FIG. 2.

FIG. 3.

FIG. 4.

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ATTORNEY
METHOD OF WELL CEMENTING WITH CONDUIT COATED WITH HEAT SENSITIVE MATERIAL

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10 Claims. (Cl. 166—21)

ABSTRACT OF THE DISCLOSURE

A method of cementing wells to be subjected to steam treating or thermal stimulation, wherein a heat sensitive or thermoplastic material is periodically applied to the external surface of a substantial section of a string of well pipe prior to cementing the pipe string in a well bore. During steam ing or heat treating operations, wherein heat is applied to the pipe string, the thermoplastic material will melt and flow. The well pipe originally coated is thus free to expand and/or grow during thermal stimulation and pipe failure is substantially inhibited.

The present invention relates to a new and improved method of cementing wells, wherein a low bond strength is obtained. It especially relates to a method of cementing pipe in a well bore wherein a heat sensitive material is applied to the outside diameter of the pipe which permits a cement bond to the pipe, but which bond can be readily broken by the application of heat.

One of the popular forms of secondary petroleum recovery is steam stimulation, the additional of thermal energy to a reservoir traversed by a well bore by steam injection. The same well is generally used for injection and production. Although the injection of steam into wells to raise the temperature of viscous crude oils and reduce the viscosity thereof for improved production is not new, it has only recently become a popular means of secondary recovery. U. S. Patent No. 3,193,009 describes a typical steam injection process. Numerous articles on steam stimulation and/or steam injection have been written in the last few years. Some of these articles which describe steam stimulation processes and their advantages and disadvantages are: "Steam Injection Wins New Support" by Carl J. Lawrence in the Apr. 8, 1963 issue of The Oil and Gas Journal; "The Quiet Noise Over Steam Flooding: What's It All About" by J. E. Kastrop in the February, 1964 and March, 1964 issues of the Petroleum Engineer; and "Steam Stimulation—Newest Form" by W. D. Owens and Van E. Suter in the Apr. 26, 1965 issue of The Oil and Gas Journal. One of the earliest articles on steam stimulation is "Recovery of Oil from Depleted Sands by Means of Dry Steam" by Smith L. Stovall in the August 13, 1934 issue of The Oil Weekly.

Although some degree of success has been achieved with steam stimulation, there have been numerous failures. One of the major causes of steam stimulation failure is casing or well pipe collapse. For example, if a 2000 ft. string of casing is heated 400 °F, the casing string will expand or grow about 5 ft. If it is free to move, if it is not free to move, the casing may buckle and fail under the resulting compressive stress. As steam stimulation processes proceed, the injection of steam into the well pipe at relatively high temperature, 300°—500° F., or even higher, the increased stress on pipe in casing is a serious problem.

Several means have been employed to prevent pipe failure. Among these are the use of higher grades of pipe and couplings of sufficient strength to withstand expected stress; pre-stressing of the well pipe; and to reduce the temperature of the well pipe. The latter is sometimes accomplished by the use of a packer and injection tubing. Varying degrees of success have been achieved using these prior art methods, but the cost of employing them has often made the project uneconomical.

The present invention is adapted to overcome the problem of casing or pipe failure in wells wherein the pipe or casing is subjected to high temperature, i.e., temperatures of about 300° F. or higher.

A principal object of the present invention is to provide a method of cementing pipe or casing in a well wherein the pipe is permitted to grow or expand during the application of high temperatures to the pipe during steam ing operations or other thermal well stimulating processes. When the pipe is cooled to formation or ambient temperature, the pipe is permitted to contract to its original size.

Another object of the present invention is to provide an economical method of cementing a pipe or casing in a well to be subjected to thermal stimulation.

Other objects and advantages of the present invention will be readily understood from the description of the invention set forth hereinafter.

SUMMARY OF THE INVENTION

The present invention provides a novel well completion technique for wells to be subjected to steam injection or thermal treatment. Maximum free casing or pipe movement is permitted thus minimizing temperature induced stresses. One section of the pipe must be bonded securely for segregating fluids that might be subjected to interzonal flow as in a normal cementing operation.

After a well is drilled and prior to setting a string of pipe or casing in the well bore, a substantial predetermined or desired section of the pipe string is peripherally coated on its external surface with thermoplastic or heat meltable material. The material must be sufficiently adhered to the pipe so that little, if any of it, will be removed during placement of the cement slurry. A portion of the pipe string is left free of the thermoplastic or heat meltable material, and this is preferably the lower portion of the pipe string. The action of pipe to be bonded securely to the cement will be at the top of the producing formation.

The entire string of pipe is placed in the bore hole and then cemented in place in the usual manner. The upper string of pipe coated with the thermoplastic material is preferably cemented with a high perlite cement slurry which exhibits low shear bond strength, but remains thermally competent. A high temperature good bonding cement, such as a silica flour cement is preferably used for cementing the lower or uncoated portion of the pipe string. After the cement has set, the lower end of the pipe string adjacent the producing zone is thoroughly anchored in place, with the pipe section securely bonded to cement. The upper or coated section of pipe is only lightly bonded to the cement, if at all.

Perforating of the pipe adjacent the producing formation is accomplished in a manner well known in the art. Fluids may then move from the producing formation into the casing or be injected into the formation via the casing.

When steam or other heat is introduced into the well pipe, the pipe becomes heated to the extent that the thermoplastic material melts and flows. The coated section of pipe expands or grows upon the application of heat thereto, and returns to its normal position when the heat is removed. The heating and cooling cycle may be continued at desired intervals and casing or pipe failures are substantially inhibited.

Briefly, the present invention is an improved method of cementing pipe in a well bore traversing a subterranean formation, which comprises inserting a pipe or tubular
conduit having an exterior surface covered with a heat sensitive material which will enable a cementitious material such as a hydraulic cement or the like to be initially bonded to the pipe upon setting, which will melt or flow upon the application of heat to the internal pipe surface, thereby enabling the bond to be broken when desired; displacing cementitious material into the annulus defined by the pipe and the surrounding formation; and permitting the cementitious material to set. The cement or cementitious material does not necessarily have to bond to the heat sensitive material upon setting as long as such material will stay adhered to the pipe.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a vertical longitudinal section through a well bore illustrating a well cemented in the manner of the present invention after cementing has been completed but prior to the introducing of steam into the well. A steam injection source is also shown schematically.

FIG. 2 is a longitudinal vertical section of a well bore containing a pipe therein coated with a heat sensitive material prior to the introduction of steam or heat into the well bore.

FIG. 3 is a view similar to FIG. 2, wherein steam is being introduced into the well bore and partial melting or heating of the heat sensitive material has taken place.

FIG. 4 is a view similar to FIG. 2 wherein the steaming or heat treating operation has been completed, and the well pipe or casing had returned to its original position.

Basically, oil well cementing is a process of mixing a cement-water slurry and pumping it down through steel casing or pipe to critical points located in the annulus around the pipe, in an open hole or in a permeable formation.

Prior to cementing operations, the pipe, casing or casing string is coated with a heat sensitive or thermoplastic material which will melt and flow or become deliquescent at temperatures above formation temperatures or at the desired temperature. Some materials suitable for this purpose are thermoplastic resins, epoxy resin compounds, polyamide resins, hot melt materials, grease, paraffins, asphaltic materials, tar and others.

In cementing a well using the novel method of this invention, a string of pipe coated with a suitable or desired heat sensitive material is first placed in a bore hole. A hydraulic cement slurry containing desired additives is pumped down the pipe and out the end of the pipe, or through perforations in the pipe. The slurry is then forced up the annular space between the string of pipe and the walls of the bore hole. The cement is then allowed to set.

Although certain cement mixes are preferable when the well is to be subjected to thermal stimulation treatments such as steam injection, cement mixes with which this invention may be generally employed include those in which any hydraulic cement of the character of portland or pozzolan cement is the principal cementitious composition, the amounts of the essential ingredients of the invention being governed by the amount of this type of cement present in the mix. Any of the common aggregates and fillers may be employed in various proportions to meet different structural requirements. These include stone, gravel, slag, sand, pozzolanic materials, fly-ash, perlite and the like, and such specialized materials as metallic aggregates, aluminum powder, etc.

The invention is also applicable to neat cement mixes containing no aggregate or filler. All such mixes are comprehended hereinafter by the term "hydraulic cement mix or slurry."

As indicated above, the invention does not preclude the use of other additives, as well as aggregates and fillers, for modifying various characteristics of the mixes for special purposes. For example, air entraining agents, cement dispersing agents, pigments, water-repellent compounds, low fluid loss additives, tracing materials, friction reducers, accelerators, retarders, heavyweight and lightweight additives, etc., may also be used.

