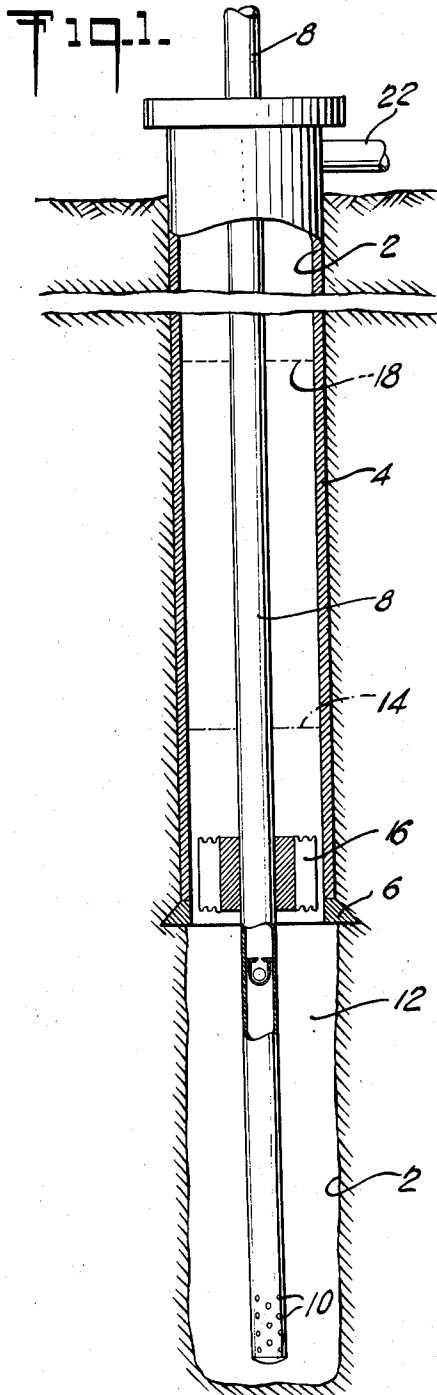
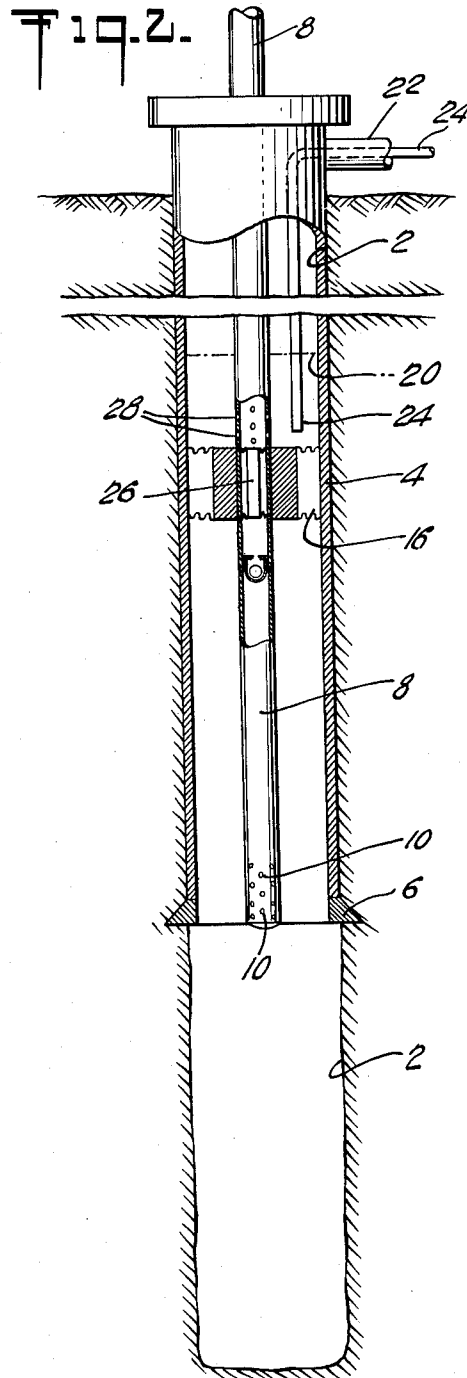


