ABSTRACT OF THE DISCLOSURE

A well completion method which uses a completion assembly arranged on the lower end of a tubing string including spaced-apart swab cups adapted to engage the wall of a casing pipe through which the tubing string is lowered and having a screen therebetween. A plug is set in the casing pipe below a formation it is desired to produce. The casing pipe is filled with a liquid. The completion assembly is run in the casing pipe on the tubing string until the completion assembly is adjacent and above the producing formation. A perforator gun assembly is lowered through the tubing string and completion assembly to the level of the formation, the perforator gun assembly is perforated, and the perforator gun assembly is removed from the tubing string. The tubing string and attached completion assembly is then lowered to the casing plug, in which position the swab cups straddle the perforations in the formation. Sand control material preferably surrounds the screen, and after the completion assembly has been positioned adjacent the formation, the liquid is pumped through the completion assembly to wash such material into the perforations formed in the formation. The well is then produced through the completion assembly.

BACKGROUND OF THE INVENTION

The present invention concerns well completion operations, and in particular, method and apparatus for controlling sand production during the production of hydrocarbons (gas and oil) through wells penetrating subsurface hydrocarbon-containing formations.

Sand control during the production of hydrocarbons is a common problem in many shallow hydrocarbon-producing areas. Prevention of formation damage is also a problem in many of the wells which have sand control problems. The theory that sand production can cause formation damage by "particle tilting" has recently been postulated. Other common types of formation damage which are caused by formation invasion of foreign fluids include clay swelling, water blocking, and emulsion plugging. The well completion method and apparatus according to the present invention prevents formation damage which may be caused by either sand production or foreign fluids.

SUMMARY OF THE INVENTION

Briefly, the invention provides a solution to the problem of sand control by simultaneously (1) controlling sand production by gravel-packing the new producing zone or interval immediately after perforating, and (2) preventing damaging fluids from entering the formation. The latter is achieved by the commonly used method of perforating with differential pressure into the well bore provided the formation pressure is high enough, or by using a formation-compatible oil if the formation pressure is lower than the hydrostatic head of the oil in the well bore.

In more particularity, the well completion method of the invention employs a completion assembly arranged on the lower end of a tubing string including spaced-apart swab cups adapted to engage the wall of a casing pipe through which the tubing string is lowered and having a screen therebetween, and comprises the steps of setting a plug in the casing pipe below a formation it is desired to produce; filling the casing pipe with a liquid (oil or water); running the tubing string and attached completion assembly in the casing pipe to a level above the formation; lowering a perforator gun assembly through the tubing string and completion assembly to the level of the formation; perforating the formation, and then removing the perforator gun assembly from the tubing string; lowering the tubing string and attached completion assembly to the casing plug, in which position the swab cups straddle the perforations in the formation. Preferably, a sand control material initially surrounds the screen and liquid is pumped through the completion assembly to wash the sand control material into the perforations in the formation. The well is then produced.

The completion assembly apparatus preferably includes a sawtoothed nipple positioned adjacent the lowermost swab cup when the completion assembly is arranged in the casing pipe. In addition, a perforated nipple and a releasing collar are connected in the tubing string.

BRIEF DESCRIPTION OF THE DRAWING

FIGS. 1 to 3 are vertical, partly sectional views showing the completion assembly of the invention in various positions for carrying out the steps of the completion method.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, in FIGS. 1 to 3 is shown a well casing string 10 penetrating a subsurface formation 11. A wireline set bridge plug 12 is positioned in casing 10 below formation 11. A production tubing string 13, suspended from the earth's surface within casing string 10, is coupled at its lower end to a completion assembly 14. Tubing string 13 is preferably provided with a perforated nipple 15, releasing collar 16, a pump seating nipple (or gas-lift mandrel) 17, and a joint of tubing 18 arranged between nipple or mandrel 17 and releasing collar 16.

