Oct. 31, 1967 J. W. RHEA ET AL 3,349,844

REPAIR OF CHANNELS BETWEEN WELL BORES

Filed July 8, 1964

2 Sheets-Sheet 1

FIG. 1.

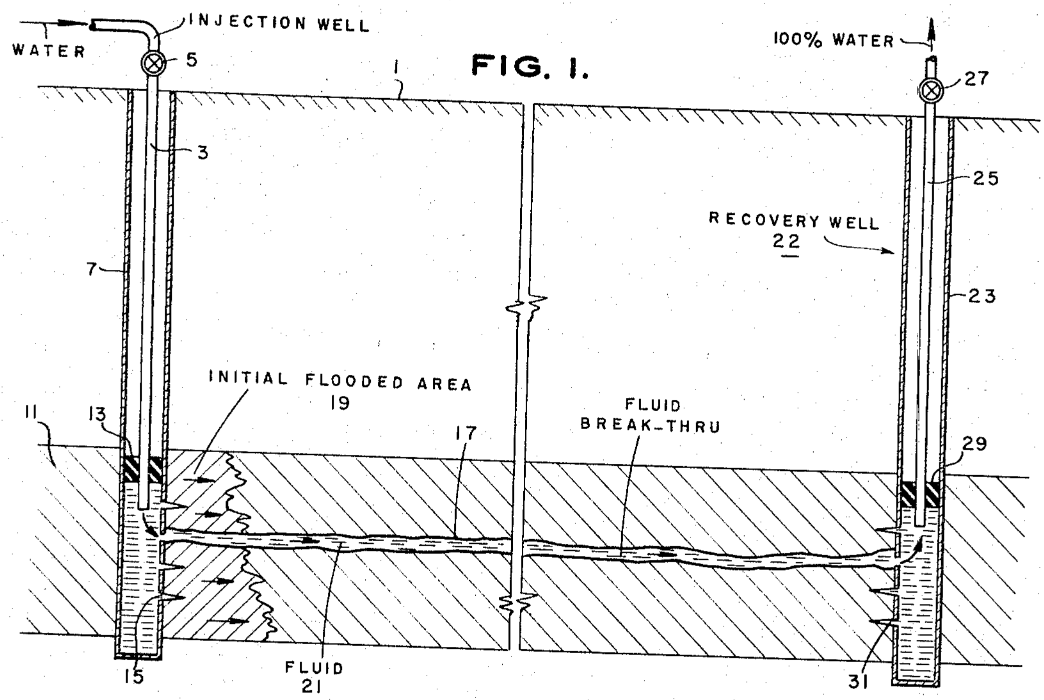
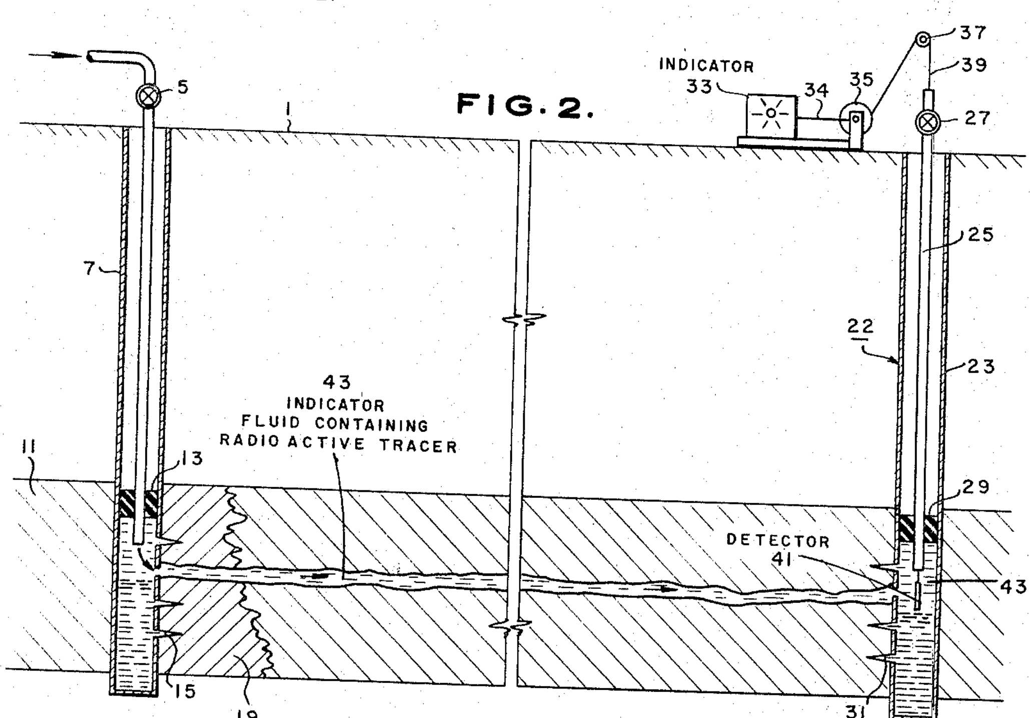