Referring to FIG. 1, a well bore 10 has been drilled and a well casing or pipe string 11 set therein. The pipe string 11 has perforations 12 in the lower end thereof which permit fluid passage between the producing formation 13 and the casing 11. The upper portion of the pipe string 11 adjacent the formation 14 above the producing formation 13 is coated with a heat softening or meltable coating 17 and cemented with a cement 16 having a low shear bond strength. The lower portion of the pipe string 11 adjacent the producing formation is cemented with a high strength thermally competent cement and anchored rigidly in the hole 10.

A steam generating unit 21 is positioned at the surface near the well bore 10 with steam generator tubes 22 therein. A line 23 connects the pipe 11 with the steam generator tubes 22. A valve 24 is placed in the line 23 at a convenient place for controlling entry of steam into the pipe string 11. A water pump 20 is positioned near a water source for pumping or supplying water to the steam generating unit. Steam is generated when it is desired to treat or heat the formation 13. The steam is subsequently injected into the pipe 10 via the line 23 through the perforations 12 and into the formation 13. The steam heats the pipe 10 causing the coating 17 to melt. The upper portion of the pipe string 11 is thus free to expand and grow. The coating 17 is of sufficient thickness that maximum expansion of the pipe is permitted without damage to the cement 16 and the cement 16 is not in direct contact with the upper portion of the pipe string 11 at any point.

The line 23 is of sufficient flexibility or so constructed that vertical movement of the pipe 11 will not disrupt or disengage the steam generating apparatus 21 or line 23.

In FIGS. 2-4, the casing 30 is coated with a heat softening or heat meltable material 31 and adjacent cement 32 adjacent the formation 33. In FIG. 3, the heat softening material 31 has begun to melt and flow and a portion thereof 31a is seen in the cement 32. The casing 31 has expanded to occupy the space formerly held by the heat softening material 31a now in the cement composition. In FIG. 4, the casing 30 has returned to its normal position and the heat softening material 31b is all in the cement composition thus leaving an annular space between the casing 30 and the cement 32 where the heat softening material 31a was previously or as shown in FIG. 2.

EXAMPLE I

Procedure: Specimen of pipe were prepared by cutting 6-inch sections of 2-inch I.D. steel pipe and 4-inch I.D. steel pipe. The outer surface of each of the 2-inch specimens were coated with a heat sensitive material and each specimen was then centered within a 4-inch specimen. The annulus between the 2-inch pipe and 4-inch pipe was filled with a conventional cement slurry and cured. After the desired curing time the specimens were subjected to shear bonding strength tests using standard testing procedures as outlined in a paper entitled "Bonding Studies of Cementing Compositions to Pipe and Formations" by George W. Evans and L. Gregory Carter (A.P.I. Paper No. 906-7-D), presented at the Spring Meeting of the Southwestern Division of Production of the American Petroleum Institute in Odessa, Texas on March 21-23, 1962.

The shear bond strength tests results are recorded in Table I.
3,406,756

5 TABLE I.—DATA

Cement—A.P.I. Class A cement. Water—5.2 gallons per sack of cement. Curing time—7 days. Curing temperatures—100° F.

Material: Bond strength (p.s.i.)

<table>
<thead>
<tr>
<th>Varnish+grease+closed in pressures</th>
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<tr>
<td>Varnish+grease</td>
<td>6.6</td>
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<tr>
<td>Rubber</td>
<td>8.05</td>
</tr>
<tr>
<td>Paraffin</td>
<td>25.46</td>
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* Applied 2500 p.s.i. for 7 days.

EXAMPLE II

A number of laboratory tests were made to determine cementing compositions which would minimize bonding to the casing but which would also be thermally competent.

Procedure: Four different cementing compositions were prepared using an air mixer. Perlite was wet with water under 2000 p.s.i. pressures prior to adding to the cement slurry. All samples were first cured at 110° F. under 1500 p.s.i. pressure for 24 hours, with a portion of the samples being tested for strength under standard procedures. The remaining samples were then cured at 400° F. under 3000 p.s.i. pressures for an additional 24 and 72 hours. Shear bond was estimated from the correlation presented in the above referred to paper on bonding studies.

<table>
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<th>TABLE II.—DATA</th>
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<td>Slurry Number</td>
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Compressive Strength, p.s.i.

