APPARATUS FOR UNDERGROUND RETORTING

Filed July 20, 1959 2 Sheets-Sheet 1

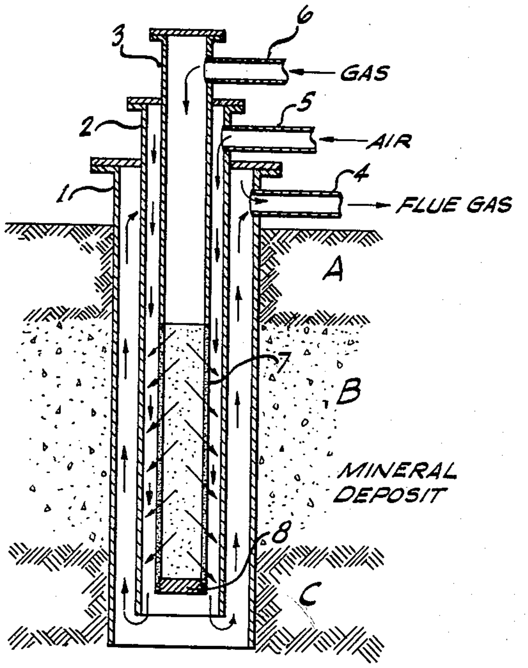

FIG. 1

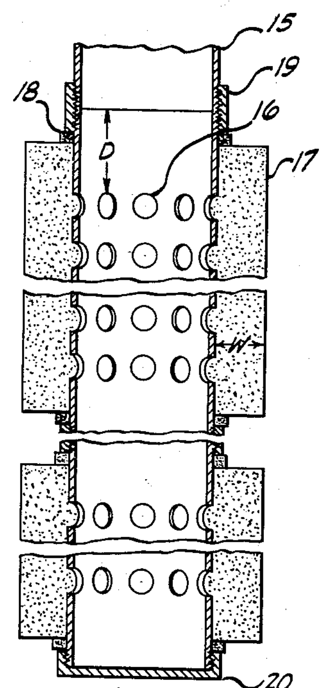

FIG. 3

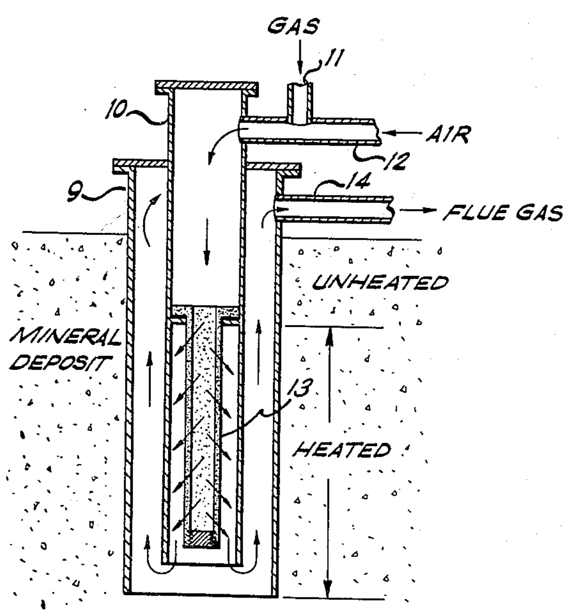

FIG. 2

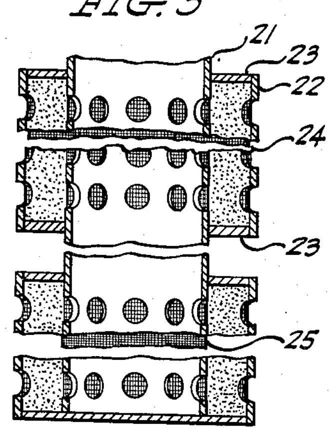

FIG. 4

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2 Sheets-Sheet 2

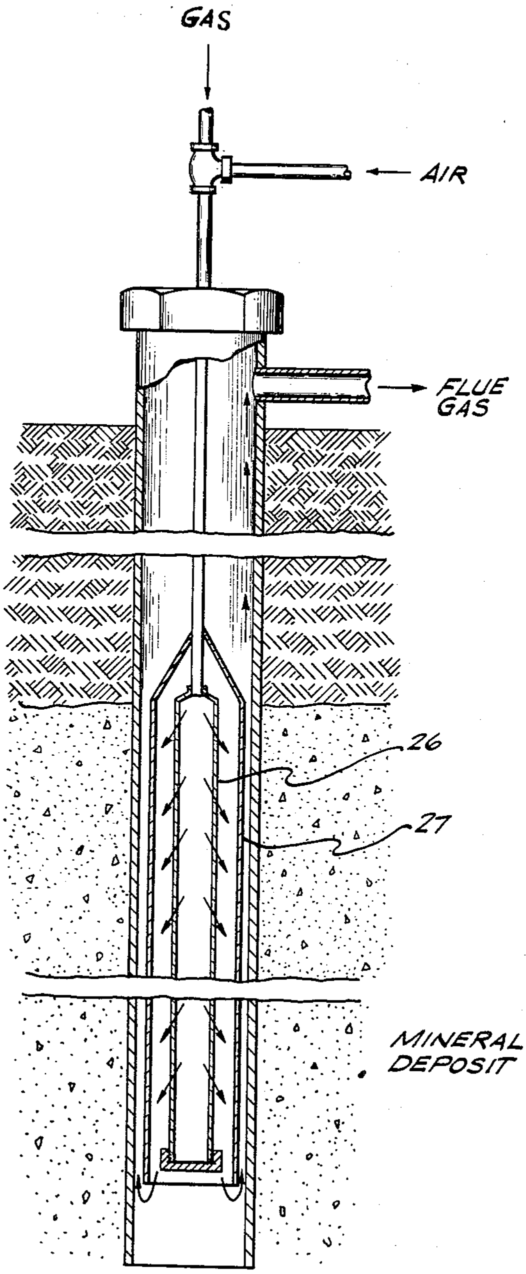

FIG. 5

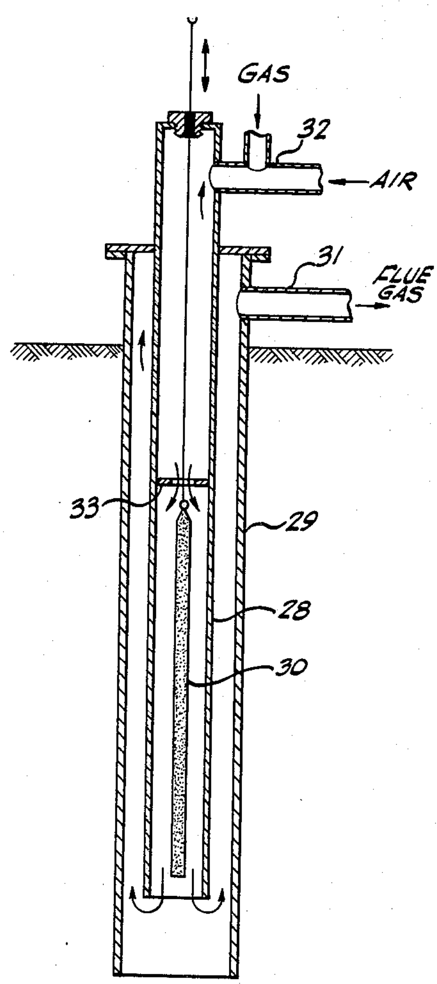

FIG. 6

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APPARATUS FOR UNDERGROUND RETORTING

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This invention relates to a novel method and apparatus for uniformly heating an elongated region of mineral deposits located beneath the earth's surface, and more particularly concerns a method and apparatus for the thermal recovery of hydhocarbon values from subterranean deposits comprising the same.