FIG. 2.



INVENTORS.
JOHN W. RHEA,
JOE V. MORSE,
John B Davidson
ATTORNEY.

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FIG. 3.

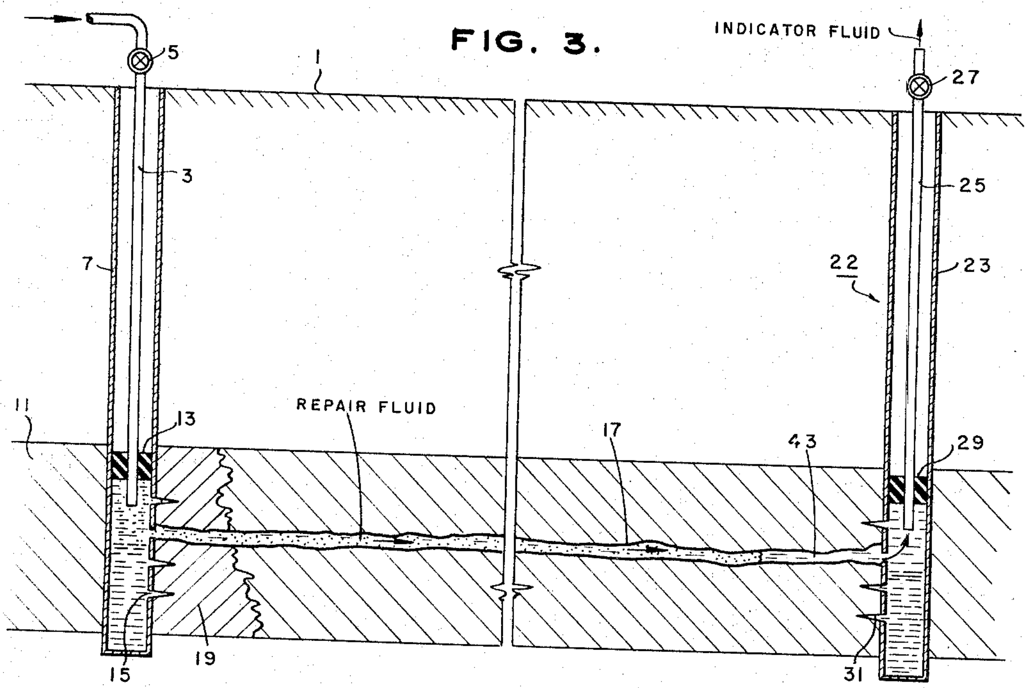
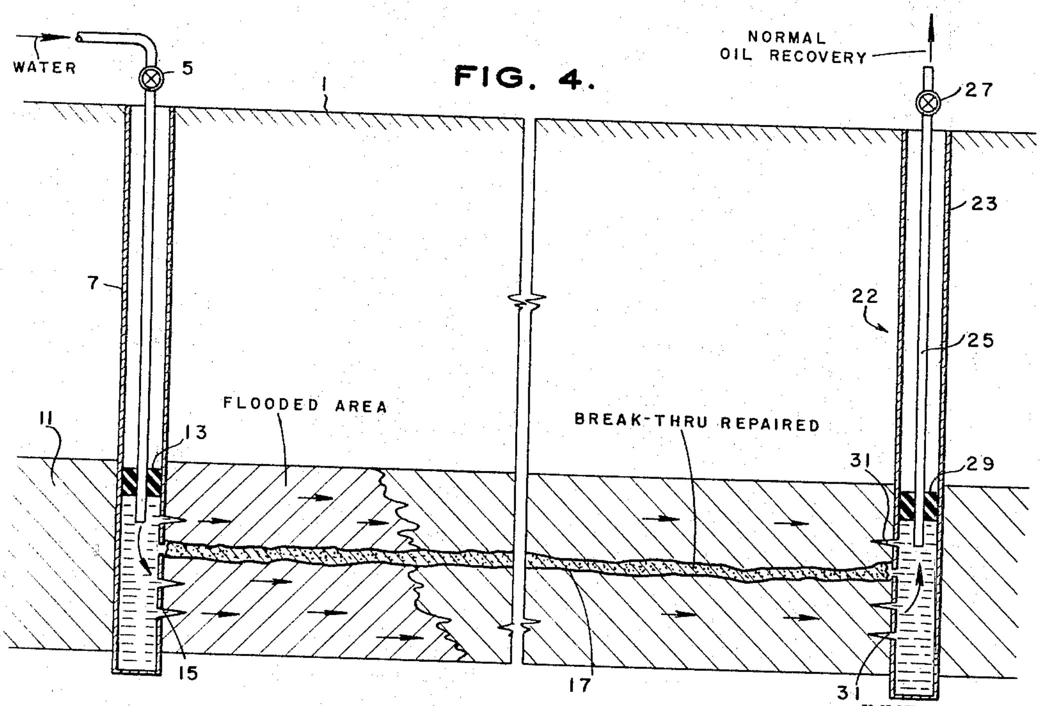


FIG. 4.



INVENTORS.
JOHN W. RHEA,
JOE V. MORSE,

John B. Davidson

ATTORNEY.

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REPAIR OF CHANNELS BETWEEN WELL BORES

John W. Rhea and Joe V. Morse, Monahans, Tex., assignors, by mesne assignments, to Esso Production Research Company, Houston, Tex., a corporation of Delaware

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5 Claims. (Cl. 166—4)

This invention relates generally to secondary recovery operations, and more particularly to a technique for repairing channels between well bores that deleteriously affect secondary recovery operations for recovering oil and gas deposits from earth formations.

When the primary energy of an oil or gas reservoir in the earth has been spent, it is customary to institute secondary recovery operations wherein a fluid under pressure is injected into the earth from a first well bore, and earth fluids are withdrawn from the reservoir to a second well bore. The secondary recovery fluid may be a gas or may be water. When water is used, various chemicals may be added thereto for the purpose of compensating for characteristics of the earth formations that may deleteriously affect the secondary recovery operations.

From time to time premature breakthrough of injected fluids into a producing well has been experienced during secondary recovery operations. Such breakthroughs are caused by channels between the well bores that permit direct fluid communication therebetween. Such channels either may be normally occurring or may be fractures in the earth produced as the result of the application of excessively high injected fluid pressures. Such fractures have been experienced most often in certain West Texas fields where there are a number of pressure-sensitive planes in formations. The Sand Belt Trend fields in the area of Monahans, Tex., contain a number of such planes.

In the past attempts have been made to repair such channels by pumping plugging materials such as cementitious mixtures into the channels. Such attempts have been unsuccessful for the most part.

In accordance with the teachings of the present invention, there is formed at the earth's surface a preparatory or indicator fluid having an apparent viscosity of at least 30 centipoises at 300 r.p.m. on a Fann viscosimeter and a water loss of no more than 20 cc. API. Also, there is prepared a cementitious mixture having a water loss no more than 60 cc. API. Preferably, the first one-half of the indicator fluid is radioactive such that its radioactivity is at least 0.1 to 0.5 millicurie per barrel. (The term "barrel" as used herein designates the standard 42 U.S. gallon barrel commonly used as a measure in oil field practice.) The indicator fluid is pumped into the fracture through the first well bore ahead of the cementitious mixture. Preferably, the volume of the indicator fluid is at least equal to the volume of liquid in the first well bore between the earth's surface and the level of the channel opening into the first well bore during the repair operations. The arrival of the fluid at a predetermined location in the second well bore is detected to determine the volume of the channel between the well bores. Preferably, this is accomplished by positioning a radioactivity detector at a given level in the second well bore, such as in the vicinity of the opening of the channel into the second well bore, so that a change in the radioactivity detected thereby will signify the arrival of the indicator fluid at the given level in the second well bore. After detection of the fluid, additional cementitious mixture is pumped into the channel until the indicator fluid is displaced from the channel and the cementitious mixture substantially fills the channel. Subsequent injection of secondary recovery fluids into the formation through the first well bore is delayed until the cementitious mixture has hardened.

