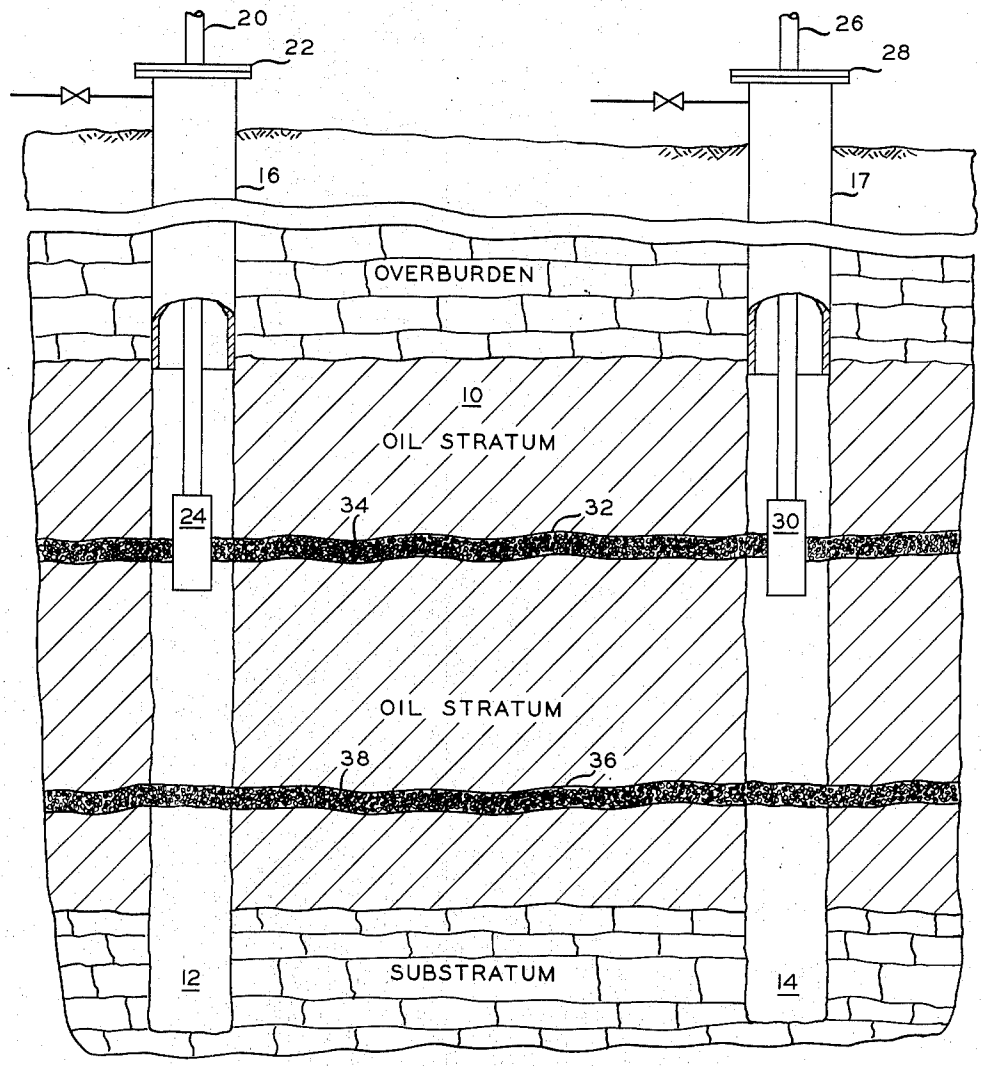
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HEAT STIMULATION OF FRACTURED WELLS

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HEAT STIMULATION OF FRACTURED WELLS

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This invention relates to a process for the production of hydrocarbons from an oil-bearing stratum by heat stimulation.

The application of heat to an oil-bearing stratum around a well therein is conventional practice. The principal difficulty in heat stimulation of a well by this technique to produce more oil from the stratum is in causing the heat to penetrate deep enough into the well to produce substantial amounts of oil therefrom. This invention is concerned with a method or technique for heating a stratum containing oil and, particularly, heavy viscous oil or semi-solid to solid hydrocarbon material at normal stratum temperatures.

Accordingly an object of the invention is to provide an improved process for the production of hydrocarbons from a fractured stratum around a well therein by heat stimulation thereof. Another object is to provide a method of propping a fracture open so that heating to a substantial depth in the stratum by means of a propping agent is feasible. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises filling a fracture around a well in an oil-bearing stratum with metal pellets to form a continuous layer of the pellets in the fracture which serves as a heat conducting medium for heating the stratum remote from the well by application of heat to the pellets contiguous to the well. The heating is effected without in situ combustion or in the absence of free-oxygen, by means of a suitable down-hole heater such as a gas-fired burner or an electric heater. The pellets may be composed of any metal or alloy of metals but pellets of aluminum or aluminum alloy, consisting essentially of aluminum, are preferred because of their good heat conductance and their relatively low density which facilitates the injection thereof into fractures in the stratum to be produced. Magnesium pellets or pellets composed of an alloy containing magnesium, such as Mg-Al, are also suitable but more expensive than those composed principally of aluminum.

The use of aluminum pellets in propping fractures in a stratum to increase the production of oil has been practiced heretofore. However, in such practice the aluminum pellets or those formed from an aluminum alloy have not been injected into the fracture in sufficient concentration to provide pellet to pellet conduction of heat thru the fracture deep into the stratum as is provided in the process of this invention. A description of conventional practice is found in the Petroleum Engineer, November 1960, at page B–40 in an article by J. E. Kastrop entitled, "New Fracture Propping Process Uses Aluminum Pellets." In the practice discussed therein the well is fractured by any suitable method, such as injecting a fracturing fluid comprising a gas, a liquid, or a mixture of gas and liquid, and the pellets are injected into the fractures or "tailed in" in suspension or dispersion in a suitable carrier fluid which may comprise gelled water, diesel oil, kerosene, and similar gelled heavy hydrocarbons. Water-in-oil emulsions are also suitable. A concentration of pellets in the carrier fluid of at least 5 pounds per gallon of fluid is required to provide a continuous layer of pellets in the fracture. After the propping pellets have been "tailed in" to form a continuous layer in the fracture, the pressure is reduced in the injection well and the excess

pellets are removed from the well in conventional manner.

The pellet size to be used is in the range of 6 to 16 mesh. The layer of pellets in the fracture may be more than one pellet thick so as to facilitate the heat conduction during the heating step. The pellets may be of uniform diameter or of mixed diameters within the above range.

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 an arrangement of wells and fractures in a stratum for use in accordance with the invention.

Referring to the drawing, a stratum **10** is penetrated by wells **12** and **14** which are cased substantially to the upper level of the stratum by casings **16** and **17**, respectively. Tubing string **20** extends thru the well head **22** on casing **16** and carries a downhole heater **24**. A similar arrangement of tubing **26**, well head **28** and heater **30** is provided in well **14**. Stratum **10** is fractured by conventional method around each of wells **12** and **14** at a selected level to produce fracture **32** which extends laterally outwardly from each wall so as to intersect intermediate wells **12** and **14** and provide communication therebetween. After fracturing, metal pellets **34** are "tailed in" by injecting a suspension of pellets in a suitable heavy or viscous liquid and at sufficient concentration (at least 5 pounds of aluminum pellets per gallon of carrier fluid) to form a continuous conductive layer of the pellets extending radially outwardly from each well. After the continuous solid conductive layer of pellets is positioned in the fracture, downhole heaters **24** and **30** are positioned opposite or at the same level as the fractures and the heating step is effected with continuation thereof until heat has been conducted into the stratum laterally in all directions at least several feet and preferably until the stratum has been heated substantially above normal temperature as far out as the continuous layer of pellets extends. The heating period may take several days or weeks, depending upon the depth to which the pellets extend from the wells and the extent of the section of stratum heated. The heating of the stratum along the fractures by conduction of heat thru the pellets has the effect of rendering the in-place hydrocarbon material more fluid or less viscous so that the resulting oil flows into the well, thereby increasing production from the stratum. Heating can be continued until heat penetrates deep from the fracture. The economics of the process will determine the length of the heating period.

In thick strata, it is desirable to fracture at more than one level as at **36** in the drawing and again fill the fracture with a continuous layer of metal pellets **38** followed by heating the pellets by means of a heater at the well bore and allowing the heat to be conducted deep into the stratum. The heating in the different fractures is preferably conducted simultaneously, but it may be effected successively.

