A process of perforating an oil-bearing subterranean formation wherein the perforations in the reservoir are caused by a hole-producing apparatus, the improvement comprising perforating the reservoir in the presence of a micellar dispersion. The micellar dispersion can be at a pressure sufficient to cause the dispersion to displace out into the reservoir after the perforations are effected. Cleaning of the perforations, removing mud filtrates, etc., are effected with the dispersion. Where water sensitive reservoirs are perforated, an oil-external dispersion is used since it is compatible with such reservoirs.

13 Claims, No Drawings
USE OF MICELLAR SOLUTIONS TO IMPROVE PERFORATING PROCESS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an improved process of perforating an oil-bearing subterranean reservoir. Such is accomplished by perforating the reservoir in the presence of a micellar dispersion—the dispersion can be at a pressure sufficient to cause the micellar dispersion to rapidly flow out into the reservoir once the perforations are made. The micellar dispersion is comprised of hydrocarbon, aqueous medium, surfactant, and optionally, cosurfactant and/or electrolyte (can be an acid). In addition, propping agents, fluid loss control agents, corrosion inhibitors, weighting agents, etc. can be incorporated into the micellar dispersion.

2. Description of the Prior Art

Perforating of a cased or an open-hole well bore is generally done with shaped charges or bullets. The shaped charges are usually mounted on a carrier strip while the bullets are mounted in a cylindrical gun. The perforating tool is then lowered into the well bore at the desired depth and thereafter the shaped charges or bullets are activated resulting to perforate the reservoir. The perforations generally extend 1.5 to 2.5 feet out into the reservoir. Of course, shorter or longer perforations of the reservoir can be obtained due to the energy in the shaped charge or bullet and also due to the design of the bullet or shaped charge.

When perforating reservoir rocks, liquid is generally present in the well bore. This is preferred when perforating a reservoir rock that is not well cemented or one that is unconsolidated. It is desired that the liquid present in the hole be one that is compatible with the reservoir and preferably be one that will clean the perforations. When the reservoir contains water-sensitive clays, it is preferred that the liquid be non-aqueous.

Also, it has been postulated that a differential pressure toward the well bore may be desired in perforating certain reservoirs. Such dictates there be a minimum pressure head of liquid. In certain cases, a container at atmospheric pressure may be attached to the perforating gun and the combination sealed off from the rest of the reservoir by a packer—when the perforating gun is fired, the container is opened to allow fluid flow into the well bore. A chamber permits differential pressure toward the well bore and permits washing of the perforations back toward the well bore once the perforations are made.

U.S. Pat. No. 2,693,856 to Allen teaches a well completion method wherein a well is perforated in the presence of a fluid of sufficient weight and/or viscosity to prevent displacement of heavier muds into the perforations.

U.S. Pat. No. 2,805,722 to Morgan et al. teaches perforating a formation by first displacing the drilling mud with an emulsion containing a weighting agent, thereafter submerging the perforating tool in the emulsion and then perforating the formation. Clean perforations are obtained. The emulsion is heat-stable and has a low fluid loss characteristic at high reservoir temperatures.

U.S. Pat. No. 2,832,425 to Reistle, Jr. teaches a method of perforating a well in the presence of an acid-soluble material to form an acid-soluble filter plug. The filter plug is subsequently removed by treating same with an acid. As a result, clean perforations are performed.

U.S. Pat. No. 2,837,164 to Allen teaches a well completion method wherein drilling mud is first displaced with a suspension of finely divided solids capable of forming a filter plug in the perforations once the perforations are obtained. The finely divided solids are present in a liquid vehicle. Once the perforations are formed, the solids tend to temporarily plug the perforations. Thereafter, the solids tend to chemically react between themselves and eventually destruct the filter plug leaving a clean perforation.

U.S. Pat. No. 2,894,584 to Birdwell et al. teaches a well completion process wherein a cased well is perforated in the presence of an emulsion. The emulsion contains a weighting agent dissolved in one of the emulsion components.

U.S. Pat. No. 3,170,517 to Graham et al. teaches fracturing and stimulating a cased well by introducing into the casing a fluid at a pressure sufficient to cause fracturing of the formation and thereafter perforating the casing and permitting the fluid to fracture the formation.

German Patent 193,630, U.S. Counterpart is U.S. Ser. No. 738,530 filed June 20, 1968, and now U.S. Pat. No. 3,517,745, defines a process for perforating a deep well by first lowering the perforating tool into the reservoir, filling the reservoir with a chemical that will react with material that tends to plug the formation once the perforations are obtained (e.g., mixtures of acids such as HF and HCl), then pressurizing the liquid to a pressure so that when the perforations are effect, the liquid will move out into the formation and thereafter perforating the formation. Diesel fuel can be pumped in on top of the acid to pressurize the liquid.

SUMMARY OF THE INVENTION

Applicants have discovered a method of increasing the efficiency of perforating a subterranean reservoir by perforating the reservoir in the presence of a micellar dispersion. The micellar dispersion can be pressured to a pressure sufficient to "drive" the micellar dispersion out into the reservoir once the perforations are made; or, a container or like means can be present in the hole that will permit a differential pressure toward the well bore once the perforations are obtained, the latter causes a washing action of the perforations and fluid plus debris flow back into the well bore. In addition, the micellar dispersion can contain fluid loss control agents as well as acid in the aqueous phase.

PREFERRED EMBODIMENTS OF THE INVENTION

Perforations within a subterranean reservoir are obtained using conventional perforating methods. Shaped charges and bullets are examples of conventional perforating means. Such perforating means are called perforating guns, perforating tools, hole-producing apparatus, perforating apparatus, etc. The perforations are effected on cased wells in addition to open hole wells. The perforations extend out into the reservoir. In a cased well, the perforations extend through the casing well, the cement in the annulus between the casing and the well bore, and then out into the reservoir rock.

During the perforating process, there is usually debris, by-products from the perforating tool, etc. which contaminate the reservoir rock and in general adversely influence fluid flow through the perforations. Also, the well bore may be contaminated with drilling
mud filtrates and other contaminants that were present before the perforating tool is activated. This invention improves fluid flow in the perforating process.

To effect cleaning of the perforations and to facilitate fluid flow after perforating job is effected on the reservoir rock, the perforating is done in the presence of a micellar dispersion. The micellar dispersion can be oil-external or water-external. Oil-external is preferred wherein the reservoir contains water sensitive clays.

The micellar dispersion is comprised of hydrocarbon, water, surfactant, and optionally cosurfactant and/or electrolyte. In addition, other additives such as fluid loss control agents, gelling agents, propping agents, corrosion inhibitors, oxygen inhibitors, bactericides, weighting agents, etc. can be incorporated into the micellar dispersion. Examples of composition include about 2 to about 70 percent, preferably about 10 to about 60 percent and more preferably about 20 to about 50 percent by volume of hydrocarbon; about 5 to about 95 percent, preferably about 10 to about 80 percent and more preferably about 20 to about 70 percent by volume of aqueous medium; about 4 to about 20 percent or more of surfactant, the surfactant can be 50 percent or more active sulfonate; about 0.01 to about 20 percent and preferably about 0.1 to about 5 percent by volume of cosurfactant; and about 0.001 to about 10 percent and preferably about 0.01 to about 5 percent by weight, based on the aqueous medium, of electrolyte. It is desired that the micellar dispersion be reactive with the reservoir rock, the aqueous medium can contain about 0.001 to about 10 percent and preferably about 0.01 to about 5 percent by weight of an acid, examples of acids include hydrochloric acid, phosphoric acid, and hydrofluoric acid; preferably the aqueous phase has a pH less than 1 when it is desired the dispersion be reactive.

The hydrocarbon can be crude oil (both sweet and sour crude oil), a partially refined fraction of crude oil such as gas oil, kerosine, gasoline, naphthas, etc.; and a refined fraction of crude oil such as propane, butane, pentane, heptane, decane, etc. The hydrocarbon can be a synthesized hydrocarbon, e.g. substituted aryl compounds, and can be halogenated hydrocarbons.

The aqueous medium can be soft water, brackish water, or a brine water. Where the water contains ions, it is preferred that the ions be compatible with those within the subterranean formation being perforated.

The surfactant can be anionic, cationic, and nonionic but is preferably a petroleum sulfonate having an average equivalent weight within the range of about 350 to about 525, and more preferably about 390 to about 460 and most preferably about 410 to about 430. Also, it is preferred that the sulfonate be a monovalent cation-containing petroleum sulfonate.

The cosurfactant can be an alcohol, ester, aldehyde, ketone, amine, or a compound containing the combination of two or more functional groups such as hydroyx, ether, amine, etc. and which contain 1 to about 20 carbon atoms and preferably about three to about 16 carbon atoms. The cosurfactant is preferably an alcohol such as isopropanol, n- and isobutanol, amyl alcohols, 1- and 2-hexanol, alkaryl compounds such as p-nonyl phenol, and alcohol liquors such as fusel oil.

The electrolyte can be an inorganic salt, inorganic base, inorganic acid (preferred where the micellar dispersion is desirably reactive with the reservoir rock), organic base, organic acid, and organic salt.

Specific examples of micellar dispersion components are found in U.S. Pat. Nos. 3,254,714 to Gogarty et al., 3,275,075 to Gogarty et al., 3,301,325 to Gogarty et al., 3,506,076 to Jones; 3,506,071 to Jones; 3,497,066 to Jones et al.; and U.S. Ser. No. 829,739 to Jones et al., filed June 2, 1969, now abandoned. To shift the thermostability range of the micellar dispersion to higher temperatures, technology known in the art can be used as well as that technology included in U.S. Pat. No. 3,493,047 to Davis et al.; U.S. Pat. No. 3,500,912 to Davis et al.; U.S. Pat. No. 3,493,048 to Jones; U.S. Pat. No. 3,508,611 to Davis et al.; U.S. Ser. No. 870,244 to Davis et al., filed Nov. 6, 1969, now U.S. Pat. No. 3,578,082; and U.S. Ser. No. 862,447 to Davis et al., filed Aug 30, 1969, now U.S. Pat. No. 3,540,552.

Fluid loss control agents can be incorporated into the water phase or the hydrocarbon phase of the micellar dispersion. Preferably, the agents are incorporated into the water phase, examples of such agents include silica flour, guar gum, polyacrylamides including partially hydrolyzed polyacrylamides, etc.

The reservoir is perforated while the perforating tool is submerged in the micellar dispersion. The micellar dispersion can be at a pressure sufficient to cause the micellar dispersion to be driven out or rapidly flow out into the reservoir once the perforations are effected. However, the micellar dispersion can be at a lesser pressure such that it will tend to leak or migrate out into the reservoir under the hydrostatic head of the micellar dispersion and any additional fluid present on top of the micellar dispersion. Where the reservoir is characteristic of a "not well cemented" sand, e.g., unconsolidated sand, it is preferred that the micellar dispersion be pressured under sufficient pressure to cause the micellar dispersion to rapidly displace out into the reservoir once the perforations are effected. If the reservoir rock is dolomite, a limestone or a well-cemented sand, then it is preferred that the perforating process be carried out in the presence of a chamber or container which will automatically open or collapse upon the firing of the perforating gun and will permit a differential pressure towards the well bore rather than away from the well bore—such will cause a washing action of the perforations first out into the reservoir and then back into the well bore into the chamber. The latter tends to wash the perforations of any sediments or residue which may be caused by the perforating process and will permit the deposition of this residue back into the well bore, e.g., a basket at the terminal end of the casing. The chamber which may be present while the perforation is effected can be a container under atmospheric pressure but be capable of withstanding reservoir pressure, the container having a trap door or like means which automatically opens or collapses upon the firing or immediately after the firing of the perforating tool and which permits liquids to flow into the void space of the chamber—such permits a differential pressure toward the well bore and thus a washing effect of the micellar dispersion first out into the perforations and then back into the well bore and into the chamber. Where the chamber or container is used, it is preferred that the section of the well bore to be perforated be backed off from the rest of the well bore and that the valving at the surface be manipulated to facilitate pressure differential after firing of the perforating tool. That is, if it is desired that the differential pressure be
away from the well bore, then the valving at the well head can be shut in and the well bore pressured up, preferably with a gas. However, where the differential pressure is preferably toward the hole, after the perforations are effected, the valving can be initially opened at the well head to facilitate the differential pressure toward the well bore and can immediately be "shut in" once the fluids start flowing up the well bore.

Where the reservoir is an unconsolidated sand, it may be desired that the micellar dispersion contain agents which will tend to consolidate the reservoir rock. Such can be effected by incorporating into the water or oil phase of the micellar dispersion, depending upon the solubility of the consolidating agent. Examples of consolidating agents include resins such as phenol aldehyde, phenol formaldehyde, alkyds, acrylic acid, epoxy, and the like.

The micellar dispersion tends to clean the perforations, solubilize mud filtrates, etc. which were deposited during the initial drilling of the well, and also remove contaminating agents which were deposited during the cementing of the casing. In addition, the acidic phase of the micellar dispersion can chemically react with the reservoir rock and other residue caused during the perforating process. The overall effect of the micellar dispersion during the perforating of the reservoir is to facilitate flow of hydrocarbon toward the well bore by removing these residua.

This invention is especially useful in perforating a reservoir where the well is intended to be used as a water injection well. In such a case, it is preferred that the micellar dispersion be at a pressure sufficient to "drive" or cause the micellar dispersion to rapidly disperse out into the reservoir through the perforations once they are effected in the reservoir rock. In such a case, the micellar dispersion tends to solubilize waxy occlusions, mud filtrates, etc., in the immediate vicinity of the well bore. Also, the micellar dispersion tends to solubilize hydrocarbon in the immediate vicinity of the well bore and thus increase the relative permeability to the flow of water. Water can optionally be flowed behind the micellar dispersion or the well bore can be pumped out or bailed out after the perforating job is effected. Where the reservoir is an unconsolidated sand, it may be desired to immediately follow the micellar dispersion with water that is characteristic of the interstitial water.

Where the well is a production well, either oil or gas, the micellar dispersion is preferably designed to solubilize water within the immediate vicinity of the well bore. Thus, once the perforations are effected within the reservoir rock, the micellar dispersion tends to migrate out into the reservoir rock through the perforations and solubilize the water in the immediate vicinity of the well bore. After this is effected, the natural pressures of the reservoir tend to push the micellar dispersion containing the solubilized water or components of the micellar dispersion containing the solubilized water back into the well bore—the relative permeability to the flow of hydrocarbon is increased due to the removal of the water within the immediate vicinity of the well bore. Also, waxy occlusion, mud filtrates, etc., are solubilized by the dispersion.

It is not intended that this invention be limited by the specifics taught herein. Rather, all equivalents obvious to those skilled in the art are intended to be incorporated within the scope of the invention as defined in the specification and appended claims.

What is claimed is:

1. An improved method of perforating a subterranean reservoir wherein the perforating tool is lowered into the well bore and thereafter the perforating tool is activated to cause perforations out into the reservoir rock, the improvement comprising perforating the reservoir while the perforating tool is submerged in a micellar dispersion.

2. The process of claim 1 wherein the micellar dispersion contains about 2 to about 70 percent by volume hydrocarbon, about 5 to about 95 percent volume aqueous medium, about 4 percent to about 20 percent by volume surfactant, and optionally about 0.01 to about 20 percent by volume cosurfactant and/or about 0.001 to about 10 percent by weight, based on the aqueous medium, electrolyte.

3. The process of claim 1 wherein the micellar dispersion contains an aqueous phase having a pH less than 1.

4. The process of claim 1 wherein the micellar dispersion is at a pressure sufficient to cause the micellar dispersion to disperse out into the reservoir once the perforations are effected in the reservoir rock.

5. The process of claim 4 wherein the reservoir rock is unconsolidated sandstone.

6. The process of claim 1 wherein the perforating of the oil-bearing reservoir is carried out in a portion of the well bore that is packed off from the rest of the well bore and wherein a container under a pressure less than the reservoir pressure is present and wherein upon perforating the reservoir rock, a void space within the container is permitted to be filled with reservoir liquids.

7. An improved method of perforating a subterranean formation wherein a perforating tool is lowered into a well bore in communication with the reservoir and wherein the perforating tool is activated to cause perforations out into the reservoir rock, the improvement comprising carrying out the perforating process in the presence of a micellar dispersion which submerges the perforating tool therein, the micellar dispersion containing about 2 to about 70 percent by volume hydrocarbon, about 5 to about 95 percent by volume of aqueous medium, about 4 to about 20 percent of a petroleum sulfonate having an average equivalent weight within the range of about 350 to about 525, and optionally about 0.01 to about 20 percent by volume of cosurfactant and/or about 0.001 to about 10 percent by weight, based on the aqueous medium, of an inorganic electrolyte.

8. The process of claim 7 wherein the inorganic electrolyte is an inorganic acid.

9. The process of claim 7 wherein the micellar dispersion is oil-external.

10. The process of claim 7 wherein the aqueous phase of the micellar dispersion contains a fluid loss agent.

11. The process of claim 7 wherein the reservoir is an unconsolidated sandstone.

12. The process of claim 11 wherein the micellar dispersion contains a consolidating agent to consolidate at least a portion of the unconsolidated sandstone.

13. The process of claim 7 wherein at least a portion of the reservoir to be perforated is packed off from the other portion of the well bore and wherein a container having a void space and under a pressure substantially less than the reservoir pressure is present in the portion of the well bore to be perforated and also wherein the void space within the container is permitted to fill with the reservoir fluids once the perforations are effected in the reservoir rock.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,754,599 Dated August 28, 1973
Inventor(s) Jack L. Hummel et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 1, line 8: Delete "too" and insert --tool--.

Claim 2, line 3: After "%" insert --by--.

Signed and sealed this 1st day of January 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

RENE D. TEGTMeyer
Acting Commissioner of Patents