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METHOD OF PREVENTING HYDRATE FORMATION IN PETROLEUM WELL PRODUCTION STRINGS

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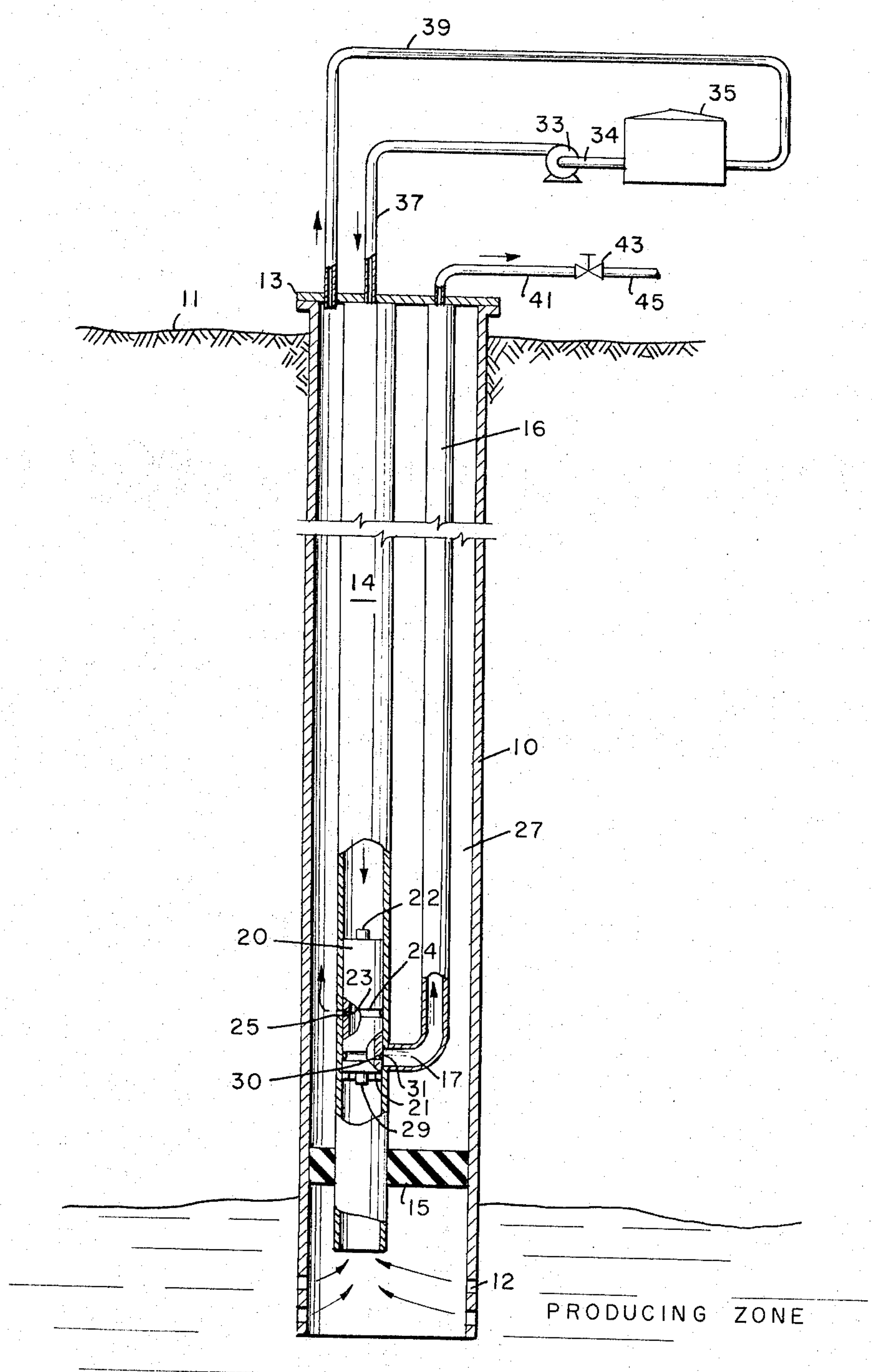

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METHOD OF PREVENTING HYDRATE FORMATION IN PETROLEUM WELL PRODUCTION STRINGS

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ABSTRACT OF THE DISCLOSURE

The formation of hydrates and deposition of solids in a production tubing string carrying petroleum well fluids having a high hydrogen sulfide, dissolved sulfur and water content may be prevented by maintaining the fluid pressure within the production tubing throughout the length thereof above the bubble point of said well fluids.

This invention relates to a sytem for preventing hydrate formation and solid deposition in the production tubing strings of deep wells, such as are used, for example, in the production of underground oil and gas formations, etc. More particularly, this invention is directed to a system for preventing hydrate formation and solid deposition in wells producing fluids having a relatively high hydrogen sulfide content and containing some hydrocarbons and moisture.

It is well recognized by those familiar with oil well production techniques that as the produced fluid flows upwardly through the tubing string certain pressure-temperature conditions may occur such that a phenomenon known as fluid "flashing" results. The phenomenon of fluid flashing is accompanied by a severe temperature drop which causes the sudden formation of hydrates that plug the tubing string to the extent that production is substantially reduced or, in many cases, completely prevented.

In most wells the aforementioned hydrates form only at the lower temperatures reached at the upper end of the tubing string. Consequently, in the past, the prevention of hydrate formation has been controlled by the application of heat to the upper end of the tubing string thereby keeping the temperature above the critical level. However, hydrates occur at much higher temperatures in fluids containing hydrogen sulfide than in the production of "normal" hydrocarbon fluids and, as a result, may plug the tubing string at great depths. For example, hydrates can occur at 120° F. in a fluid containing 80% hydrogen sulfide. Accordingly, prior art methods, such as the application of heat to prevent hydrate plugging, are impractical and ineffective in the production of fluids containing substantial amounts of hydrogen sulfide since there is no effective and economical way to transmit the amount of heat required to the great depths at which such plugging occurs.

Moreover, the production of fluids containing substantial amounts of hydrogen sulfide is additionally complicated by the deposition of solid sulfur throughout the length of the tubing string irrespective of the aforementioned hydrate problems associated with the production of these fluids. As the fluid containing hydrogen sulfide flows upwardly through the tubing string the pressure on the fluid decreases due to the reduction of the static head in the fluid column. It has been found that sulfur solubility decreases markedly with decreases in pressure and temperature and as a result the sulfur deposits in the tubing string as the fluid flows upwardly toward the surface. If not prevented, the sulfur deposits will accumulate and plug the tubing string.

Therefore, it is the primary object of the invention to produce a well in a manner so as to prevent plugging of

the production tubing string by either the formation of hydrates and/or the deposition of solid materials out of the produced fluid.

Broadly, the invention comprises maintaining the tubing string pressure at a value sufficient to prevent hydrate formation and/or solid deposition. Of course, it is to be understood that this maintained pressure value will vary depending upon the composition of the production fluid, etc.

More specifically, the invention comprises producing a fluid having a high hydrogen sulfide content (e.g. 50–100% H_2S or H_2S with dissolved sulfur, the balance being primarily hydrocarbons containing water or water vapor) by maintaining the pressure on the said fluid above the bubble point throughout the well bore to prevent (1) hydrate formation (due to the lower temperature which results from "flashing" etc.) and (2) sulfur deposition resulting from the decreased solubility of sulfur at decreased pressures and temperatures. One particular aspect of the invention comprises the application of an external energy source, such as a bottom hole pump or compressor, to maintain the pressure in the production tubing string at or above a pressure at which hydrates form, and/or solids deposit, as determined from the pressure-volume-temperature evaluations of the produced fluids.

Other objects and advantages of the invention will be understood from the following detailed description taken with reference to the accompanying schematic drawing.

Referring to the drawing, there is shown a well casing **10** extending from a location at the surface of the earth **11** downwardly into a production zone such as an oil-bearing formation. The lower end of casing **10** has a circumferential perforations **12** to allow fliuds from the producing zone to enter the casing **10**. The casing **10** is closed at its upper end by a cover member **13**. A first tubing string **14** extends downwardly from the casing cover member **13** and terminates near the lower end of the casing **10** adjacent the producing zone. A conventional sealing packer **15** is positioned in the lower end of the casing **10** to stabilize the lower end of the tubing string **14** which extends through a perforation formed therein. The sealing packer **15** is preferably positioned at or near the upper strata of the producing zone to prevent fluid communication between fluids being produced from the producing zone and the interior portion of the casing **10** located above the packer **15**. A second tubing string **16** extends downwardly from the casing cover member **13** to a location slightly above the packer **15** where it communicates, through a branched connection **17**, with the interior of the first tubing string **14**.

A fluid operated bottom hole pump **20** is shown as seated on an annular inwardly protruding landing shoulder **21** formed within the tubing string **14**. The outer diameter of the pump **20** is slightly smaller than the inner diameter of the tubing string **14** so that the pump may be readily lowered to the landing shoulder **21** and retrieved therefrom. To insure that the produced fluids from the producing zone do not pass upwardly around the outside of the pump **20** when the latter is seated on the landing shoulder **21** of the tubing string **14**, the pump is preferably provided with O-ring sealing members (not shown) about its circumference on both its upper and lower ends.

A power oil inlet opening **22** is provided on the upper end of the pump **20** and a power oil outlet opening **23** is provided in the side of the pump. The outlet opening **23** communicates with a circumferential groove **24** formed on the outer surface of the pump **20**. The tubing string **14** is provided with a bore **25** which is located a measured distance from the internal landing shoulder **21** so that when the pump **20** is lowered into position on the landing shoulder the outlet groove **24** of the pump and the bore **25** of the tubing string **14** will be laterally adjacent one another thereby allowing spent power oil to escape upwardly through the annular space **27** to the upper end of the casing **10**. The lower end of the bottom hole pump **20** is provided with an inlet opening **29** which allows produced fluids from the producing zone to flow upwardly through the inlet opening **29** and into the lower portion of the pump **20**. An outlet opening **30**, for the escape of produced fluids, is formed in the side of the pump **20** at a location adjacent the branched section **17** which communicates the tubing string **14** with the tubing string **16**. The outlet opening **30** communicates with a circumferential groove **31** formed in the outer surface of the pump **20** to allow the produced fluids to flow out of the pump outlet **30** into the tubing string **16**, regardless of whether or not the outlet **30** is axially aligned with the branched section **17**. The pump **20** is a conventional fluid operated bottom hole pump whose operation will be more fully described infra.

The bottom hole hydraulic pump **20** is supplied with operating energy by means of a variable delivery pump **33** located on the surface **11**. A power oil storage reservoir **35** is preferably provided near the pump **33**, and communicates therewith through a pipe **34**, to insure that the driving pump **33** may supply an adequate and uniform delivery of power driving oil to the bottom-hole pump **20**.

As shown, a reduced diameter tubing **37** extends from the variable delivery driving pump **33** down through the cover member **13** of casing **10** to allow fluid communication between the tubing **37** and the first tubing string **14**. A second reduced diameter tubing **39** extends through the casing cover member **13** to allow fluid communication between the casing annulus **27** and the power oil storage reservoir **35**.

A third tubing **41** penetrates through the casing cover member **13** into communication with the second tubing string **16**. A choke or pressure relief valve **43** is located in the tubing **41** to insure that an adequate surface back pressure (i.e., a back pressure sufficient to prevent hydrate formation and/or solid deposition) will be maintained on the produced fluid flowing upwardly through the second tubing string **16**. A pipe **45** may lead to any desired facility for storing the produced fluids.