March 12, 1963

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DURING THERMAL RECOVERY OPERATIONS
Filed Sept. 16, 1960

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METHOD FOR CLOSING DOWN AN INJECTION WELL DURING THERMAL RECOVERY OPERATIONS

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Filed Sept. 16, 1960, Ser. No. 56,515
7 Claims. (Cl. 166—39)

This invention relates to the secondary recovery of hydrocarbons from underground formations traversed by a well bore and in one specific embodiment relates to the closing down of thermal recovery operations by stopping the provision of combustion supporting gas to an underground formation through the well bore.

In some thermal recovery methods for the production of hydrocarbons contained in an underground formation, air, oxygen or other combustion supporting gas is introduced through the well bore into the formation. This gas is used either to force the hydrocarbons from the formation or to support an in situ combustion which in turn serves to produce hydrocarbons from the formation. Such recovery procedures are hazardous from the standpoint of explosions in the well bore caused by the accidental ignition of combustible mixtures of fluid hydrocarbons and the combustion supporting gas. The explosions damage expensive well producing equipment and in some cases may harm personnel and equipment at the surface above the well. Thus, it is necessary for the safety of personnel and equipment to remove oil from the well bore before initiating recovery operations wherein a combustion supporting gas is introduced into the well bore. In the process of removing the standing volume of oil from the well bore, water or other non-combustible, heavier-than-oil liquid is utilized to lift the oil from the well bore. However, when oil is removed in this manner, a large volume of water is left in the well bore and the surrounding formation. It is known that the introduction of water into a hydrocarbon-containing formation is harmful to the formation from the standpoint of the production of hydrocarbons. A method of preparing a well bore containing a standing volume of oil for a secondary recovery operation in which a combustion supporting gas is introduced through the well bore into a surrounding underground hydrocarbon-containing formation is the subject of a co-pending application for patent entitled "Wellbore Completion Method," filed on December 30, 1959, by Don L. Harlan et al., Serial No. 863,045, now Patent No. 3,019,838.

In the method disclosed in this co-pending application, the production equipment employed therein includes a tubing string having fluid-tight well sealing means, such as a packer, affixed at a point along its length, and inserted in a well bore. A non-combustible heavier-than-oil liquid is introduced into the well bore in an amount sufficient to raise the interface of the oil and non-combustible liquid to a level just above that at which the packer will be set for the recovery operation, after which the packer is set at the desired level for the recovery operation and a non-combustible fluid is introduced into the well bore above the packer for exerting substantial pressure against the packer. The secondary recovery process in the formation adjacent the lower portion of the well bore is initiated thereafter. The heavier-than-oil, non-combustible liquid is preferably water or brine, both of which are readily available near most oil leases.

Non-combustible fluids used to pressurize a packer include inert gases such as nitrogen, carbon dioxide, or gases consisting principally thereof, and water and liquids such as brine. The oil lifted to the annular space above the well sealing means does not constitute a hazard when

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employing inert gas to pressurize the annular space above the packer. Inert gas such as nitrogen is used advantageously in instances when it is undesirable to permit water or brine above the packer to go into the formation when the packer is unseated.

Accordingly, it is an object of the invention to provide a novel method for closing down an injection well during thermal recovery operations.

Another object of the invention is to provide a new method for preventing undue damage to the hydrocarbon formation undergoing secondary recovery operations.

Still another object of the invention is to provide a method of resuming production of a well undergoing thermal recovery operations which has been used for the injection of combustion supporting gas without danger of explosion therein and contamination of the hydrocarbon formation because of safety provisions.

These and other objects, advantages and features of the present invention will become apparent from the following description of the invention and by reference to the accompanying drawing wherein:

FIG. 1 is a diagrammatic sectional view of an injection well bore containing equipment in position at the beginning of thermal recovery operations; and

FIG. 2 is a diagrammatic sectional view of a well bore and the equipment of FIG. 1, together with modifications thereof, for use with the invention.

In accordance with the illustrated embodiment of my invention, there is disclosed a novel method by which an injection well bore for use in thermal recovery operations of a hydrocarbon-containing underground formation may be closed down without the danger of forming explosive mixtures and undue contamination of the producing formation.

In FIG. 1, equipment is positioned in the well bore 2 having a casing 4 and a casing shoe therefor at 6. The equipment is assembled so that the lower end of the string of tubing 8, having perforations at 10, is at or near the bottom of the well bore 2, so that the string of tubing 8 can be used to discharge a fluid at the bottom of the standing column of oil 12 in the well bore, with the oil-gas interface indicated at 14. Packer 16 is shown unset in FIG. 1 and positioned as low as possible in the casing 4.

A non-combustible liquid which is heavier than oil, e.g. water, is pumped down tubing 8 and injected through the perforations 10 at the bottom of the column of oil 12. In this manner, water is provided until the column of oil is lifted to a level in the well bore where the oil-water interface is just above the level at which the packer is to be set for the initiation of a thermal recovery operation.

The position of the packer when set is determined by the desired position of the producing equipment below it. In FIGS. 1 and 2, wherein the equipment is designed for the spontaneous initiation of in situ combustion by the introduction of chemicals, the lower end of the tubing string is positioned adjacent the end of and just inside the casing 4, when the packer 16 is set (see FIG. 2). Thus, when the oil-water interface reaches the level shown by the line of dashes at 18, FIG. 1 and line 20, FIG. 2, the string of tubing 8 is raised to place the lower end thereof in proper position and the packer is set in position just below the oil-water interface 20, FIG. 2, to provide a fluid tight seal with the well bore, and water is then introduced through the opening at 22 of the casing 4.

One method of introducing water into the annulus between the tubing 8 and the casing 4 above the set packer 16 is through the small tubing 24 inserted into the annulus and reaching beneath the interface 20 so that water is provided with little turbulence beneath the interface to prevent the formation of emulsions and to main-

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tain the separation of oil and water, while the water column slowly displaces the oil through the opening 22 at the top of the casing 4. In some instances, it is not necessary to have the tubing 24 inserted in the annulus to a level beneath the interface 20 depending on the characteristics of the oil-water interface.

When the oil has been removed from the annulus, the water introduction is terminated leaving a standing column of water over the packer 16.

When it is undesirable to pressurize the packer 16 with water, an alternate method of pressurizing the packer is to inject an inert gas into the annulus above the packer while maintaining a reasonably gas tight seal at the well-head. The oil column located in the annulus above the packer will add to the pressure on the packer without hazard. The well bore is now ready for the preparation of the formation for an in situ combustion operation or other thermal recovery process using air or other combustion-supporting gas as a drive to force hydrocarbons from the formation.

In preparing the hydrocarbon-bearing formation for an in situ combustion operation, air as a combustion-supporting gas is pumped through the tubing 8 into the well bore below the packer 16. The initial volume of air entering the well bore drives the relatively small amount of water remaining therein into the formation. Thereafter, sufficient pressure is supplied to establish permeability to adjacent well bores traversing the formation. As has been mentioned, the mixture of a combustion-supporting gas and fluid hydrocarbons in the confinement of the well bore is hazardous. The oil which was displaced by water from the well bore was removed because of this hazard, and by the method employed in order to prevent too much water from going into the formation and to complete the well in a manner designed to reduce the possibility of a downhole explosion. Any explosion in the relatively small diameter tubing would be inconsequential and an explosion occurring in the annulus below the packer would be effectively dampened by the pressurized packer. Once permeability has been established in the formation, in situ combustion is initiated by either chemical or mechanical means, as disclosed in the co-pending application, and adjacent wells are monitored for gas production to check the existence of in situ combustion.

After the desired time interval has elapsed while thermal recovery procedures are taking place, steps are taken to close down the in situ combustion in order to put the well on a production basis. This begins by stopping of the compressor which furnishes air for injection as the combustion-supporting gas to the underground hydrocarbon formation. Following the cessation of the provision of the air, the well bore is purged with nitrogen immediately (about two well bore volumes) after which dead lease crude oil, amounting to about 100 barrels, from which the more volatile portions have been removed, is pumped into the formation, followed by the monitoring of wellhead pressure of the tubing and the annulus.

The nitrogen is pumped through the tubing 8 so that the atmosphere in the well bore below the level of packer 16 consists entirely of nitrogen; and the amount of dead lease crude oil pumped into the formation through the same tubing may or may not extend in the tubing above the level of packer 16, depending upon the permeability of the formation and conditions therein following the in situ combustion.

The filling of the annulus with water is largely a safety measure in order to provide for safer operation during the air-injection period and also to provide a quenching fluid after the injection of the air. However, any stimulation of production by in situ combustion adjacent the well (near well burn) for remedial purposes might be destroyed by dumping of the annulus water into the formation, since the introduction of water into an oil-

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producing formation is usually detrimental to the flow of oil (except in throughput water flooding operations). Since such dumping of water is an extreme measure, the dumping of oil rather than water into the formation probably can be done as safely and at the same time enhance well productivity stimulation by a possible near well burn.

There is also a possibility that a second near well burn might result after the well is put back into production. It may be assumed that a complete burn has occurred some radius away from the well bore. In this burned out volume, only rock matrix and a combustion supporting gas such as air exist at the time the compressor is closed down. Since the rock matrix will probably be hot, some coking of the injected oil may occur. Therefore, after the oil is injected, a coked zone could exist at the outer edge of the oil "ring." Outside of the coked zone, hot air would exist in the rock matrix. Upon the resumption of production, oil and heated air would flow towards the well bore. Thus a condition could exist then which would be conducive to the initiation of a second near well burn. However, at this time, the reaction zone would move towards the producing (or former injection) well. Propagating a second burn adjacent the well bore might result in additional well stimulation. So that production could be controlled accordingly, in view of the possibility of the second near well burn, the producing stream temperature should be checked and if it becomes abnormally hot, necessary steps should be taken to close the well down.

Following the pumping of the dead lease crude oil into the formation, a blanking or close-off plug, shown diagrammatically at 26, is set in the tubing 8, at the packer 16, after which the tubing above and adjacent the blanking plug is perforated by some means, such as a mechanical perforator, the perforations being indicated at 28. The water in the annulus is then displaced by oil, either by providing the oil through the tubing to the annulus or from the annulus to the tubing. After the oil has displaced the water from the annulus the packer is unseated and the tubing is pulled preparatory to putting the well back into production.

After the well has been put on a production basis, the gas, oil and water rates are monitored, and appropriate analyses and measurements are made of the gas, oil gravity and the float temperatures in accordance with producing directives, and if unsafe conditions become imminent, the well is closed down.

Thus there has been shown and described a method by which an injection well, used for providing a combustion supporting gas to an underground hydrocarbon-bearing formation for a thermal recovery process to stimulate production thereof, may be closed down without danger of a well bore explosion, because of the presence in the formation of the combustion supporting gas, and the chance of contamination of the underground formation, due to safety measures taken therefor.

Although a specific embodiment of the invention has been shown and described, it is to be understood that modifications thereof may be made without departing from the scope of the invention as disclosed in the appended claims.

I claim:

1. The method of closing down an injection well used in the thermal recovery of hydrocarbons contained in an underground formation traversed by a well bore having a casing and a string of tubing therein extending from the surface thereof and with a packer between said casing and said tubing and located adjacent said formation for further production of said formation comprising the cessation of the introduction of a combustion supporting gas into said formation through said string of tubing in said well bore, the purging of said well bore through said string of tubing below the level of said

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packer with an inert fluid followed by the provision of a petroleum product to said formation adjacent said well bore, closing off communication through said string of tubing between said formation and said surface above said well bore by insertion of close-off means in said string of tubing adjacent the level of said packer and opening communication through said string of tubing in said well bore between said surface and the annulus defined by said string of tubing and casing in said well bore adjacent and above the level of said packer and said close-off means, displacing a non-combustible fluid pressurizing said packer in said annulus with oil, and placing the well back into production.