A number of processes have been proposed whereby heat is employed to facilitate the recovery of hydrocarbon values from subterranean deposits such as bituminous sands, oil shale, bituminous and sub-bituminous coals, oil-soaked diatomite, heavy petroleum deposits, etc. In most of said processes at least part of the heat is supplied from a burner positioned in a bore hole drilled into the deposit. For example, according to one process which has been applied to the treatment of tar sand deposits, a plurality of relatively closely-spaced holes is drilled into the deposit, and heat is generated in a selected number of these holes by combustion of gas or other fuel in a suitably positioned burner device. The surrounding sand is thereby heated and the volatile petroleum fractions are driven towards a production bore hole from which they are recovered. The heavier ends which fail to volatilize are pyrolyzed by continued heating. As previously practiced, a single burner has been positioned at the base of the formation or at a point along the combustion tube. This technique results in localized heating, which is useful with shallow formations but not readily applicable where the formation is vertically extended. Attempts to use this localized heating to transmit heat to an elongated zone within subterranean deposits have employed flow reversal methods, alone, or with packed annular zones of coarse inert material around the burner zone, or with an annular fluidized bed of finely divided inert solids. In the flow reversal method of heating, a combustion tube is concentrically placed within the bore hole and extended nearly to the base of the hole. Combustible gases and air are mixed in the tube and ignited at a selected point. The flame front is prevented from rising to the top of the burner by flame arrestors positioned within the burner upstream from the flame. The combustion gases pass down the extended burner tube to the base of the hole where they reverse their direction and flow upwardly through the annulus between the burner tube and bore casing. It has been found that a high temperature zone within the shale deposit exists immediately adjacent the burner flame, and that the temperature of the shale at points vertically removed from this high temperature zone are substantially less. This type of operation is not entirely satisfactory because the heat is not efficiently distributed and because the localized high temperature zone causes thermal failure of the burner tube. While use of a fluidized bed of solids within the annulus between the burner and casing improves heat transfer to the shale, it does not completely eliminate the uneven heating along the bore hole and is disadvantageous in that it causes a high erosion rate of the metal surfaces.

It is a purpose of this invention to provide an improved method for subterranean heating. It is also a purpose of the invention to provide a unique burner construction which achieves uniform heating over an extended length and has a long service life.

These purposes are achieved by providing a continuous elongated combustion zone extending the length of an

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elongated portion of the mineral deposits. The elongated combustion zone is achieved by use of a porous metallic, glass or ceramic combustion tube and will be described by reference to the drawings which form a part of this application.

In the drawings, FIGURES 1, 2 5 and 6 show the placement of the novel burner construction in the mineral deposits. FIGURES 3 and 4 show alternative features of construction of the burner tubes. Although FIGURES 1, 2 and 5 show a vertical disposition of the burner tubes, it is apparent that a horizontal or inclined placement could also be employed, if desired.

Referring now to FIGURE 1, a mineral deposit, B, is shown located beneath an upper layer, A, which may comprise gravel, earth or stone or an unheated portion of the mineral deposit. In accordance with this invention, a hole is bored through the earth's surface and into the mineral deposit. A metal casing **1** is positioned within the bore hole in the conventional manner. Disposed within casing **1** are concentric tubes **2** and **3**. Casing **1**, and tubes **2** and **3** are closed at their upper ends. Conduit **4** connects with casing **1** to provide for removal of flue gases, conduit **5** communicates with tube **2** for the introduction of air or gas, and conduit **6** communicates with inner tube **3**, also for the entrance of air or gas. The unique construction of this invention is in the use of a gas-permeable tube **7** connected to the lower portion of central tube **3**. Permeable tube **7** is sealed at its lower end by plate **8** which may be permeable, but is preferably impermeable to gas flow. Any suitable connection between permeable tube **7** and metal tube **3** may be employed, such as by cementing, threading or by use of a collar joint.