Completion assembly 14 is composed of a tubular screen or perforated liner 20 positioned between upper and lower swab cups 21 and 22, respectively, and a sawtoothed bottom joint 23. A shear release safety joint 24 may be located above lower swab cup 22 and below screen 20, if desired. Sand control material (gravel, glass beads, walnut hulls, aluminum pellets, etc.) 25 is retained in the annulus between screen 20 and the wall of casing 10 by swab cups 21 and 22 when the completion assembly is run in casing 10, as shown.

A through-tubing perforating gun 35, suspended on a cable 36, is shown in FIG. 2 positioned adjacent formation 11. Perforations or holes 37 have been formed in formation 11 by perforator gun 35.

As seen in FIG. 3, perforations 37 contain sand control material 25.

The purpose of tubing string 13 is to produce oil and/or gas fluids from producing formation 11. Artificial lift equipment may be used on the pump seating nipple (or gas-lift mandrel) 17, depending upon eventual needs. The joint of tubing 18 allows room for a rod pump housing (not shown). Releasing collar 16 permits disconnecting tubing string 13 below pump seating nipple 17 from completion assembly 14 in order to circumvent gas locking if a rod pump is run. Perforated nipple 15 allows fluid to bypass swab cups 21 and 22 while completion assembly 14 is lowered into position in casing string 10. The upper and lower double swab cups 21 and 22 provide (1) a reservoir for the sand control
3 gravel 25, and (2) a seal to force fluids produced from formation 11 to flow through gravel 25 and screen 20. Screen 20 retains the sand control gravel 25 but allows formation fluids from formation 11 to flow sand-free into the casing 10 above. The shear release safety joint 24 simplifies fishing operations if it becomes necessary to pull the completion assembly for any reason. The sawtoothed bottom joint 23 is used to space screen 20 across perforations 37 when resting on the bottom bridge or cement plug 12. The sawtoothed bottom joint, when set on plug 12, provides resistance to rotation if tubing 13 is disconnected at the releasing collar 14.

In operation, referring first to FIG. 1, bridge plug 12 (or cement plug) is set in casing string 10 to isolate the existing production formation 11. Then, approximately 1000 feet of diesel oil containing a surfactant is spotted in the bottom portion of casing 10, and the remainder of casing 10 is filled with untreated diesel oil. The diesel-surfactant mixture is spotted in the bottom of the hole by circulating the mixture through a tubing work string run in the well after setting bridge plug 12 and removed after spotting the mixture. Instead of filling the well 10 with treated or untreated diesel oil, it may be filled with salt water if the pressure of formation 11 is known to be high enough to provide pressure into the well bore after perforating. Completion assembly 14 is thereafter run in casing 10 on tubing 13 to approximately 100 feet above formation 11, as illustrated in FIG. 1. Through-tubing perforator gun 35 is then lowered through tubing 13 on conductor cable 36 to adjacent production formation 11 and fired to form perforations 37 in formation 11, as shown in FIG. 2. Remains of perforator gun 35 and cable 36 are now removed from the well bore.

At this stage in the method, the operator has two options, depending upon whether there is vacuum or zero pressure at the earth's surface or pressure at the earth's surface. When there is vacuum or zero pressure, completion assembly 14 is immediately lowered until sawtoothed bottom joint 23 rests upon bridge plug 12 (see FIG. 3). However, when there is pressure, after retrieving the remains of the perforator gun, a wireline set plug (not shown) is installed in tubing 13 approximately 200 feet below the earth's surface and completion assembly 14 is lowered to rest upon bridge plug 12 by lowering tubing 13 through a tubing stripper (not shown) at the earth's surface.

Once completion assembly 14 is lowered to bottom, two to five barrels of the completion fluid (surfactant-diesel mixture) are pumped into formation 11 through tubing 13 to wash gravel 25 into perforated holes 37, as illustrated in FIG. 3. It is only necessary to fill these perforations with gravel. Fracture pressures are avoided. The surfactant-diesel fluid provides water wetness to the gravel and stimulates formation 11, which may have been damaged from cement or mud filtrate.

If there is pressure at the surface after perforating, a Christmas tree is installed, the wireline plug installed in tubing 13 is pulled, and the well is flowed through a choke. However, if there is vacuum at the surface at perforating, tubing 13 is released from completion assembly 14 at releasing collar 16, tubing 13 is raised a joint, subsurface pump and rods (not shown) are run, and the well is produced.

The results of field applications of this well completion method were as follows:

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Zone</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>A........</td>
<td></td>
<td>1 Well flowed I M C., sand-free gas before well was recompleted uphole for oil (Zone 2).</td>
</tr>
<tr>
<td>A........</td>
<td></td>
<td>2 Low pressure gas well was completed uphole for oil (Zone 8).</td>
</tr>
<tr>
<td>A........</td>
<td></td>
<td>3 Well pumped 100% salt water; to be completed uphole for oil.</td>
</tr>
</tbody>
</table>

The advantages of this completion method are: it provides immediate sand control after perforating regard-

less of vacuum or pressure conditions at the earth's surface; it prevents formation damage resulting from clay swelling, emulsion plugging, water blocking, or "particle tilting"; and it is economical, the components are inexpensive, and rig time is less than with conventional gravel packing or stimulating methods.

Various modifications and changes may be made in the preferred embodiments within the scope of the appended claims without departing from the spirit of this invention. For example, where unconsolidated sand grains are relatively large, the gravel may be omitted and the screen alone used for sand control. In such case, the annulus volume should be minimized by using the largest diameter screen that is practical and by keeping the upper and lower swab cup assemblies as close together as practical. The slot size of the screen is commensurate with sand grain size.

Having fully disclosed the objects, advantages, method, and apparatus of my invention, I claim:

1. A well completion method which uses a completion assembly arranged on the lower end of a tubing string including spaced-apart swab cups adapted to engage the wall of a casing pipe through which said tubing string is lowered and have a screen therebetween comprising the steps of: setting a plug in said casing pipe below a formation it is desired to produce; filling said casing pipe with a liquid; running said tubing string and attached completion assembly in said casing string to a level above said formation; lowering a perforating gun assembly through said tubing string and completion assembly to the level of said formation; perforating said formation with said perforator gun assembly; removing said perforator gun assembly from said tubing string; lowering said tubing string and attached completion assembly to said casing plug, in which position said swab cups straddle said perforations in said formation; and then producing said well.

2. A method as recited in claim 1 including the steps of installing a plug in said tubing string near the surface after removing said perforator gun assembly from said tubing string where, following perforation of said formation, there is pressure at the surface, and installing a Christmas tree, pulling the wireline plug, and producing the well through a choke.

3. A method as recited in claim 1 including the steps of releasing said completion assembly from said tubing string, raising said tubing string a joint, running subsurface pump and rods in said tubing string after removing said perforator gun assembly from said tubing string where there is a vacuum at the surface.

4. A method as recited in claim 1 in which sand control material initially surrounds said screen, and following the step of lowering the completion assembly to adjacent said formation, liquid is pumped through the completion assembly to wash said material into the perforations in said formation.

5. A method as recited in claim 1 including the steps of installing a plug in said tubing string near the surface after removing said perforator gun assembly from said tubing string where, following perforation of said formation, there is pressure at the surface, and installing a Christmas tree, pulling the wireline plug, and producing the well through a choke.

6. A method as recited in claim 4 including the steps of releasing said completion assembly from said tubing string, raising said tubing string a joint, running subsurface pump and rods in said tubing string after removing said perforator gun assembly from said tubing string where there is vacuum at the surface.
7. Apparatus for use in well completion operations comprising:
   a tubular screen;
   spaced-apart swab cups arranged on each side of said screen;
   a sawtoothed nipple positioned adjacent one of said swab cups;
   a perforated nipple positioned adjacent said other swab cup;
   a releasing collar connected to said perforated nipple;
   a tubing string connected to said perforated nipple and lowerable through a casing pipe; and
   sand control material surrounding said screen when said tubing string is being lowered through said casing pipe.

8. Apparatus as recited in claim 7 in which said tubing string is provided with a pump seating nipple arranged above said releasing collar.

9. Apparatus as recited in claim 7 in which said tubing string is provided with gas-lift valves arranged above said releasing collar.

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U.S. Cl. X.R.

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