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CONSOLIDATION OF HYDROCARBON GAS-BEARING SANDS BY INVERSE SITU COMBUSTION

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This invention relates to the consolidation of hydrocarbon-containing sands surrounding a well bore by the in situ combustion of oil in the sand adjacent the well. The control of said movement from an underground oil or gas bearing formation in which sand is unconsolidated is a problem often presented to oil well operators, particularly in certain areas such as the Gulf Coast. Numerous methods have been used heretofore for preventing the movement of sand into the well bore. These include the use in the well bore of gravel packing, plastic coated walnut shells, screens or liners and the squeezing of plastic material into the formation. All of these methods are expensive and often fail, and a less costly, more effective procedure is highly desirable.

The present invention provides a novel method of consolidating loose sands in oil or gas bearing formations which is less costly and generally more effective than procedures used heretofore. The procedure involves an in situ burning of oil in the sand adjacent a borehole by an inverse burning method wherein the oxygen-containing gas used in the combustion flows in a direction opposite to the movement of the flame front.

In one embodiment of the invention, an unconsolidated oil sand penetrated by a borehole is treated to consolidate the sand by first injecting a free oxygen-containing gas, preferably air, through the well into the oil sand to provide a pocket or bubble of gas therein surrounding the well bore. The oil in the sand is then ignited in any known or suitable manner to provide a burning zone adjacent the well bore. Oxygen-containing gas from the pocket is allowed to flow through the burning zone to maintain combustion of the ignited oil for a time, and the combustion gases are withdrawn from the well. The flame front moves from the borehole wall inwardly into the formation and leaves the burned sand in a consolidated condition. After substantially all of the oxygen-containing gas has been used in the combustion, the well can then be placed in production for the recovery of oil. By this procedure an annular shaped zone of consolidation of any desired width can be formed in the sand surrounding the well bore and the well can then be produced without encountering difficulties resulting from sand movement. In the above described procedure the flame front moves from the borehole wall outwardly into the formation while oxygen-containing gas flows in the opposite direction. This inverse burning procedure is essential for practicing the invention. If the forward burn procedure is attempted, i.e., with the air flowing from the well into the formation, it is found that the sand remains unconsolidated. This is for the reason that the hot coked sand incompletely consumes the air before it can reach the main combustion zone, so that all of the coke is burned out and the sand is left in a clean loose condition. On the other hand, when the inverse burning procedure is used as described above, the oxygen reaches the main combustion front first where there is an excess of fuel to complete consumption of the oxygen. Hence there is no oxygen left to burn the coke and the latter remains in the sand to serve as a binder for the sand grains. The initiation of burning of the oil sand at the borehole wall can be effected by any of the procedures known to the art in the in situ combustion methods adapted for secondary recovery of oil. These include utilizing an electrical heater, a downhole gas burner or the injection of hot gases as well as the use of chemical agents that will cause combustion by reaction (e.g. phosphorus). Initiation of the burning can be done near the end of the period when the oxygen-containing gas is injected into the formation or after the flow of the injected gas has been reversed.

The amount of air or other oxygen-containing gas that is introduced into the formation before establishing the burning zone can be determined for any distance into the formation that it is desired to consolidate the oil sand. This can be ascertained by determining the content of oil that will remain in the sand when air is passed through it and then calculating the amount of oxygen necessary to burn most of the hydrocarbon within the desired consolidation distance. As a general rule in practicing the invention, air would be pumped into the formation from one to several days before ignition of the oil is effected. The invention is also applicable in the consolidation of gas bearing sands which do not normally contain any liquid hydrocarbons or which contain liquid hydrocarbons that would be mainly volatilized and swept out of the formation by the flow of air without substantial combustion. Application of the invention to gas sands involves, in addition to the steps heretofore described for oil sands, the introduction of a quantity of oil such as crude oil through the well bore into the gas bearing sand to provide a liquid medium for supporting combustion. Typically, from 50 to 300 barrels of oil are used for this purpose. The oil can be introduced either before or after injection of the oxygen-containing gas into the formation. In cases where the interstitial water content of the formation is high, it is desirable to introduce the oil into the formation ahead of the oxygen-containing gas and to include in the oil a surfactant which aids in displacing the water out into the formation. The water air can be introduced into the formation to provide the air pocket which supplies the oxygen for combustion. Introduction of the air causes some of the oil to be forced outwardly into the formation but sufficient oil remains in the interstices of the sand to support combustion. The oil is ignited adjacent the borehole and is burned by the inverse combustion procedure previously described. The incomplete combustion which occurs leaves carbonaceous residues which serve to bind the sand particles together and effect consolidation of the sand surrounding the well bore.

We claim:
1. Method of consolidating sand adjacent a well bore penetrating an unconsolidated gas bearing sand containing hydrocarbon gas without any substantial amount of heavier hydrocarbons capable of undergoing coking upon partial combustion which comprises introducing a quantity of oil through the well bore into the sand, injecting a free oxygen-containing gas through the well bore into the sand to provide a pocket of oxygen-containing gas therein surrounding the well bore, igniting the oil in the sand to provide a burning zone adjacent the well bore, and flowing gas from said pocket through the burning zone and out of the well in a path reverse to its path during injection to maintain combustion until substantially all of the oxygen-containing gas has been removed from the pocket.

2. Method of consolidating sand adjacent a well bore penetrating an unconsolidated gas bearing sand containing hydrocarbon gas without any substantial amount of heavier hydrocarbons capable of undergoing coking upon
partial combustion which comprises injecting a free oxygen-containing gas through the well bore into the sand to provide a pocket of oxygen-containing gas therein surrounding the well bore, introducing a quantity of oil through the well bore into the sand, igniting the oil in the sand to provide a burning zone adjacent the well bore, and flowing gas from said pocket through the burning zone and out of the well in a path reverse to its path during injection to maintain combustion until substantially all of the oxygen-containing gas has been removed from the pocket.

3. Method of consolidating sand adjacent a well bore penetrating an unconsolidated sand containing interstitial water and containing hydrocarbon gas without any substantial amount of heavier hydrocarbons capable of undergoing coking upon partial combustion which comprises introducing through the well bore and into the sand a quantity of oil containing a surfactant whereby interstitial water is displaced outwardly from the well bore, injecting a free oxygen-containing gas through the well bore into the sand to provide a pocket of oxygen-containing gas therein surrounding the well bore, igniting the oil in the sand to provide a burning zone adjacent the well bore, and flowing gas from said pocket through the burning zone and out of the well in a path reverse to its path during injection to maintain combustion until substantially all of the oxygen-containing gas has been removed from the pocket.

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