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COMBUSTION IN WELL WITH STEEL LINER

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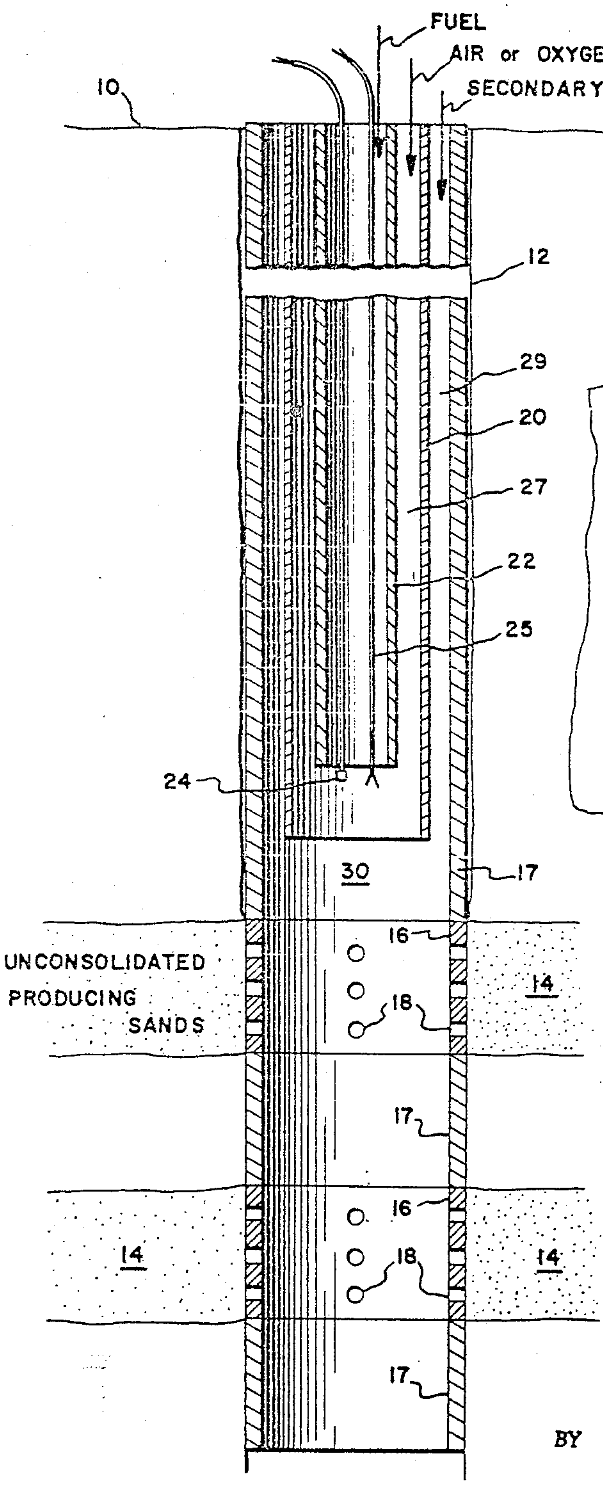
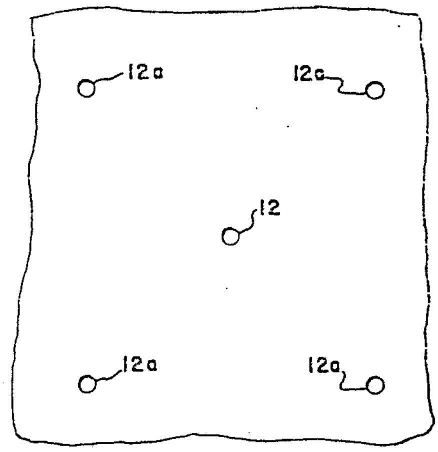


FIG. 1.

FIG. 2.



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COMBUSTION IN WELL WITH STEEL LINER

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5 Claims. (Cl. 166—39)

This invention relates to a process for the recovery of oil and gas from subterranean formations. More particularly, the present invention is concerned with a process for the recovery of the oil and gas by thermal recovery means from subterranean oil bearing formations characterized by an unconsolidated structure or friable structure such as is indigenous to California.

