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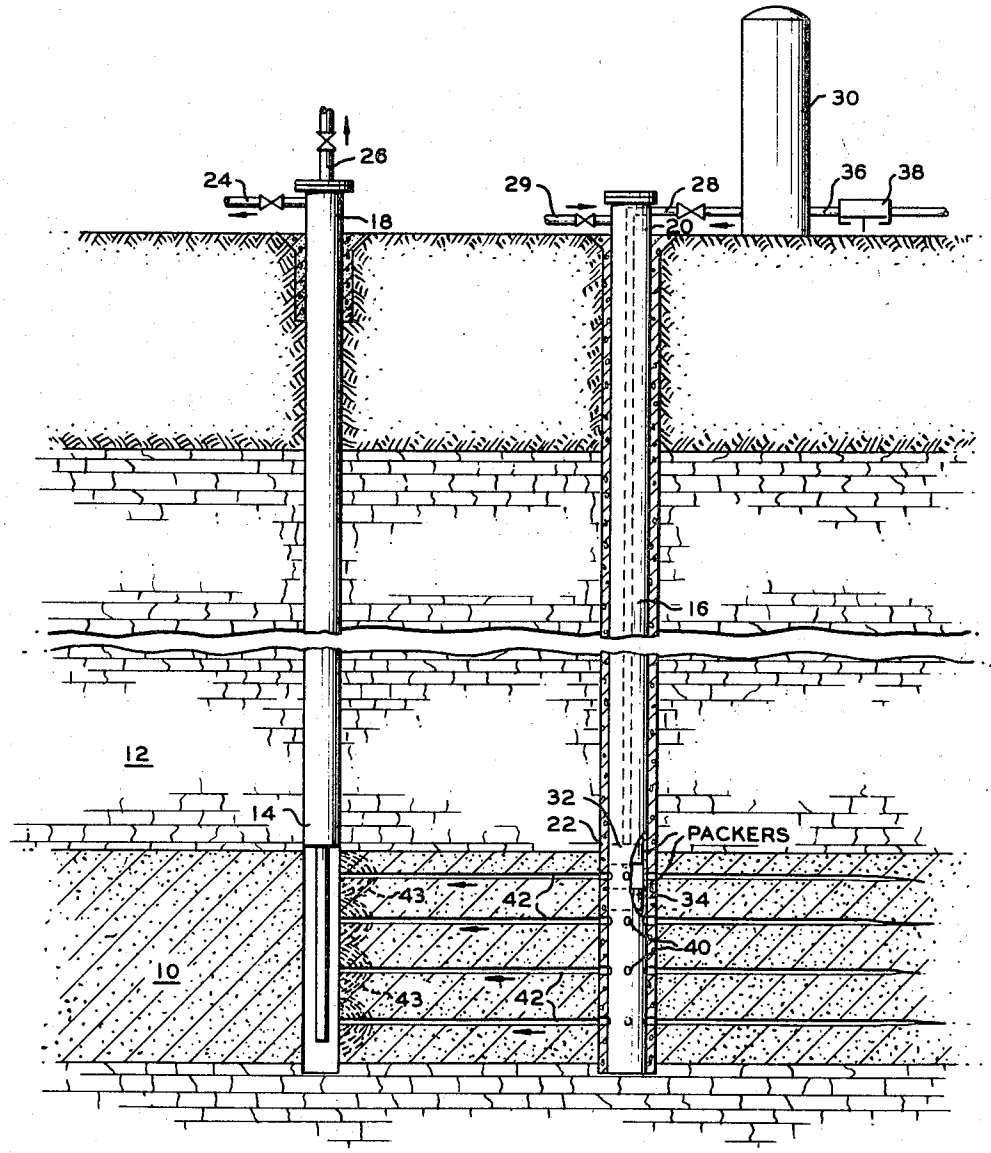
CROSS REFERENCE

SEARCH ROOM

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PROCESS FOR PRODUCING OIL

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PROCESS FOR PRODUCING OIL

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This invention relates to an improved method of in situ combustion in recovery of hydrocarbons from underground formations of low permeability containing hydrocarbon material.

