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IN SITU COMBUSTION OF LIGNITE

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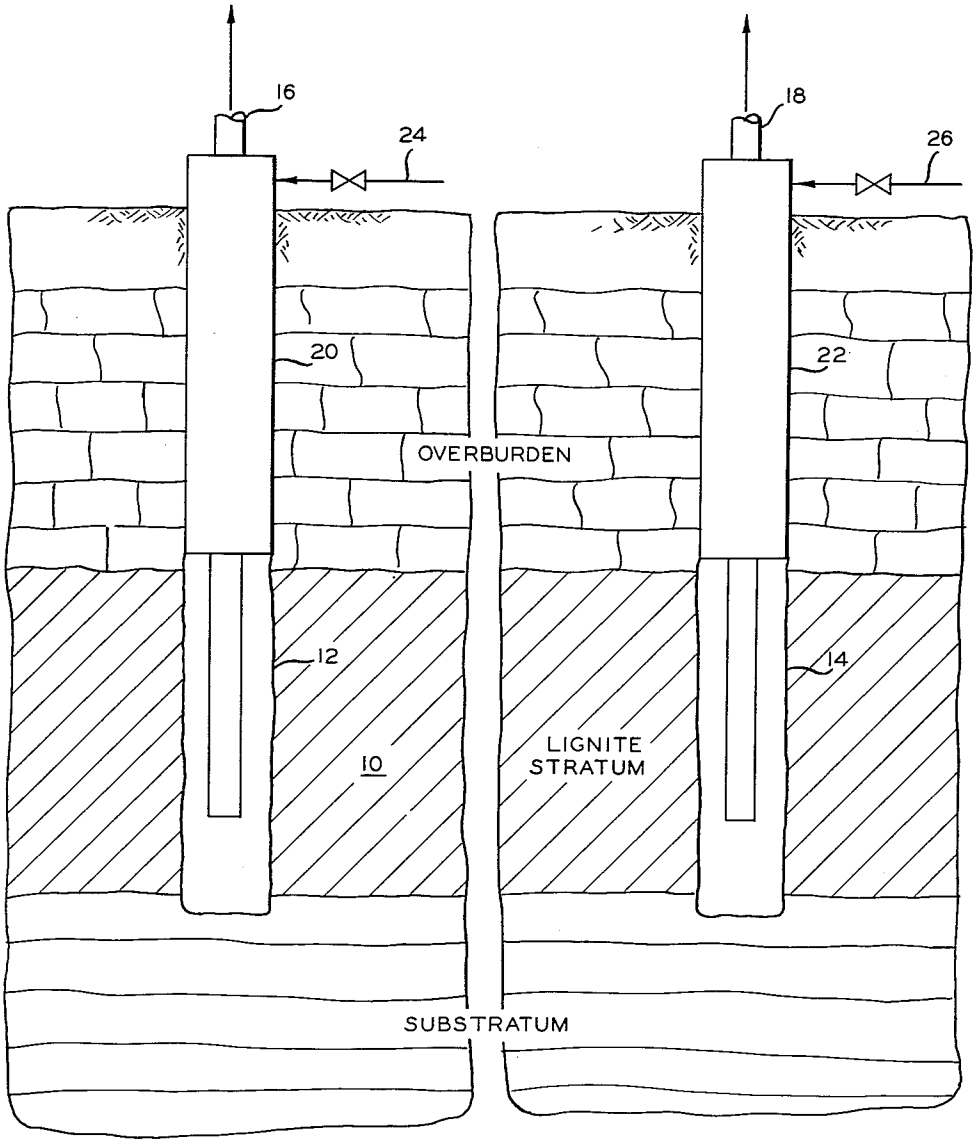

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IN SITU COMBUSTION OF LIGNITE

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This invention relates to a process for the production of combustible fluids from lignite by autogenous in situ combustion.

It has been proposed to burn subterranean fuel deposits such as oil sands, tar sands, oil shales, and coal, including lignite, in situ by both inverse and direct air injection.

We have found that the in situ combustion of lignite by igniting the same and injecting air into the ignited area sufficiently burns the lignite but because of its low ash content, the combustion forms cavities in the bed and, thereafter, combustion occurs as a flame in which most of the useful products are burned. Lignite from the Baukol-Noonan Mine of North Dakota was obtained and a number of combustion runs were made with this lignite. The lignite was packed into both stainless steel and Vycor tubes and ignition was effected at one end. The combustion front was driven thru the packed bed by both direct and indirect air injection in separate runs. The combustion temperature was slightly above 1000° F. at an air velocity of 300 ft./hr. In the tests the amounts of useful substances such as hydrogen, carbon monoxide, and hydrocarbons produced were so small as to be considered substantially negligible. This was attributed to the fact that the combustion formed cavities, clearly visible thru the transparent Vycor tubes, which allowed the lignite to burn as a flame thereby consuming substantially all of the fuel. The produced gases from the combustion tests utilizing concurrent flame propogation was 40.3 B.t.u./cu. ft. and for counter current flame propagation the produced gases had a heating value of 36.1 B.t.u./cu. ft.

We have found that many lignite deposits can be produced by in situ combustion so as to recover a significant proportion of the fuel in the deposit as valuable fuel gases and liquids. Lignites contain from 5 to about 30 weight percent of oxygen and those deposits containing at least 10 weight percent of oxygen can be economically produced by autogenous in situ combustion.

Accordingly, it is an object of the invention to provide an improved process for producing lignite deposits by in situ combustion. Another object is to provide a process for producing a lignite deposit by in situ combustion which avoids consuming all of the fuel in the deposit and produces a substantial proportion thereof as valuable fluid fuels. It is also an object of the invention to provide a process for the in situ combustion of lignite which avoids burning of the lignite by flame combustion. Other objects will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises igniting a lignite deposit or stratum in a selected area so as to establish a combustion zone and continuing the combustion by excluding extraneous oxygen therefrom and allowing the combustion to continue with the oxygen originally contained in the deposit and recovering the fluids produced by the combustion. This process is applicable to a lignite deposit containing about 10 weight percent or more oxy zen.

Ignition of the lignite is effected by drilling a borehole or well into the deposit, preferably to the bottom of the deposit, and igniting the lignite in the wall of the well by any suitable method. An effective method for the ignition step comprises extending a tubing string to the bottom of the well and packing particulate charcoal around the tubing string to the top of the lignite stratum. The charcoal

is then ignited and air or other combustion-supporting gas, such as oxygen or oxygen-enriched air, is injected into the charcoal either thru the tubing string or thru the annulus around the tubing so as to burn the charcoal and heat the lignite to combustion temperature. After consumption of the charcoal, the flow of air is cut off and the lignite burns with the oxygen originally present therein. The combustion products pass into the well and may be recovered therefrom either thru the annulus or the tubing. In order to facilitate withdrawal or recovery of the produced gases during the autogenous combustion, a flushing gas devoid of free O_2 may be injected either thru the tubing or thru the annulus so as to flush the produced gases thru the other. Combustion gas is a suitable flushing gas, although any other substantially inert gas may be utilized.

In order to illustrate the invention reference is made to the schematic drawing which is an elevation in partial section thru a lignite stratum showing an arrangement of apparatus and wells for effecting the invention. A lignite stratum **10** is penetrated by an ignition well **12** and an offset well **14** which are provided with tubing strings **16** and **18**, respectively, and with casings **20** and **22**, respectively. Casing **20** is provided with line **24** for injection of air and nonoxidizing gas. Line **26** connects with casing **22** for the same purpose.

It is to be understood that ignition well **20** may be surrounded by a ring of offset wells **14** or it may be one of a line of ignition wells flanked on either side by parallel lines of offset wells **14**.

In operation, the lignite around well **12** is ignited in conventional manner by bringing the lignite to ignition temperature and injecting air thru line **24** and the tubing-casing annulus. After ignition is established in a substantial area of the stratum adjacent well **12**, the flow of air is terminated and a relatively inert flushing gas such as combustion gas is injected thru either tubing string **16** or line **24** so as to flush out the hydrocarbons produced by the autogenous combustion. It is also feasible to produce the hydrocarbon gases and liquids resulting from the combustion thru offset well or wells **14** either thru line **26** or thru tubing string **18**. In accordance with another mode of operation, the flushing gas is injected thru the offset well **14** via either line **26** or tubing string **18** so as to flush the produced hydrocarbons into well **12** from which they are produced via tubing string **16** or line **24**.

