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3,055,425

METHOD OF INCREASING STABILITY OF CONSOLIDATED SANDS

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FIG. 1.

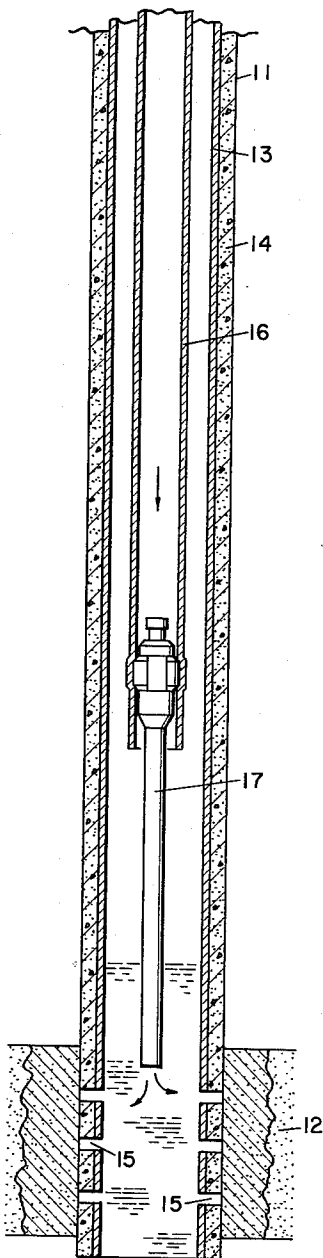


FIG. 2.

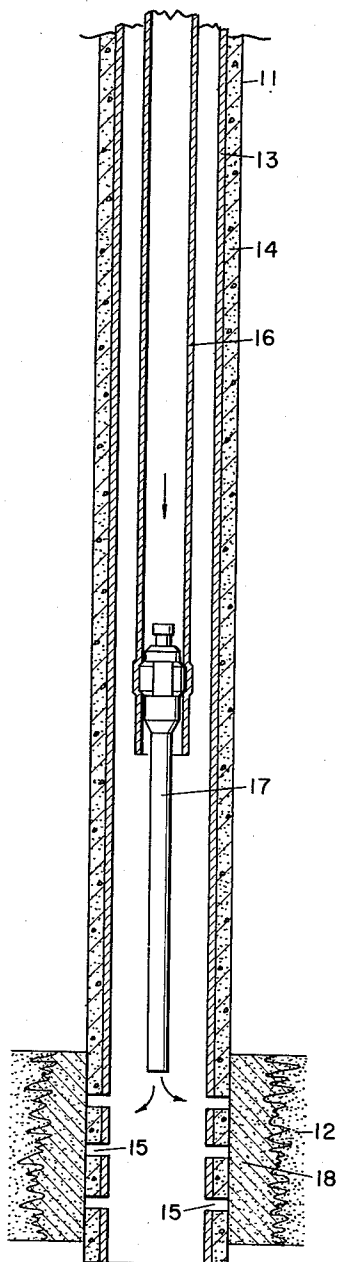
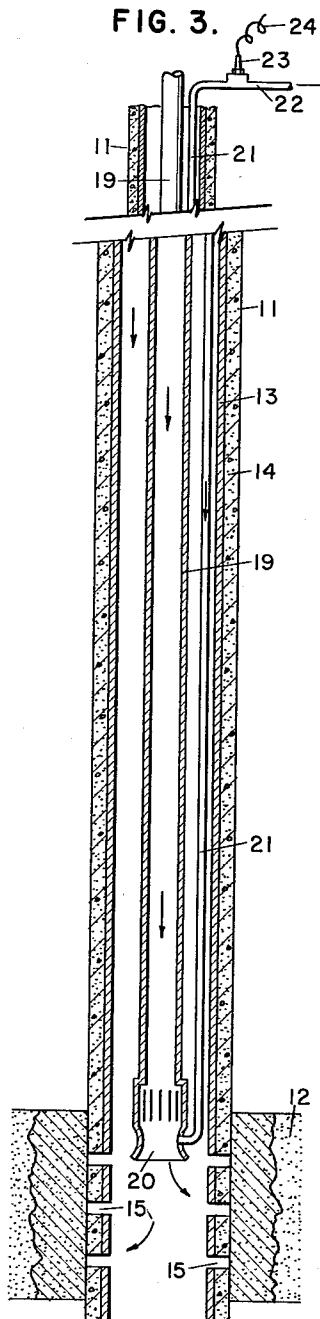


FIG. 3.



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METHOD OF INCREASING STABILITY OF CONSOLIDATED SANDS

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11 Claims. (Cl. 166—29)

The present invention is directed to a method for treating a water-containing incompetent subsurface earth zone. More particularly, the invention is directed to stabilizing a consolidated incompetent subsurface earth zone. In its more specific aspects, the invention is concerned with producing hydrocarbons from stabilized consolidated incompetent subsurface earth zones without the production of sand.