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<th>110° F. 1,500 p.s.i.</th>
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<td>314</td>
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<tr>
<td>29</td>
<td>342</td>
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<tr>
<td>59</td>
<td>655</td>
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Shear Strength, p.s.i.

<table>
<thead>
<tr>
<th>110° F. 1,500 p.s.i.</th>
<th>400° F. 3,000 p.s.i.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Day</td>
<td>2 Day</td>
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<tr>
<td>59</td>
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</tr>
<tr>
<td>59</td>
<td>100</td>
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<tr>
<td>8</td>
<td>101</td>
</tr>
<tr>
<td>20</td>
<td>288</td>
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</tbody>
</table>

Shear Bond Strength, p.s.i.

<table>
<thead>
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<th>110° F. 1,500 p.s.i.</th>
<th>400° F. 3,000 p.s.i.</th>
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<tr>
<td>1 Day</td>
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<td>20</td>
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A number of well cementing jobs have been successfully completed employing the method of the present invention. Three of such wells completed in the Cat Canyon Field, Santa Barbara County, California have been subjected to steaming operations. One well has been through six cycles (expansions and contractions) of steaming and the other two wells through one expansion and contraction cycle. All wells were steamed down the casing at 550° F. to 600° F. well head temperature in a severe test of this type of well completion. All wells reported are in good shape with no apparent failure of the casing and have been placed on production.

These wells were each cemented with a J-55 grade casing coated with 1/8 inch roofing tar to insure a low bonding strength. This is the first known successful use of this grade of casing for a well to be subjected to such high temperatures.

In this California area, casing failures have been prev-

a lent because of the high temperatures and injection pressures used in steam stimulation. Steam temperatures of 635° F. 635° F. and steam injection pressures of 2000 to 2300 p.s.i. are not uncommon.

The details of cementing the first of these wells later subjected to the six cycles of steaming is set forth hereinafter.

Cementing composition

94# A.P.I. Class "G" cement,
80# silica flour/sack of cement,
3.48# bentonite/sack of cement (2% by wt. of cement + silica flour),
98# perlite/sack of cement (12 cu. ft. perlite/sack),
Slurry yield = 10.04 cu. ft./sack of cement,
Water requirement = 7.92 cu. ft./sack of cement,
Slurry weight = 65 p.c.f. (pounds/cubic foot),
A.P.I. Class "G" cement, 40% silica flour, 3% CaCl₂ was used around the cementing shoe.

Well data

11" hole to 1986',
83/4" hole to 2430',
1578' of 7" 26# J-55 extremeline casing coated with 1/8" roofing tar (surface to 1578'),
393' of 7" 26# P-110 buttress casing (1578' - 1581'),
Float shoe with basket and six, 3/4" ports at 1981',
Cast iron baffle at 1951',
78 p.c.f. fresh water, clay base mud.

The general idea of the job was to cement the P-110 buttress casing with a high strength, thermally competent cement and anchor it rigidly in the hole. The upper portion of the pipe consisting of J-55 extremeline casing was cemented with the high perlite slurry which exhibits low shear bond strength but remains thermally competent. The J-55 pipe was also coated with 1/8" roofing tar to insure low bonding strength.

The casing was run and hung on the slips. The perlite cement slurry was mixed through a conventional low pressure mixer. The jet size was 9" x 2.57" and mixing pressure was 120 p.s.i. Slurry weight varied from 59 to 62 p.c.f. and averaged 60 p.c.f. It took 47 minutes to mix 100 cu. ft. Class "G" cement, 1200 cu. ft. perlite, 8000 lbs. silica flour and 350 lbs. bentonite. It was noted that lessening by-pass water caused the slurry to thin nicely and increased the slurry weight to 62 p.c.f. After mixing the perlite cement slurry, the jet size was changed to 9" x 2.37" and 95 sacks of Class "G" cement, 40% silica flour, 3% CaCl₂ was mixed at 117 p.c.f. in 7 minutes. Cement returns to surface were noted just before the start of mixing the Class "G" cement, silica flour slurry. A top 5W wiper rubber cementing plug was released after all cement was mixed. Cement was displaced with mud. The kickoff had not increased at 5% over theoretical displacement and the pumps were shut down at that point. The pressure was released and the float held. The job was completed at 8:34 p.m.

Samples of the cement returns were weighed and varied from 62 to 76 p.c.f. The returns appeared to be very watery. It is highly possible that the shallow Foxen sand was feeding water into the slurry as it crossed this interval. The Foxen is a well known prolific water sand.

Inspection of the surface and return samples the following morning showed the Class "G" cement, silica flour samples to be set and relatively hard; the surface perlite samples to be set but very soft; and the return perlite samples to be dehydrated (no free water) but unset and mushy.

In a preferred form of the invention, an A.P.I. Class "G" cement with one or more of the following, pozzolanic, perlite, bentonite and/or diatomaceous earth comprises the cementing slurry. Since the set slurry will be subjected to the same high temperatures as the well casing, it should be capable of withstanding such temperatures with little or no deterioration or damage thereto.
It can also be appreciated that a wide variety of thermoplastic or heat sensitive materials may be used without departing from the scope of the invention, and that the temperatures of the surrounding formations will have a direct bearing upon the heat sensitive material selected. At normal or ambient well temperatures, the material should have a substantial solidity with little or no tendency toward deliquescence. At thermal stimulating temperatures, the material should melt and flow or become deliquescent. Upon return to normal temperatures, the material may or may not return to its state prior to heating. Materials may be selected for any desired post heating state, depending upon well conditions or required effect. Once the initial bonding has been broken by thermal stimulation, subsequent heating or thermal stimulation may be carried out without deleterious effects on the well pipe or conduit means.

What is claimed is:

1. A method of cementing a pipe or conduit means in a well bore, comprising the steps of:
   (a) placing said conduit means in the well bore, said conduit means having at least a peripherally encircling portion of a section thereof continuously coated with a heat sensitive material which upon the application of heat thereto will melt and flow and a second section thereof peripherally free of said heat sensitive material;
   (b) introducing a hydraulic cement slurry into the well bore contiguous with at least a portion of the coated and uncoated sections of the conduit means and,  
   (c) allowing the cement slurry to set, thereby bonding the uncoated section of the conduit means to the cement and permitting expansion of the coated section of conduit means upon application of heat thereto and contraction of said originally coated section of the conduit means upon cooling substantially without damage to the conduit means.

2. The method of claim 1, wherein said heat sensitive material is selected from the group consisting of tar, grease, asphalt and asphaltic materials, paraffins, thermoplastic resins, epoxy resins, polyamide resins, and hot melt materials.

3. The method of claim 1, wherein the heat sensitive material is a roofing tar.

4. The method of claim 1, wherein the hydraulic cement slurry contains perlite in a ratio by volume of about 1 part cement to about 12 parts perlite.

5. The method of claim 1, wherein the cement placed adjacent the coated section of said conduit means is a low bond strength cement and the cement placed adjacent the uncoated section of said conduit means is a high bond strength cement.

6. The method of claim 1, wherein the cementing slurry contains one or more of the following: pozzolan, perlite, bentonite, diatomaceous earth and silica flour.

7. A method of cementing a pipe in a well bore traversing a subterranean hydrocarbon containing formation to be subjected to thermal stimulation, comprising the steps of:
   (a) placing said pipe in the well bore, a section of said pipe being peripherally coated on the external surface thereof with a heat sensitive material which is substantially firm at normal well temperature, but which during thermal stimulation becomes deliquescent and a section of said pipe being peripherally free of said heat sensitive material;
   (b) pumping a hydraulic cement slurry down the pipe and up the annular space between the pipe and the walls of the well bore; and
   (c) allowing the cement slurry to set, thereby bonding the uncoated section of said pipe to the cement whereby during thermal stimulation expansion of the originally coated pipe section occurs and upon cooling subsequent to thermal stimulation, contraction of the pipe occurs, all without substantially damaging the pipe.

8. The method of claim 7, wherein the heat sensitive material is selected from the group consisting of asphalt and asphaltic materials, paraffins, tars, greases, hot melt materials, thermoplastic resins, epoxy resins and polyamide resins.

9. The method of claim 7, wherein the cement placed adjacent the coated section of pipe is a low bond strength cement and the cement placed adjacent the uncoated section of pipe is a high bond strength cement.

10. The method of claim 7, wherein one or more of the following materials is added to the cementing slurry: pozzolan, perlite, bentonite, silica flour and diatomaceous earth.

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<thead>
<tr>
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<th>Inventor(s)</th>
<th>Title</th>
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<td>Andrews</td>
<td>166—1 X</td>
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<td>2,805,719</td>
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CHARLES E. O'CONNELL, Primary Examiner.
IAN A. CALVERT, Assistant Examiner.