It is well known that the recovery of oil from subterranean formations is in general an incomplete process. It is further known that energy input is required to bring oil into a well bore from remote portions of a bearing formation. Practices adapted to raise the percentage recovery of oil from a given formation have included repressuring, such as by gas and air, mechanically pumping and water flooding. Another method of recovery comprises the establishment of and propagation of a heat wave within a producing formation from an input well as a means for recovering components thereby driven to an output well. A particularly advantageous method incorporating the heat wave principle is shown in the patent art by the Smith et al. Patent No. 2,642,943. The present invention relates in particular to a process which is adapted to employ the heat wave type recovery process such as that of the Smith et al. patent.

The present invention is predicated on the fact that known methods of establishing heat waves in underground formations are inadequate when dealing with oil bearing strata comprising unconsolidated sands or friable structures. In a well located in unconsolidated strata it is necessary to keep the well casing and liner in place to avoid collapse of the bore walls. In many cases it is even necessary to gravel pack around the liner to avoid movement of sands into the bore through the liner slots provided for passage of oil or gas or their mixtures into the bore. Thus, in establishing and propagating a heat wave from an input well in unconsolidated sands, the casing and liner must remain in place to support the bore hole walls. The same is true in friable rock strata which, although consolidated, can move or collapse due to various forces such as heat and pressure. The method of the present invention is concerned with establishing a heat wave in a formation in such rock strata with the casing and liner in place in the bore hole generally opposite the strata in which the heat wave is to be established. The method is also applicable in establishing a heat wave in strata which have no particular tendency to move or collapse; however, the advantages derived by having a liner opposite the producing formation and establishing the heat wave with the liner in place would not normally be sufficient to justify the extra expense and care necessary in the present method over the use of the conventional manner of establishing the wave by firing the well opposite a bare formation. In the method of directly firing a well bore, burner exhaust gas temperatures of about 1200 to 2000° F. or more are generally obtained which sometimes is effective in cleaning an adjacent formation resulting in increased permeability through carbon burn-out; however, the use of such temperatures within a liner in establishing a heat wave across a lined bore would cause undue deformation and oxidation of the steel liner and cave-in of the well bore.

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The initial heating of strata to establish a heat wave surrounding a bore hole with the liner in place is accomplished according to the present invention at certain defined conditions of temperature and activity of the atmosphere present. Upon establishment of a heated area in this manner, the heated portion of the unconsolidated sands must be moved away from the bore hole and a heat wave established at a distance from the bore hole under conditions such that it is relatively cool in and immediately adjacent the bore hole. The heat wave can then be propagated and otherwise run to completion in any manner desired but preferably by the process described in the Smith et al. patent above-identified and the process described in the co-pending application of Pelzer, Serial No. 414,489, filed March 5, 1954.

The present invention thus is a method for the recovery of oil and gas from oil bearing underground formations through establishing a heat wave from an input well with a liner opposing the strata of propagation and particularly where the formation or strata of propagation is characterized by an unconsolidated nature or by a structure which will result in unconsolidated materials upon the application of heat, pressure or other extreme conditions, i. e. friable sands. The process is effected by establishing a heated zone of formation surrounding the input well in a manner so that the temperature of the gases entering the strata heat the well casing and the immediately adjacent sands to at least about 650° F. but not over about 900° F. At these high temperatures it is essential that no substantial amount of free oxygen, e. g. not greater than about 2 volume percent, be present in the gases contacting the liner and passing into the adjacent formation. These gases are inert to combustion and will include carbon dioxide, fuel gas, methane, nitrogen, etc. and as indicated no or only small amounts of oxygen. Although we prefer substantially no free oxygen in these gases, the permissible amount of oxygen which can be tolerated is variable and depends primarily upon temperature and character of carbon deposits in the adjacent strata. Care should be observed to avoid conditions which are substantially deleterious to the liner and/or which would oxidize sufficient carbon in the formation adjacent the liner to raise the liner temperature above about 900° F. Heating under such conditions is continued until a heated zone is established which extends radially from the hole.

When the heated zone is obtained, burning within the liner is discontinued by discontinuing the supply of air or other oxygen supply. The bore hole and the immediately adjacent strata are at a temperature of at least about 650° F. and preferably below about 900° F. After cooling the bore hole and adjacent strata to below about 400 to 650° F., as by passage of inert gases of the type described into the strata, a combustible mixture of gases is passed into the formation. The combustible gases must be below about 650° F., and preferably below about 400° F., and, for example, can be unheated to exert a cooling effect so that upon passing through the well bore liner and the immediately adjacent strata they effect a further cooling of the well bore liner, casing and strata by heat transfer to the gases. Upon reaching the frontal area of the heated zone the gases are of sufficient temperature to ignite and initiate and maintain the heat wave.

