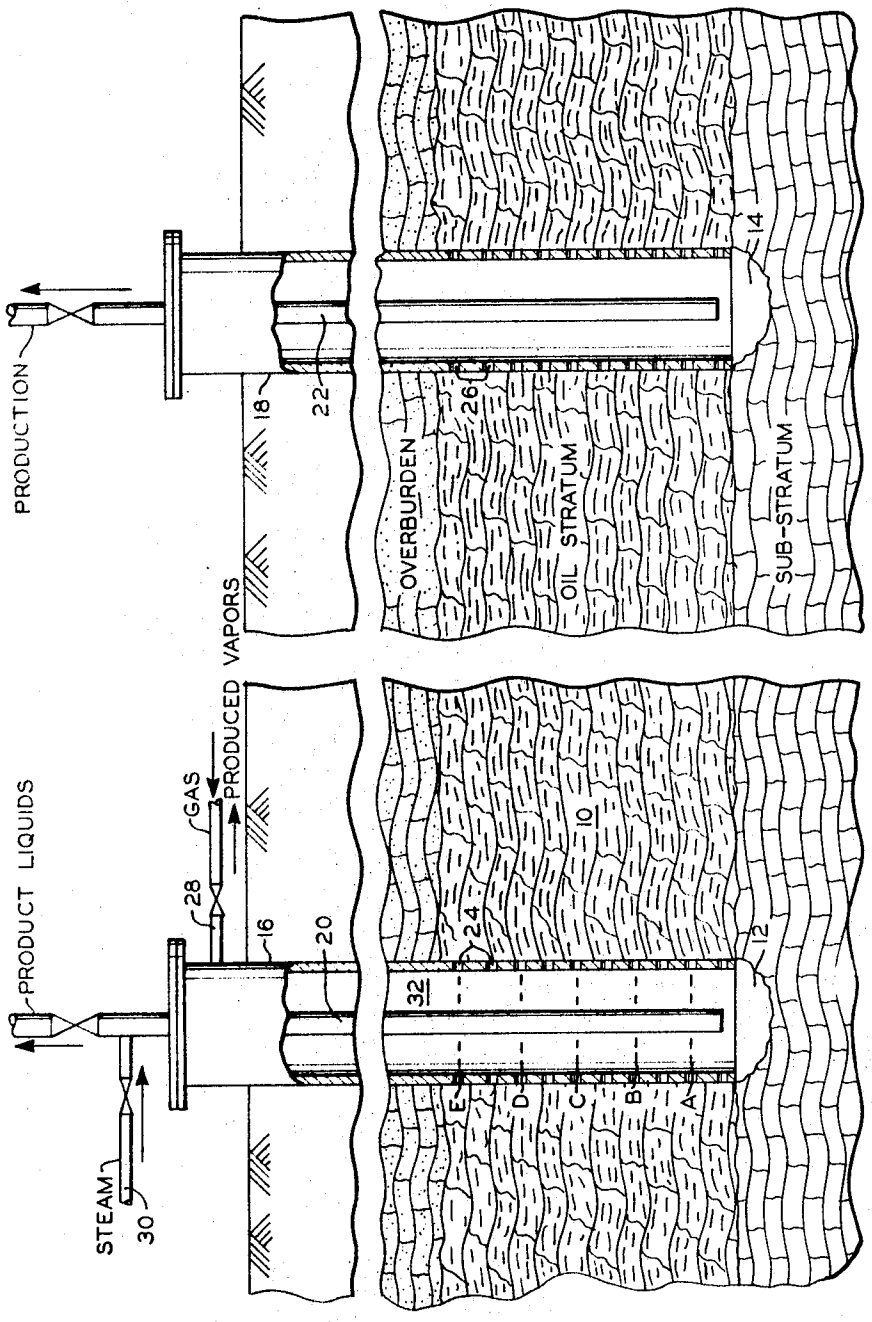
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METHOD OF CONTROLLING STEAM INJECTION INTO A RESERVOIR IN THE PRODUCTION OF HYDROCARBONS

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METHOD OF CONTROLLING STEAM INJECTION INTO A RESERVOIR IN THE PRODUCTION OF HYDROCARBONS

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ABSTRACT OF THE DISCLOSURE

In a well having a casing, a tubing and a packer-free annulus between them, the process of injecting steam into the tubing and thence into the lower portion of a permeable hydrocarbonaceous stratum, and injecting a non-deleterious gas at a higher pressure into said annulus and thence into the upper portion of said hydrocarbonaceous stratum, in the absence of a packer between the lower end of said tubing and said casing. This process may include reduction of the differential in pressure as time passes so that said steam is finally injected into substantially all sections of said stratum.

This invention relates to a method of controlling steam injection into a hydrocarbon-bearing stratum to produce hydrocarbons therefrom.

It is conventional in the petroleum industry to inject steam into an oil stratum as a secondary or tertiary production method to heat and flush out residual hydrocarbon material from the stratum either into one or more offset wells or into the well thru which the steam is injected by periodically cutting off the flow of steam and opening the well to production. The latter process is termed "huff-and-puff" steam flooding.

In steam injection processes, it is conventional to position a packer in the tubing-casing annulus near the top of the producing stratum so that steam does not rise into the annulus, dissipate heat to the overburden, and form inordinate quantities of condensate. In operation without a packer in the annulus, steam does rise into the annulus above the producing stratum with attendant aforesaid disadvantages.

This invention is concerned with a method of controlling the injection of steam into an oil-bearing stratum thru a tubing without packing off the annulus, which prevents steam invasion of the annulus above the producing stratum.

Accordingly, it is an object of the invention to provide a method of controlling steam injection into an oil stratum to produce hydrocarbons therefrom which obviates the necessity of packing off the annulus between the tubing and a casing extending to the producing stratum. A further object is to provide a steam injection method which permits controlling the level of steam injection into a producing stratum without using a packer. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

Operation during steam injection without the use of the packer in the tubing-casing annulus is desirable in order to eliminate the cost of the packer in addition to the cost of installing and servicing the packer during operation. Another advantage gained without a packer in a "huff-and-puff" steam injection process is in the higher production rates afforded during the production phase of the process resulting from allowing the produced gaseous or vaporous hydrocarbons to flow thru the injection-production well via the packerless tubing-casing annulus while producing liquid hydrocarbons in normal manner thru the tubing string, allowing the pump to handle a greater liquid thruput.

A broad aspect of the invention comprises injecting steam thru a tubing string in a well running to a hydrocarbonaceous stratum at a sufficient pressure to cause steam to flow into the stratum, simultaneously injecting a non-deleterious gas thru the annulus around the tubing string at a substantially higher pressure than the steam injection pressure, and controlling the differential pressure of the injected gases so as to maintain the annulus filled with said gas at least to the top of the stratum and exclude steam from this area. The annulus gas pressure is maintained sufficiently above the steam pressure to cause at least a minimum measurable flow rate of gas into the stratum, thus assuring the exclusion of steam from the annulus above the top of the stratum and preventing substantial loss of heat to the overburden. In one method of operating, the pressure differential between the annulus and the tubing is maintained sufficiently high to force substantially all of the steam into a lower section of the stratum and the pressure differential is gradually decreased over a period of time or periodically so as to permit steam invasion at higher levels in the stratum until steam is flowing into the entire vertical cross section of the stratum. Either the steam pressure or the inert gas pressure may be varied to control the pressure differential in the two streams.

Suitable gases for excluding the steam from the tubing-casing annulus include natural gas, which is preferred because of its ready availability and its low cost, helium, hydrogen, methane, propane, nitrogen, etc. Air can also be utilized as the control gas but it is preferred to utilize a gas lighter than steam.

In practicing the "huff-and-puff" steam injection technique, after an extended steam injection period of several weeks to several months, the injection well is opened to production and the steam pressure built up in the stratum during injection drives the heated and fluidized hydrocarbon material in liquid and gaseous form into the injection wellbore, the liquid hydrocarbons being either pumped from the bottom of the well thru the tubing or forced thru the tubing string by gas pressure, the annulus being closed to flow under these conditions. It is preferred to allow gaseous hydrocarbons to flow thru the annulus and to produce the liquid hydrocarbons thru the tubing by pumping, at faster production rates. Means are provided for pulling the downhole pump up only one joint of tubing into an expanded tubing section, following the pumping phase of the cycle, to resume steam injection thru the tubing around the pump, which is disclosed in the copending application of W. B. Belknap, Ser. No. 350,254, now Patent No. 3,289,763.

