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METHOD FOR COMPLETING WELLS TO PREVENT PARAFFIN DEPOSITS

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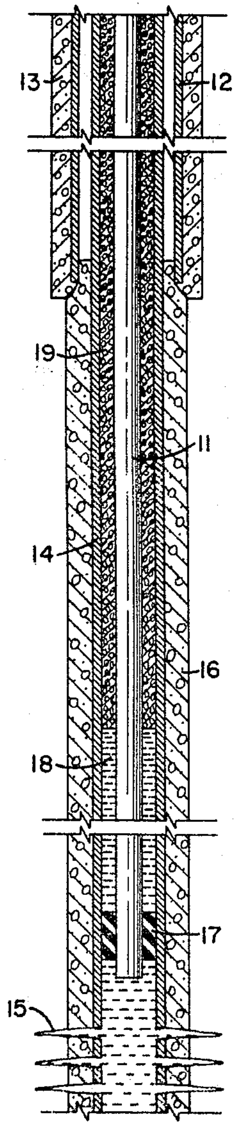

FIG. 1

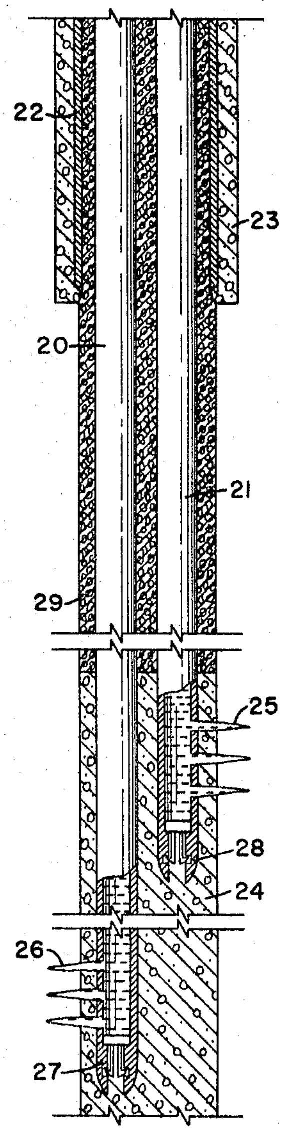

FIG. 2

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METHOD FOR COMPLETING WELLS TO PREVENT PARAFFIN DEPOSITS

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ABSTRACT OF THE DISCLOSURE

A cellular insulating material is installed around the producing string in an oil well to prevent the deposition of paraffin from crude oil passing through the string to the earth's surface.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to the completion of oil and gas wells and is particularly concerned with a method for completing wells producing waxy crude oils to prevent the formation of paraffin deposits.

Description of the prior art

The formation of paraffin deposits is a serious problem in many wells producing heavy crude oils. Such oils often contain long chain paraffinic hydrocarbons, asphaltenes, and resins which are relatively soluble at reservoir temperatures but relatively insoluble at slightly lower temperatures. The cooling which takes place as such oils move upwardly in the wellbore may be sufficient to precipitate these materials and hence paraffin deposits may be formed in the upper part of the tubing string and in the flow lines leading from the well. Plugging of the well and lines may occur if the deposits are not removed at frequent intervals. This is normally done by running scrapers through the strings and lines or treating the well with hot oil or solvents. These procedures are time consuming and expensive, particulraly in offshore operations where very small amounts of paraffin may interefere with the proper operation of automatic valves and through-the-tubing tools.

SUMMARY OF THE INVENTION

It has now been found that paraffin deposits can often be prevented by installing a cellular insulating material around the producing strings. Studies have shown that the heat losses through the pipe walls in most wells are relatively high and that the oil temperature drops rapidly as fluids move upwardly through the tubing or casing to the earth's surface. By installing a rigid foam or similar porous material in the annulus surrounding the producing string, the geothermal energy present in the oil can often be conserved so that the oil temperature does not drop to the point where paraffin deposition takes place. This avoids the necessity for periodically treating the well to remove deposits and eliminates many other problems associated with paraffin deposit formation.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 in the drawing is a schematic representation of a well provided with a rigid foam in the annulus between the tubing string and casing and FIGURE 2 depicts the use of insulating material above the cement in a multiple completion well.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

A variety of unicellular plastic foams which are rigid and relatively inert to water, brine and other subterranean fluids under reservoir conditions may be employed in carrying out the invention. Suitable materials include the expanded phenol-aldehyde and urea-aldehyde resins, polystyrenes, polyurethanes, polyethylenes, cellulose acetates and the like. These materials have very low thermal conductivities, generally on the order of about 0.02 to 0.03 B.t.u./hr./ft.^{2}/°F./ft., and are therefore excellent insulating materials. In general their heat resistance, chemical stability and mechanical strength are sufficient to permit their use under most conditions likely to be encountered in producing wells. Certain of the expanded materials have better properties than others and are therefore preferred.

