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[54] PROCESS FOR REDUCING HEAT LOSS DURING IN SITU THERMAL RECOVERY

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[56] **References Cited**

UNITED STATES PATENTS

3,358,759	12/1967	Parker	166/272 X
2,897,894	8/1959	Draper et al.	166/272
3,366,175	1/1968	Ferrell et al.	166/269 X
3,373,805	3/1968	Boberg et al.	166/303
3,380,530	4/1968	McConnell et al.	166/303
3,386,512	6/1968	Bloom	166/303

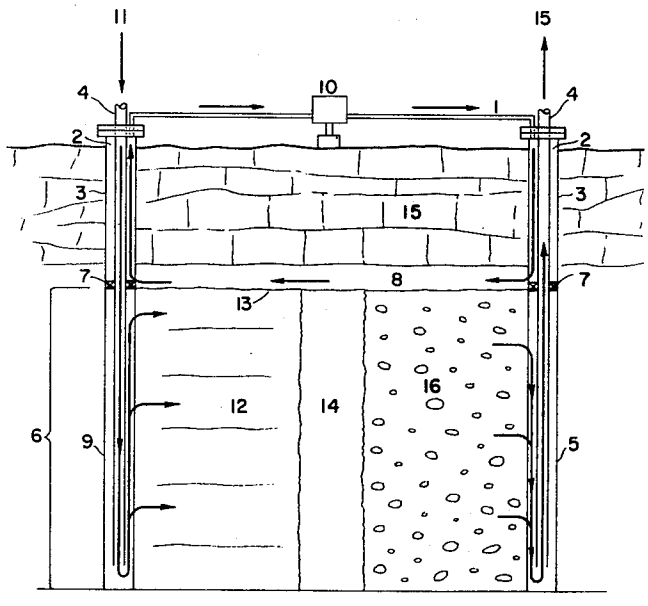
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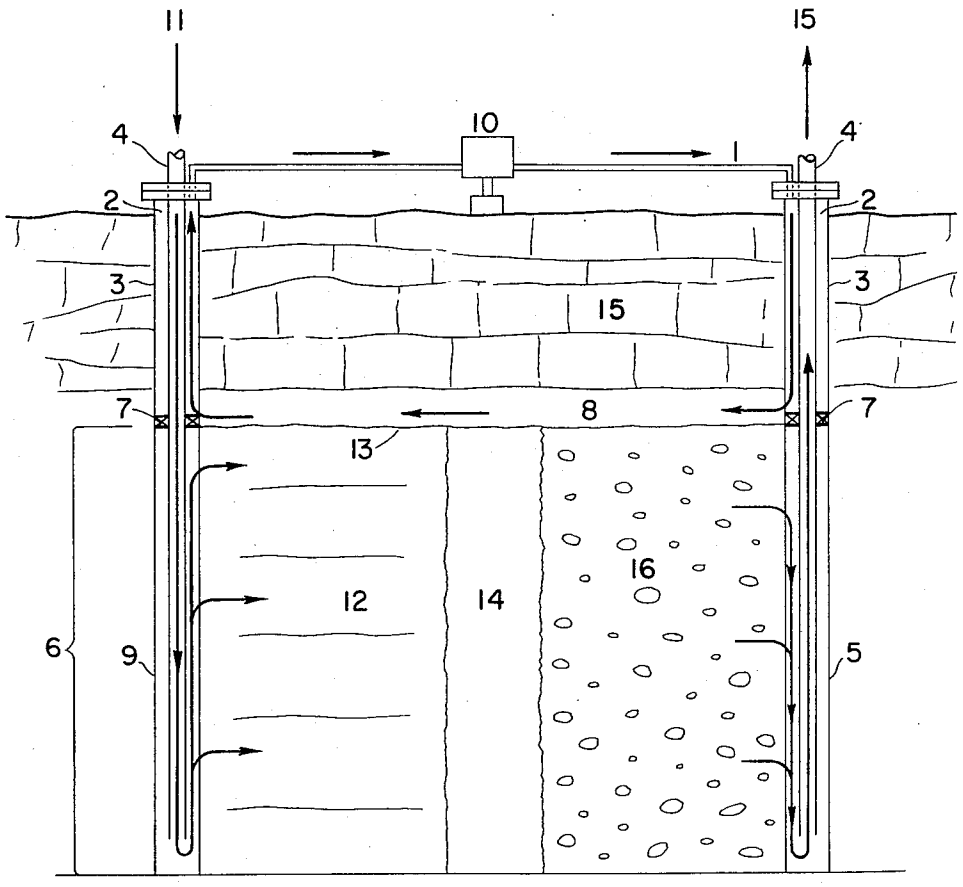
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[57] **ABSTRACT**

