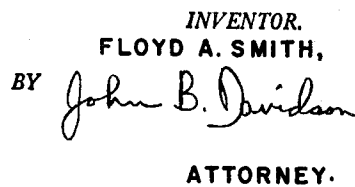


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CEMENTING AND COMPLETING WELLS IN
THE EARTH

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This invention relates to oil well cementing and completing techniques, and more particularly to completion techniques in wells wherein a single pipe string serves both as a casing and as a production conduit for producing a given hydrocarbon productive earth formation.

When it is necessary to complete a well prior to producing earth formation fluids, such as oil and gas, from a given productive earth formation, it is customary to cement a casing string to the walls of the well bore, and then to lower a production tubing string from the earth's surface to the level of the productive formation. Either before or after a production packer has been set to isolate the lower end of the tubing, the casing may be perforated to provide fluid communication between the productive earth formations and the interior of the tubing.

In many locations it has been found feasible to use a single pipe string both as casing and as the production tubing string. One technique that has been found desirable to complete wells where a single pipe string is used both as casing and tubing is to cement the pipe string to the walls of the borehole, to perforate the pipe string to provide fluid communication from the earth formation to the interior of the pipe string, and then to swab the pipe string until the hydrostatic head of fluids in the pipe string at the level of a productive earth formation is less than the pressure of the formation. While this technique has been quite successful and has met with acceptance, often it is either difficult or undesirable to swab the tubing string. Furthermore, the swabbing operation can be quite expensive and time consuming, and it is desirable that it be eliminated.

In accordance with the teachings of the present invention, a pipe string is lowered into a borehole from the earth's surface at least to the level of a productive earth formation that it is desired to produce. Cement is pumped down the pipe string and the fluids in the well are displaced and forced up the annulus around the pipe string. When the desired amount of cement has been injected into the pipe string, a cement wiper plug is pumped down the well by means of a fluid comprising a normally liquid fluid and a normally gasiform fluid. The wiper plug is pumped down the pipe string until it is latched at the bottom of the pipe string. The pressure in the pipe string at the wellhead is reduced to atmospheric until the hydrostatic pressure in the pipe string at the level of the productive earth formation is below the hydrostatic pressure exerted by the fluids in the earth formation. The pipe string then is perforated to bring the pressure in the pipe string into fluid communication with the earth formation.

Objects and features of the invention not apparent from the above discussion will become evident upon consideration of the following description thereof taken in connection with the accompanying drawing, wherein:

FIGS. 1 through 4 each are schematic illustrations of a well installation in accordance with the present invention; the respective figures illustrate various steps involved in the method of the invention.

In the figures there is shown a pipe string 17 suspended from the usual wellhead apparatus 19 and traversing a borehole 27 to a level in the earth below hydrocarbon earth formation 35. The wellhead apparatus may be

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supported by the usual surface conductor 21 which has been cemented to the earth by the cement bond 23 in the usual manner. The wellhead apparatus may include a lubricator 10 having the usual valve mechanism 11. Also included in the wellhead apparatus are valves 7 and 13 which respectively are connected to the lubricator 10 by pipes 9 and 15. The valve 7 is connected to a pipe 1, which in turn is connected to a pump, not shown, from which fluid pressure is supplied. A valve 5 controls the flow of a gasiform fluid through pipe 3 into pipe 1. Plug valve 13 controls the flow of fluids through pipe 15 from pipe string 17 in a manner that will become evident from the following description. Other equally satisfactory wellhead arrangements may be used.

After the pipe string 17 has been suspended in the borehole, cement is pumped through pipes 1 and 9, down the pipe string 17, and up the annulus about pipe string 17. Fluids left in the borehole after completion of drilling operations will be displaced by the cement. As is shown in FIG. 1, the cement slurry 33 is followed by a cement wiper plug 31. The wiper plug may be of a conventional type known to the art customarily used to force cement through a pipe string and wipe the interior surface of the pipe string free of cement. Preferably, the plug provides a positive latch and seal; a suitable assembly is that shown on page 5241 of the Composite Catalog of Oil Field Equipment and Services, 24th Edition (1960). Such plugs are customarily provided with latching dogs or other means for latching the plug in the lower end of the pipe string in a plug stop or other latching section. As shown, the cement wiper plug 31 is provided with a latch for the purpose of latching a plug stop 37 at the bottom of the pipe string 17. The wiper plug 31 is provided with latching dogs 32 for the purpose of latching the plug to the plug stop 37.

The wiper plug 31 is inserted in the pipe string through the lubricator 10 after the desired quantity of cement has been injected into the pipe string 17. The plug 31 is pumped down the pipe string 17 by means of a normally liquid fluid such as by a pump connected to pipe 1. At the same time that the liquid is being pumped into the pipe string 17, valve 5 is opened so that a normally gasiform liquid, such as nitrogen, carbon dioxide, or natural gas, is simultaneously injected into the liquid. The pressure of the gas flowing through pipe 3 and valve 5 is such that the liquid being pumped through pipe 1 will dissolve a predetermined amount with the gas. The amount of gas that will be dissolved in the liquid will vary depending upon the amount of liquid to be removed from the pipe string. Preferably, there also is dissolved in the liquid a foaming agent such as Octalphenol, to which is added ten or more moles of ethylene oxide, and various known quaternary ammonium compounds and amines having high foaming properties. The normally liquid fluid may be fresh or salt water, or oil.

