June 2, 1964 J. W. MARX 3,135,324

PREVENTION OF IGNITION IN AIR INJECTION WELLS

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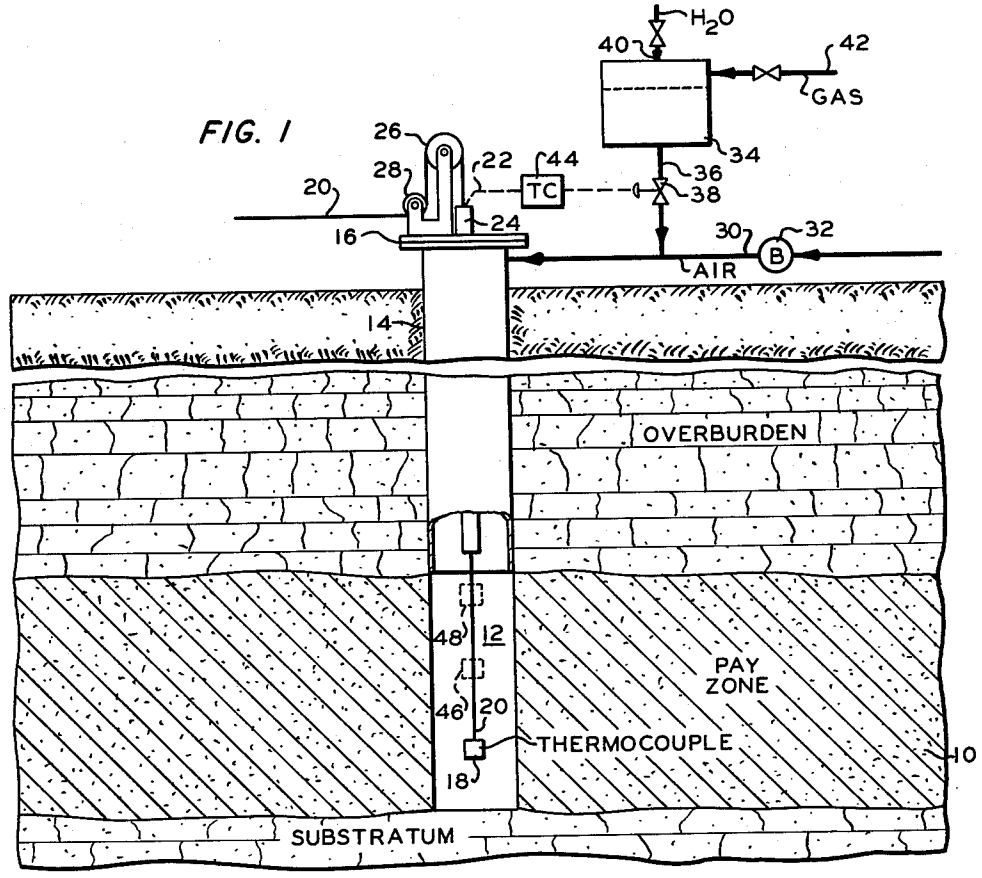
FIG. 1



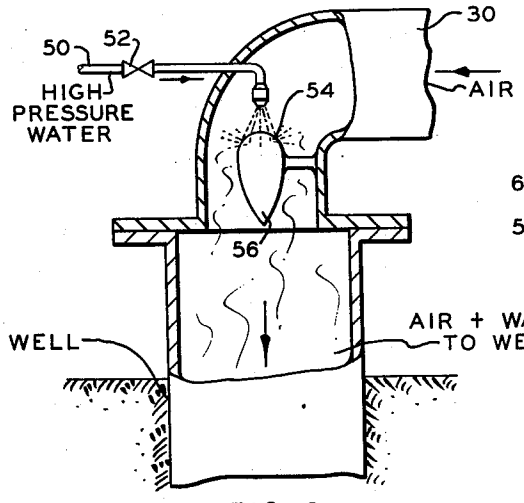


FIG. 2

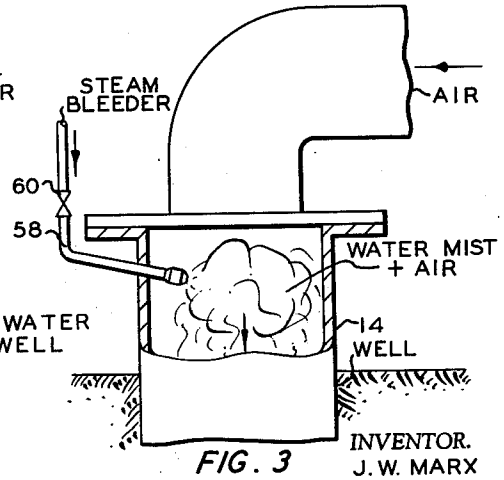


FIG. 3

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PREVENTION OF IGNITION IN AIR INJECTION WELLS

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6 Claims. (Cl. 166—4)

This invention relates to a process and apparatus for preventing undesirable or premature ignition of a carbonaceous stratum around an injection well in an in situ combustion operation involving injection of air or other combustion-supporting gas.

In situ combustion in the recovery of hydrocarbons from underground strata containing carbonaceous material is becoming more prevalent in the petroleum industry. In this technique of production, combustion is initiated in the carbonaceous stratum and the resulting combustion zone is caused to move thru the stratum by either inverse or direct air drive, whereby the heat of combustion of a substantial proportion of the hydrocarbon in the stratum drives out and usually upgrades a substantial proportion of the unburned hydrocarbon material.

The ignition of carbonaceous material in a stratum around a borehole therein followed by injection of air thru the ignition borehole and recovery of product hydrocarbons and combustion gas thru another borehole in the stratum is a direct air drive process for effecting in situ combustion and recovery of hydrocarbons from the stratum. In this type of operation the stratum frequently plugs in front of the combustion zone because a heavy viscous liquid bank of hydrocarbon collects in the stratum in advance of the combustion zone which prevents movement of air to the combustion process. To overcome this difficulty and to permit the continued progress of the combustion zone thru the stratum, inverse air injection has been resorted to. By this technique, a combustion zone is established around an ignition borehole by any suitable means and air is fed thru the stratum to the combustion zone from one or more surrounding boreholes.

In the process of recovering oil by underground combustion, it is generally necessary to inject air into the porous, permeable, oil-bearing rock for extended periods. Field test results to date indicate that spontaneous ignition may occur during such air injection at high pressures. For example, a petroleum company recently conducted an underground combustion field test in the South Belridge field, Kern County, California, in which premature spontaneous ignition occurred at the central injection well in a direct injection system. Subsequent performance indicated that this ignition was limited to the upper portion of the pay zone, and that this partial ignition detracted from the field performance in that it reduced the volumetric sweep efficiency of the direct drive front.

Spontaneous ignition at air injection wells in any counterflow combustion process would have even worse effects as it would force immediate shutdown and possibly result in loss of a whole well pattern since there would be burning at the wrong places in the pattern.

This invention is concerned with a method and apparatus for preventing undesirable or premature spontaneous combustion in either a direct or inverse drive in situ combustion process during injection of combustion-supporting, oxygen-containing gas thru an injection well in the stratum being produced.

Accordingly, it is an object of the invention to provide a process or method and apparatus for preventing spontaneous combustion in a stratum around an injection borehole during injection of air or other oxygen-containing, combustion-supporting gas into the stratum. Another object is to provide a method and means for maintaining the temperature of a stratum adjacent an injection borehole, during air injection, below ignition temperature at ambient conditions. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises sensing the temperature in an injection borehole within the stratum to be produced while injecting air or other combustion-supporting gas and, as the temperature approaches the ignition temperature of the carbonaceous hydrocarbon material in the wall of the borehole, injecting into the injected gas a fine dispersion of water such as a water aerosol in sufficient quantity or at a sufficient rate to maintain the temperature at a safe margin below the ignition temperature. The apparatus comprises, in combination with a cased injection well extending into a stratum to be produced, a temperature sensing device in the well within the stratum, a supply of water under sufficient pressure for injection and dispersion, a line leading from the water supply into the well, a valve in this line, and means responsive to the sensed temperature of said sensing device in operative control of said valve.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing of which FIGURE 1 is an elevation thru a section of stratum showing an arrangement of apparatus in accordance with the invention; FIGURE 2 is an elevation in partial section showing another embodiment of the water dispersion means; and FIGURE 3 is a view similar to FIGURE 2, showing another embodiment of the water injection means.

Referring to FIGURE 1, a carbonaceous stratum **10**, such as an oil sand, is penetrated by a well or borehole **12** provided with a casing **14** extending to the stratum, and a wellhead **16**. In one embodiment a thermocouple **18** is suspended on a cable **20**, including an electrical conductor cable **22**, thru tubing **24**. Tubing **24** is provided with valve means (not shown) for maintaining an air tight seal around the cable. Movement of the cable up and down in the well is facilitated by pulleys **26** and **28** or by other suitable means.