Objects and features of the invention not apparent from the foregoing discussion will become evident upon consideration of the following detailed description thereof taken in connection with the accompanying drawings wherein FIGS. 1, 2, 3, and 4 are elementary, simplified schematic diagrams of well installations and associated apparatus for use in connection with the invention, for the purpose of illustrating various steps of the invention.

With reference now to the figures generally, and particularly to FIG. 1, there is shown a cased well bore **7** extending from the earth's surface **1** to the level of a hydrocarbon-containing earth formation **11**. A tubing string **3** extends through the well bore from the earth's surface to the level of formation **11** within the casing, and a production packer **13** is used to close the annulus between the tubing and the casing so that fluid pressure can be exerted below packer **13** through tubing string **3**. The customary well head apparatus is not shown in order to avoid unnecessarily cluttering the drawing. A valve **5** is illustrated which controls the flow of fluid through tubing string **3**. The tubing string **3** at its upper end is connected to a pump (not shown) for the purpose of injecting secondary recovery fluids into the tubing string **3** under pressure.

The casing is illustrated as having a number of perforations **15** below the level of packer **13** for the purpose of providing fluid communication between the well bore below packer **13** and formation **11**. A production or recovery well **22** spaced apart from the injection well is provided with a casing string **23** which may be cemented to the walls of the borehole in the usual manner, and a tubing string **25** controlled by valve **27** for the purpose of conducting produced fluids from formation **11** to the earth's surface. The tubing string **25** may or may not be provided with a production packer **29**, and the casing string **23** is perforated by perforations **31** as is customary.

In FIG. 1, a secondary recovery fluid, such as suitably treated water, is shown as being injected into tubing string **3** through perforations **15** into formation **11**. A channel or fracture **17** through the formation from one of the perforations **15** to one of the perforations **31** provides a path for direct fluid flow between the two well bores. This channel may be a fracture formed after initially flooded area **19** has been swept by the secondary recovery fluid as the result of the required secondary recovery fluid pressure having been sufficiently great to fracture the formation along a plane of weakness thereof, or may be caused by hydraulic fracturing when completing or stimulating the well. The secondary recovery fluid **21** will follow the path of least resistance and will flow from borehole **7** to borehole **22** through channel **17** rather than flowing through the interstices of formation **11**. While the fracture is shown as having occurred in a horizontal plane, it is to be understood that the fracture may have occurred along a vertical plane or along a tilted plane, or may have varied between various angles of inclination as it was propagated through the formation.

As stated above, to repair the formation damage, initially there is formed at the earth's surface an indicator fluid **43** having an apparent viscosity of at least 30 centipoises at 300 r.p.m. on a Fann viscosimeter and a water loss of no more than 20 cc. API. This indicator fluid may comprise either an aqueous or non-aqueous carrier fluid such as water, lease oil, diesel oil, or other suitable, commonly available fluids. For the purpose of increasing the viscosity thereof and reducing the water loss, an organic colloidal water loss agent is mixed therewith. The water loss agent may be either a hydrophilic organic colloidal agent such as starch, carboxymethyl cellulose, hydroxyethyl cellulose, guar flour, gum tragacanth, Irish moss, and albumin, or an oleophilic organic colloidal agent such as uncured butyl rubber, uncured polypropylene, uncured butadiene polymer, uncured polystyrene, uncured natural rubber, and blown asphalt. Manifestly, a hydrophilic organic colloidal agent will be used when an aqueous carrier fluid is used, and an oleophilic organic colloidal agent will be used when a non-aqueous carrier fluid is used. Of the above, guar flour is preferred as the thickening and water loss control agent. Preferably, between 20 and 40 pounds of the preferred thickening and water loss control agent is used per 1000 barrels of carrier fluid, according to depth and formation temperature.

In a preferred embodiment of the invention, there is added to the carrier fluid and water loss control agent a sufficient amount of a radioactive material to produce a radioactivity of at least 0.1 millicurie per barrel of the mixture, according to expected dilution. The radioactive materials should have a half life of at least one day, sufficient so that a detectable and measurable amount of radioactivity will remain in the fluid after a time interval equal to the interval required for the liquid to traverse the distance between the well bores through the channel therebetween, as described hereinafter. The most desirable radioactive agent for this purpose is iodine soluble in oil or water. However, other radioactive materials may be used.

