

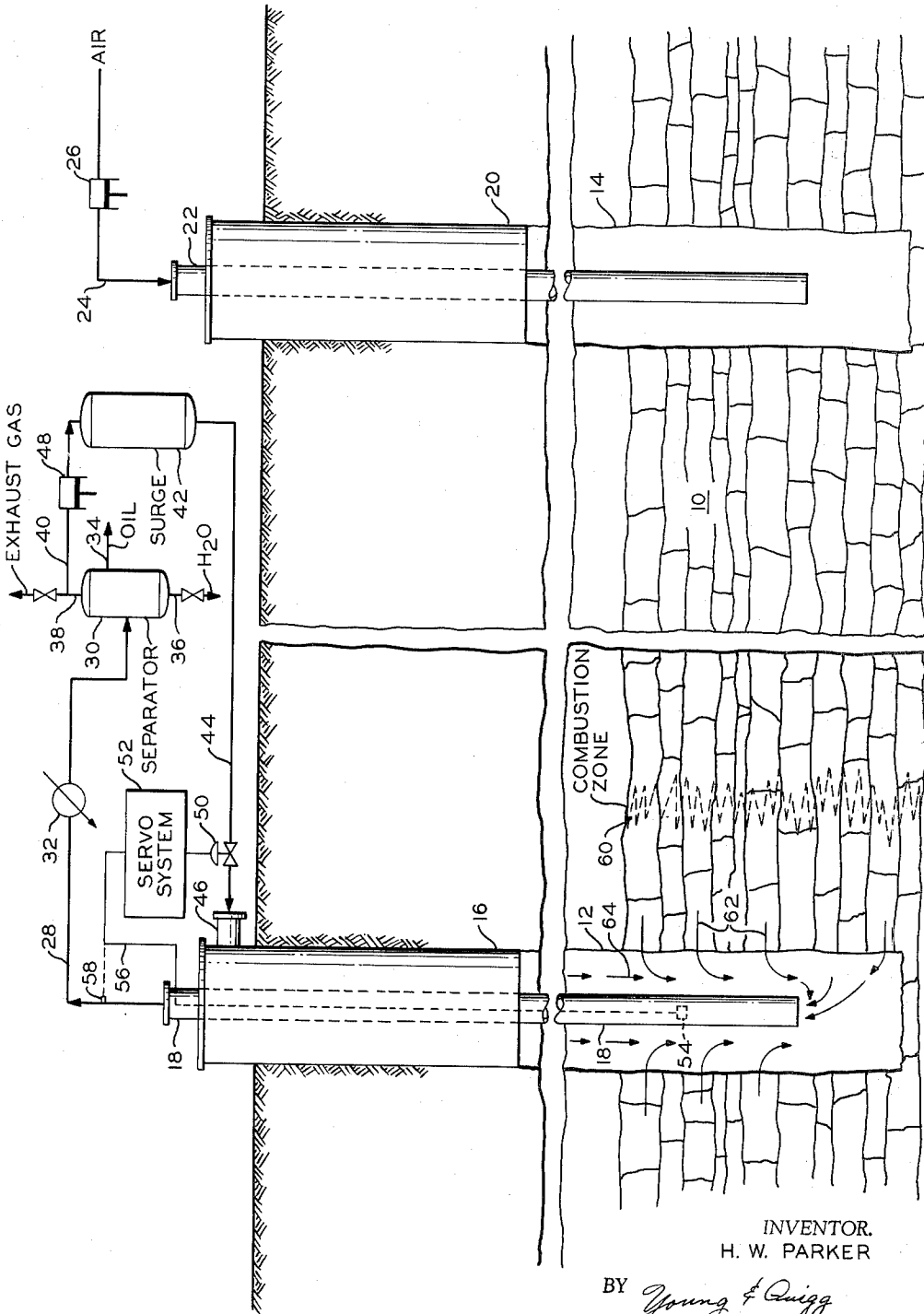
Aug. 24, 1965

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3,202,219

APPARATUS FOR PROTECTION OF IN SITU COMBUSTION WELLS

Filed Feb. 9, 1962



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APPARATUS FOR PROTECTION OF IN SITU COMBUSTION WELLS

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Filed Feb. 9, 1962, Ser. No. 172,330
3 Claims. (Cl. 166—53)

This invention relates to an apparatus for protection of production wells utilized in producing carbonaceous strata by in situ combustion.