In operation, natural gas or other gaseous fuel is introduced through conduit **6** into central tube **3**. The gas flows down into tube **7** and passes through the walls thereof into a flowing air stream which is introduced into tube **2** through conduit **5**. The flow of gas through tube **7** into the air stream is achieved by maintaining a higher pressure on the gas stream than on the air stream. Combustion is initiated in a conventional manner in the annular zone between tubes **2** and **7**, and takes place along the entire length of tube **7**, thereby providing an elongated combustion zone which may be of any suitable length corresponding to the length chosen for the permeable tube **7**. The flue gases are discharged from the lower open end of tube **2** and reverse their direction of flow to pass upwardly through the annular zone between casing **1** and tube **2**, and are removed through conduit **4**. Heat is transmitted from the combustion zone by radiation to this upwardly flowing stream of flue gases and to the mineral deposits in zone B throughout the entire length of the burning zone, and heat is transmitted by convection from the flue gases to the mineral deposits. By this method a combustion zone with a uniform temperature is maintained along the length of the mineral deposit. Although casing **1** is shown to extend the length of the bore hole, it may be considerably shorter where the mineral matrix is sufficiently consolidated so as not to fall into the hole. Suitable consolidation may occur naturally or be achieved by coking the hydrocarbons in the deposit immediately adjacent the bore hole. This coking may be accomplished by introducing high temperature combustion gases into the hole.

Conventional ignition techniques presently employed to ignite gas burners in oil wells can be employed in the annulus surrounding the burner to ignite the burners of my invention. These techniques themselves constitute no inventive step in my system; they merely serve for the ignition of the gas stream after it passes through the porous wall and enters the annular combustion zone surrounding the porous burner. Among the suitable ignition techniques which are employed in the annular zone surrounding the porous burners are the following:

Dynamite and percussion caps;

Electrically actuated heating coils and spark plugs which are positioned within the annular combustion zone and which are initiated by a supply of electrical energy from above ground; and

Chemical ignition techniques wherein a capsule of sodium or potassium is dropped into the well bore and followed by injection of water. The sodium or potassium is then released by mechanical breaking or dissolution of the capsule to react with water and release heat to ignite the gas.

Referring now to FIGURE 2, a modified form of the invention is shown. In this embodiment, a single tube **10** is concentrically disposed within casing **9**. The gas and air are introduced into tube **10** via inlets **11** and **12**, respectively, and the gas-air mixture flows downwardly through tube **10** into permeable tube **13** which is shown to be connected to the lower end of tube **10** by a collar joint. The gas and air stream diffuses through tube **13** into the combustion zone which surrounds the same. The gas is ignited by any of the aforedescribed techniques and the resultant combustion occurs on the outside of this tube and is prevented from backing into the permeable tube **13** by proper adjustment of the gas and air flow rates. If desired, central tube **10** may be extended downwardly as indicated so as to insure that the gases from the combustion zone flow to the base of the formation before reversal into an upwardly directed flow to the flue gas outlet conduit **14**.

FIGURE 3 shows an alternative method of construction for the gas permeable tube, and can be used to obtain a burner of greater strength than is possible with glass or ceramic tubes, alone. This construction comprises a central metal tube **15** which is perforated at suitable intervals by holes **16** and is sealed at its lower end by cap **20**. A sleeve **17**, constructed of a permeable ceramic or sintered glass material, surrounds the perforated portion of tube **15**. The diameters of tube **15** and gas-permeable sleeve **17** are so chosen to insure a tight fit. The permeable sleeve extends a substantial distance, D, above the perforated portion of tube **15** to prevent gas flow from bypassing the permeable sleeve and flowing between the sleeve and the tube. A suitable sealing material **18** is placed above and below the permeable sleeve **17** to insure a gas-tight fit, and is suitably held in place by coupling **19**. If desired, the perforated portion of tube **15** can be on a separate piece of pipe and thereby permit connection to any suitable length of pipe to position the burning zone at any depth in the mineral deposit. Also if desired, several of these burning zones may be provided on a single string of pipe separated by an impermeable portion of pipe, thereby permitting simultaneous heating of multiple zones of mineral deposits. The thickness, W, of permeable sleeve **17** is selected to maintain sufficient thermal insulation between the outer burning zone and metal tube **15**. This is to eliminate any difficulties encountered due to the differences in thermal expansion of the dissimilar ceramic sleeve and the tube.