The distance the heated zone will extend from the bore at the conclusion of the heating step can vary widely. This zone will in all cases be wide enough so that the cooling gases will not unduly dissipate the heat wave or front while cooling down the bore hole and immediately adjacent strata. Actually the cooling gases move the heat wave outwardly from the input well and until combustion gases are introduced the cooling gases will exert a temperature reducing effect towards the heat front. When the bore hole is cooled to less than about 650° F., or less than about 400° F., as the case may be, and sufficient of the adjacent strata is also cooled to avoid carbon burn-out which would raise the liner temperature above about 650° F., the combustion gases are introduced to propagate the heat wave and recover oil or gas or their mixtures from the output well. Thus, the width or radius of the heated wave will provide for a sufficient cooling zone and yet after cooling the wave must be hot enough to support combustion. During the heating step it is advantageous to obtain the 650 to 900° F. temperature for at least about a five foot radius from the bore hole and preferably at least about ten feet. Cooling gases are preferably introduced until the liner and at least about the adjacent three feet of strata are cooled below about 650° F. and preferably below about 400° F.

The invention will be described further by reference to the attached drawing in which Figure 1 shows a well bore in communication with unconsolidated producing sands of the type described partly in section and partly in elevation and shows one type of burner apparatus (schematic) and liner which can be used with advantage in practicing the present invention; and

Figure 2 is a typical five-spot pattern of input and output wells.

Referring now to the drawing, the numeral **10** represents the earth's surface through which an input well bore **12** has been drilled to provide communication with oil-producing formations **14**. A plurality of output wells **12*a*** are provided in spaced relation with the input well, as in a five-spot pattern, see Figure 2, to facilitate recovery of materials from the strata. The unconsolidated nature of the producing strata requires the use of liners **16** opposite the strata and casing **17** which extend above and below the producing strata. Liners **16** are, in general, cylindrically-shaped members characterized by shape and size to fit somewhat snugly within a bore hole and close off the bore hole from the unconsolidated sands. This may be accomplished with standard liners by utilizing packing means such as gravel (not shown) and serves to prevent sands from entering the bore hole and interfering with production. This is especially important in view of the fact that oil bearing formations comprising unconsolidated sands generally occur at a plurality of vertically spaced points at any given area or are of such great thickness they are treated as being a plurality of strata. For efficient production under such circumstances communication with all of the producing strata may be effected. However, the filling of a bore hole by sands pouring into it from a higher producing strata obviously would be disadvantageous. To prevent this, liners such as members **16** have found wide use. Where liners are cemented in place, conventional expansion joints (not shown) are used in practicing the present invention as the temperature reached may be damaging. Liners **16** are provided with slot-like apertures **18** to provide the necessary controlled communication of the well bore with the strata.

Disposed within the bore hole **12** to a distance extending to immediately above the slotted portion of a liner is a secondary casing member **20**. An additional tubular member **22** is disposed centrally within casing member **20**. An igniting means, such as indicated by numeral **24**, advantageously is employed and disposed, for example, at the lower extremity of the central tubing member **22**. The numeral **25** represents a thermocouple or other temperature indicating means provided to follow down hole temperatures. To establish the heated portion of the strata in accordance with the present invention a fuel such as natural gas or a low molecular weight hydrocarbon gas, for example methane, is passed from the earth's surface to the burner area through the centrally

disposed tubular member **22**. An oxygen-containing gas is passed to the burner area through the annular space **27** defined by tubular members **22** and **20**. As the fuel and oxygen mix in the presence of the actuated igniter means **24**, burning occurs with concomitant release of heat. A secondary gas is passed into the well bore simultaneously with the air and fuel in the annular space **29** defined by casing members **20** and **17**. The secondary gas mixes with the hot combustion products produced by the burning of the fuel and serves to dilute it to cool the gases to the point, i.e. below about 900° F., where they can be permitted to enter liner slots **18** and thus the formation. To facilitate this mixing, a mixing space **30** can be provided between the burner area and liner slots; generally a space of about 2 to 3 feet or more is adequate.

