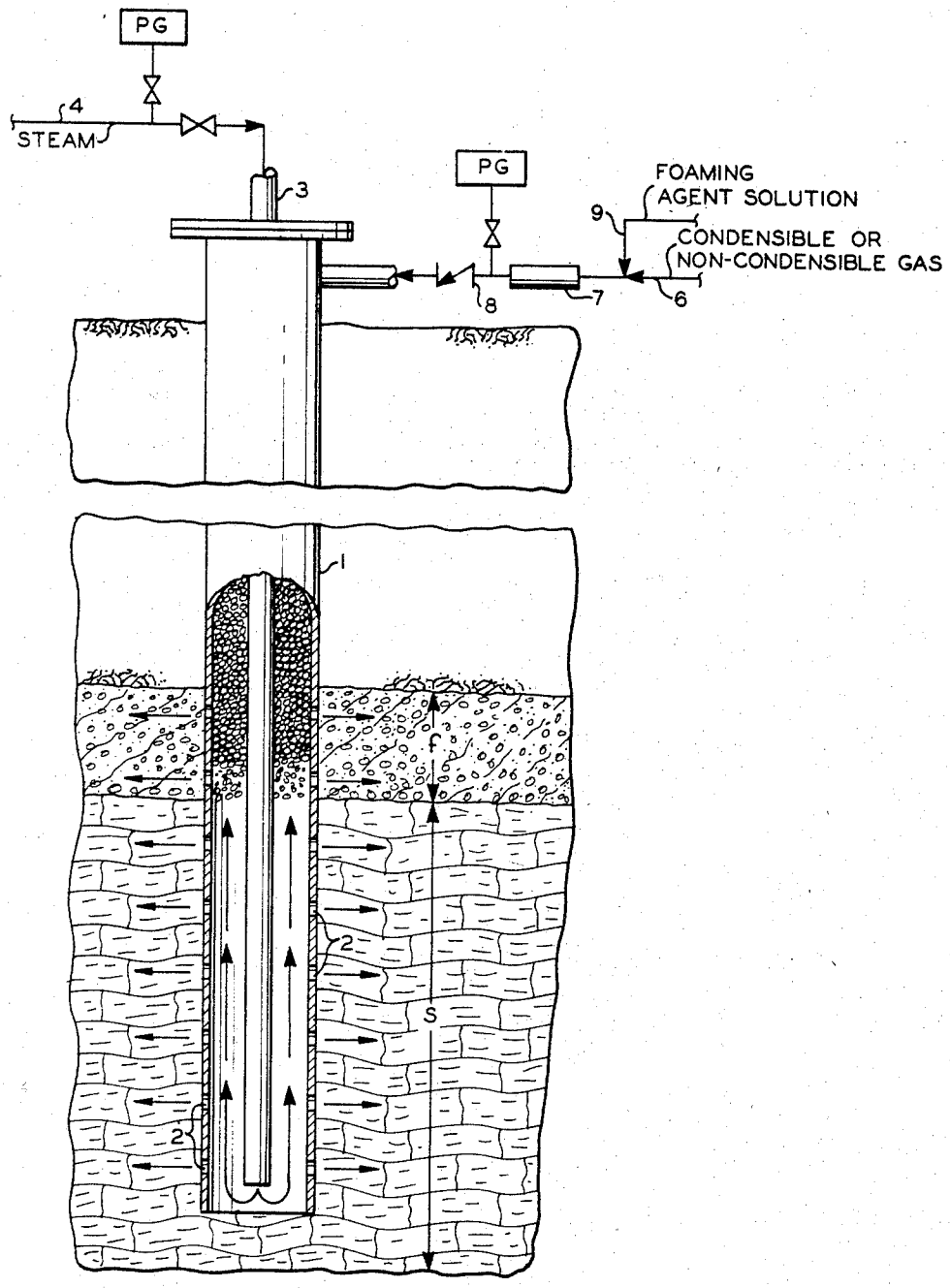
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FLUID INJECTION METHOD

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INVENTOR
A. J. CORNELIUS

BY
Young & Quigg
ATTORNEYS

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FLUID INJECTION METHOD

Archie J. Cornelius, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

The invention contemplates the use of a column of foam pressure balanced against a flowing column of medium, e.g., a hot fluid such as steam or gas, being injected into a formation, such as an oil-bearing stratum, to control the level at which the injected medium is forced into the formation, so that the level at which medium injection occurs can be changed by altering the pressure on the foam column relative to that of the medium being injected. The use of this invention also reduces well bore heat loss as the foam insulates the tubing through which steam can be injected.

Concepts

One of the concepts of the invention involves supplying down a hole or passageway in a formation a column of foam and injecting the medium to be injected down another passageway to a point above or below the foam and maintaining the pressure at the foot of the foam column such that the injected medium must enter the formation at substantially the level of the foam medium interface.

In another of its concepts, the invention provides for varying the level at which the injected medium is forced into the formation by varying the pressure exerted by the foam column at its bottom against the entering injected medium in a manner to move the meeting place or level of the foam column bottom and the injected medium to another desired level.

In a more specific concept of the invention, the injected medium is forced into the formation by way of a tubing within a casing while the annulus between the tubing and the casing is filled with a column of foam, as later more fully described.

The invention is particularly adapted for use in oil production. Accordingly, it will be described in connection with such application. However, one skilled in the art of injecting various media into formations will understand that the invention can be applied to production of other materials from the earth or to treatment of such materials therein.

The beneficial use of steam in the production of certain oil-bearing formations or reservoirs poses certain problems. It is difficult to control sufficiently injection of steam as uniformly as possibly over the producing level as is desired. Further, the minimization of thermal effects on the well casing is highly desirable, since expansion due to heating of the well casing is undesirable, as understood by those in this art. Thus, when the tubing and pump are set above the producing interval, analyses of results of steam injection show the majority of steam entering the top of an approximately 100 ft. thick formation while hot water or steam condensate enters the bottom of the formation. Further, with wells approximately 5000 ft. deep, the casing expansion is in excess of 15 ft.

To minimize thermal effects of the steam on the well casing, best practice has been to use a steam packer to prevent steam from entering the annulus of the well and to inject steam through the tubing string to the bottom of the well, thus assuring better steam distribution over and into the formation.

I have now conceived that the casing-tubing annulus can be pressured with a condensible or non-condensible foam and that, if this is done, the use of a packer can be eliminated. Thus, steam can be injected down the tubing at a pressure slightly higher than the pressure at the foot of the foam column in the annulus, insuring movement of the steam into the bottom portion of the pay or formation. When steam injection has progressed for a sufficiently long period of time so that the major portion of the steam has entered the bottom strata of the pay, the annulus pressure can be reduced so that the steam will displace the foam column upward and can thus enter into a higher stratum. By operating step-wise in the fashion described, steam enters the entire face of the pay zone with minimum amount of by-passing due to buoyancy and/or permeability variation effects.

It is an object of this invention to provide a method for injecting fluid into a formation. It is another object of this invention to provide a method for injecting a fluid, e.g., steam, into a hydrocarbon-bearing formation. It is a further object of this invention to provide a method for injecting a hot medium, such as steam, into a well extending into a hydrocarbon- or petroleum-bearing formation. It is a still further object of this invention to provide a method for injecting a hot medium into an oil well without use of a packer. It is a still further object of this invention to provide a method for injecting a hot fluid into an oil well at various levels which can be controlled by a control of pressure and without the use of a packer.

Other concepts, objects and advantages of the invention are apparent from a study of this disclosure, the drawing and the appended claims.

According to the invention, there is provided a method of injecting a fluid into a formation below the earth's surface which comprises providing a column of foam in a passageway leading to a portion of said formation into which said fluid is to be injected, by way of another passageway injecting said fluid to said portion of said formation below said column of foam, maintaining on said column of foam a pressure sufficient to retain it substantially in place against the pressure of said fliud being injected and injecting said fluid at a pressure sufficient to force the same into said formation below said column of foam.

Further, according to the invention, as it is applied to a well having a piping therein and a casing or an annulus portion, the foam column is provided in one of said piping and annulus and the medium is injected into the formation through the other of said piping and said annulus.

Referring to the drawing, **1** is a casing perforated at points **2** and containing therein tubing **3** to which steam can be admitted at **4**. A condensible or a non-condensible gas is passed into casing **1** by way of pipe **6**, foam generator **7**, which, in this instance, is a porous plug, through check valve **8**. There is admixed with the gas thus passed into casing **1** a foaming agent added to conduit **6** by way of pipe **9**. The gas and foaming agent, on passing through porous plug **7**, generate a foam which passes through check valve **8** into casing **1** and down to a certain level, for example, to near the top of the producing formation, as shown in the drawing, or to the bottom of the well below the end of the tubing. The pressures of the foam and steam are adjusted so that the foam column remains in the casing down to a certain level. Check valve **8** cooperates to accomplish this end. As shown in the drawing, some foam is allowed, in this example, to escape into the upper portion of the producing formation, as indicated at *f*. Steam, which is prevented from rising up through the annulus by the weight of the column of foam and the

pressure thereon, passes through perforations 2 into the producing formation throughout a stratum indicated by *s*. One skilled in the art in possession of this disclosure, having studied the same, will see at once that, by suitably balancing the length of the column of foam and its pressure and the injection pressure of the steam, it is possible to gradually or step-wise inject the steam into various portions of the formation. As shown in the drawing, steam has been injected initially into the lower portions of the formation and the column of foam has gradually been shortened or allowed to shorten so that steam now is being injected over substantially the full height of the producing formation, except for the small portion indicated by *f*.

The amount of foam to be injected will be controlled in the field by balancing the tubing and annulus pressures with appropriate allowance for hydrostatic and friction pressure drops. The volume of foam may be estimated by multiplying the steam injection rate by the ratio of the formation thickness where foam and steam, respectively, are entering, *f/s* in the drawing, and the ratio of the foam's mobility to the steam mobility, i.e.

$$i_f = i_s f/s \frac{M_f}{M_s}$$

where

i_f=foam injection rate, b.p.d.
i_s=steam injection rate, b.p.d.
f=formation thickness foam enters, ft.
s=formation thickness steam enters, ft.
M_s=steam mobility
M_f=foam mobility.

Assuming $f/s=.1$ and $M_f/M_s=1/600$, only 1/6000 as much foam as steam must be injected.

The foaming agent may be selected from a large number of commercially available surfactants, such as Triton X–100 manufactured by Rohm and Haas, Igepal CO–990 manufactured by Antar Chemicals, Arquad C–50 manufactured by Armour Industrial Company or Ethomeen 18/60 stearyl amine. Other surfactants than these examples may be employed.

In general, the foam can be generated by combining 50 to 1500 volumes of condensible or non-condensible gas with one volume of liquid solution which contains 0.01 to 1.5 percent of a suitable foaming agent.

A typical application would involve the injection of 10,000 lbs./hr. of saturated steam into a 100 ft. thick pay formation down a 1500 ft. long tubing string at 1000 p.s.i.a. bottom hole pressure. With $M_f/M_s=1/600$ only about 0.743 ft.^{3} of foam per hour must be injected at the sand face to maintain the foam/steam interface 10 ft. below the top of the pay. At a 1000:1 gas to liquid ratio and a one percent foaming agent concentration in the liquid only 5.56 (10^{-5}) gallons per hour of surfactant is required. The low foam requirements also requires a modest expenditure, such as for several compressed gas cylinders, to furnish the gas for the project. Allowing for thermal expansion of the gas, only 0.4 ft.^{3} of gas at 80° F. and 1000 p.s.i.a. is required to deliver 0.743 ft.^{3} at 545° F. injection temperature.

It will be evident from the foregoing discussion, description of the drawing and the specific example given that the invention is entirely operative without use of packers with which it is not ordinarily feasible to differentiate between producing zones in a real way. Further, minimization of thermal stress in the well casing and tubing are possible and there is also possible control of the injection level of the generated foam enabling differential control of injection of steam, for example starting with the deepest formation, as described. Elimination of the steam packer minimizes expense and also eliminates the problems which occur when the packers are stuck in a well.

As noted, the foam can be a mixture of any suitable foaming agent and a condensible or a non-condensible gas. The process can take advantage of the high apparent viscosity of a foam and this eliminates the need to inject excessive amounts of foam into the upper pay zones during the operation.

When a condensible gas is used to produce the foam, when the foam is displaced into the colder parts of the reservoir, the effective mobility block collapses and this facilitates steam injection into upper zones during the latter phases of the injection operation. The condensible foam feature of the invention facilitates back flow production when the invention is applied to a "huff and puff" operation.

The foam can be generated in situ or pumped into the well and can be made of any number of chemicals as indicated. The choice can be made dependent upon whether the foam is generated at the surface or in the well.

It is evident from the foregoing discussion that the foam will fill the annulus and, accordingly, will decrease convection and radiation well bore heat losses.

With use of the check valve noted, the steam or other fluid to be injected down to the tubing can be injected at a pressure slightly larger than that of the annulus which, however, is maintained sufficiently high to insure the movement of the steam into the bottom portion of the pay. When steam injection has progressed a sufficiently long period of time and it is determined that the majority of the steam has entered the bottom stratum of the pay, the annulus pressure is reduced so that the steam can enter an upper stratum. In this step-wise fashion, steam enters the entire face of the pay zone with a minimum amount of by-passing due to buoyancy and/or permeability variation effects.

In lieu of the steam, there can be used natural gas or vaporized hydrocarbons or other gases which, when heat is desired in the formation, are preheated before injection or are otherwise heated as may be desired.

It will be evident from a consideration of this disclosure and the several concepts of the invention as therein set forth, that the foam need not be injected into an annulus surrounding the steam or other fluid injection means. It is sufficient that the foam, in some cases, can be made to enter into the formation to form a blanket over the top thereof so that the steam which is injected at a lower point is caused to spread throughout the formation. By releasing the pressure on the foam gradually, steam can be introduced to higher and higher levels or strata.

The commercially available surfactants to which reference has been made herein are well known. Thus, the Triton X–100 and Igepal CO–990 are materials of the alkyl phenoxy polyethoxy ethanol class. As noted, other surfactants can be employed, for example, Alconox which is sodium hexametaphosphate manufactured by Alconox, Incorporated, and the ordinary soaps, such as are available for use in the household. Detergents, such as Trend manufactured by Purex Corporation, Ltd., can advantageously be used.

Reasonable variation and modification are possible within the scope of the foregoing disclosure, the drawing and the appended claims to the invention the essence of which is that the injection of steam without a packer has been accomplished by employing a column of foam at a relative pressure such and against the pressure of a fluid being injected that the fluid being injected can be injected into a formation in the earth in a controlled manner at a desired or at various levels, the level being determined by the depth to which and at which the foot of the column of foam is maintained at any given time.

I claim:

1. A method for injecting a fluid into a formation below the earth surface which comprises injecting to a portion of a formation into which a fluid is to be injected a column of foam, maintaining said column of foam above said formation, separately injecting the fluid to be injected to said portion of said formation below said column of foam, maintaining on said column of foam a pressure

sufficient to retain it substantially in place against the pressure of said fluid being injected and injecting said fluid at a pressure sufficient to force the same into said formation below said column of foam.

2. A method according to claim 1 wherein there are provided a well bore having a tubing therein forming an annulus, the foam is pumped into one of said tubing and annulus and the fluid injected is injected through the other of said tubing and said annulus.

3. A method according to claim 2 wherein the fluid to be injected is steam.

4. A method according to claim 3 wherein the fluid employed to produce the foam is a condensible gas which is admixed with a foaming agent to produce said foam.

5. A method according to claim 4 wherein there is provided a well bore having therein a casing and said casing has therein a string of tubing, the steam is injected through the tubing and the foam is disposed in the annulus and thus protects the casing against adverse temperature effects due to the heat of the steam.

6. A method according to claim 1 wherein the formation is an oil-bearing formation, the fluid to be injected is steam, the steam is injected through a tubing string within a well bore and the foam is disposed in the annulus between said tubing string and the well wall.

7. A method according to claim 6 wherein, as steam injection progresses, the column of foam is gradually raised so that the steam penetrates the formation at successively higher levels.

8. A method according to claim 1 wherein the formation is an oil-bearing formation, the fluid to be injected is steam or a gas, the steam is injected through a tubing string within a well bore and the foam is disposed in the bottom of the well below the end of the tubing.

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STEPHEN J. NOVOSAD, *Primary Examiner.*