When producing thru offset wells such as a surrounding ring of wells in a 3, 5, 7, or 9-spot pattern, steam injection and gas injection are either continuous or intermittent (to provide a soaking period) and the heated and more fluid hydrocarbon material is driven into the production wells surrounding the injection well.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing, which is an elevation in partial section of a pair of wells penetrating an oil stratum arranged for operation of the invention.

Referring to the drawing, stratum **10** is penetrated by wells **12** and **14** which are provided with casings **16** and **18** and tubing strings **20** and **22**, respectively. The casings **16** and **18** extend thru stratum **10** and are perforated as at **24** and **26**, respectively. Casing **16** is provided with a gas injection line **28** which may serve as a vapor production line during the production phase of the "huff-and-puff" operation. A steam injection line **30** connects with tubing **20** at the wellhead for injection of steam to the

bottom of the well, tubing **20** extending substantially to the lowermost level of stratum **10**. When using the "huff-and-puff" method, well **14** and other surrounding wells are usually shut in to enhance the building up of pressure in the stratum surrounding well **12**. When utilizing direct steam drive, well **14** and other surrounding wells are open to production thru tubing **22**.

In operating in accordance with the invention, utilizing the "huff-and-puff" or the direct drive method, steam is introduced thru line **30** at a pressure substantially above normal stratum pressure so as to cause steam to flow into stratum **10** and, simultaneously, gas such as natural gas is injected thru line **28** into annulus **32** at a higher pressure than the steam pressure in tubing **20** so as to overcome the heavier column of steam in tubing **20** and force gas into stratum **10**, thereby excluding steam from annulus **32** above the top of stratum **10**. It is feasible to maintain the gas injection pressures sufficiently high to assure the entry of steam into the lower section of the stratum such as below level A or level B until substantial injection has been effected, thereby overcoming the tendency of steam to preferentially invade upper levels of the stratum or areas of higher permeability therein. The pressure differential between the gas in annulus **32** and the steam in tubing **20** is then decreased, gradually or periodically, so that steam rises in the wellbore within stratum **10** and eventually reaches level E. When there is only a minimum measurable flow rate of steam thru line **28**, the operator can be certain that steam is entering the stratum at level E as well as all lower levels. Under these conditions, the annulus **32** above level E is maintained full of injected inert gas and steam injection is effective at all levels of the stratum as long as steam is flowing at a substantial rate thru line **30**.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

We claim:

1. A method of controlling the injection of steam into a permeable hydrocarbonaceous stratum to produce hydrocarbons therefrom, said stratum being penetrated by a well including a casing extending at least to the top of said stratum (any portion extending into said stratum being perforated) and a tubing extending to a lower section of said stratum forming a packer-free annulus with said casing comprising the steps of:

(a) injecting steam thru said tubing at a selected pressure substantially above stratum pressure so as to drive steam into at least the lower section of said stratum;

(b) injecting a non-deleterious gas into the upper end of said annulus at a pressure substantially above the steam pressure of step (a) so as to prevent steam invasion of said annulus above said stratum; and

(c) wherein the differential between gas and steam injection pressures is maintained sufficiently high for a substantial period of time to restrict steam injection to a lower section of said stratum and thereafter said differential is reduced over a substantial period of time until there is substantially no gas injection into said stratum and steam is injected into substantially all sections of said stratum.

2. The process of claim **1** wherein steam and gas injection are terminated after a relatively long injection period and said well is opened to production of vaporous and liquid hydrocarbons for a substantial period and the cycle of injection and production is repeated.

3. The process of claim **2** wherein vaporous hydrocarbons are produced thru said annulus and liquid hydrocarbons are produced thru said tubing.

4. The process of claim **1** wherein production of fluid hydrocarbons driven from said stratum by the injection steps is effected thru at least one offset well.

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