2. In a thermal recovery operation of hydrocarbons contained in an underground formation traversed by a well bore wherein air is introduced into said formation through a string of tubing positioned in said well bore and having a packer fixed therealong adjacent said formation and pressurized in the annulus between said string of tubing and the casing of said well bore by a non-combustible heavier-than-oil fluid, the steps of ceasing the provision of air to said formation through said tubing, purging said well bore below said packer with an inert gas and providing a petroleum product through said string of tubing to said formation adjacent said well bore, closing off in said string of tubing communication between said formation and the surface above said well bore by a close-off plug in said string of tubing adjacent the level of said packer, initiating communication in said string of tubing between said surface and said annulus above the level of said close-off plug and adjacent said packer, displacing said non-combustible heavier-than-oil fluid from said annulus, and placing said formation back into production.

3. In the thermal recovery operation as set forth in claim 2, the pressurization of said packer being accomplished by a non-combustible fluid selected from the group consisting of heavier-than-oil liquids and inert gases.

4. In the thermal recovery operation as set forth in claim 2, the pressurization of said packer being accomplished by a non-combustible, heavier-than-oil fluid including an aqueous liquid.

5. The method of closing down an injection well used in the thermal recovery of hydrocarbons contained in an underground formation traversed by a well bore wherein air is introduced into the formation through a string of tubing positioned in said well bore having a casing with a packer affixed to said string of tubing adjacent said formation and being pressurized by a non-combustible heavier-than-oil liquid in the annulus defined by said string of tubing and said casing, for further production of said formation, the steps of stopping the introduction of air into said formation through said tubing, the purging of said well bore below said packer with an inert fluid thereafter followed by the provision of a petroleum product to said formation adjacent said well bore through said tubing, the closing off of communication through said tubing between the surface above said well bore

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and said formation by a close-off plug in said tubing located adjacent said packer and the inception of communication between said tubing and said annulus between said tubing and said casing of said well bore above said close-off plug adjacent the level of said packer, the displacement of said non-combustible, heavier-than-oil liquid from said annulus by a petroleum product, and the resumption of production of said formation subjected to thermal recovery.

6. In the secondary recovery of hydrocarbons from an underground formation traversed by a bore hole wherein a combustion supporting gas is injected into said formation through said well bore having casing and tubing in position therein, with a packer therebetween adjacent said formation pressurized by a non-combustible heavier-than-oil fluid provided the annulus defined by said casing and said tubing, the method of closing down the injection well for further production of said formation comprising the steps of stopping the provision of a combustion supporting gas to said formation through said tubing, the purging of said well bore below said packer with an inert fluid thereafter followed by the provision of a petroleum product to said formation adjacent said well bore through said tubing, closing off communication of said formation through said tubing with the surface above said well bore by a close-off plug positioned in said tubing adjacent said packer and initiating communication between said tubing and said casing above the level of said close-off plug and near said packer, displacing said non-combustible, heavier-than-oil fluid from said annulus, and resuming production from said formation thereafter.

7. In the secondary recovery of hydrocarbons from an underground producing formation by an in situ combustion operation, a method of closing down an injection well traversing said formation for further production therefrom, said well having casing and tubing therein to define an annulus therebetween and with means for providing a fluid tight seal between said casing and said tubing pressurized by a non-combustible liquid in the annulus between said casing and said tubing comprising the cutting off of the supply of a combustion supporting gas to said formation through said tubing and said well bore below said packer, the purging of said tubing by an inert fluid, the providing of a petroleum product to said formation adjacent said well bore through said tubing, the closing off of communication through said tubing between said formation and the surface above said formation by a close-off plug positioned in said tubing adjacent said fluid tight seal and the initiating of communication between said tubing and said annulus above the level of said close-off plug and near said packer, the displacing of said non-combustible liquid from said annulus, and the initiating of further production from said formation.

References Cited in the file of this patent

UNITED STATES PATENTS

2,906,340	Herzog	Sept. 29, 1959
2,958,380	Schild	Nov. 1, 1960