

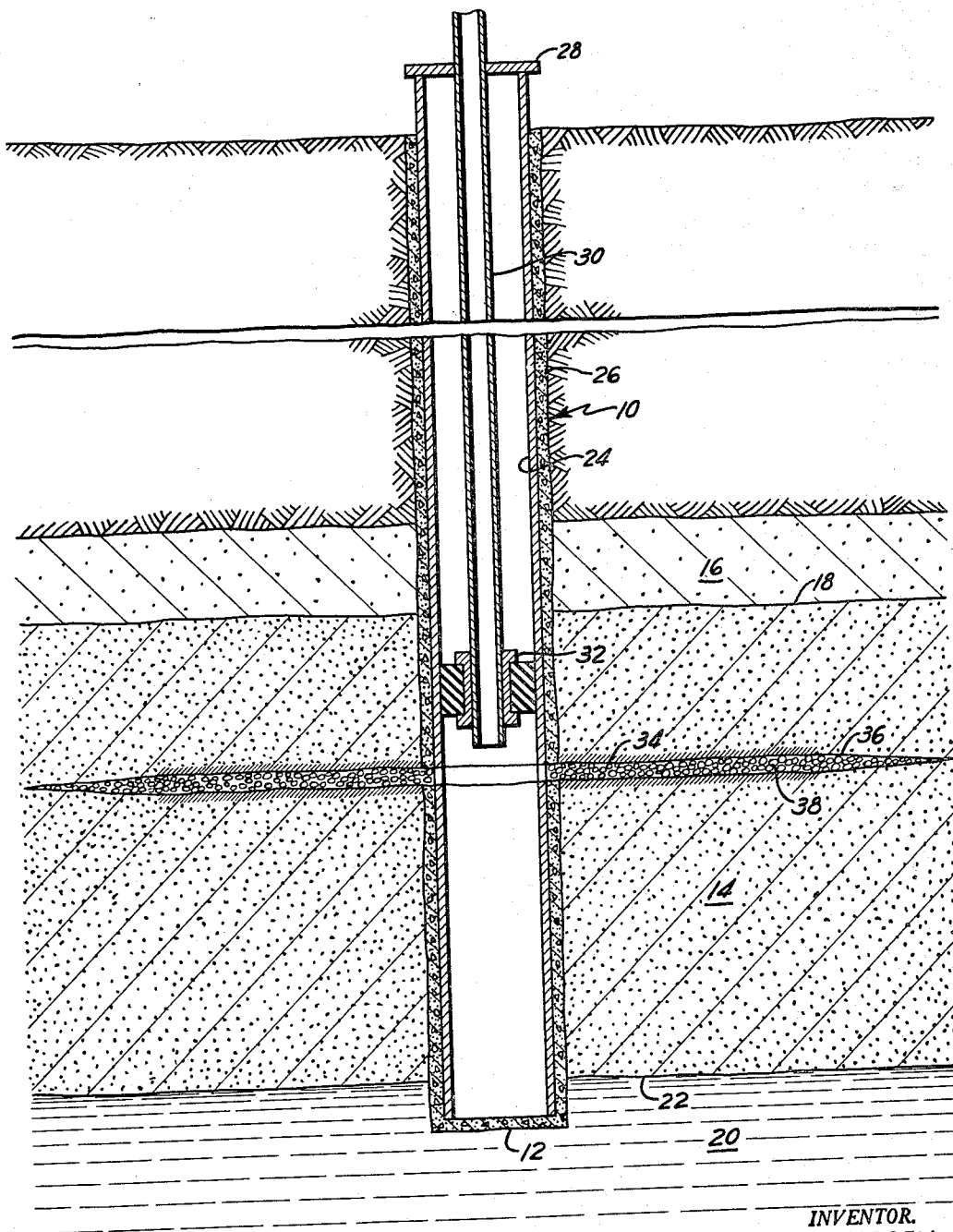
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REDUCTION OF GAS AND WATER CONING INTO OIL WELLS

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REDUCTION OF GAS AND WATER CONING INTO OIL WELLS

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9 Claims. (Cl. 166—33)

This invention relates to the production of oil from oil-bearing formations and more particularly to the reduction in the rate of flow of gas and water into oil wells.