FIGURE 4 shows another embodiment of the permeable tube burner. This construction comprises a central tube **21** which is perforated similarly to tube **15** of FIGURE 3, and is similarly closed at its lower end. Surrounding the perforated portion of tube **21** is a second concentric tube **22** which is supported by rings **23**. Tube **22** is also provided with a plurality of perforations. Between tubes **22** and **21** is packed an annular bed of unconsolidated silica, sand or quartz grains, which is permeable to gas flow. These grains are prevented from falling through the perforations in tubes **21** and **22** by outer screen **24** and inner screen **25**. Again, these burning zones may be constructed on separate pieces of pipe and connected to any desired length of pipe to permit the proper location within the mineral deposit.

FIGURE 5 illustrates an alternative type of construc-

tion. The gas permeable burner **26** in this embodiment is constructed of a gas permeable metal and is connected to a supply of air and combustible gas. The gas and air flow into this permeable burner and diffuse into the annular zone between the burner and the casing wall. The gas is ignited by any of the aforedescribed techniques and the resultant combustion occurs in this annular zone along the entire length of the permeable burner **26**. A second concentric tube **27** may surround the permeable burner to insure that the combustion gases will flow to the base of the formation before reversal to the point of removal above the ground. Use of a permeable metal tube simplifies construction and provides a burner which is somewhat easier to install than a glass or ceramic burner.

Another embodiment of the invention is illustrated by FIGURE 6. In this embodiment, a single tube **28** is concentrically positioned within casing **29**. A ceramic rod **30**, which is of a length corresponding to the depth of the mineral deposit, is supported within inner tube **28**. Inlet **32** for the introduction of a combustible gas mixture, and outlet **31** for the removal of flue gas, communicate with tube **28** and casing **29**, respectively. Gas and air flow downwardly through tube **28** and are withdrawn through conduit **31**. Combustion is initiated by igniting the gas stream flowing out of tube **31**. However, any other conventional ignition technique is suitable. This combustion is permitted to back up into the burner until the flame front exists at the lower end of tube **28**. The ceramic rod **30** is lowered so that its lower end is within the combustion zone at the base of tube **28**. The ceramic rod slowly heats up by conduction, and a red-hot zone progresses up the length of rod **30**. As this zone moves up the ceramic rod, the combustion zone follows it until a combustion zone exists within tube **28** along the entire length of the ceramic rod. An annular ring **33** may be placed within tube **28** above the ceramic rod to momentarily increase the combustible gas flow rate and thereby prevent the combustion zone from moving up tube **28** to the gas inlets or, if desired, tube **28** may be of a reduced diameter at its upper end to serve the same purpose. Other flame arrestors, such as screens or grids, may also be employed. The ceramic rod **30** is shown to be movable in a vertical direction. However, to simplify construction, particularly where the depth of the mineral formation is known, the ceramic rod may be rigidly supported within tube **28**.

Suitable ceramic material for constructing the aforementioned gas-permeable elements may comprise permeable ceramics of alumina, zirconia, sandstone, and aluminum silicates such as sillimanite, or clays. These gas-permeable ceramics are commercially available in a wide rang of permeabilities and in a variety of shapes, including tubular elements.

Gas-permeable glass suitable for use in this invention is made by sintering of glass powders to obtain a shatterproof porous glass permeable to gas flow. This type of glass is also commercially available.

Suitable gas-permeable metals for construction of the burners of this invention are made by sintering of metal powders. These sintered metals are commercially available in bronze and a wide range of stainless steel alloys, such as 304, 309, 316, 347, nickel, Monel, etc. The permeabilities of these metals may range from a value of 80 cubic feet of air per minute per square foot at 0.01 p.s.i. pressure drop for a one-sixteenth inch thick stock of a highly permeable material to a permeability of 27 cubic feet of air per minute at 10 p.s.i. pressure drop for a one-eighth inch stock of low permeability material.