During drying out of the stratum either tubing string **16** or **18** may be continued to the bottom of the hole to remove produced water or a pump may be utilized for this purpose.

In some lignite strata or deposits the moisture conditions therein are not conducive to autogenous in situ combustion. In such deposits it is necessary to drill an offset well in the deposit spaced a short distance from the ignition well and dry out the intervening lignite. A preferred practice comprises drilling a ring of wells around the ignition well and injecting air thru the offset wells so as to drive water from the intervening stratum into the ignition well from which it is forced or pumped so as to dry out the stratum. It is also feasible to inject air thru the ignition well and recover the flushed out water thru the wells in the ring. After the flushing step, ignition is initiated around the ignition well in the aforesaid manner, or in any other suitable manner, and produced gases are recovered therefrom as the combustion proceeds. Heating the lignite up to about 600° F. with drying gas may be practiced before igniting the lignite. It is desirable in some applications to inject a flushing gas into the ignition well so as to force the same to the combustion zone to flush out combustion products and fluids and to carry heat into the unburned stratum. This flushing procedure may be practiced continually at slow injecting rates or intermittently. The O_2-free flushing fluid may also be injected

thru the offset well or wells to flush produced fluids into the ignition well.

Autogenous in situ combustion of lignite consumes most of the fuel deposit but leaves a substantial carbon residue. However, this technique does produce a substantial proportion of the lignite deposit as valuable fluids utilizable as fuel and for other purposes.

Combustion catalysts may be utilized as an aid in initiating combustion. Iron-containing catalysts appear to be the most effective.

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.

We claim:

1. A process for producing fuel gases and liquids from a lignite stratum containing water and at least about 10 weight percent oxygen by autogenous in situ combustion which comprises providing an ignition well and at least one offset well therein; injecting air thru one of said wells and passing same thru the lignite to the other well to drive moisture therefrom and dry out the intervening lignite; thereafter, igniting said lignite around said ignition well to establish a combustion zone; continuing the combustion with the oxygen contained in said lignite while excluding air and extraneous O_2 from the combustion zone; injecting an O_2-free flushing gas into said stratum thru one of said wells at least periodically so as to flush produced fluids from said stratum into the other of said wells; and recovering gases and liquids produced by the combustion.

2. A process for producing fuel gases and liquids from a lignite stratum containing at least 10 weight percent oxygen by autogenous in situ combustion which comprises providing a well extending from ground level into said stratum and a tubing string in said well forming an annulus with the wall of said well; igniting the lignite adjacent said well by heating same to ignition temperature and injecting combustion-supporting gas thru one of said annulus and said tubing so as to contact the heated lignite with said gas and establish a combustion zone in said lignite; after ignition is effected, terminating the flow of said gas and substituting therefor an O_2-free flushing gas to remove from said well fluids produced by the combustion.

3. A process for producing fuel gases and liquids from a lignite stratum containing at least 10 weight percent oxygen by autogenous in situ combustion which comprises providing a well extending from ground level into said stratum; igniting the lignite around the wall of said well to establish a combustion zone therein by heating said wall to ignition temperature and contacting the heated wall with combustion-supporting gas; terminating the contacting with said gas and passing a stream of O_2-free flushing gas in contact with the combustion zone to flush out fluids produced by said combustion; and recovering flushed fluids produced by the combustion.

4. The process of claim 3 wherein said flushing gas is injected thru said offset well and fluids are produced thru said ignition well.

5. The process of claim 3 wherein said flushing gas is injected thru said ignition well and fluids are produced thru said offset well.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,034,580 May 15, 1962

Frederick E. Frey et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, lines 19 and 22, for the claim reference numeral "3", each occurrence, read -- 1 --.

Signed and sealed this 30th day of October 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents