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HEATING OF AN EARTH FORMATION Penetrated By a WELL BOREHOLE

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This invention relates to the heating of an earth formation and relates more particularly to a means for heating uniformly the face of an earth formation along a well borehole penetrating the formation.

Earth formations are heated for various purposes. Thus, in the production of petroleum from an earth formation, the formation may be heated to decrease the viscosity of the petroleum oil within the formation. The heating may also be employed to remove paraffin from the formation. Hydration and swelling of clay minerals within the formation may be eliminated or minimized by heat within the formation. The formation may also be heated in carrying out the in-situ combustion process to initiate combustion within the formation.

Heating of an earth formation is commonly effected by operation of a suitable heater positioned alongside the formation within a well borehole penetrating the formation. A fluid, such as water, or a gas, is ordinarily passed downwardly through the well borehole over the heater and into the formation. The fluid passing over the heater becomes heated and upon entering the formation transfers the heat to the formation. The heater, because of the small diameter of the well borehole relative to the length of the formation, is of necessity, a long slender heater.

It has been found that an elongated heater fails to heat uniformly an earth formation adjacent to the heater. The fluid passing over the top portion of the heater and entering the formation adjacent thereto is heated to some extent. However, the fluid passing over the entire length of the heater and entering the formation adjacent to the bottom portion of the heater is heated to a greater extent. Thus, the lower portion of the formation is heated to a greater extent than the upper portion of the formation.

Where the heating is for the purpose of initiating combustion within the formation, for example, combustion as a result of the non-uniform heating, may be initiated at the lower portion of the formation but not at the upper portion. Attempts to correct this condition by positioning the heater above the formation to be heated are ineffective from the standpoint of supplying heat to the formation. However, they also result in a heating, by radiation primarily, of the well borehole adjacent to the heater with the result that cement behind casing becomes heated sufficiently to undergo high temperature degradation.

It is an object of this invention to effect introduction of uniformly heated oxidizing fluid to an earth formation to initiate combustion in the formation. It is another object of this invention to heat uniformly a combustion-supporting gas with a well borehole heater preparatory to introduction of the gas into an earth formation adjacent to the heater. It is a more specific object of this invention to initiate combustion within an earth formation penetrated by a well borehole uniformly over substantially its entire face at approximately the same time.

The single figure is a vertical-sectional view, partly schematic, of one embodiment of my invention. I have discovered that the objects of the invention may be achieved by passing the fluid downwardly through the well borehole over a source of heat, isolating the heated fluid physically and thermally from the walls of the well borehole during passage over the source of heat, and thereafter passing the fluid upwardly through the well borehole and into the formation. A heater provided with a reflecting jacket may be employed. The fluid is passed between the heater and the reflecting jacket to the bottom portion of the heater. The reflecting jacket isolates the fluid physically and thermally from the walls of the well borehole lying adjacent to the heater. The fluid is then introduced into the formation.

Referring to the figure, well borehole 10 penetrates earth formation 11. As illustrated, the bottom of the well borehole is just below the bottom of the formation 11 and the well borehole is provided with liner 12 which extends from the bottom of the well. The liner may extend to the surface of the earth. However, the liner may not extend to the surface of the earth in which case it may be supported within the well borehole by a hanger. Perforations 13 are provided in the liner along its length adjacent to the formation 11. Casing 14 lines the wall of the well borehole to the top of the formation 11 and is cemented in place by means of cement 15.

Heater 20 comprises heater housing 21, heating element 22, and reflecting jacket 23. Reflecting jacket 23 extends along substantially the entire length of the housing 21. A plurality of collars 24 are welded or otherwise immovably joined to both the housing and the reflecting jacket and serve to support the reflecting jacket about the housing. The collars also serve to maintain the reflecting jacket in spaced relation with the housing and provide annulus 25 between the reflecting jacket and the housing. A plurality of channels 30 for the passage of fluid are provided in each of the collars. The heater is attached to cable 31.

Heating element 22 is positioned within the housing 21. The heating element forms a part of this invention. An electric heating element or a gas- or liquid-fuel fired heater may be used. Any conventional heating element of these types, or of any other type, may be employed and suitable provision may be made to supply electrical current or fuel to the heating element. Preferably, an electrical heating element is employed and the electrical current may be supplied through suitable conductors (not shown) made part of, or otherwise associated with, the cable 31.

The reflecting jacket 23 is, as the adjective indicates, capable of reflecting radiation. To effect this purpose, the jacket is made of a material which can be polished on the inner surface which would face heater housing 21 and the annulus 25. The polished surface will reflect thermal radiation. If desired, a polished, reflecting surface may be joined to the inner surface of the jacket in lieu of polishing the surface per se of the jacket. The jacket, also, is made of a material which, at least on its inner surface, is capable of resisting oxidation. A suitable material for the reflecting jacket is stainless steel.

To assist in resisting oxidation, the inner surface of the reflecting jacket may be provided with a surface coating or layer 32 of a transparent, vitreous material such as heat resistant glass, for example, "Pyrex" glass. The surface coating 32 is bonded or otherwise firmly joined to the surface of the reflecting jacket.

The outer surface of the jacket, i.e., the surface which would face the walls of the well borehole 10, is preferably, although not necessarily, also reflecting to thermal radiation. The outer surface of the reflecting jacket may be rendered reflective by polishing. If desired, a polished reflecting surface may be joined to the outer surface of the jacket in lieu of polishing the surface per se of the jacket. To assist in resisting oxidation, the outer surface of the jacket may be provided with a surface coating or layer 33 of a transparent, vitreous material similar to the surface coating or layer 32. This surface is bonded or otherwise firmly joined to the outer surface of the jacket.