In heating the strata about the well bore, about 40 to 60 parts of secondary gas can be used for each part of fuel burned in order to cool the combustion products from their high temperature, i. e. about 4000° F., to the desired temperature, that is, a minimum of about 650° F. and a maximum of about 900° F. The quantity of fuel employed and the quality of the oxygen-containing gas and of the secondary gas are such that no substantial free oxygen is permitted to exist between the general burning area and the liner slots previously described. This is accomplished to advantage by employing slightly less oxygen than the stoichiometric quantity necessary for complete combustion of the primary fuel. By this procedure, all of the free oxygen will be combined and converted to an inert form. By limiting the maximum temperature to about 900° F. and having substantially no oxygen present, lampblack formation and oxidation of the metal liner will not normally occur. If conditions obtaining are such that lampblack formation can occur at 900° F. and below, it may be desirable to operate under conditions such that no unburned fuel contacts the liner at temperatures above about 400 to 600° F.

The cooling step which follows immediately upon establishing sufficient heated area about the well bore is effected by the use of inert gases, for example, low molecular weight hydrocarbon gases or nitrogen or carbon dioxide or other inerts which do not contain substantial free oxygen. By inert gases is meant a gas or mixture of gases having a composition which is not combustible under the conditions encountered. While it is possible to employ gases containing small quantities of oxygen, for instance up to about 2 percent, during the cooling step this can occur only when the conditions defined by the nature of carbonaceous materials in the strata adjacent the well bore and temperatures are such that undue burning or temperature rise does not occur. While recognizing this possibility of use of small quantities of oxygen we prefer to avoid the presence of oxygen as it does not contribute to cooling in any unique or necessary manner and can possibly complicate matters by effecting combustion and resulting in temperature rise. Cooling can be accomplished by cutting off the supply of fuel and oxygen-containing gas while continuing to supply secondary gas to the system and is continued until the well bore liner and the immediately adjacent strata are cooled to a temperature of say below about 650° F. and preferably below about 400° F. At this point, as a generality, it is possible to introduce a combustible mixture without effecting combustion at the liner or in the first several feet of cooled strata. This combustible mixture to advantage is at a temperature below that of the strata immediately adjacent the well bore so that further cooling is accomplished by its passage and heat utilization is more efficient as a result of the heating of the combustible mixture as it passes through the strata to the heat wave front. By combustible it is meant a free oxygen-containing gas, advantageously containing from about 2 to 6 volume percent of oxygen, which, upon contact with the heat wave frontal area at the temperature occuring there, will burn thereby raising the temperature so that with further quantities of the gas it is capable of effecting burning of residual carbonaceous materials remaining in the strata at that point, that is, materials unmoved by the influence of the previous thermal drive effected in heating the strata. As the wave is now removed from the general area of the well bore the temperature can be permitted to rise and a heat wave, for example, in the sense of the Smith et al. process or the Pelzer process previously identified can be propagated.

In practicing the invention, an input well and at least one output well are provided for communication with the oil bearing formation. Existing wells can be used though it is frequently more advantageous to drill special wells for practicing the invention since the spacing desired can then be obtained with greater ease. The wells are cased in the manner which is usual for formations of the type under consideration with slots being provided in the liners at formation level. Heat is then introduced into the strata to establish the first heated zone previously described. Heat can be introduced by burning gases at the earth's surface and passing the heated combustion products into the well bore and into the formation; or, and preferably, heat can be supplied by burning a fuel in the well bore at approximately formation level by use of a burner and igniter apparatus in the manner described above.

Employing a burner and igniter apparatus, sufficient concentric pipes are placed within the well to provide two separate annular spaces and a central conduit. A thermocouple or other temperature indicating means and an igniter means, each with the necessary leads, are lowered through the central conduit. Fuel, e. g. methane or natural gas, is passed into the well bore through the central conduit while air, or other free oxygen-containing gas, and a secondary mixing gas such as a flue gas are passed into the well bore separately through annular spaces as have been described. A primary gas containing about 50 to 90 B. t. u. per cubic foot of mixture normally is sufficient to provide the necessary heat. A typical concentration of fuel, air and secondary gas mixture which can be used contains about 2 percent fuel and 4 percent oxygen. Other concentrations can, of course, be employed providing all free oxygen is consumed and sufficient secondary gas is present to cool the combustion products to at least as low as 900° F. before they contact the liner and strata. After ignition has begun the igniter apparatus can be withdrawn slightly to prevent damage to it while the thermocouple is permitted to remain in the flame; a separate thermocouple in contact with the liner can be employed to follow liner temperatures if desired. After sufficient burning has been effected to heat the strata radially for say 10 feet, which normally occurs in about 3 to 10 days or more, fuel and air introduction are stopped while the supply of secondary gas is continued to cool the well bore, casing and the first few feet, e. g. 4 feet, of the heated zone.

The well bore and the first few feet of formation are cooled, i. e. to below about 650° F. and preferably below about 400° F., in about 12 to 36 hours when using the secondary gas as coolant. Combustion within the strata is then initiated by passing unheated oxygen-containing gases and fuel into the strata from the well bore being careful to avoid use of explosive mixtures where low molecular weight hydrocarbons are used as fuel. A mixture containing about 10 to 40 or more B. t. u. per cubic foot of air normally is sufficient to widen and move the heated annular heat wave in the formation. The cold gas mixture further cools the bore, liner and strata while becoming heated and upon reaching the front of the heated zone is at sufficient temperatures to ignite spontaneously, thereby further heating the strata at the wave front. This burning is continued by continuing the supply of air and fuel; when the temperature in the wave is sufficient to permit burning the residual carbonaceous materials of the strata, fuel supply to the strata can be discontinued if desired. Oxygen supply is, of course, continued so long as the maintenance and propagation of the heat wave is desired, or until such point that the heat wave can be completed by switching to an in situ steam drive effected by passing water into contact with the wave in the manner described in the Pelzer application.

Frequently, as noted above, unconsolidated producing sands are of great vertical width or occur on a plurality of levels or both. The present invention can be practiced under such circumstances simply by establishing heat waves in the manner described in one area or formation at a time, packing it off from outside communication (in the input well) except for supply of the propagation gases and then performing the process on the next formation or zone. For this purpose the igniter apparatus can be adapted to move vertically in the well bore so that it can be placed at the formation desired. Alternatively, a large section of the lined bore hole can be heated and then cooled through lowering of the burner apparatus and then propagation of the wave effected through the treated section.

What is claimed is:

1. In a method for the recovery of oil and gas from an oil bearing underground formation having a steel liner adjacent a strata in which a heat wave is to be propagated wherein an input well provides communication with the bearing formation and recovery of products is effected by establishing and propagating a heat wave within the formation, the method of establishing a heat wave which comprises establishing a heated zone of strata about said input well by passing substantially inert gases heated to an elevated temperature of at least about 650° F. but not in excess of about 900° F. from said input well bore through said liner and into said formation, then cooling said input well bore and a portion of the heated zone of formation immediately adjacent said input well in the absence of a substantial amount of free oxygen and until the temperature of said input well and a portion of the immediately adjacent formation is below about 650° F. and then establishing and propagating a heat wave within said formation by passing an oxygen-containing combustion gas into said input well and into said formation to the heated front of said formation and burning combustibes there.

2. The method of claim 1 in which said heated inert gases are obtained by burning a fuel with air containing not more than a stoichiometric quantity of oxygen and the resulting combustion products are mixed with sufficient secondary gas to result in a gaseous mixture of the desired temperature.

3. The method of claim 1 in which the temperature of cooling is below about 400° F.

4. The method of claim 3 in which the initially-heated zone extends radially from said input well for at least about five feet and the cooled portion of the formation is at a temperature of below about 400° F. and extends radially from said input well for at least about three feet while leaving a heated front hot enough to support combustion of the oxygen-containing combustion gas passed into the formation.

5. The method of claim 3 in which the initially-heated zone extends radially from said input well for at least about ten feet and the cooled portion of the formation is at a temperature of below about 400° F. and extends radially from said input well for at least about three feet while leaving a heated front hot enough to support combustion of the oxygen-containing combustion gas passed into the formation.

References Cited in the file of this patent

UNITED STATES PATENTS

2,506,853	Berg et al.	May 6, 1950
2,642,943	Smith	June 23, 1953
2,668,592	Piros et al.	Feb. 9, 1954
2,788,071	Pelzer	Apr. 9, 1957