The use of in situ combustion to produce hydrocarbons from oil-containing strata is becoming more prevalent in the petroleum industry. In effecting this type of production, the stratum to be produced is ignited around a well bore penetrating same and the resulting combustion zone is moved into the stratum toward one or more offset wells therein. In some applications, air or other combustion-supporting gas is injected thru the offset wells and thru the stratum to the combustion zone which is caused to move toward the offset wells inversely to the flow of air. In this technique of operation, the well around which the combustion is initiated also functions as a production well. Other applications of the in situ combustion process inject air thru the well around which combustion is initiated so as to drive the combustion zone by direct drive toward the offset wells. In this manner, the offset well or wells become production wells.

In either case (direct or inverse drive of the combustion front) hot produced gases flow into the production well, from the beginning of production when utilizing inverse drive, and somewhat later in the production operation when utilizing direct drive of the combustion zone. The produced gases, particularly during inverse drive reach temperatures as high as 2,000° F. and are usually at least 800° in temperature. Such high temperatures have a deleterious effect upon production well equipment and sometimes fuse the rock around the production well so as to reduce the permeability of the borehole wall sufficiently to interfere with production.

It is also desirable to maintain the production well temperature within reasonable limits because of the fact that a certain proportion of the injected air appears in the production borehole by bypassing the combustion zone and the presence of the oxygen in the production well in admixture with hot produced hydrocarbons results in combustion of the hydrocarbon which not only destroys valuable production but also increases the temperature in the well. This invention is concerned with a method and apparatus for effectively controlling the production well temperature within limits which avoid damage to the well equipment and assure preservation of the produced hydrocarbons.

Accordingly, it is an object of the invention to provide an apparatus for controlling production well temperatures. Another object of the invention is to provide an apparatus for controlling production well temperatures utilizing coolant produced in the process. A further object is to protect well equipment during in situ combustion production and preserve produced hydrocarbons. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises an apparatus for cooling the hot effluent from a production well being utilized in an in situ combustion process to condense most of the produced hydrocarbons, separating the condensed liquid from the effluent, and passing the uncondensed gases into the production well within the stratum being produced so as to mix the cooled gases with the hot produced gases and reduce the temperature thereof to

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a range which does not deleteriously affect the well equipment and which prevents combustion of hydrocarbons with bypassed oxygen as these gases enter the well. The uncondensed gases from the process consist principally of CO₂ and nitrogen, the major portion of the produced hydrocarbons having been condensed from the effluent by the quenching and/or cooling step applied to the produced gases.

The amount or rate of recycle of uncondensed gases from the cooled well effluent depends upon the rate of production of hot gases in the production well and the temperature level of these gases entering the well. The temperature of the produced gases, preferably at a location within the lower end of the tubing string conducting the produced gases to the well head, is sensed and the sensed temperature is utilized to control the rate of flow of cool gas into the well so as to maintain the temperature at the sensing point within a safe range, the broad range being 250–750° F. and, preferably, 500 to 650° F.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing which is an elevation in partial section illustrating a preferred arrangement of apparatus for controlling the temperature in the production well.

Referring to the drawing a carbonaceous stratum 10 is penetrated by a production well 12 and an offset well 14. Well 12 is provided with a casing 16 and a tubing string 18 extending from within stratum 10, preferably, from a lower level therein, thru the well head. Well 14 is also provided with a casing 20 and a tubing string 22 for injection of air or other combustion-supporting gas from line 24 in which is positioned a blower or compressor 26.

A production or effluent line 28 connects tubing string 18 with a separator 30. A condenser or other cooling means 32 is positioned in line 28. Cooler 32 may comprise a quench vessel into which is injected a water spray or other liquid or gaseous coolant or it may comprise an indirect heat exchanger. The essential function of this piece of equipment is to reduce the temperature of the effluent passing therethru to a level which condenses most of the hydrocarbon material in the effluent so that the liquid hydrocarbon may be withdrawn from separator 30 via line 34. Condensed water is vented thru line 36 and uncondensed gases are vented thru line 38.