A particularly effective class of expanded materials for use in wells where moderate temperature conditions prevail are the unicellular polyurethanes. These may be prepared by the reaction of a dicarboxylic acid ester of a polyfunctional alcohol containing free hydroxyl groups, an adipic acid ester of glycerol for example, with a di- or polyisocyanate such as toluene di-isocyanate. The di- or polyisocyanate reacts in part with the hydroxyl groups on the ester to form polyurethane bonds. Due to the increase in temperature as the exothermic reaction takes place, the carboxyl groups react with isocyanate groups to form cross-links and liberate carbon dioxide. A tough spongy mass which turns into a very hard rigid foam is formed. A thermal blowing agent such as trichloromonofluoromethane, "Unicel" or "Porofor" may be included to increase the production of gas and thus obtain a lower density material. Surface active agents, fillers and other additives can also be included if desired. This method and other techniques which may be used to produce rigid polyurethane foams, including the use of free flowing powders which melt, expand and cure when heated, have been described in detail in the literature and will be familiar to those skilled in the art. Prepared compositions based on these techniques which can be used to produce the rigid foams are available commercially.

Small spheres or "microballoons" of phenolic plastic or similar material which can be bonded together with a polyester, phenolic or epoxy binder may also be used to produce cellular materials within the wellbore. The bonding action produces a rigid, low density material sometimes referred to as a "syntactic" foam. The spheres used are generally filled with nitrogen and normally have diameters on the order from about 0.001 to about 0.0015 inch. The use of such materials is particularly advantageous in that the bonding does not require heat and can be carried out in situ without difficulty.

The cellular plastics referred to above are utilized in accordance with the invention to form zones of low thermal conductivity surrounding the tubing or casing strings in wells which produce crude oils normally presenting paraffin deposition problems. The location of the low thermal conductivity zones will depend primarily upon the way in which the well is completed. FIGURE 1 of the drawing depicts a well producing oil from a subterranean formation through a single string of tubing **11**. Surface pipe **12** surrounded by cement **13** extends through the shallow formations near the earth's surface. Casing string **14** extends from the surface to a point below perforations **15** and is surrounded by cement sheath **16**. A production packer **17** has been installed in the well between the tubing and casing a short distance above the producing zone. A packer fluid **18** is located in the annulus above the packer to equalize the pressure across it and prevent leaks. The mud used in drilling the well or a specially compounded fluid designed to reduce corrosion and provide added hydrostatic pressure on the upper face of the packer may be employed as the packer fluid. An auxiliary packer, not shown, may be installed between the casing and tubing above the packer fluid to isolate the expanded material from the fluid if desired.

The unicellular plastic material employed in the well of FIGURE 1 is indicated by reference numeral **19.** This material is located immediately above the packer fluid and extends upwardly to the earth's surface. The location of the bottom of the plastic is determined primarily by the heat losses which take place as the produced oil flows upwardly through the tubing string. The plastic should extend downwardly far enough to prevent cooling of the oil below the cloud point before it reaches the earth's surface. In most cases the lower end of the plastic should extend from the surface to a depth of about 1000 to about 2000 feet. The geothermal gradient for the particular area, the depth of the formation, the expected production rate of the well, the water-oil ratio, the cloud point of the particular oil and other considerations may dictate location of the plastic at a shallower or deeper point. Heat transfer calculations based on temperature surveys can be used to determine the optimum location for the plastic material. As pointed out earlier, the weight of the packer fluid may be increased to maintain the required hydrostatic head if the height of the fluid column is less than that which would otherwise be used.

FIGURE 2 of the drawing depicts a tubingless multiple completion well in which a unicellular plastic foam has been installed to prevent paraffin deposition. The well shown contains pipe strings **20** and **21** which extend through surface pipe **22** and the surrounding cement sheath **23** to the producing zones. The lower section of the well has been cemented in the usual manner, as indicated by reference numeral **24**, and the producing strings have been perforated to provide communication with the oil bearing formations. The perforations in the upper zone are indicated by reference numeral **25**; while those in the lower zone are indicated by reference numeral **26**. Conventional cementing shoes **27** and **28** are located at the lower ends of the pipe strings. Cellular plastic material **29** fills the space surrounding the producing strings above the cement. This insulates the pipe strings from one another and from the surrounding formation. Again, the optimum depth to which the cellular plastic should extend below the earth's surface can be readily determined by heat transfer calculations which will be familiar to those skilled in the art.

The method utilized for installation of the cellular plastic material will depend upon the particular plastic composition selected. Many of the expanded or foamed materials can be prepared by incorporating blowing agents into liquid resin mixtures which on heating liberate gases by chemical reaction or by adding compounds to liquid polyesters to form gas and at the same time cross-link the resulting foam into a rigid structure. These reactions generally require the mixing of two prepared components and the application of heat and can be carried out by means of electrical heaters lowered into the wellbore through one or more tubing strings. Single compositions which can be injected and later heated in the wellbore to melt, expand and cure them are also available. Volatile carrier fluids can be employed to aid in the injection of solid materials. If preformed hollow plastic spheres or "microballoons" and a binder are used, the application of heat is generally unnecessary. Certain polymers containing blowing agents can also be hardened and solidified to produce rigid foams by heating and subjecting them to radiation from a radioactive source lowered into the wellbore through the producing string. With polyethylene and similar polymers, the cross-linking reaction takes place very rapidly in the presence of neutrons and gamma rays and results in a marked improvement in the physical properties of the material.

In carrying out the invention, it is generally necessary to remove the packer fluid or other liquids from the section of the wellbore in which the cellular material is to be placed. This can be done by lowering a string of small diameter tubing into the space to be filled with the cellular material and then injecting air or gas into the space to displace the liquid to the surface through the small diameter string. After the space has been voided, the material or materials to be used for producing the cellular foam may be introduced. If polystyrene beads containing a blowing agent, a powdered mixture of a polyurethane type resin containing free isocyanate and a finely divided solid which releases water at elevated temperatures, or a similar single component system is employed, the reactive material may be introduced through the line used for the removal of fluids from the wellbore. Where two or more reactants must be introduced separately and mixed to form the expanded material in situ, one or more additional strings of small diameter tubing may be provided. In some cases liquid constituents may be preheated at the surface to avoid the necessity of providing heat at the reaction site. In most cases, however, an electrical heater positioned in the production string about which the cellular material is to be formed will be utilized to provide the heat needed. Where considerable heat is required, the foam-forming reaction can be carried out in stages, raising the heater in the tubing string following the production of foam at each level. In such cases, sufficient time for the curing of each batch should be provided before additional reactive material is introduced into the wellbore. The foam-forming reactions generally take place rapidly and hence the entire operation can be completed in a relatively short time.

The small diameter tubing strings employed for introduction of the reactive material are normally removed from the wellbore before completion of the reaction. The presence of the foam does not interfere with conventional production and workover operations. In the event, however, that the foam must be removed to permit replacement of casing or tubing or for other reasons, most of the foams can be destroyed by treatment with suitable solvents, acids or bases. Polystyrene, for example, can be readily dissolved in aromatic hydrocarbons. Phenol formaldehyde, urea formaldehyde and other phenolic resins decompose in the presence of strong alkalines. Acids can be used for removal of the polyurethanes. The method of the invention is particularly advantageous for overcoming paraffin deposition problems in offshore wells where workover equipment is not readily available. The foamed materials can be readily installed in the annular spaces of wells completed in a variety of different ways and are relatively inexpensive. They provide highly effective insulation against heat transfer and thus permit the control of paraffin deposition at relatively low costs.

We claim:

1. A method for preventing the formation of paraffin deposits in a well containing a pipe string through which waxy crude oil is withdrawn to the earth's surface without heating the oil in place which comprises installing a rigid cellular plastic foam in said well, said foam surrounding said pipe string and extending into the well from a point near the earth's surface to a depth sufficient to prevent cooling of said oil to a temperature below the cloud point as the oil passes through said pipe string.

2. A method as defined by claim **1** wherein said plastic foam is a unicellular polyurethane.

3. A method as defined by claim 1 wherein said rigid foam is produced in situ by heating foam-producing reactants within the wellbore.

4. A method as defined by claim 1 wherein said rigid foam is produced by the bonding together of gas filled plastic spheres.

5. A method as defined by claim 1 wherein said rigid foam is produced by the cross-linking of a foamed plastic in the wellbore in the presence of radiation.

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