A continuous blanket of an inert gas is introduced between the hydrocarbon bearing reservoir and the overburden rock. The gas in injected in either a countercurrent or co-current direction with the progress of the thermal recovery front. By this injection an insulation medium is provided by the inert non-condensable gas such that heat losses to the overburden rock are reduced to a nominal amount and a more efficient thermal recovery process is achieved.

4 Claims, 1 Drawing Figure





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PROCESS FOR REDUCING HEAT LOSS DURING IN SITU THERMAL RECOVERY

BACKGROUND OF THE INVENTION

The present invention relates to a process for the thermal recovery of oil from subterranean reservoirs. More particularly, the process of the present invention is a method for the reduction of heat losses during thermal recovery of oil from subterranean reservoirs.

In the thermal recovery of oil it is desirable to add new energy to displace the oil. The energy generally takes the form of mechanical displacement such as the pushing of oil with another fluid. In particular, in steam flooding the energy dissipation may be both through a gas and a fluid, with the major steps of the process being the displacement of fluids due to the invasion of water at the reservoir temperature with simultaneous continuous transition from water near reservoir temperature to hot water as one becomes close to the center of the wellbore, followed by a condensation zone where, among other things, steam is condensed into water and then the actual steam zone about the wellbore. Steam injection for in situ thermal recovery of oil enhances recovery in that the viscosity of the heavy crude oil is decreased dramatically with an increase in temperature thereby making the viscous crude more flowable in the reservoir rock and drastically reducing the oil to water mobility ratio. As crude oil is heated, as with most liquids, it increases the volume and the amount of swelling proportional to the temperature rise. This phenomena varies with the particular crude but may materially effect the reservoir volume factor which serves to assist in adding extra energy to the displacement process. A further phenomena which occurs during steam injection is steam distillation. In steam distillation, displacement of oil in front of the water bank leaves residual oil in the pore spaces, whereas the steam zone contacts it at high temperatures and vaporizes substantial quantities of the heavy crude in accordance with the vapor pressures of the hydrocarbons contained therein. This releases constituents within the oil, thereby distilling off the crude oil and allowing it to be more easily produced from the formation.

With all thermal recovery process and, in particular, with the in situ recovery of oil using steam drive to enhance the production of heavy crude oils from subterranean reservoirs, there is a tremendous heat loss from the pay zone or producing horizon to the overburden and underburden rock zones which materially decreases the efficiency of the thermal recovery project. The steam drive process is limited as to the actual amount of heat which may be effectively propagated throughout the reservoir from the wellbore as a majority of the heat is lost to the overburden and underburden rock and little heat dissipated to the unproduced crude oil as the distance from the wellbore increases. What is required is a method for limiting the amount of heat loss to the overburden and underburden rock zones such that more heat may be propagated throughout the reservoir and increased oil production may result.

It is an object of the present invention to provide a method for the improved thermal recovery of oil from subterranean reservoirs.

It is a further object of the present invention to provide an insulating medium by the use of a non-condensable inert gas to insulate the reservoir through which thermal recovery is being initiated from the overburden rock so as to eliminate heat losses thereto.

It is still a further object of the present invention to provide for a method for providing a non-condensable gas insulating media at the interface between the overburden rock and viscous oil pay section so that heat losses to the overburden rock are reduced through a continuous counter-current injection of air into the formation and by the use of the natural characteristics of the interface formed between the overburden and reservoir rock.

With these and other objects in mind the present invention will be more fully developed in the following discussion with particular reference to the disclosed drawing.