The reflecting jacket 23 may be provided with a collar 34 extending entirely around the housing. There may
also be positioned within the well borehole an anchor 35 extending entirely around the wall of the well borehole. The collar 34 is adapted to contact the anchor 35 in fluid tight relationship when the heater 28 is positioned within the well borehole. There is thus effected a fluid-tight barrier to prevent flow of fluid downwardly from the well borehole along the outer surface of the reflecting jacket into the formation 11.

The reflecting jacket 23 serves several functions. One of its functions is to conduct fluid passed downwardly through the well for introduction into an earth formation along the heater case 21 through the annulus 25. As a result, all of the fluid which flows past the heater housing passes from the annulus at the same temperature. Another function is to provide heat by radiation to the fluid flowing through the annulus. A third function is to minimize heat transfer to the walls of the well borehole other than along the formation to be heated.

In operation, the heater is lowered by means of cable 31 through the well borehole 10 to a position opposite an earth formation to be heated. In the figure, formation 11 is the formation to be heated and this formation, as previously mentioned, is at the bottom of the well borehole. Should the well borehole extend downwardly below the formation to any great extent, or at least to penetrate a permeable formation below the formation to be heated, it is preferred to employ a packer or other sealing device within the well borehole. The packer or other sealing device would be positioned within the well borehole just below the formation to be heated to prevent damage to cement, if any, located below the formation to be heated. In any case, it will be positioned within the well borehole above the next lower permeable formation to prevent downward flow of fluid into the lower permeable formation. In the event the heater housing is not provided with collar 34 and anchor 35 is not provided on the liner 12, a packer or other sealing device will be employed between the top of the reflecting jacket and the walls of the well borehole to prevent fluid by-passing the heater and entering formation 11.

With the heater positioned within the well borehole, fluid is passed downwardly through the well borehole and the heater element 22 is energized, as by flow of electrical current thereto where an electrical heater is employed. The fluid passed downwardly through the well borehole passes through the channels 30 in the collars 24 and thus passes through the annulus 25 over the outer surface of the housing 21. The fluid, in passing over the outer surface of the housing, becomes heated and the heated fluid passes out of the annulus 25 to the bottom portion of the heater. The fluid then enters through the perforations 13 in the liner 12 into the formation 11. The arrows indicate the direction of fluid flow.

The reflecting jacket is exposed to radiant heat from the heater housing. However, since the inner surface of the jacket is reflective, this radiant heat from the heater housing will be reflected back to the fluid within the annulus 25. Thus, the temperature of the jacket along its length is more or less uniform. As a result, the fluid in its passage from the annulus 25 into the formation does not pick up any substantial amount of heat from the jacket. Further, where the outer surface of the jacket is also reflective, radiant heat from the formation 11 will also be reflected from the jacket.

Heated fluid will not enter, except for an insignificant amount by convection currents, the space 40 within the well bore-hole above the top level of the formation 11. The jacket will, as mentioned, reflect the radiant heat from the heater housing. Thus, the cement within the well borehole in the portion thereof adjacent the jacket will not be subjected to high temperatures causing degradation.

The fluid entering the formation through each of the perforations will, as indicated, be substantially at the same temperature. Thus, the entire face of the formation through which the heated fluid enters will be heated to substantially the same temperature. Where heating of the formation is employed to initiate combustion within the formation, the entire face of the formation will attain ignition temperature at substantially the same time and ignition will thus be effected simultaneously at all portions of the face of the formation.

Heating in accordance with the invention may be effected for various purposes. Thus, as described previously, heating may be for the purpose of initiating combustion within the earth formation. Heating may also be employed to dehydrate a clay formation. In water drive for the purpose of secondary recovery of hydrocarbon from a formation, the fluid employed will be water and the formation will be heated substantially along its face with the heated water. Heating can be employed in conjunction with acidizing, and with gas drive for the secondary recovery of hydrocarbon. Heating can also be employed for removal of paraffin.

Variations in the procedure and apparatus described may be made by those skilled in the art. For example, while the formation to be heated has been described as being covered by a liner in the well borehole, it will be understood that the formation need not be covered with a liner. Thus, the well borehole may be left open at the formation to be heated and the heated fluid passed from the heater into the open formation.

Having thus described my invention, it will be understood that such description has been by way of illustration and example and not by way of limitation, reference for the latter purpose being had to the appended claims. I claim:

1. A heater for an earth formation penetrated by a well borehole comprising a heater housing, a heating element within said housing, collars mounted upon said housing and provided with perforations for the passage of a fluid, and a jacket surrounding said housing and mounted upon said collars whereby said collars separate said housing from said jacket to provide a fluid conducting annulus between said housing and said jacket, said jacket having an inner surface facing said housing reflective of thermal radiation and a transparent coating of vitreous material fixed to the inner surface of said jacket.

2. A heater for an earth formation penetrated by a well borehole comprising a heater housing, a heating element within said housing, collars mounted upon said housing and provided with perforations for the passage of a fluid, and a jacket surrounding said housing and mounted upon said collars whereby said collars separate said housing from said jacket to provide a fluid conducting annulus between said housing and said jacket, said jacket having an inner surface facing said housing reflective of thermal radiation and provided with a transparent coating of vitreous material fixed to said inner surface and an outer surface reflective of thermal radiation and provided with a transparent coating of vitreous material fixed to said outer surface.

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