There is also formed at the earth's surface a cementitious mixture which may be any of the cements commonly used in oil field practice for the purpose of bonding casing strings to surrounding earth formations. However, other materials may be used, such as materials that will pack in the channel to form a relatively solid impermeable mass. Such a material can be granulated calcium carbonate having a particle size no greater than 200 mesh. It is preferable, however, to use a cementitious mixture. To the cementitious mixture, other fracture control fluid is added to a hydrophilic water loss control agent, such as one of the colloidal agents described above or other commonly used water loss control agents for cementitious mixtures, sufficient in amount to reduce the water loss of the mixture to no more than 60 cc. API.

In FIG. 2 there is shown a radioactivity detector **41** lowered through tubing string **25** to the level of channel **17** between the well bores. The radioactivity detector **41** is suspended on a cable **39** about a sheave **37**. Cable **39** is reeled on a reel **35** having an electrical connection **34** to an electrical indicating device **33**. The electrical connection extends from the indicating device **33** to the radioactivity detector **41** so that electrical output signals are transmitted to indicator **33** so that an operator at the earth's surface will be able to ascertain the radioactivity being detected by detector **41** in accordance with the amplitude of the electrical signals indicated by indicator **33**. The indicator fluid **43** described above containing the radioactive agent is illustrated as being pumped through tubing string **3** into the fracture or channel **17** to displace the secondary recovery fluid **21** through channel **17** into the recovery well bore **22** and out the tubing string **25**. When the indicator fluid **43** arrives at the recovery well bore **22** the electrical signal produced by detector **41** will indicate a substantial increase in the radioactivity being detected thereby. The indicator fluid should be at least equal in volume to the volume of tubing string **3** and the space below packer **13**, and may be greater than this volume if desired. The volume of the indicator fluid injected into the tubing string **3** is measured, as is the volume of the cementitious mixture therebehind. Preferably, the volumetric measurement is continuous rather than batchwise. The cementitious mixture is injected into tubing string **3**, as illustrated in FIG. 3, to displace the indicator fluid **43** through the fracture. Inasmuch as the volume of tubing string **3** and the space therebelow is known, and inasmuch as the volume of the injected fluids is known by virtue of the detection of the arrival of indicator fluid **43** at recovery well bore **22** by detector **41**, the volume of cement required to fill the channel or opening **17** can now be ascertained. An additional quantity of cement is injected into the channel or fracture **17** to displace the indicator fluid **43** into recovery well bore **22**. Preferably, valves **27** and **5** are now closed, the fracture is kept under pressure, and cement will not be squeezed therefrom into the well bores. After the cement has hardened, conventional waterflooding operations may again commence. It may be necessary to circulate any additional cement out of injection well bore **7** in the usual manner and, if the perforations are plugged with cement, it also may be necessary to reperforate the injection well bore.

In connection with the invention, it should be noted that where fractures are vertically inclined, the detector **41** should be positioned at a sufficiently high level in recovery well bore **22** that the entire volume of the fracture will be filled with indicator fluid **43** when the arrival of the indicator fluid at a given level in the well bore **22** is detected. This is no problem, however, inasmuch as the volume of the well bore below the level of the radioactivity detector is known. In order to prevent an unnecessary number of perforations **15** from being plugged by cement, it may be desirable to position a bridge plug below the perforation in communication with channel **17**, or to position a straddle packer above and below such perforation or perforations.

Other techniques of detecting the arrival of the indicator fluid at a given level in the well bore may be used, such as detecting the arrival of the indicator fluid at the earth's surface by incorporating a quantity of ammonium thiocyanate in the indicator fluid and periodically adding a few drops of concentrated ferric chloride solution to the sample of the fluid issuing from tubing string **25** until a color change occurs. This latter technique is described in an article by J. L. Boyd et al. appearing in the periodical World Oil, September 1962, page 68.

Having described the principle of the invention and the best mode contemplated for applying that principle, it is to be understood that the apparatus described is illustrative only and that other means can be employed without departing from the true scope of the invention.