The recovery of hydrocarbons from hydrocarbon-containing underground formations by in situ combustion has come into considerable prominence in recent years, particularly in the recovery of oil from shale and other formations of low permeability. One of the difficulties involved in in situ combustion techniques is the difficulty in transporting oxygen (air) to the combustion zone. This is particularly true in impervious or only slightly permeable formations. The present invention provides an improved method of providing air passageways in a formation of low permeability and simultnaeously establishing and/or promoting combustion with movement of the combustion zone thru the formation.

Accordingly, it is an object of the invention to provide an improved process for recovery of hydrocarbons from a hydrocarbon-containing formation by in situ combustion. Another object is to provide an improved technique for establishing air passageways from one or more input wells to a production well in the initial stages of in situ combustion utilizing inverse flow of air. A further object is to provide an improved method of fracturing a formation and simultaneously propping the fracture open without the aid of special propping agents. Other objects of the invention will become apparent from a consideration of the accompanying disclosure.

In order to practice in situ combustion in a hydrocarbon-containing formation, such as an oil shale, it is of prime importance to have means for transporting oxygen to the combustion zone and means for the removal of liquids and gases. If natural fractures for the transportation of air or oxygen exist in the shale formation, the countercurrent or inverse air method can be used without further fracturing. If there are no fractures, or if the fractures are inadequate, the formation can be fractured by any of the recognized ways to provide air channels. Ordinarily, oil shale formations are impevious to air and therefore no channels are usually found. Hence, it is essential to in situ combustion in a formation of low permeability to air to provide fractures for the passage of air and other gases thru the formation.

A more recent technique employed in in situ combustion is appropriately designated as inverse air injection. In this type of operation, combustion is initiated around a production borehole and air is injected into the formation thru one or more surrounding boreholes at sufficient pressure to cause the air to flow thru the formation or fractures therein to the combustion zone so as to support combustion therein and advance the combustion front countercurrently to the flow of air. This technique is disclosed and claimed in the co-pending application of J. C. Trantham et al., Serial No. 529,916, filed August 22, 1955. The process of my invention is concerned with the inverse air injection type of operation and comprises fracturing the formation with a compressible fluid such as air, nature gas, or combustion gas, including engine exhaust gases. The fracturing is effected in the well thru which inverse air is introduced to the formation to initiate or sustain combustion in the formation around the production well and advance the combustion front toward the input wells. Fracturing

with a compressible fluid such as air, alone, or in admixture with a liquid as in the aerated drilling fluid technque, almost no special equipment is required. The fracturing fluid is readily available and the dynamic response of the formation to the fluid is advantageous. In field tests of the invention utilizing air as the fracturing fluid, the air pressure during injection exceeds a critical value of about one p.s.i.g. per foot of depth (for a well approximately 50 feet in depth) at which time the injection well takes air in surges. Surging is evidenced by surging of the pressure gauge on the well head and by surging of the automatic compressor. When the injection pressure is reduced by one or two p.s.i.g. the surging stops. This surging effect indicates fracturing of the formation probably in a horizontal plane or planes with a slight lifting of the overburden.

A further advantages of using a compressible fluid resides in the fact that when fracture starts, upon build up of pressure, the compressed fluid stored in the well bore and in storage tanks and lines of the compressed fluid system rushes into the fracture and produces a large fracture job almost independently of the volume rate of delivery of fluid by the compressor. This is in contrast to the use of an incompressible fluid, such as oil, where slight flow into new fractured areas reduces the pressure below that required for further fracturing and the pumps must supply a large volume of additional fluid rapidly in order to effect adequate fracturing. Another advantage of the present technique lies in the low cost of the fracturing fluid and the simplicity of the equipment required. The instant method also eliminates the requirement of propping agents. After a fracture is made, alternately decreasing and increasing the pressure of the fracturing gas creates debris in the fracture which functions as a propping agent. The fracturing gas rushes out of and into the fracture by this procedure, as the pressure is rapidly varied to produce a "fluttering" action. A specific advantage is obtained when air or other combustion supporting gas is utilized as the fracturing fluid because the fracturing of the formation renders the combustion supporting gas immediately available at the ignition well for the start of in situ combustion or for advancing the combustion zone radially outwardly from the ignition well or borehole in the event a combustion zone has already been established around the injection well.

A more complete understanding of the invention may be had from a consideration of the accompanying drawing which is a schematic elevation of apparatus in a formation for effecting the process of the invention.

Referring to the drawing, a formation **10** underlying an overburden **12** is penetrated by an ignition borehole **14** and an injection borehole **16**. These boreholes are provided wtih casings **18** and **20**, respectively. Casing **20** is cemented in, at least thru the formation as at **22**. Casing **18** terminates at about the upper level of the formation. The well head or casing **18** is provided with a gas outlet line **24** and tubing **26** for use in recovering liquid products by conventional methods. Casing **20** is closed and is provided with fluid injection line **28** which leads from a fluid surge tank **30** to a suitable level in the well such as the level between packers **32** and **34**. A line **29** connects with casing **20** and with an air source (not shown). Pressure or surge tank **30** has connected with its lower section a line **36** in which is positioned a compressor **38** for supplying pressurized fracturing fluid and/or injection air to borehole **16**.

The casing and cement at various levels in formation **10** in borehole **16** is penetrated in known manner by perforations **40** which serve as openings into the formation for fracturing and for injection of combustion supporting fluid. Formation **10** is fractured at several levels **42** and these fractures extend from injection well **16** to

ignition well 14 to provide continuous passageways for combustion supporting gas. Areas 43 are initial combustion zones.

In practicing the invention with the arrangement of apparatus shown in the drawing, a set of fractures in horizontal planes at different levels is produced. The selective fracturing is effected by perforating the casing and cement at the selected levels and then packing off the casing by means of packers 32 and 34 so that fracturing fluid enters the packed off area thru the line 28 extending thereto without being supplied to the other selected areas. After fracturing of the formation at one selected level the packers are moved to the next selected level and the procedure is repeated until all of the horizontal fractures desired are produced. It is also feasible to fracture at more than one level at the same time. It is also possible and desirable in some instances to progressively cement portions of the bottom of the hole upwardly to isolate the selected regions to be fractured.

In practicing one technique of the invention, the formation adjacent borehole 14 is simultaneously heated to the desired level with injection of fracturing air in borehole 16 at the corresponding level so that the heated formation is brought to combustion supporting temperature by the time that the fracturing fluid effects the fracture and arrives at the ignition area. In this manner, in situ combustion by inverse air injection is immediately established and can be continued merely by injection of air thru borehole 16. After ignition and in situ combustion are initiated in this manner at the topmost level illustrated in the drawing air is injected thru line 29 while packers 32 and 34 are repositioned for the next fracturing step. Succeeding fracturing steps are effected in the same manner with initiation of the in situ combustion inverse air injection technique operating automatically in each fracture and at each fracture level as fracturing air reaches borehole 14.

Burning of hydrocarbon in the fractures heats the formation above and below the fractures so as to render the hydrocarbon therein more fluid and fluidizes solid hydrocarbon (kerogen) present in the formation. In this manner a substantial proportion of the hydrocarbon material in place in the formation is retorted therefrom and is recovered in both gaseous and liquid form from well bore 14 by conventional means, gases being recovered from line 24 and liquids thru tubing 26.

Continued injection of air thru borehole 16 gradually moves the combustion front thru the formation to the injection well and continued injection of air after the combustion front arrives at well 16 effects the reversal of the combustion front and drives the same back to ignition well 14. This phenomenon which is known as "thermal echo" is supported by combustion of residual coke deposited in the formation on the initial burnthru by combustion of hydrocarbons condensed in the formation back of the combustion area during inverse air injection and other hydrocarbon material driven from the formation during the inverse air injection phase.

While the drawing and discussion relate to an operation utilizing one injection well 16, in the practical application of the process in the field, a 5 or 7-spot well pattern is generally utilized in effecting recovery of the hydrocarbon material from a generally circular area around a production or ignition well 14. The invention has been described principally in its application to impervious oil shale but it is not restricted to this application. Other hydrocarbon-containing formations of low permeability to air such as coal deposits and, particularly, lignitic deposits which are of low porosity, are amenable to production by inverse air in situ combustion in the manner of the invention.