SUMMARY OF THE INVENTION

The objects of the present invention are accomplished by a process for the thermal recovery of viscous crude oil from subterranean reservoirs. The process is an improvement upon the process wherein steam is injected into the reservoir through an injection well and water, steam and oil are simultaneously produced from the reservoir through one or more production wells. The improvement comprises injecting a non-condensable gas into the upper region of the reservoir so as to form an insulating barrier between the reservoir and the overburden rock. Within the scope of the process of the present invention is the injection of the non-condensable gas between the reservoir and the overburden through an induced radially directed horizontal fracture pattern. The fracture is formed between the reservoir and overburden rock, from the injection well to the production well, prior to the injection of the non-condensable gas.

Generally, the non-condensable gas is selected from the group consisting of air, carbon dioxide, flue gas, natural gas and nitrogen. It is preferred that the non-condensable gas be injected into the production well and produced from the steam injection well so that a counter-current injection pattern to that of the steam injection flow is maintained. In a fractured system the non-condensable gas may be injected at pressures greater than the overburden rock pressure so as to lift the overburden rock and afford a greater passageway for the non-condensable gas to pass through. It is also preferred that the steam be injected at pressures lower than those at which the non-condensable gas is injected so that a pressure barrier is built up by the non-condensable gas such that contact therewith by the steam will repel the steam and further insulate the overburden rock.

BRIEF DESCRIPTION OF THE DRAWING

The present invention may be more fully understood by particular reference to the following drawing in which:

The FIGURE illustrates one embodiment of the process of the present invention as applied to a subterranean reservoir.

DETAILED DESCRIPTION OF THE INVENTION

Injection of steam into reservoirs which contain heavy viscous oil has been found to provide an excellent method for the recovery of these oils from subterranean reservoirs. Introduction of heat into the reservoir lowers the viscosity of the oil and renders it more mobile for ultimate displacement and recovery. Inherent in the problem of steam injection, however, is the large loss of heat through the wellbore to the over and underburden formations. The wellbore losses may be generally diminished by insulation of the injection tubing string and placement of insulating means, for example asbestos insulation, between the casing and tubing string. The heat losses to the surrounding formation above and below the producing horizon containg the viscous oil is, however, a considerably more difficult problem.

It has been found that by injecting a continuous flow of air, or another non-condensable gas, to form an insulating medium at the interface between the overburden rock and viscous oil producing horizon, a considerable curtailment in heat loss to the overburden rock may be achieved. The simultaneous injection of the non-condensable gas through the production tubing annulus of either the injection or production wells and thereby into the formation through the upper portion of the formation and exiting from the subsequent production or injection well serves two-fold purpose in that it both insulates the steam injection stream from the normally encountered wellbore losses and insulates the reservoir steam bank from heat losses to the overburden rock.

The present invention may be more fully developed by reference to the FIGURE wherein injection well **5** consisting of casing **3** completed within reservoir **6** has injection tubing string **4** hanging in the injection well **5**. The annulus is isolated from the majority of reservoir **6** by isolation means, for example a packer **7**. Non-condensable gas is injected through line **1** into the annulus **2** formed between the casing **3** and injection tubing string **4** into the interface **8** between the reservoir **6** and the overburden rock **15**. The non-condensable gas is subsequently produced from the annulus formed between casing **23** and tubing string **24** of production well **9** and which is isolated by isolation means, for example packer **27**. Steam **11** is injected into reservoir **6** through tubing string **24** so as to form a steam bank **12** and a condensed steam front **14** within reservoir **6**. Compression means **10**, which may be an air pump, are supplied so that non-condensable gas may be recycled and continuously countercurrently injected into the non-condensable gas zone **8** between the reservoir **6** and overburden rock **15**. It is preferred by the countercurrent injection of a non-condensable gas at a temperature less than the saturation temperature of the steam, the steam bank **12** or leading edge of the steam injected contacts an insulating media which is a temperature lower than the steam and is more readily insulated from the overburden formation by the formation of a condensed steam, non-condensable gas interface **13**, which is formed within the reservoir between the steam front **12** and the non-condensable gas zone **8**.

It is preferred that the steam be introduced at a pressure from about **10** psi to about **100** psi lower than that of the non-condensable gas so that it will be generally repelled as it condenses at condensed steam-non-condensable gas interface **13** and forms an insulating barrier between the non-condensable gas zone **8** and the reservoir **6**. Therefore, by the process of the present invention little, if any, heat is transmitted to the overburden rock **15** and thereby affords more heat to the condensed steam front **14** for its propagation through the reservoir **6** and subsequent production of oil **16** therefrom.