In one embodiment of the invention the stratum to be produced is fractured at different levels around one well or a plurality of wells and heat stimulation is applied to the metal pellets in the fractures until the stratum intermediate the fractures is heated and produced so as to be sufficiently permeable from removal of oil, semi-solid, or solid hydrocarbon material to permit production thereof by in situ combustion. The stratum is ignited while hot from the heat stimulation step by injecting air thru one of the fractures and withdrawing combustion gas and produced oil thru the other fracture and a well connected therewith, thereby moving a combustion front vertically thru the stratum. The combustion front may be moved thru the stratum either by counterflow of air, providing

the stratum is allowed to cool below ignition temperature before injecting air thru the fracture remote from the ignition fracture. In direct flow, the air feeding the combustion zone is fed thru the fracture in which combustion is initiated. In counterflow combustion, the stratum is ignited in one fracture by heating the adjacent stratum and injection of air thereto and, after combustion is initiated, the flow of air thru the ignition fracture is terminated and the air is injected thru the other fracture so that it reestablishes combustion at the original combustion zone and causes the combustion front to move inversely or countercurrently to the flow of air to the injection fracture. A hot flushing gas may be passed thru the fractures and/or thru the stratum between fractures to increase oil flow.

The process of this invention may be effected around a single well, such as well **12**, without the use of offset wells, such as well **14**. In this type of operation the same fracturing and propping technique is utilized and the heating is applied to the continuous conducting layer of pellets in one or more fractures at different levels around the well to cause the hydrocarbon material in the stratum to become more fluid and flow more readily into the well for recovery by conventional techniques such as by pumping. Also, it is desirable to apply the heat stimulation step in spaced apart fractures around the same well at different levels until the intervening stratum has been increased in permeability sufficiently to permit movement of a combustion front vertically thru the stratum and thereafter effecting this procedure so as to denude the stratum of carbonaceous material.

The process of the invention is applicable to virgin strata as well as to the recovery of hydrocarbons from strata which have been produced by natural gas drive or by other means, such as fluid flooding and miscible fluid drive. The process is particularly applicable to strata containing heavy hydrocarbon material which renders other methods of production difficult or inoperable.

The process may be effected in wells in a 5-, 7-, or 9-spot pattern as well as in parallel lines of wells. Again referring to the drawing, well **12** may be considered a central well surrounded by a ring of wells **14**. Well **12** may also be representative of one well in a line of wells which is generally parallel with a second line of wells in which well **14** is located. There may also be another line of wells parallel with and on the opposite side of wells **12** from wells **14**.

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 heating a stratum penetrated by a pair of wells at spaced points and recovering oil therefrom which comprises the steps of

(a) fracturing said stratum at a selected level around each well so that the fractures provide communication between said wells;

(b) injecting small metal pellets into the resulting fracture in a carrier fluid in a concentration of at least 5 pounds per gallon of fluid;

(c) continuing the injection of pellets and fluid until a continuous conductive layer of pellets extends from well to well;

(d) heating the pellets contiguous to both wells by means of downhole heaters so as to conduct heat from said heaters thru the layer of pellets from well to well;

(e) continuing the heating step so as to further heat said pellets and the adjacent stratum and cause oil to flow into said wells;

(f) recovering the oil thus produced;

(g) repeating steps (a) thru (f) at a second level in said stratum and continuing the heating until the stratum intermediate said levels is sufficiently permeable to permit producing same by in situ combustion;

(h) thereafter, while said stratum is hot, igniting same along the fractures at one level by injecting air thereto thru said wells;

(i) continuing the injection of air so as to move a combustion zone thru the stratum from one fracture level to the other; and

(j) recovering the produced hydrocarbons thru at least one of said wells.

2. The process of claim **1** wherein prior to said in situ combustion step a hot non-oxidizing flushing gas is passed thru the fractures from one well to the other to flush oil from said stratum to increase oil recovery.

3. The process of claim **1** wherein said metal pellets consist essentially of aluminum.

4. The process of claim **1** wherein each well is substantially free of said pellets and heat is transmitted from said heaters to the pellets in said fractures principally by radiation and convection.

5. The process of claim **1** wherein said pellets are of a size in the range of 6 to 16 mesh.

6. The process of claim **5** wherein said pellets consist essentially of aluminum.

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