While the discussion of fracturing relates chiefly to air as the compressible fracturing fluid, air or other gas may be mixed with a liquid such as hydrocarbon oil or water in proportions which render the mixture (aerated liquid) sufficiently compressible to function to advantage in fracturing in accordance with the invention. The function of the gas in the mixture is to build up a potential of readily available pressure which acts quickly and automatically to increase the fracturing once a fracture is initiated. When hydrocarbon oil is utilized in the fracturing fluid, it provides additional readily combustible fuel for heating the formation and retorting the hydrocarbon therefrom. The term "mixture" as used herein includes alternate slugs of liquid and gas as well as a froth of gas and liquid.

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.

I claim:

1. A process for recovering hydrocarbons from a formation of low permeability containing hydrocarbons comprising penetrating said formation with first and second spaced-apart boreholes within fracturing distance thru said formation; producing a fracture in said formation from the first to the second of said boreholes by direct application of fracturing pressure thereon thru the first borehole from a sufficiently large volume of readily compressible fluid comprising gas to provide surges of fluid into said fracture to immediately occupy and extend same deeper into the formation and maintain supporting pressure to hold said fracture open, thereby establishing gas communication thru said fracture between said boreholes; alternately decreasing the fluid pressure in said first borehole so as to close said fracture and then increasing said pressure so as to open said fracture, thereby causing rapid flow of gas out of and into said fracture to create and shift debris therein which acts to prop said fracture open when said fluid pressure is reduced below a supporting level, heating an area of said formation adjacent said second borehole to a combustion-supporting temperature of said hydrocarbon therein; while said area is at said temperature flowing pressurized combustion-supporting gas thru said fracture to the heated area so as to initiate and support combustion of the hydrocarbon material in said area; continuing the flow of said combustion-supporting gas to said area so as to cause the resulting combustion front to move thru said formation countercurrently to the flow of said gas; and recovering hydrocarbon fluid produced by said combustion from said second borehole.

2. The process of claim 1 utilizing air as the compressible fracturing fluid and as the combustion supporting gas.

3. The process of claim 1 wherein said compressible fluid comprises a mixture of hydrocarbon oil and a gas.

4. The process of claim 1 wherein said compressible fluid comprises a mixture of a hydrocarbon oil and air.

5. The process of claim 1 wherein said compressible fluid comprises a mixture of water and air.

6. A process for fracturing a carbonaceous formation which comprises penetrating said formation with first and second boreholes within fracturing distance thru said formation; producing a fracture in said formation from the first to the second of said boreholes by direct application of fracturing pressure thereon thru one of said boreholes from a sufficiently large volume of readily compressible fluid comprising gas to provide surges of fluid into said fracture to immediately occupy and extend same deeper into the formation from said one borehole and maintain supporting pressure to hold said fracture open; after fracturing has occurred, alternately decreasing the fluid pressure so as to close the fracture and increasing said fluid pressure so as to open the fracture and cause said fluid to rush out of and into said fracture thereby creating debris therein which serves as a propping agent.

7. The process of claim 6 wherein said fluid is air.

8. The process of claim 7 including the steps of heating said formation adjacent the other of said boreholes

to at least combustion temperature before said fracture is made so that same is ignited as air reaches the hot area thru the fracture; continuing the feeding of air thru said fracture to the ignited area to propagate a combustion front thru said formation; and recovering produced hydrocarbons thru said second borehole.

9. A process for fracturing a carbonaceous formation which comprises penetrating said formation with first and second boreholes within fracturing distance thru said formation; producing a fracture in said formation from the first to the second of said boreholes by direct application of fracturing pressure thereon thru said first borehole from a sufficiently large volume of combustion supporting gas to provide surges of fluid into said fracture to imediately occupy and extend same deeper into the formation and maintain supporting pressure to hold said fracture open; before said fracture is made, heating said formation adjacent said second borehole to at least combustion temperature so that same is ignited as said gas reaches the hot area thru said fracture; continuing the

feeding of said gas thru said fracture to the resulting combustion front to cause same to move thru said formation toward said first borehole; and recovering produced hydrocarbons thru said second borehole.

10. The process of claim 9 using air as the pressurizing and as the combustion-supporting gas.

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