The recycle system comprises conduit 40, surge tank 42, and conduit 44 which connects with the annulus of the well thru connector 46. A compressor 48 in line 40 maintains a relatively constant pressure in surge tank 42, drawing gas from exhaust line 38.

A motor valve 50 in conduit 44 controls the flow rate therein and is controlled or regulated by a servo-system 52 which is operatively connected therewith. A thermocouple or other temperature sensing means 54 positioned in the well adjacent the stratum, such as in the lower end of tubing 18, is connected by means of line 56 with the servo-system. An alternative but less effective location of the thermocouple is at 58 in line 28. The servo-system may be either electric or pneumatic, both systems being in conventional use for receiving a signal in response to a sensed temperature and emitting a signal which is used to control a motor valve. The motor valve may be either pneumatically or electrically operated as both types are commercially available.

In operation, a combustion zone 60 is being moved thru the stratum lying between wells 12 and 14 by air injected thru line 24 and tubing string 22. If the process is a direct drive process, the combustion zone is initiated around well 14 so that the combustion zone is moved toward well 12. In the event an inverse drive is being utilized, the stratum is ignited around well 12 and the resulting combustion zone is being moved toward well

14 inversely to the flow of air thru the stratum. In either event hot produced gases are flowing from the combustion zone into well 12 and into the lower end of tubing string 18 as shown by the arrows 62. The hot gases pass thru the tubing 18 and line 28 thru cooler and condenser 32 to separator 30. The effluent is cooled to a temperature below about 200°, the temperature of cooling depending upon the type of hydrocarbons being produced. Cooled uncondensed gases are recycled from line 38 thru line 40, compressor 48, surge tank 42 and conduit 44 under the control of valve 50 into the well annulus which leads to the lower end of tubing 18. This recycling of cooled gas passes down the annulus as shown by arrows 64 and causes mixing of the cooled gas with the produced gases and tempering of the latter so that the sensed temperature at 54 is maintained within the range of 250 to 750° F. and preferably, 500 to 650° F.

It is desirable to maintain the temperature of the effluent gas in tubing string 18 and line 28 at a sufficiently high temperature so that substantially all of the produced hydrocarbons flow out of the well in vapor form so that pumping equipment in the well is not required. Another advantage in maintaining the effluent gas temperature relatively high, but below temperatures which prevent combustion with bypassed oxygen and damage to the production well and its equipment, lies in maintaining minimum volume of gas (measured at standard temperature and pressure) passing thru the production line. If more recycled gas is utilized in order to maintain low temperature in the effluent line, this imposes additional volume requirements in the separation equipment. Hence, it is advantageous to use as small a volume of temperature controlled gas as possible and still maintain the temperature below a safe level.

Thus it can be seen that the process of the invention utilizes readily available gas in line 38 at suitable temperature for cooling in the production well. This recycled gas is principally nitrogen and CO₂ and is non-deleterious to the equipment and in the produced gases.

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. Apparatus comprising in combination a tubing string in a production well penetrating a combustible carbonaceous stratum, said string extending thru the well head at least to the level of said stratum; an effluent line connected with said tubing string at the well head; cooling means in said effluent line for liquifying hydrocarbons passed therethru; separation means in said effluent line for separating condensed liquids from uncondensed gases, including separate outlets for water, oil, and uncondensed gases; conduit means connecting the separate outlet for uncondensed gases of said separation means with the well bore within said stratum having a compressor therein for passing uncondensed gases from said separation means into hot produced gases passing from said stratum to the lower end of said tubing string; flow control means in said conduit; temperature sensing means for sensing the temperature of effluent hot gases; and means for regulating said flow control means in response to the sensed temperature so as to control said temperature within a desired range.

2. The apparatus of claim 1 wherein said temperature sensing means is in said well adjacent said stratum.

3. The apparatus of claim 1 wherein said temperature sensing means is in said effluent line.

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