A typical example of this invention is as follows: The apparatus shown by FIGURE 5 is employed to supply heat to a tar sand deposit 50 feet below the earth's surface. The deposit is 30 feet thick, and it is desired to supply 31,000 B.t.u.'s per hour to the sand. A two and one-half inch bore is drilled into the deposit and a gas-permeable stainless steel burner made from one-eighth inch stock with a one and one-half inch outside diameter is inserted in the bore hole. This burner is 30 feet long and extends from the top to the bottom of the deposit. A one-fourth inch pipe is connected to the top of the metal burner to supply 310 cubic feet per hour of a combined gas and air stream. In order to insure even diffusion of the combustible mixture into the annulus surrounding the burner, it is necessary to maintain a high pressure drop through the burner walls relative to the gas flow pressure drop down the porous metal tube. A stainless steel of relatively low permeability is chosen to provide a diffusion pressure drop which is 150 to 830 times as great as the gas flow pressure drop within the permeable metal burner. The actual diffusion pressure drop through the tube is 4.15 inches of water. As a result, even distribution of the gas-air mixture is obtained and a combustion zone surrounds the permeable tube over the entire thickness of the deposit. This example is by way of illustration only and is not to be construed as limiting the scope of the invention which is directed to providing an elongated combustion zone throughout the entire depth of thick mineral deposits.

I claim:

1. A burner in combination with a well bore which penetrates an oil sand interval to be heated, a combustible gas and an air supply conduit connected to the upper end of a tubing string, said tubing string extending into said well bore and connected therein to said burner, a casing within the upper extremity of said well bore and a conduit communicating with said casing for the removal of flue gases therefrom; said burner comprising an elongated metal tube perforated along its length and connected to said tubing string, a second perforated metal tube concentric with and surrounding said first tube, said second tube being of lesser diameter than said well bore to form an annulus therebetween, a first ring laterally positioned between the non-perforated ends of said first and second tubes, and a second ring laterally positioned between the opposite non-perforated ends of said tubes, a cap over the lower end of said first tube, a first metal screen around the outer periphery of said first tube extending from said first ring to said second ring, a second metal screen around the inner periphery of said second tube extending from said first ring to said second ring, and an annular bed of unconsolidated granular material packed between said first and second screens and said first and second rings.

2. The combination of claim 1 wherein said well bore

penetrates a plurality of oil sand intervals to be heated and wherein a plurality of said burners are attached to said tubing string so as to extend substantially the depth of its respective oil sand interval.

3. The combination of a well bore penetrating a subterranean oil sand interval which comprises a first tubing string and a second tubing string concentrically disposed within said first tubing string, said first and second tubing strings extending into said well bore, a conduit communicating with the upper end of said well bore for removal of flue gas therefrom, said second tubing string extending to the upper level of said oil sand interval, said first tubing string extending to the lower level of said oil sand interval, a gas permeable tube concentrically disposed within said first tubing string and connected to the lower end of said second tubing string, said gas permeable tube being closed at its lower end and terminating at the lower level of said oil sand interval, said gas permeable tube having an uninterrupted wall of uniform permeability to gases so as to permit diffusion of a gas therethrough, a combustible gas supply conduit connected to the upper end of said second tubing string, an oxidizing gas supply conduit connected to the upper end of said first tubing string, a combustible gas supply means connected to said combustible gas supply conduit and an oxidizing gas supply means connected to said oxidizing supply conduit, said combustible gas supply means being adapted to supply combustible gas at a pressure greater than the pressure of oxidizing gas supplied by said oxidizing gas supply means so as to cause said combustible gas to diffuse through said gas permeable tube and admix with said oxidizing gas within said first tubing string.

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