The radial flow pattern of fluids from underground formations into wells results in high flow velocities near the borehole of the well. The resultant high pressure drop adjacent the well causes water present below oil in the pay zone to cone upwardly around the well and flow into the well. Similarly, gas above the oil cones downwardly and flows into the well with the oil produced from the well.

It is common for the regulatory agencies in oil producing states to penalize operators of wells which produce at high gas to oil ratios; hence, gas coning may cause a marked reduction in the rate at which an operator may produce oil from a well. Water coning, which increases the ratio of water to oil produced in the well, is objectionable because of the resultant increased corrosion of equipment in the well as well as because of the cost of lifting, separation, and disposal of the water produced by the well.

Among the methods that have been used in an attempt to reduce the production of water and gas from oil wells is to set a plug in the borehole to a level above the oil-water interface and to set a packer below the gas-oil interface. Oil is then produced into the well above the plug or below the packer. These methods are often largely ineffective because the coning is caused by the pressure drop from the formation into the well and increased rates of flow necessitated by the reduction in area through which the fluids flow into the well further aggravates the water and gas coning problem. Another method that has been suggested for overcoming water and gas coning is to inject a fluid from the well into the water or gas zone to change the pattern of pressure differentials surrounding a well and thereby prevent the coning. Such a method has the disadvantage of requiring separate tubing and packers as well as pumping equipment at the well head to recycle the fluid into the water and gas zones to prevent the coning.

This invention resides in a method of reducing the flow of water and gas into oil wells and simultaneously stimulating production of oil from the wells in which a substantially horizontal fracture is made to extend from the borehole of a well into the oil zone of an oil-bearing formation. A sealing composition is then displaced into the fracture and from the fracture into the formation above and below the fracture and the fracture is held open while the sealing composition sets. The fracture is extended radially beyond the plugged walls and propped open to allow flow of oil into the outer extremities of the fracture and through the fracture to the well.

The single figure of the drawing is a diagrammatic illustration in vertical section of a well which has been treated in accordance with this invention to reduce the flow of gas and water into the well.

Referring to the drawing, a well indicated generally by reference numeral 10 is drilled to a total depth 12 through an oil-bearing formation having an oil zone 14. The oil-bearing formation is illustrated with a gas cap 16 above a gas-oil interface 18. A water layer 20 below a water-

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oil interface 22 is under the oil zone 14 of the oil-bearing formation.

Casing 24 is set in the well 10 to total depth and is cemented in place by a sheath 26 of cement in accordance with the conventional practice. The upper end of the casing 24 is closed by a cap 28. A product tubing 30 extends downwardly through the casing and through a packer 32 set in the casing in the vicinity of the oil zone 14.

A horizontal fracture 34 is made in the oil zone 14 of the oil-bearing formation. In the cased borehole illustrated in the drawing, fracture 34 is made by milling through a section of the casing and cutting a horizontal notch through the cement sheath 26 and into the formation surrounding the well 10. The horizontal notch is then extended to form a fracture 34 by conventional fracturing procedures, for example, in the manner described in Patent No. 2,699,212 of Newton B. Dismukes suitably modified to form a horizontal rather than a vertical fracture. The cutting of the notch in the formation, which may be performed by mechanical, hydraulic, or explosive means, orients the fracture subsequently formed in the desired plane.

The fracture 34 can be made in the formation by conventional techniques in which a suitable liquid is pumped down through the tubing 30 at a pressure high enough to overcome the overburden pressure and the strength of the formation rock. Water or lease crude oil are commonly used in the fracturing of formations from oil wells. In some instances it may be desirable to add synthetic or natural gums or polymers, soaps, or gelling agents to the fracturing liquid to increase the resistance of flow of the liquid into the formation. Such viscosity-increasing materials can subsequently be removed or destroyed in accordance with the usual procedures by flushing or by the introduction of a material adapted to reduce the viscosity of the fracturing liquid.

Location of the horizontal fracture 34 in the oil zone 14 will depend on the purpose of the fracture. If the principal problem is gas coning and fluids are to be delivered into the well only through the fracture 34, the fracture should be near the bottom of the oil zone 14. If the principal problem is water coning, the fracture should be located near the top of the oil zone 14. If it is desired to prevent both gas and water coning the fracture is preferably located at a height h above the oil-water interface 22 where h is the distance between the oil-water interface 22 and the gas-oil interface 18 and

$$k = \frac{p_o - p_g}{p_w - p_o}$$

where p indicates density and the subscripts o , g , and w signify oil, gas, and water, respectively.

After fracture 34 has been formed, a sealing material is displaced into the fracture. The pressure applied to the sealing material is controlled to displace the sealing material into the formation above and below the fracture rather than to extend the fracture radially.

A wide variety of sealing materials are suitable for use in this invention. For example, the sealing material may be merely a finely powdered solid material such as silica powder or finely divided clays which damage the walls of the fracture to prevent subsequent flow of fluids through those walls. A number of natural or synthetic organic compounds which will polymerize or condense to form solid resinous materials, insoluble in oil and water, can be used. Typical suitable materials are synthetic resin-forming materials such as phenol-formaldehyde mixtures and urea-formaldehyde mixtures or monomers of acrylonitrile or butadiene. A large

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number of such natural or synthetic materials have been suggested for displacement into formations to seal the formations to prevent the influx of water. An aqueous slurry of hydraulic cement is suitable for use in formations sufficiently permeable to allow cement slurries to be displaced into them.

Another method of sealing the faces of the fracture is to displace an aqueous solution of a salt from the fracture into the formation above and below the fracture and follow the solution with a gaseous material which penetrates the formation and reacts with the salt solution to form a precipitate for a substantial depth into the formation. An aqueous solution of aluminum sulfate followed by gaseous ammonia, which may be mixed with an inert gas such as nitrogen or methane to prevent condensation of the ammonia, are suitable for this purpose. Still another method which is particularly suitable when an aqueous fracturing fluid has been used is to inject silicon tetrafluoride into the fracture and displace it into the formation above and below the fracture. Silicon tetrafluoride hydrolyzes upon contact with water and forms a solid siliceous deposit which effectively plugs the formation.

After injection of the sealing material into the formation a propping agent suspended in a liquid is pumped down the well and displaced into the fracture. The liquid used as a medium for carrying the propping agent into the fracture flushes the sealing composition from the fracture into the formation and thereby insures the fracture being maintained open. The well is then shut in for a period sufficient for the sealing material to set to form the desired seal in the formation above and below fracture 34 to prevent flow of fluids from the formation into the fracture.

Following the setting of the sealing composition, a fluid, preferably a liquid, is pumped down through tubing 30 and displaced into the fracture. The pressure applied to the fluid is increased and pumping of the fluid into the fracture is continued at a rate to extend the fracture radially beyond the plugged walls, as indicated at 36. Preferably, a propping agent, indicated by reference numeral 38, is added to the liquid pumped into the extension 36 after the extension has been formed, to prop the extension open.

The fracture 34 with sealed walls adjacent the well 10 and an unsealed extension 36 at its extremity can also be made in an essentially continuous operation. The fracture 34 is formed by pumping a fracturing fluid containing the sealing agent into the formation at pressures adequate to fracture the formation. That fluid is followed by fracturing fluid free of the sealing composition. Pumping of the fracturing fluid free of the sealing composition is continued for a period adequate to displace the sealing composition into the formation and to extend the fracture radially beyond the portion of the formation containing the sealing composition. Propping agent is incorporated in the fracturing fluid free of sealing composition. After the fracture 34 has been extended the desired distance, the well is shut in to allow the sealing composition to set.

Oil is produced from the well 10 by flowing from the oil zone 14 into the extension 36 of the fracture 34 and thence through the fracture 34 into the borehole of the well. The oil is lifted from the well by any suitable conventional means. Because of the large diameter of the extension 36, the area through which the oil can enter the extension is large and the resultant velocity of the oil flowing into the extension is low. As a result of the low velocity, the pressure drop from the formation into the fracture 34 is low and pressure differentials encouraging the formation of gas and water cones are reduced to a minimum. The sealing of the walls of the fracture adjacent the well limits the entrance of fluids into the fracture 34 to the extension 36; hence, there is no tendency for gas and water to cone adjacent the well.

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In a specific embodiment of this invention a well is drilled through an oil-bearing formation extending from a depth of 3853 feet to 3903 feet. A survey indicates a water-oil interface at 3888 feet. A notch is cut in the formation at 3870 feet and packers are set at 3865 and 3875 feet. A lease crude oil is pumped into the formation at a rate which increases the pressure at the well head to 5200 pounds per square inch, at which pressure fracturing occurs. Ten barrels of the polyisocyanate composition described in paragraph C, column 12 of United States Letters Patent No. 2,889,883, is pumped into the fracture and followed by 10 barrels of lease crude containing one pound per gallon of 4-6 mesh sand. The well is then shut in for 24 hours. Ten barrels of lease crude are pumped into the fracture and followed by 250 barrels of lease crude containing a thickening agent such as napalm and one pound per gallon of 4-6 mesh sand to extend the fracture beyond the sealed walls of the fracture. The well is again shut in for 24 hours and then placed on production.

The process of this invention allows the formation of a single barrier which will prevent both gas and water coning during production of oil from a well. This invention is particularly useful in preventing gas or water coning in thin pay zones because it is necessary only to make a single fracture into the pay and there is little possibility of damage to the barrier created to prevent coning of water or gas.

I claim:

1. A method of reducing the flow into a well of fluids other than oil during the production of oil from an oil-bearing formation penetrated by the borehole of the well, said oil-bearing formation having an oil zone and a zone of a fluid other than oil adjacent to and communicating with said oil zone, comprising forming a substantially horizontal fracture from the borehole into the oil zone of the formation, injecting a fluid sealing material capable of forming a solid material insoluble in oil and in water into the fracture and into the walls of the fracture to seal said walls substantially permanently and continuously from the borehole of the well to the outer extremities of the fracture and thereby prevent flow of oil and water through the sealed walls into the fracture, maintaining the fracture open while said walls are being sealed, injecting a fluid into the fracture under a pressure adapted to extend the fracture radially beyond the sealed walls of the fracture, and propping the fracture and extension of the fracture whereby on production of the well fluids enter the extension of the fracture and flow through the fracture to the well.

2. A method of treating a well to reduce coning into the well of fluids other than oil in the production of oil from an oil-bearing formation penetrated by the borehole of the well, said oil-bearing formation having an oil zone and a zone of a fluid other than oil adjacent to and communicating with said oil zone, comprising cutting a substantially horizontal notch in the oil zone, injecting a fracturing fluid into the notch to create a substantially horizontal fracture extending from the notch into the oil zone of the formation, sealing the walls of the fracture with a sealing material insoluble in oil and in water while maintaining the fracture open to form a substantially permanent and continuous barrier to flow of fluids through said walls into the fracture, extending the fracture radially beyond the sealed walls of the fracture and propping said fracture and extension of the fracture open whereby on production of the well formation fluids enter the extension of the fracture and flow through the fracture to the well.

3. A method of treating a well to reduce coning of fluids other than oil into the well during the production of oil from an oil-bearing formation penetrated by the borehole of the well, said underground formation having an oil zone and a zone of a fluid other than oil adjacent to and communicating with said oil zone, comprising

forming a substantially horizontal fracture extending from the borehole of the well into the oil zone of the formation, injecting a fluid sealing material capable of forming a solid material insoluble in oil and in water into the fracture and into the walls of the fracture, injecting a liquid containing a propping agent into the fracture to carry the propping agent into the fracture and displace the sealing material from the fracture into the formation adjacent the walls of the fracture, shutting the well in for a period to allow setting of the sealing material to form a substantially permanent and continuous barrier to flow through said walls into the fracture, extending the fracture radially beyond the sealed walls thereof, and depositing a propping agent in said extension whereby on production of the oil fluids enter the extension of the fracture and flow through the fracture to the well.

4. A process as set forth in claim 3 in which the sealing material is a liquid capable of setting to form a synthetic resin insoluble in oil and in water

5. In a method of producing oil from a pay zone containing a gas zone above an oil zone and a water zone below the oil zone, the improvement comprising forming a substantially horizontal fracture extending from the borehole of a well into the oil zone, displacing into the fracture a fluid sealing composition capable of forming a solid material insoluble in oil and in water, displacing a wash liquid having a propping agent suspended therein into the fracture to prop the fracture open and flush the sealing composition therefrom, maintaining pressure on the well to prevent flow from the formation into the fracture while the sealing composition sets to seal the walls of the fracture, extending the fracture radially beyond the sealed walls of the fracture, and depositing a propping agent in the extension of the fracture whereby fluids enter said extension and flow through the fracture for production from the well.

6. A method of treating a well to reduce coning into the well of fluids other than oil during the production of oil from an oil-bearing formation penetrated by the borehole of the well, said oil-bearing formation having an oil zone and a zone of a fluid other than oil adjacent to and communicating with said oil zone, comprising forming a substantially horizontal fracture from the borehole into the oil zone of the formation, injecting a propping agent into the fracture, propping the fracture open, injecting an aqueous solution of aluminum salt into the fracture and from the fracture into the formation, injecting gaseous ammonia into the fracture whereby said ammonia enters the formation and reacts with the aluminum salt to form a precipitate plugging the formation adjacent the walls of the fracture to form a substantially permanent and continuous barrier to flow of fluids through said walls into the fracture, extending the fracture beyond the plugged walls of said fracture and depositing a propping agent in said extension of the fracture.

7. A method of treating a well to reduce coning into the well of fluids other than oil during production of oil from an oil-bearing formation penetrated by the borehole of the well, said oil-bearing formation having an oil zone and a zone of a fluid other than oil adjacent to and communicating with said oil zone, comprising form-

ing a substantially horizontal fracture from the borehole into the oil zone of the formation, depositing a propping agent in the fracture to prop the fracture open, injecting an aqueous fluid into the fracture and into the walls of the fracture, displacing the aqueous fluid from the fracture, injecting silicon tetrafluoride into the walls of the fracture whereby the silicon tetrafluoride is hydrolyzed to plug the walls of the fracture and thereby form a substantially permanent and continuous barrier to flow of fluids through said walls into the fracture, extending the fracture radially beyond the plugged walls thereof, and depositing a propping agent in the fracture and the extension of the fracture.

8. A method of treating an oil well penetrating an oil-bearing formation having an oil zone and a zone of a fluid other than oil adjacent to and communicating with said oil zone to reduce coning of fluids other than oil into the well comprising forming a substantially horizontal fracture extending from the well into the oil zone by injecting a fracturing fluid containing a sealing composition capable of forming a solid material insoluble in oil and in water down the well and into the oil zone under a pressure adequate to fracture the formation, following the fracturing fluid containing the sealing composition with a fracturing fluid free of sealing composition to displace sealing composition from the fracture into the formation adjacent the walls of the fracture and to form an extension of the fracture, injecting a propping agent into the fracture, and shutting in the well to allow the sealing composition to set and form a substantially permanent and continuous barrier to flow of fluid through the formation adjacent the fracture radially inward from the extension.

9. A method of treating an oil well penetrating an oil-bearing formation to reduce coning of fluids other than oil into the well during production from the well, said oil-bearing formation having an oil zone and a zone of a fluid other than oil adjacent to and communicating with said oil zone, comprising forming a substantially horizontal fracture extending from the well into the oil zone, substantially permanently plugging the formation adjacent the walls of the fracture with a material insoluble in oil and in water to prevent flow of oil and of water from the formation through the plugged formation into the fracture, and thereafter extending the fracture radially beyond the plugged walls of the fracture to form an extension of the fracture, depositing a propping agent in the fracture and extension thereof, and reducing the pressure on the well, whereby oil flows into said extension and through the fracture for production from the well.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,172,471

March 9, 1965

Joseph E. Warren

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 61, for "3,004,498" read -- 3,004,598 --.

Signed and sealed this 3rd day of August 1965.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents