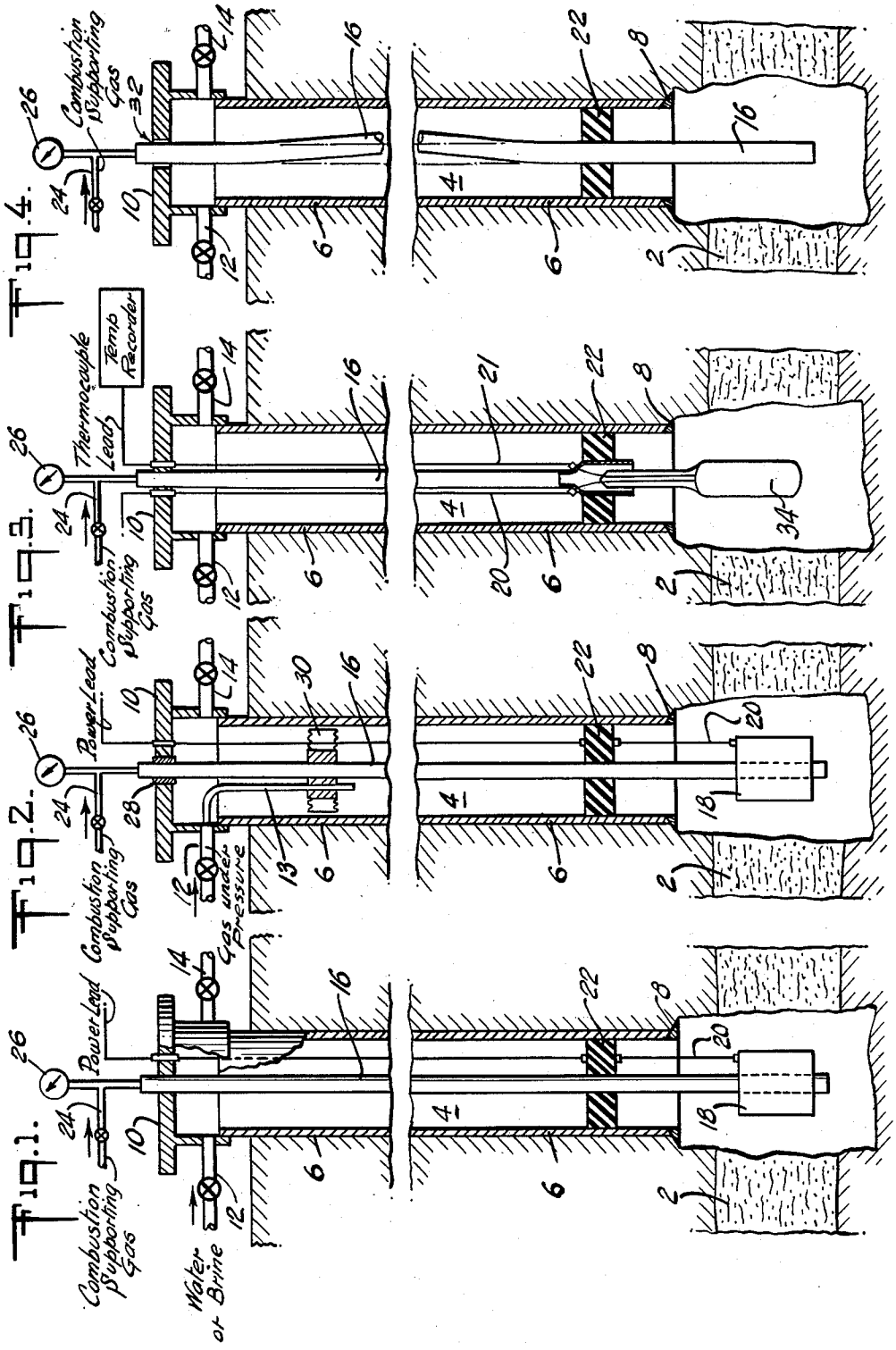
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METHOD FOR THE COMPLETION OF A WELL BORE

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METHOD FOR THE COMPLETION OF A WELL BORE

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This invention relates to a novel method for completing a well for the production of hydrocarbons contained in underground formations by thermal recovery means. More particularly, it concerns a well completion method useful in thermal recovery operations wherein a combustion supporting gas is injected into an underground formation through the well.

In some thermal recovery methods for the production of hydrocarbons contained in an underground formation, air, oxygen or other combustion supporting gas is injected through a well into the formation. The gas is either used to force the hydrocarbons from the formation or to support an in situ combustion which in turn serves to produce hydrocarbons from the formation. The use of this type of gas near fluid hydrocarbons produces a potentially dangerous situation in that admixture of these two components produces a highly combustible composition. Ignition of a highly combustible composition in the confined space in and adjacent the well bore will produce a destructive explosive force capable of damaging the well bore and producing equipment in the well. Furthermore, explosions of this nature have been known to cause extensive harm to personnel and equipment at the surface.

In accordance with the present invention, the method of completing a well to reduce the possibility of a down hole explosion and resulting well and equipment damage during recovery of hydrocarbons from an underground formation comprises first setting the producing equipment for recovery by thermal means, including the insertion in the well bore of a flow tube, placing a fluid-tight seal between the walls of said well bore and said producing equipment at a substantial distance down the well bore, said seal positioned upward of the formation, applying substantial pressure against the upper side of said seal, and then injecting a combustion supporting gas through said flow tube into the well bore below said seal. The pressure against the upper side of the seal is produced by filling the well above the seal with a liquid such as water, brine, oil, etc. It is preferable, however, when injecting the combustion supporting gas at relatively high pressure to employ a non-combustible liquid such as water or brine. Another method of applying pressure to the seal is to establish another seal at the well head or below the well head and substantially upward from the lower seal, and then to inject a gas under pressure such as air, nitrogen, combustion product gas etc., between the two seals and into the annulus established by the flow tube and well bore. Still another method of applying pressure to the seal is to allow the seal to support all or a part of the flow tube and equipment in the well.

Complete understanding of this invention will be obtained by examination of the accompanying drawings as described by the following specification wherein:

FIG. 1 is a broken sectional view depicting the method of the invention wherein a liquid is used to establish downward pressure on a seal in the well.

FIG. 2 is a broken sectional view depicting a well wherein gas under pressure is used to exert a force against a seal in the well.

FIG. 3 is a broken sectional view of a well wherein the equipment for an in situ combustion process is shown in conjunction with the preferred form of the method of this invention.

FIG. 4 is a broken sectional view of a well wherein the flow tubing string is shown to stand free at the well head in order to have its weight applied to the seal in the well.

As seen in the drawing the equipment for recovery of hydrocarbons from an underground fromation 2 is set in the well broadly designated as 4. Well 4 mainly comprises imperforate casing 6, casing shoe 8, well head 10 having valved pressure line 12 and valved relief line 14.

In FIG. 1 flow tubing string 16 has been inserted into the well by first attaching a heater assembly 18, having power lead 20 extending therefrom, to the lower portion of the spring 16. A packer 22 is positioned around the tubing string 16 so that there is a sufficient length of tubing string between the heater assembly and the packer to enable the heater to hang adjacent the producing formation while the packer 22 is upward thereof. Packer 22 is of any type having the necessary qualities to withstand the pressures exerted thereon from above and below and the high temperatures which are produced below. The tubing string 16 is lowered into the well so that the heater is at the desired level and then the packer 22 is set to provide a fluid-tight seal in the annulus between the imperforate casing 6 of the well and the tubing string 16.

In the embodiment of the invention depicted in FIG. 1, after producing equipment is set, water, brine or other available fluid is introduced into the well by opening the valved inlet 12 and pressure relief outlet 14. When the desired amount of fluid has been pumped into the well, the particular thermal recovery process employed is begun including the injection of a combustion supporting gas, such as air, through valved inlet 24 employing gauge 26.

In the embodiment of the invention shown in FIG. 2, gas under pressure, preferably an inert gas, is injected through inlet 12. The well head is sealed as at 28 and valved outlet 14 remains closed. Alternatively a packer 30 shown unset, situated a short distance down the well is set to produce an upper fluid tight seal and gas under pressure is pumped through inlet 12 which extension 13 through packer 30. Either of these alternative methods of injecting gas under pressure into the annulus surrounding tubing string 16, are suitable methods for applying downward pressure against seal or packer 22.

In the embodiment shown in FIG. 4, pressure is applied to the packer 22 by applying the weight of the tubing string. This is done by freeing or partially freeing the tubing string 16 from support at 32 or, should the tubing string be suspended above the well head, by slacking off the supporting element.

The method of this invention is particularly useful when used in connection with thermal recovery by in situ combustion wherein the hydrocarbons in an underground formation are heated and forced from the formation by hot gases produced by the burning of a portion of the hydrocarbons or injected fuel and where the combustion is supported by the injection into the zone of combustion of a combustion supporting gas. Two methods of well completion for initiating in situ combustion processes are demonstrated in FIGS. 3 and 4. In FIG. 3, the producing equipment, including ignitor 34 with power lead 20 and thermocouple lead 21, is set in the well as previously described. Downward pressure against the packer 22, in this instance, is provided by fluid in the annulus above the packer. A combustion supporting gas such as air is injected through the well into the formation to establish permeability through the formation to producing

wells. Thereafter, power is sent to the ignitor 34 and a burn is initiated. Improved well equipment particularly suited to the method of this invention for initiating in situ combustion is disclosed in copending application S.N. 862,877 filed of even date herewith by Billy H. Towell et al.