A particular application of the present invention is related by the following example:

EXAMPLE

The heat loss from a formation having an effective thermal conductivity proportional to the conductivity the solid matrices of the formation and to the fluid contained within the pores of the solid matrix formation with approximately a 37 percent pore volume was determined. The thermal conductivity of the solid matrix was 1.6 Btu/ft.-hr.-°F, and the thermal conductivity of the fluid within the reservoir, which in the case of the present invention could be a non-condensable gas, such as air having a thermal conductivity 0.000064 cal./cm. sec.0° C, were utilized. This data yields a resultant thermal conductivity for the formation of 0.2 Btu/ft.-hr.-°F fluid contained therein is 0.8 Btu/ft.-hr.-°F. Since generally the heat loss rate is proportional to the square root of the thermal conductivity, it can be seen that the thermal conductivity of the reservoir containing reservoir fluids in the matrices is 0.8 Btu/ft.-hr.-°F, thereby having a proportional constant of the square root of 0.8 or of approximately 0.9. The new loss of heat rate from the reservoir treated with the process of the present invention would have a thermal conductivity loss proportionate to the square root of 0.2 or equaling 0.45. Calculation shows that the heat loss would be halved as the calculation considers only the loss to the overburden rock and not that loss through the underburden rock so that the heat loss should be diminished by approximately 25 percent or from a heat constant of 0.9 to a heat loss constant of 0.675.

The insulating process of the present invention provides an excellent method for containing the heat within the reservoir and propagating the steam front therethrough. It has further been found, through the use of the process of the present invention, that fracturing the reservoir in a radially directed horizontal pattern between the reservoir and overburden rock from the injection well to the production wells, subsequent to the injection of the non-condensable gas, will form a highly permeable fracture network through the formation through which the non-condensable gas may be injected. This fracturing provides an excellent means through which exacting control of the amount of non-condensable gas injected may be maintained. In further respect, the injection of the non-condensable gas may be at pressures greater than the overburden rock pressure such that the fracture is parted an exacting width. This fracture parting provides an insulating media exactly maintained at all times so that no heat loss to the overburden formation may occur. The fracture may be initiated by the use of a hydraulic fluid such as water or may be initiated by an increasing injection of non-condensable gas until the formation is parted. By the initial slow injection of the non-condensable gas in the directed manner followed by subsequently increasing amounts of non-condensable gas injection, the radially directed horizontal pattern may be formed between the production and injection wells such that exacting amounts of medium space between the reservoir and the overburden rock may be maintained. Generally, non-condensable gases which may be used both for the fracturing and insulating steps of the process may be selected from the group consisting of air, carbon dioxide, flue gas, natural gas and nitrogen.

By use of the process of the present invention the heat loss to the overburden rock is significantly decreased. The inherent problem with steam injection processes of the large loss of heat to the overburden formation is curtailed, along with the requirements for insulating the steam injection wellbore.

The present invention has been described herein with respect to particular embodiments thereof. It will be appreciated by those skilled in the art, however, that various changes and modifications can be made without departing from the scope of the invention.

Therefore, I claim:

1. In the process of the thermal recovery of viscous crude oil from a subterranean reservoir wherein steam is injected into the reservoir through an injection well and water, steam and oil are produced from the reservoir through one or more production wells, the improvement comprising:

a. fracturing the reservoir in a radially directed horizontal pattern between the reservoir and overburden rock from the injection well to the production well; and

b. injecting a non-condensible gas in the upper regions of the reservoirs through the radially directed fracture so as to form an insulating barrier between the reservoir and the overburden rock.

2. The process of claim **1** further including injecting the non-condensable gas at pressures greater than the overburden rock pressure.

3. The process of claim **1** in which the non-condensable gas is selected from the group consisting of air, carbon dioxide, flue gas, natural gas and nitrogen.

4. The process of claim **1** in which the steam is injected at a pressure about 10 psi to about 100 psi lower than that at which the non-condensable gas is injected.

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