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GRAVEL PACKING OF WELLS

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This invention relates to the art of gravel packing of oil and gas wells, and relates more particularly to an improved fluid for the emplacement of the gravel.

In completing oil and gas wells, the usual practice is to set casing on top of the productive zone, drill through the latter with a bit of slightly smaller diameter than that of the last casing set, and place a liner, i. e., a section of perforated or screened pipe, extending from the bottom of the casing to the bottom of the productive sand. Oil is then allowed to flow into the liner, whence it may be pumped or depending upon conditions may flow of its own accord to the top of the well.

It is recognized that this procedure in many cases is imperfect, for in the first place the small diameter of the bore hole which finally penetrates the productive zone is so small that the flow of fluids from the formation into the hole is restricted more than it would be if the hole were of larger diameter. This also has the effect of causing a larger pressure gradient in the last few inches of formation adjacent the walls of the bore hole so that the tendency of the formation to disintegrate is increased, and undue amounts of sand are sloughed from the formation against the liner; depending upon whether the perforations in the liner are smaller than the sand, the latter either passes through and the sand produced along with the oil and other fluids, or the sand clogs the perforations of the liner and greatly reduces its permeability. For these reasons it has become an increasingly common practice to underream the bore hole in the productive formation below the casing, so that the bore hole is enlarged to sometimes 2 or 3 feet in diameter within the productive formation. A liner of normal size, say 4, 6, or 8 inches in diameter, is placed within the underreamed bore hole as before, and the space between the liner and walls of the formation are filled by one means or another with a pack of gravel, the individual grains of which are just small enough so that the passage of sand into the liner is prevented. Thus the effective drainage area of the well is vastly increased, the tendency of the formation to slough sand is inhibited, any slight sloughing of sand which takes place will not seriously impair the permeability of the drainage system, and finally no sand gets into the crude oil as taken from the well.

Several methods may be employed to place the gravel where it is desired in the annular space between the liner and the walls of the productive formation. One method which is sometimes used

involves the use of a window in the liner near the top thereof, whereby gravel may be poured or circulated therethrough and into the annular space, the circulating fluid returning through the liner. Another method involves the use of a liner, the perforations of which are temporarily closed by a sheet of cement on the inside of the liner. In this very common method the gravel is circulated either down tubing and through the bottom of the liner, using a mud fluid of sufficient gel-strength to support the gravel, the fluid returning the space between the tubing and the casing after having deposited its burden of gravel, or the gravel may be circulated in the opposite direction, the circulating fluid returning up through the tubing.

Thus it may be seen that in the majority of cases a circulating fluid is used for the actual emplacement of the gravel, as in this manner the gravel can be positively placed where it is desired to be. As circulating fluids ordinary clay-laden drilling fluids are by far the most common. Water and oil have been proposed as emplacement fluids, and they have been used, although in the case of these latter there is no satisfactory control over the movement of the gravel as the gravel is free to flow more or less according to Stokes' law down through the emplacing fluid. The use of a fluid such as oil or water would also in practice render the use of the method of circulating the gravel down through the tubing and upward into the annular space impossible of use, as prohibitively great rates of flow would be needed to transport the gravel upward. Water suffers also from the very great disadvantage that it tends to water-off the productive formation, permanently reducing its permeability to oil.

On the other hand, the use of a mud-laden aqueous drilling fluid, the usual method employed, suffers from the very great disadvantage that a certain amount of the clay is almost of necessity left within the gravel pack, no matter how great an effort is made to remove it by circulating oil or water after the gravel pack is in position. The result is that although such a gravel pack performs very effectively as far as preventing infiltration of sand into the well is concerned, the permeability of the gravel pack has been greatly reduced, particularly its permeability to oil.

One of the objects of this invention is to provide a fluid of improved characteristics for the emplacement of gravel packs.

Another object is to provide a means of laying

down gravel packs having the maximum permeability attainable for the particular gravel size and degree of compaction used.

Another object of the invention is to provide an emplacement fluid capable of supporting gravel without permanently clogging the interstices of the gravel pack.

Another object of the invention is to provide a fluid of high gel-strength which will not water-off the productive formation when used for the emplacement of a gravel pack therein.

Other objects will become apparent as description of the invention proceeds.

According to this invention an oil and water emulsion is used as the emplacement fluid for laying down gravel packs. This may be an oil-in-water emulsion if desired, but it is much preferable to use a water-in-oil emulsion, as the latter does not tend to water-off the productive formation, and is more compatible with the natural emulsion usually found in the productive zone. For the oily phase of such an emulsion crude oil may be conveniently used; or if desired mineral spirits, such as kerosene or similar distillates, or mixtures thereof with crude oil, may be used instead. For the aqueous phase water will normally be used; in rare instances it may be desirable to substitute other hydrophobic liquids therefor, such as an aqueous solution of glycerol, or methyl-alcohol or the like.

These emulsions may be generally made by using the standard equipment at the surface of the well, which generally includes high pressure jetting apparatus for mud mixing and for the hydration of dry clays. If relatively refined mineral spirits are used, such as kerosene, calcium oleate may be used as the emulsifying agent. For example, about 3% by weight of oleic acid is added to the oil and about 3% by weight of calcium hydroxide is added to about $\frac{1}{2}$ as much water, and the latter is introduced into the former at a relatively high temperature, and under conditions of severe agitation. This will produce an emulsion of the desirable water-in-oil type. An emulsion of this type may also be produced with the use of di-glycolstearate, if desired, although the stability is likely to be less. An unstable emulsion is by no means necessarily to be avoided, however, for if the breaking thereof can be delayed until the gravel pack is placed, the breaking of the emulsion, either spontaneously or by means of the introduction of known emulsion breakers, may hasten the process whereby the emplacement fluid is completely removed from the gravel pack. If crude oil is used, much smaller amounts of emulsifying agents need be used, particularly if the water is somewhat acidulated, and indeed many crudes will form a water-in-oil emulsion when made with acidulated water without the addition of any other emulsifying agent whatsoever. Oil-in-water emulsions may be used if desired; they are somewhat easier to prepare with refined oil but perhaps somewhat harder to prepare with crude oil, and offer the great disadvantage that the continuous phase is water instead of oil, so that water may be left in the gravel pack and can never be displaced by the oil which is produced from the formation, so that the full permeability of the gravel pack is not realized, and one of the objects of this invention is thereby defeated.

As an example of the result to be obtained by this procedure, the results of the following may be cited:

A quantity of carefully selected and cleaned

dry sand was placed in a cylindrical container so arranged that the permeability of the pack thereby formed could be readily determined. The permeability of the pack was determined to be 66 darcys, using a certain test oil. When the same quantity of dry sand was laid down with water and oil then forced through at a pressure gradient up to $3\frac{1}{2}$ lbs. per sq. in. per in., the permeability was found to have dropped slightly to 59 darcys. Another equal amount of dry sand was mixed with a typical light-bodied semi-colloidal clay drilling fluid such as is in common use in California for drilling wells and for placing gravel packs. After the pack was in place the mud was then displaced completely as possible with the same oil at the same pressure, but the maximum permeability attainable was 13 darcys, less than 20% of the permeability which would have been attained had the mud not been used in placing the pack. The mud, as has been said, was a semi-colloidal mud fluid free from sand, and the gravel pack contained no particles larger than 28 mesh and no particles smaller than 50 mesh. Then a new sample of sand was taken, mixed with a water-in-oil emulsion having an initial gel-strength of 100 grams as determined on the Stormer viscosimeter, and an apparent viscosity of about 208 cpe. as determined at 600 R. P. M. on the same instrument, being plastic enough to support the gravel, laid down in the cylinder, and the permeability determined by oil after the latter had displaced the emulsion, under the same pressure as used before. The permeability as determined was 78 darcys, slightly more than even the original sand, possibly because the degree of compaction was not quite as great due to the supporting qualities of the emulsion. This last experiment was repeated introducing a slug of oil containing a small amount of an emulsion breaker of the modified resin type just before the permeability determination was made; a permeability of 71 darcys was observed, this being closer to that of the original dry sand because of slightly better compaction, or perhaps because of within the range of experimental error.

The foregoing shows what remarkable results may be expected in the hole by the use of this improved fluid. Almost any desired gel-strength may obtain in the fluid used if a water and oil emulsion is used. On the other hand, if an aqueous clay-laden fluid of 100 grams Stormer gel-strength were used, only a very small amount indeed of the total mud could be displaced with oil, and if an attempt were made to wash the gravel pack with water before bringing the well in, it is extremely problematical if the entire gravel pack could be completely reached by such washing water, and in any case it is scarcely to be hoped that all of the clay solids would be removed by such treatment. In an emulsion of the type described, however, the fluid is 100% liquid, and contains no solid matter except the supported gravel. As the oil is produced from the formation, it gradually commingles with the emulsion, being miscible therewith, and so lowers its gel-strength that ultimately it is all swept away. The removal is made even more quickly if the emulsion tends to break spontaneously. The art of the preparation of emulsions of any desired characteristics is well-developed and well-known, and we have confined ourselves to only a few practical notes herein; but it is apparent that any skilled chemist can produce emulsions suit-

able for the employment in the process of this invention.

It is further to be understood that the expressions "gravel packing", "gravel pack" and gravel" are used descriptively and not limitatively to include other packings than gravel; further, that various changes may be made as to environment and agents, within the scope of the appended claims without departing from the spirit of this invention.

Having thus described the invention, what is claimed is:

1. In the art of gravel-packing wells, the process comprising, introducing the gravel by an emulsion at least one of whose phases is soluble in petroleum.

2. In the art of gravel-packing wells, the process comprising, introducing the gravel by an emulsion whose external phase is soluble in oil.

3. In the art of gravel-packing wells, the process comprising, introducing the gravel by an emulsion at least one of whose phases is an oil.

4. In the art of gravel-packing wells, the process comprising, introducing the gravel by an emulsion of water and oil.

5. In the art of gravel-packing wells, the process comprising, introducing the gravel by a water-in-oil emulsion.

6. In the art of gravel-packing wells, the process comprising, introducing the gravel by an oil-in-water emulsion.

7. In the art of gravel-packing wells, the process comprising, introducing the gravel by an unstable emulsion at least one of whose phases is soluble in petroleum.

8. In the art of gravel-packing wells, the process comprising, introducing the gravel by an emulsion of water and oil and thereafter causing breaking of the emulsion.

9. In the art of gravel-packing wells, the process comprising, introducing the gravel by a water-in-oil emulsion and thereafter introducing an emulsion breaker into such emulsion.

10. A gravel pack for oil wells comprising gravel and an emulsion at least one of whose phases is soluble in petroleum.

11. A gravel pack for oil wells comprising gravel and an emulsion at least one of whose phases is an oil.

12. A gravel pack for oil wells comprising gravel and an emulsion of water and oil.

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