The present invention may be briefly described as a method for treating a water-containing incompetent subsurface earth zone penetrated by a well. In the practice of the present invention, there is injected into the incompetent zone a liquid halide of silicon to consolidate the incompetent zone. Thereafter the consolidated zone is heated to an elevated temperature substantially above the temperature of the incompetent zone for a time sufficient to stabilize the incompetent zone. After the incompetent consolidated zone has been stabilized, hydrocarbons such as oil and/or gas are then producible therefrom.

In the practice of the present invention, the consolidated zone may be heated by any one of several methods. Thus, for example, hydrocarbons may be burned in the consolidated zone to heat same. In a similar manner, a heater may be placed in the well adjacent the consolidated zone and hydrocarbons burned in the heater and the hot gases generated by the burning then injected into the consolidated zone. Likewise, hot fluids may be flowed down into the well and injected into the consolidated zone. Such hot fluids include by way of illustration and not by way of limitation, hot oil, gases such as flue gases, and the like, water, and steam.

Usually, the consolidated zone will be heated to an elevated temperature substantially above the temperature of the incompetent zone. The temperatures may range from about 300° F. up to about 1900° F. Higher temperatures may be employed if desired.

To stabilize the consolidated zone, it will be desirable to heat the consolidated zone for a time sufficient to stabilize same. Ordinarily this time may range from about 6 hours up to about 48 hours, although longer heating times may sometimes be desirable.

When flue gases are employed, especially when generated in the well, it may be desirable to use an underground burner such as described in the patent to Kaasa, U.S. 2,722,278, issued November 1, 1955, or as described by Piro et al. in U.S. Patent 2,668,592, issued February 9, 1954. Likewise, underground burners are described in the patent to Prokop et al., U.S. 2,808,248, issued October 1, 1957. Hot flue gases may be generated at the earth's surface in accordance with the methods described in the Brogdon patent U.S. 2,756,029, and the Axelrad et al. patent U.S. 2,756,035.

The hot fluids may be heated at the earth's surface by any of many well-known means; for example, many means are known for heating hot oil, gases, water, and steam and it is within purview of this invention to heat the hot fluid at the earth's surface in any of the several well-known methods. The present invention will be further illustrated by reference to the drawing in which:

FIG. 1 is a showing of the injection of hot fluids into a consolidated incompetent zone;

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FIG. 2 illustrates the heating of a consolidated incompetent zone by burning injected free oxygen-containing gas in the hydrocarbon-containing zone; and,

FIG. 3 illustrates the generation of hot gases in the well and heating the incompetent zone therewith.

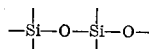
Referring now to the drawing in which identical numerals will be employed to designate identical parts and particularly to FIG. 1, numeral 11 designates a well drilled from the earth's surface, not shown, to penetrate an incompetent earth zone 12 from which hydrocarbons are producible and which allows the production of sand therewith by virtue of the loose nature of the zone 12. Arranged in the well bore 11 is a casing 13 cemented in place with cement 14. The casing 13 and cement 14 are perforated to communicate the casing 13 with the zone 12 by means of perforations 15. Arranged in the casing 13 is a tubing string 16 which extends from the earth's surface to above the incompetent zone 12. Sealingly suspended in the lower end of the tubing string 16 is a tubular extension member 17.

Prior to the treatment in accordance with the present invention, the incompetent zone 12 is treated to consolidate same at least adjacent the well bore 11. This is accomplished by injecting into the incompetent zone 12 a liquid halide of silicon. The halide may suitably be silicon tetrachloride although it is contemplated that other high molecular weight chlorides or halides of silicon may be employed. For example, silicon hexachloride may be used. The octachloride of silicon may be used, however, it is preferred to employ the tetrachloride.

The liquid halide of silicon is preferably injected into the incompetent zone 12 as a solution in oil containing from about 2% to about 80% by volume of the liquid silicon halide. A preferred concentration is within the range from about 4% to about 40% by volume of the oily solution. The oil may be crude oil or fractions thereof; for example, a kerosene solution of silicon tetrachloride may be used.

In the practice of the present invention prior to consolidating the incompetent zone 12 it is desirable to remove all aqueous fluids from the region of the incompetent zone 12 in the casing 13. This may be done by displacing aqueous fluids such as drilling mud with a blanketing fluid such as oil and then injecting the oily solution of silicon tetrachloride into the incompetent zone 12 to consolidate it by reaction with water therein.

It has been found that while silicon tetrachloride and the liquid silicon halides of the present invention can satisfactorily consolidate zones such as 12, the consolidated zones lose strength when subjected to prolonged flow of water. The chemistry of the reaction to consolidate sands with silicon tetrachloride and the like is believed to involve several steps in which the first is the hydrolysis of the halides to produce amorphous hydrated silicon. The hydrated silica is believed to be unstable because of the presence of four hydroxyl groups on a single silica atom. This instability leads to the splitting out of water to form a



linkage along with cross-linkages to make a very stable material when the reaction is complete. Due to the size of the molecules built up in this manner and due to the retention of unreacted Cl⁻ atoms on the silicon, and due to the immobility of the hydrated silica, it is difficult for this reaction to become complete in a sand body such as an incompetent subsurface earth zone. After contact with water, the result frequently is that many hydroxyl groups are left on the molecule and the presence of these hydroxyl groups imparts solubility or peptization through the incompletely reacted material. Thus when water

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flows through the treated consolidated sand, the bonding material is removed and the consolidation may be destroyed. In accordance with the present invention, the reaction is caused to go to completion by heating the treated consolidated sands to remove hydroxyl groups.

In accordance with the mode of FIG. 1, a hot fluid such as oil is injected down the tubing string 16 and through the tubing extension member 17 and thence through the perforations 15 to heat the consolidated incompetent zone 12 to a temperature within the range given and for a period of time sufficient to stabilize the consolidated incompetent zone by removal of hydroxyl groups. After the treatment by heating to an elevated temperature for the period of time indicated, the injection of hot fluid in accordance with FIG. 1 is discontinued and a pressure differential from the stabilized consolidated incompetent zone 12 into the casing 13 is established and oil production is then possible without the production of sand and without the consolidated incompetent zone losing its stability.

Referring now to FIG. 2, heating of the consolidated incompetent zone 12, which contains water and hydrocarbons after treatment with silicon tetrachloride, may be established by blowing a free oxygen-containing gas such as air down through the tubing string 16 and the tubing extension member 17 and through the perforations 15 into the consolidated incompetent zone 12 and then igniting the hydrocarbons and oxygen in the zone 12 to cause a zone of combustion 18 to exist therein which will heat the consolidated incompetent zone to an elevated temperature for a period of time sufficient to stabilize the consolidated incompetent zone.

After the consolidated incompetent zone has been heated by combustion in the zone of combustion 18, the flow of free oxygen-containing gas is discontinued and a pressure differential is then established into the well bore such as by reducing the pressure therein by swabbing and thereafter hydrocarbons may be produced through the tubing extension 17 and the tubing 16.

Referring now to FIG. 3, a different mode of practicing the invention is illustrated and in this mode a tubing string such as 19 has dependent therefrom and attached thereto a burner 20 to which is connected an auxiliary line 21. Auxiliary line 21 supplies a combustible mixture of hydrocarbon gas and air in a ratio of about 15 parts of air to about one part of hydrocarbon gas through line 22 at the earth's surface which is provided with a spark plug 23 and a means for supplying electrical energy thereto by way of 24. At the same time, a combustible mixture is flowed down the tubing string 19 and excess air is provided through the casing-tubing annulus 25. The combustible mixture in lines 22 and 21 is ignited in the burner 20 to cause the generation of hot flue gases in the region of the incompetent zone 12 such that the hot flue gases may be flowed through the perforations 15 out into the consolidated incompetent zone 12 which has previously been treated with silicon tetrachloride to consolidate the sand.

After the consolidated incompetent zone has been treated for a sufficient length of time to stabilize same, hydrocarbons may then be producible through the tubing string 19 by lowering the pressure differential from the formation into the well casing 13 to allow production of hydrocarbons.

In the several modes of practicing the invention such as described with respect to FIGS. 1 to 3, inclusive, it is desirable and necessary that water be present in the incompetent zone for reaction with the liquid silicon halide to cause hydrolysis thereof and to bond the sand grains together. If sufficient water is not present in the incompetent zone 12, it may be desirable to inject fresh or salt water into said zone as may be desired.

The present invention will be illustrated further by the several examples. In one operation several flow tubes were packed with different sands and saturated with oil

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and connate water to simulate an oil producing sand. This was accomplished by first saturating the flow tube containing sand with a 3% salt solution and then flowing oil through the sand until connate water was reached. The sand was then treated with an oil solution of silicon tetrachloride containing either 10% or 20% of silicon tetrachloride. While it is preferred to use an oil solution of silicon tetrachloride or liquid silicon halide, it is within the purview of this invention to use a pure liquid silicon halide as may be desired. After treatment, these sands were then subjected to flow of 3% salt water at room temperature. It was found that the consolidated sand lost strength and became unstable in 1 to 6 days as shown in Table I.

TABLE I

Stability of Sand Consolidated With Silicon Tetrachloride to the Flow of 3% Salt Water at 77° F.