When the wiper plug 31 has latched onto plug stop 37, valves 5 and 7 are closed. Previous to the time that the cement plug is pumped down the pipe string 17, valves 11 and 13 have been closed. Plug valve 13 is opened as is depicted in FIG. 2. Immediately the gasiform fluid dissolved in the liquid in pipe string 17 will attempt to come out of solution. Bubbles will form throughout the liquid column in the pipe string 17. When a foaming agent is incorporated in the liquid, the gas bubbles will agitate the liquid column to produce foam which will rise with the gas bubbles, as shown by arrows 39, to transport liquid in the pipe string 17 up and out of the pipe string and through valve 13 and pipe 15 into a mud pit or other reservoir located in the immediate vicinity of the well bend. While the gas bubbles alone may be effective to lift a desired amount of liquid out of the pipe string, it is apparent that inclusion of a foaming agent in the fluid

column will substantially enhance the efficiency of the action.

After the normally gasiform fluid in the pipe string has come out of solution and has been dissipated out the top of the pipe string through valve 13, valve 13 may be closed. The level of the liquid remaining in the pipe will be as illustrated in FIG. 3. As is illustrated in FIG. 4, a perforating gun 45 or other perforating means may be lowered into the pipe string 17 after the cement slurry 33 has set up and solidified. When the gun 45 is actuated, perforations 47 will be produced to bring the interior of the pipe string into fluid communication with the earth formation 35. In view of the fact that a portion of the liquid in the pipe string has been removed, the well may be brought into immediate production without the necessity of swabbing the pipe string.

In another manner of practicing the invention, the normally liquid fluid may be pumped into the pipe string either along with or followed by a normally gasiform fluid, such as liquefied petroleum gas. When the cement plug has become latched in the plug stop, the valve 13 is opened only enough to allow the liquefied petroleum gas to gasify and to be bled through the valve 13. When equilibrium conditions have been reached in the liquid in the pipe string (i.e., when as much gas as possible has been bled through valve 13), the amount of liquid remaining in the pipe string will be sufficiently reduced to permit perforating the pipe string as described above. The gas bled through valve 13 may be recompressed and stored in its original container.

From the above description, it is manifest that the invention is highly advantageous in that no swabbing is necessary in order to complete a tubingless well installation, and that the well can be brought into production in a minimum amount of time. There is no chance of sticking of swabs or of accidental breaking of wire lines associated with swabbing apparatus such as would seriously delay bringing the well into production in the event of an accident.

The invention is not necessarily to be restricted to the specific structural details or arrangement of parts herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of the invention.

The object and features of the invention, as well as the preferred manner of carrying out the invention, having been completely described above, what is claimed is:

1. A method of completing a well containing a pipe string extending from the earth's surface into a hydrocarbon-containing earth formation and having wiper plug latching means near the lower end thereof, comprising: pumping a cementitious fluid down the pipe string and

up the annulus thereabout with a wiper plug driven by pressurized, normally liquid fluid and pressurized, normally gasiform fluid until the wiper plug is latched in the wiper plug latching means to close the pipe string and prevent cementitious fluid from flowing up the pipe string; releasing the pressure on the normally liquid fluid and normally gasiform fluid in the pipe string; and, when equilibrium conditions obtain in the fluid column, perforating the pipe string at the level of the productive earth formation.

2. A method of completing a well containing a pipe string extending from the earth's surface into a hydrocarbon productive earth formation, and having a wiper plug latching section near the bottom end thereof, comprising: forcing cement down the pipe string and up the annulus thereabout with a wiper plug driven by a pressurized liquid which is saturated or supersaturated with a compressed gasiform fluid, until the wiper plug is latched in the latching section of the pipe string to close the pipe string and prevent cementitious fluid from flowing up the pipe string; suddenly releasing the pressure on the liquids so that the gasiform fluid entrained throughout the liquid column will transport the liquid out of the top of the pipe string while leaving solution so that hydrostatic pressure in the pipe string at the level of said productive earth formation is less than the hydrostatic pressure exerted by fluids in the earth formation; and perforating the pipe string at the level of productive formation.

3. The method of claim 1 wherein the gasiform fluid is nitrogen and the pressurized liquid is water.

4. The method of claim 1 wherein the gasiform fluid is carbon dioxide and the pressurized liquid is water.

5. A method of completing a well containing a pipe string extending from the earth's surface into a hydrocarbon-containing earth formation and having wiper plug latching means near the lower end thereof, comprising: forcing a cementitious fluid down the pipe string and up the annulus thereabout with the wiper plug driven by pressurized, normally liquid fluid and pressurized, normally gasiform fluid until the wiper plug is latched into the wiper plug latching means of the pipe string to close the pipe string and prevent cementitious fluid from flowing up the pipe string; bleeding the normally gasiform fluid out of the pipe string until the liquid level in the pipe string is at a predetermined level; and perforating the pipe string at the level of the productive earth formation.

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