In the operation of the system the produced fluid will flow out of the producing zone up through the end of the first tubing string **14** located below the packer **15** and into the lower inlet opening **29** of the bottom-hole pump **20**. The pump **20** is a standard conventional hydraulically operated device which is equipped with a standing valve (not shown) in the lower inlet **29** and a movable piston (not shown) located in its upper end and adapted to move downwardly when power oil is supplied under pressure through the upper inlet opening **22**. As the piston moves downwardly, under the pressure of the power oil, supplied from the driving pump **33**, the standing valve in the lower inlet **29** closes and the produced fluid which has entered the lower end of the pump **20** is forced out of the outlet opening **30** into the second tubing string **16**.

The pump **20** is designed in a conventional manner so that when the said piston reaches the bottom of its stroke the spent power oil flows into the casing annulus **27** via the outlet port **23** and the bore **25** of the pump and first tubing string **14**, respectively, and then back to the storage reservoir **35** via the tubing **39**. The piston then returns to its uppermost position and the standing valve in the lower pump inlet **29** opens to allow more fluid from the producing zone to enter the lower end of the pump **20**. By adjusting the valve **43** an adequate surface back pressure may be maintained on the produced fluid to assure an operating pressure in excess of the bubble point pressure from the bottom-hole pump **20** to the surface.

Preferably, the pressure on the produced fluid in the tubing string **16** is maintained at a minimum of 50–200 p.s.i. above the bubble point so that the fluid will remain a saturated liquid thus preventing the formation of hydrates and/or the deposition of solids within the tubing string **16**. This minimum pressure requirement of 50–200 p.s.i. above the bubble point is generally sufficient to account for the inherent fluctuations which occur in known pumping systems of the type herein disclosed. For example, the pressure is maintained at a minimum of 1500–1700 p.s.i. for a fluid containing 80 percent hydrogen sulfide.

In some instances it has been found that the bottom-hole pressure at the producing zone is sufficiently high to allow production of the fluid without the necessity of supplying an external source of energy. Under these circumstances the bottom-hole pressure is sufficiently high to maintain the pressure of the produced fluids above the bubble point throughout the length of the tubing string.

Therefore, a modified form of the invention comprises extending a single tubing string from the surface down to the producing zone and employing a choke or pressure relief valve, such as shown at **43**, in the single tubing string at the surface. By adjusting the choke valve, the pressure throughout the tubing string may be maintained above the bubble point thereby preventing hydrate formation and solid deposition without the use of a bottom-hole pumping system.

I claim as my invention:

1. In the production of an underground reservoir which produces a fluid containing hydrocarbons, moisture and over 50% hydrogen sulfide, a method of preventing hydrate formation and sulfur deposition within a tubing string extending from the surface down into communication with said reservoir fluid, said method comprising:
   - (a) extending a first tubing string within a well bore from the surface down into communication with said reservoir fluid;
   - (b) emplacing a sealing element circumferentially around the exterior of said first tubing string and into sealing engagement with said well bore at a location near the upper extent of said reservoir;
   - (c) extending a second tubing string within the well bore from the surface down into fluid communication with said first tubing string at a location near the top of said sealing element;
   - (d) positioning a hydraulically actuated bottom-hole pump within said first tubing string at a location such as to cause produced fluids from said reservoir to flow upwardly only through said second tubing string;
   - (e) placing a valve means within said second tubing string at the surface to regulate fluid flow through said second tubing string; and,
   - (f) operating said bottom-hole pump and said valve means to maintain the pressure within said second tubing string above the bubble point of said reservoir fluid.

2. A method as in claim **1** wherein said produced fluid contains 50–100% hydrogen sulfide.

3. A method as in claim **1** wherein said pressure is maintained at least 50–200 p.s.i. above the bubble point of said produced fluids.

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