In FIG. 4, well equipment is shown which can be used for the spontaneous ignition method of establishing in situ combustion. Briefly this method comprises utilizing a tubing string with a packer and injecting a chemical or composition which will cause combustion in the hydrocarbon formation upon the introduction of a combustion supporting gas. Generally, air is injected through tubing string 16 into the formation to establish permeability. After desired permeability is established the air injection is stopped and a small mass of inert gas is injected. Thereafter, the chemical capable of spontaneous ignition, such as a drying oil, is injected into the formation via tubing 16. When sufficient chemical has been injected to initiate combustion, air or oxygen is again injected into the formation to promote ignition and support combustion.

In situ combustion methods employ a maximum air or gas injection pressure of approximately one pound p.s.i. for each foot of overburden. The volume injected must be sufficient for supporting combustion and is dependent upon the formation permeability and porosity.

In all of the previously described thermal recovery methods a hazardous situation exists with the possibility of explosion and resulting well and equipment damage. The method of completing a well in accordance with this invention substantially decreases the hazard involved in this type of operation.

The imperforate casing 6, flow tubing 16, and with packer 22 seated therebetween, and with the well head 10 fastened to the casing 6, forms an elongated container of annular configuration having a valved inlet at 12 and valved outlet at 14. Thus, when pressure is applied on the packer 22, as in the case of FIG. 1, the pressure within this elongated container will remain substantially constant. This is of particular importance especially when an in situ combustion operation is to be used for production (as in the cases of FIGS. 3 and 4) inasmuch as the pressure applied downwardly against the packer 22 must be as great as that exerted upwardly as a result of the in situ combustion operation, to prevent "blow out" of the production equipment within the well bore. The structure of FIG. 3 is substantially that of FIG. 1, to retain a substantially constant pressure applied against the seated packer 22, and in the case of FIG. 2, the upper packer 30 is set in a fluid-tight seal before pressure is applied against sealed packer 22. In the case of FIG. 4, the partial suspension of tubing string 16 will provide a substantially constant pressure exerted against the seated packer 22.

Obviously, other modifications and variations of the invention as hereinabove set forth may be made without departing from the spirit and scope thereof, and therefore, only such limitations should be made as are indicated in the appended claims.

We claim:

1. In the method of reducing the chance of a well bore explosion during the recovery of hydrocarbons from an underground hydrocarbon bearing formation via a well bore penetrating into said formation, the steps of setting imperforate casing in said well bore and a string of flow tubing within said casing, providing a fluid-tight seal between said imperforate casing and said string of flow tubing at a substantial distance down said well bore and upward of said formation, applying pressure to the upper surface of said seal and maintaining such pressure at substantially constant value by injecting a non-combustible fluid into the annulus defined by said flow tubing and said imperforate casing above said seal, and injecting a combustion supporting gas into said formation through said flow tubing.

2. The method of claim 1 wherein the fluid is essentially water.

3. In the recovery of hydrocarbons by thermal means from an underground hydrocarbon bearing formation wherein a combustion supporting gas is injected through a well bore penetrating into said formation, the method of reducing the possibility of a down hole explosion in said well bore with resulting well bore damage comprising the setting of imperforate casing in said well bore and a string of flow tubing housed therewithin, providing a first fluid-tight seal between said imperforate casing and said flow tubing at a substantial distance down said well bore and upward of said formation, providing a second fluid-tight seal between said imperforate casing and said flow tubing upward of said first fluid-tight seal, injecting gas under pressure into the annulus defined by said imperforate casing in said well bore and said flow tubing therewithin between said seals, and maintaining the pressure thereof at substantially constant value, and injecting a combustion supporting gas into the formation through said flow tubing.

4. In the method of reducing the possibility of a down-hole explosion in a well bore during the recovery of hydrocarbons from an underground hydrocarbon formation by an in situ combustion process wherein a combustion supporting gas is injected into said formation via a well bore penetrating the same for said in situ combustion process, the steps comprising the setting of an imperforate casing in said well bore and a string of flow tubing housed within said imperforate casing, providing a fluid-tight seal between said imperforate casing and said flow tubing at a substantial distance down said well bore and upward of said formation, applying pressure to the upper surface of said seal and maintaining said pressure at a substantially constant value by injecting a non-combustible fluid into the annulus defined by said imperforate casing in said well bore and said flow tubing therewithin above said seal, and injecting a combustion supporting gas into said formation through said flow tubing.

5. The method of claim 4 wherein the fluid consists essentially of water.

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