An air line **30** connects with casing **14** below the wellhead as shown or this line may pass thru the wellhead, similarly to tubing **24**. A blower **32**, or other suitable means, passes a stream of pressurized air thru line **30** into the well. A source of water under pressure, such as a tank **34**, is connected with the well either directly or thru line **30** by means of line **36** containing motor valve **38**. Water is admitted to tank **34** from line **40** as needed and pressurizing gas is passed into tank **34** thru line **42**.

A temperature controller **44** is connected with cable **22** and with motor valve **38**. This instrument **44** is set to maintain a suitable well temperature as sensed by the thermocouple **18**, such as 300 or 400° F.

It is also feasible to utilize a series of vertically spaced apart thermocouples such as **18**, **46**, and **48** in fixed or vertically adjustable position within stratum **10**. In this arrangement, the maximum temperature sensed by the series of thermocouples actuates temperature controller **44** which operates valve **38** to introduce dispersion of water into the injected gas.

IN FIGURE 2, a high pressure water line **50** containing flow control valve **52** leads into air line **30** and is positioned so as to direct water onto a hemispherical solid surface **54** on device **56**. This arrangement of apparatus assures the formation of a very finely divided water mist which is carried by the injected air into the well.

In FIGURE 3, a steam line **58** leads thru casing **14** into the path of the injected air and is provided with a flow control valve **60**. This embodiment of the apparatus and process bleeds steam into the injection air to provide water droplets needed to maintain control of the temperature of the stratum in the well.

It is sometimes necessary to utilize an air injection pressure of several hundred to 1000 p.s.i.g. or more and it is, of course, essential to have available water pressure well above the air injection pressure. In such cases the steam pressure in line 58 and the water pressure in lines 59 and 36 must be adequate to effect injection and dispersion of the water against the pressure within the air line or well.

The water aerosol or mist is injected continuously in small quantities or intermittently in larger quantities automatically or by hand operation of valve 38 or the corresponding valves in the other embodiments of the apparatus. The quantity of water to be introduced varies from about an ounce to 10 or more pounds per 1,000 standard cubic feet of gas, depending on the affinity of the reservoir hydrocarbon for oxygen, the injection pressure, and the nature of the emergency involved. Native petroleum and bitumens vary greatly in their oxygen affinity, i.e., their tendency to ignite spontaneously. Heavy crude from Kern County, California, exhibits an oxygen demand of the order of 1,000 times as much as some typical Missouri bitumens. Such crude definitely tends to ignite spontaneously upon prolonged exposure to high pressure air and, as previously pointed out, spontaneous ignition actually did occur during preliminary air injection operations on a recent underground combustion field test in the South Belridge field. While some crudes and bitumens exhibit far less tendency to ignite spontaneously than the Kern County example, it is good insurance to have available in all underground combustion operations means for injecting finely dispersed water into the injection gas.

It might be well to note that the combustion front can itself tolerate small quantities of well-dispersed water, so that injection well bores can thus be kept cool without extinguishing the counterflow combustion front.

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. In a process for pressurizing a stratum with an oxygen-containing, combustion-supporting gas prior to establishing a combustion zone therein by injecting said gas thru an injection well and producing fluid thru at least one offset well wherein spontaneous combustion tends to occur adjacent said injection well, the method of preventing said spontaneous combustion which comprises injecting into said gas passing thru said injection well and the surrounding stratum a fine dispersion of water in adequate concentration to maintain the temperature of said stratum around said injection well below ignition temperature.

2. The process of claim 1 including the steps of sensing the temperature in said injection well adjacent said stratum and regulating the rate of water injection so as to maintain said temperature below ignition temperature.

3. The process of claim 2 wherein a temperature sensing device is moved vertically along said stratum between the top and bottom thereof, at least periodically, to sense its temperature at various levels and the maximum sensed temperature is used to regulate the flow of water.

4. The process of claim 1 wherein the amount of water injected is in the range of 1 oz. to 10 pounds per 1000 standard cubic feet of gas.

5. The process of claim 1 wherein the water is injected by bleeding steam into said well.

6. The process of claim 1 including the subsequent steps of conitnuing the injection of said gas until said stratum is pressurized and O_2 is passing into said production well in sufficient concentration to support combustion of said stratum; thereafter, igniting said stratum adjacent said production well; and continuing the injection of said gas and said dispersion into said stratum thru said injection well so as to prevent ignition of said stratum adjacent said injection well while effecting inverse in situ combustion in said stratum.

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