered down the wellbore, completion fluid flows upwardly through the ball valve 30 and bore 27 filling the tubing 14. The assembly is lowered through the wellbore 10 until the lower end of the liner 13 touches the bottom of the wellbore 10 and then is raised a short distance, e.g. about 1 foot (see FIG. 1).

The liner 13 is then separated from the tubing 14 by shearing the bolts 45. The shear stress can be applied by permitting the bolts 45 to support the weight of the tubing 14 until failure occurs. Preferably, however, the bolts 45 are sheared by pressuring up the tubing 14. The pressure seal provided by the ball valve 30 and the O-ring 44 prevents the passage of fluid downwardly through the opening 37. When the force acting on the upwardly exposed surfaces of the plug member 16 exceeds the shear strength of the bolts 45, the plug member 16 breaks free of the outer retrieving member 17 permitting the liner 13 with the plug member 16 connected thereto to settle on bottom of the wellbore 10. The tubing 14 with the retrieving member 17 connected thereto is raised several feet above the top of the liner 13 and positioned for beginning the aggregate placement step of the operation.

In some applications it may be necessary to use a retrievable packer 47 to pressure seal the casing-tubing annulus. The packer 47 located a short distance above the retrieving member 17 is seated by rotation of the tubing 14. With the packer 47 set, the aggregate suspended in a carrier fluid such as lease oil is pumped down the tubing 14, squeezed through the casing perforations, and pressure packed against the formation 11. The pressure and rate of injection is sufficient to deform the formation 11 providing a pressure packed zone 48 diagrammatically illustrated in FIGS. 2 and 3. The aggregate particles are particularly sized to prevent migration of formation sands.

At the conclusion of the placement step, the aggregate is tightly packed outside the casing 12 and in the liner-casing annulus. It should be noted that the liner perforations are sufficiently small to screen out the aggregate. The plug member 16 prevents the aggregate from entering the top of the liner 13. Near the end of the placement step, the injection rates and pressures are reduced or aggregate concentration increased to effect "sand-out"; that is, when the formation 12 is incapable of receiving the aggregate-fluid slurry at the injection conditions. When surface pressure indicates that sand-out has been achieved, the slurry remaining in the tubing 14 can be pumped to the surface by reverse circulation through a bypass valve provided in the packer 47.

The packer 47 is not released until the pressure therebelow has bled into the formation causing the aggregate to settle around the liner 13. The packer 47 is then unseated and the tubing 14 lowered to tag the top of the excess aggregate deposited in the casing 12. If the top of the packed interval in the casing 12 is found to be near the plug member 16, additional aggregate can be spotted to ensure that the liner 13 is completely encased in the aggregate. This is particularly important because the aggregate opposite the blank section 19 of the liner 13 provides a pressure seal at the upper end of the liner-casing annulus and prevents produced fluids from bypassing the liner 13.

The retrieving member 17 is then washed down through the excess aggregate and over the plug member 16. The serrations in the end 36 aid in the washdown action. The outer periphery of the plug member 16 can be provided with longitudinal circulation slots, one shown as 49 in FIG. 5, to permit the fluid to circulate down the tubing 14 and around the plug member 16. The retrieving member 17 is washed down until the threaded section 42 engages the threaded pin 21 of the plug member 16. The tubing 14 is then rotated clockwise mating the sections 21 and 42. It should be noted that this connection provides the second means for interconnecting the members 16 and 17. With the plug member !6 connected to the retrieving member 17, circulation is maintained through the bore 27, port 28, and slots 49. Continued clockwise rotation of the tubing 14 backs off the left-hand threads of plug member end 22 from the liner 13 permitting the plug member 16 to be retrieved on the tubing 14 as shown in FIG. 3.

A particular advantageous feature of this operation is that it ensures that the aggregate is tightly packed around the blank section 19 of the liner 13 thereby providing a fluid seal in the upper portion of the liner-casing annulus. To further aid in this seal, a jam-on packer (not shown) can be run and set on the upper end of the liner 13.

In summary, the method and apparatus according to the present invention offers several advantages over the conventional methods and tools. Foremost, it permits the setting of the liner 13 and placement of the aggregate in a single operation. Moreover, it permits independent manipulation of the tubing 14 which is important when using a packer during the placement operations. The large flow area through the retrieving member 17 permits the injection of the gravel with very lit-

tle pressure loss. And finally, it provides a positive control for ensuring that the reserve aggregate substantially covers the blank section **19** of the liner **13**.

I claim:

1. A method of gravel packing a liner in a wellbore comprising the steps of: (a) lowering and locating a liner assembly in the wellbore on a tubing string, said liner assembly comprising a production liner and a closure plug retrievably mounted in the upper end of said production liner; (b) separating said tubing string and said liner assembly; (c) flowing an aggregate material through said tubing string at a pressure sufficient to pack the aggregate material about the outer periphery of said production liner, said closure plug preventing the aggregate material from entering the interior of said production liner; and (d) retrieving said closure plug.

2. The method as recited in claim **1** wherein the step of flowing an aggregate material through the tubing string is performed with the lower end of the tubing string located above the liner assembly and the volume of aggregate material is sufficient to provide a packed zone in the wellbore which substantially covers the liner assembly.

3. The method as recited in claim **2** wherein the step of flowing the aggregate material through the tubing string is followed by the step of lowering the tubing string while circulating fluid therethrough to remove aggregate material disposed above said production liner from the wellbore.

4. The method as recited in claim **1** wherein said closure plug is retrieved on said tubing string.

5. A liner setting apparatus comprising: a plug member adapted to be retrievably connected to the upper end of a production liner and serving to prevent the entry of fluid therein when connected thereto; a retrieving member adapted to be connected to the lower end of a tubing string; first connection means for joining said plug member and said retrieving member, said first connection means being releasable to permit separation of said retrieving member and said plug member; a second connection means for joining said retrieving member to said plug member after said first connection means has been released and being operative to retrieve said plug member from said liner.

6. The invention as recited in claim **5** wherein said first connection means includes frangible means which is rupturable by the application of a shear force in a direction tending to separate the plug member and the retrieving member.

7. The invention as recited in claim **6** wherein said retrieving member has formed therethrough an axial opening, said opening being in fluid communication with the interior of said tubing with said retrieving member connected to said tubing, said plug member being sized to be received in said opening and including means for pressure sealing said opening when joined to said retrieving member by said frangible means so that fluid pressure in said tubing applies a shear force on said plug member for rupturing said frangible means.

8. The invention as recited in claim **7** wherein said opening provides a flow area at least equal to the flow area of said tubing.

9. The invention as recited in claim **6** wherein said plug member is adapted to be connected to said liner by a left-hand threaded connection, and said second connection means includes a right-hand threaded connection between said plug member and said retrieving member.

10. The invention as recited in claim **9** wherein said retrieving member is in the form of a hollow sleeve and adapted to slidingly receive portions of said plug member, said member having a flow passage extending axially therethrough and a one-way valve mounted in said flow passage to permit only upward flow of fluid through said passage.

11. A liner setting apparatus comprising: an outer retrieving member adapted to be connected to the lower end of a tubing string and having an axial opening formed therein; an inner plug member adapted to be mounted on the upper end of a production liner, said inner plug member being detachable from said liner; frangible means interconnecting said outer member and said inner plug member and being rupturable by the application of pressure internally of said tubing string to permit separation of said members; said plug member and said retrieving member having mating portions for rejoining said members after said frangible means has been ruptured to permit detachment of said plug member from said liner by manipulation of said tubing.