		Length of time core was stable, days
20	Sand:	
	Friendswood	1+
	Ottawa	3
	Do	4
	Do	6
25	Do	6

In order to illustrate the practice of the present invention, a second group of flow tubes containing sand was prepared, saturated, and consolidated in the same manner as described supra. These treated sands were cleaned and dried prior to heating. Heating was then accomplished at several temperatures from 110° C. up to 1000° C. These results are shown in Table II.

TABLE II

Effect of Heating on the Stability to Water of Ottawa Sand Consolidated With SiCl₄ (Hasting Field Water at 160° F.

		Time to failure of core, days
40	Temp. for 1 day, ° C.:	
	No heating	½
	110	2
	200	3
	320	9
	725 (2 days)	21
45	1000 (2 days)	101

¹ Strong.

From the data presented in Table II it is clear that heating increases the stability of the sands to the flow of water. For example, one of the consolidated sands heated for two days at 1000° C. was still strong after 101 days and showed no indication of deterioration from flowing water through it.

In another operation, a flow tube containing sand from the Hull Field in Texas was prepared, saturated, and treated as described above. The treated sand was cleaned and dried and then treated with a mixture of crude oils from the Conroe, Hawkins, and Racoon Bend Texas Fields. In order to prevent too much deposition of solids and coking on heating, a portion of the crude oil was removed by soaking the sand in hexane before heating. The so-treated consolidated sand was then heated at 250° C. for 40 hours. After heating, 3% salt water was flowed through the core at room temperature. This core as treated in accordance with the present invention, has remained stable for a period of over 6 months.

While in the practice of the present invention illustration has been given of flowing a 3% salt solution through the heated consolidated sand, it is contemplated that other aqueous solutions may be flowed therethrough. In fact, any aqueous fluids found in the sands will ordinarily be contacted with the heated consolidated incompetent formation.

The practice of the present invention is quite advantageous and useful in that by heating a consolidated sand,

it may be made stable to water over a long period of time. This allows the production of hydrocarbons without the concomitant production of sand.

The nature and objects of the present invention having been completely described and illustrated what we wish to claim as new and useful and secure by Letters Patent is:

1. A method for treating a water containing incompetent subsurface earth zone penetrated by a well which comprises injecting into said incompetent zone a liquid halide of silicon to consolidate said incompetent zone, and then heating said consolidated zone to an elevated temperature above 300° F. for a time of at least six hours to stabilize said consolidated incompetent zone against flow of water therethrough.

2. A method for treating a water-containing incompetent subsurface earth zone penetrated by a well which comprises injecting into said incompetent zone a liquid halide of silicon to consolidate said incompetent zone, and then heating said consolidated zone to an elevated temperature above 300° F. substantially above the temperature of said incompetent zone by injecting a hot fluid into said consolidated zone for a time of at least 6 hours to stabilize said consolidated incompetent zone against flow of water therethrough.

3. A method in accordance with claim 2 in which the hot fluid is steam.

4. A method in accordance with claim 2 in which the hot fluid is water.

5. A method in accordance with claim 2 in which the hot fluid is gas.

6. A method in accordance with claim 2 in which the hot fluid is oil.

7. A method in accordance with claim 2 in which the liquid halide is injected as an oil solution containing from about 2% to about 80% by volume of the liquid halide.

8. A method for treating a water-containing incompetent subsurface earth zone penetrated by a well which comprises injecting into said incompetent zone a liquid halide of silicon to consolidate said incompetent zone, and then heating said consolidated zone to an elevated temperature above 300° F. substantially above the temperature of said incompetent zone by burning hydrocar-

bons in said consolidated zone for a time of at least 6 hours to stabilize said consolidated incompetent zone against flow of water therethrough.

9. A method for treating a water-containing incompetent subsurface earth zone penetrated by a well which comprises injecting into said incompetent zone a liquid halide of silicon to consolidate said incompetent zone, and then heating said consolidated zone to an elevated temperature within the range from about 300° F. to about 1900° F. for a time within the range from about 6 to about 48 hours to stabilize said consolidated incompetent zone against flow of water therethrough.

10. A method for producing hydrocarbons from an incompetent subsurface earth zone containing water and hydrocarbons penetrated by a well, which comprises injecting into said incompetent zone a liquid halide of silicon to consolidate said incompetent zone, heating said consolidated zone to an elevated temperature above 300° F. substantially above the temperature of said incompetent zone for a time of at least 6 hours to stabilize said consolidated incompetent zone, and then producing hydrocarbons from said consolidated incompetent zone against flow of water therethrough.

11. A method for treating a water-containing incompetent subsurface earth zone penetrated by a well which comprises injecting into said incompetent zone silicon tetrachloride to consolidate said incompetent zone, and then heating said consolidated zone to an elevated temperature above 300° F. substantially above the temperature of said incompetent zone for a time of at least 6 hours to stabilize said consolidated incompetent zone against flow of water therethrough.

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