What is claimed is:

1. In the secondary recovery of hydrocarbons from a subsurface earth formation wherein a fluid is injected into the formation through a first well bore and connate earth fluids are withdrawn through a second well bore spaced apart therefrom, a method of repairing the formation when a channel therein permits direct fluid communication between the well bores, comprising:

forming a fluid having an apparent viscosity of at least 30 centipoises, a water loss of not more than 20 cc. API, and a radioactivity of at least 0.1 millicurie per 42-gallon barrel of a radioactive material having a half life of at least one day;

positioning a radioactivity detector in the second well bore in the vicinity of the intersection of the channel and said second well bore;

pumping a quantity of said fluid into said channel through said first well bore ahead of a cementitious mixture including an organic colloidal water loss additive;

measuring the quantity of said fluid and of said cementitious mixture pumped into said first well bore;

with said detector, detecting the intrusion of said fluid into said second well bore;

after detection of said fluid, pumping an additional quantity of said cementitious mixture into said formation to fill a substantial percentage of volume of the channel;

removing excess cementitious mixture from said first well bore; and

preventing egress of further amounts of fluid from said second well bore and placing said first well bore, said channel, and said second well bore under hydraulic pressure until said cementitious mixture has hardened.

2. In the secondary recovery of hydrocarbons from a subsurface earth formation wherein a fluid is injected into the formation through a first well bore and connate earth fluids are withdrawn through a second well bore spaced apart therefrom, a method of repairing the formation when a channel therein permits direct fluid communication between the well bores, comprising:

forming a fluid having an apparent viscosity of at least 30 centipoises and a water loss of not more than 20 cc. API;

pumping a quantity of said fluid into said channel through said first well bore ahead of a cementitious mixture having a water loss no greater than 20 cc. API;

measuring the quantity of said fluid and of said cementitious mixture pumped into said channel;

detecting the arrival of said fluid at a predetermined location in said second well bore to determine the volume of the channel;

after detection of said fluid, pumping said cementitious mixtures into said channel until said fluid is displaced from said channel and the cementitious mixture substantially fills the channel; and

delaying subsequent injection of secondary recovery fluid into said formation through said first well bore until the cementitious mixture has hardened.

3. In the secondary recovery of hydrocarbons from a subsurface earth formation wherein a fluid is injected into the formation through a first well bore and connate earth fluids are withdrawn through a second well bore spaced apart therefrom, a method of repairing the formation when a channel therein permits direct fluid communication between the well bores, comprising:

forming a fluid having an apparent viscosity of at least 30 centipoises and a water loss of not more than 20 cc. API comprising a carrier fluid and an organic colloidal water loss agent;

pumping a quantity of said fluid into said channel through said first well bore at least equal in volume to the volume of liquid in the well bore between the earth's surface and the level of the channel opening into said first well bore;

following said fluid with a cementitious mixture including an organic colloidal water loss agent sufficient in quantity to reduce the water loss of said cementitious mixture to no more than 60 cc. API;

measuring the quantity of said fluid and of said cementitious mixture pumped into said channel;

detecting the instrusion of said fluid into said second well bore;

pumping an additional quantity of said cementitious mixture into said channel to fill a substantial percentage of the channel; and

delaying subsequent injection of secondary recovery fluid into said formation through said first well bore until the cementitious mixture has hardened.

4. In the secondary recovery of hydrocarbons from a subsurface earth formation wherein a fluid is injected into the formation through a first well bore and connate earth fluids are withdrawn through a second well bore spaced apart therefrom, a method of repairing the formation when a channel therein permits direct fluid communication between the well bores, comprising:

forming a fluid having an apparent viscosity of at least 30 centipoises, a water loss of not more than 20 cc. API, and a radioactivity of at least 0.1 millicurie per 42-gallon barrel of a radioactive material having a half life of at least one day;

positioning a radioactivity detector in the second well bore in the vicinity of the intersection of the channel and said second well bore;

pumping a quantity of said fluid into said channel through said first well bore ahead of a cementitious mixture having a water loss no greater than 60 cc. API, and concomitantly withdrawing fluids from said second well bore;

measuring the quantity of said fluid and of said cementitious mixture pumped into said channel;

with said detector, detecting the intrusion of said fluid into said second well bore;

after detection of said fluid, pumping into said channel an additional quantity of said cementitious mixture substantially equal in volume to the volume of said channel; and

preventing egress of further amounts of fluid from said second well bore to place said first well bore, said channel, and said second well bore under hydraulic pressure until said cementitious mixture has hardened.

5. In the secondary recovery of hydrocarbons from a subsurface earth formation wherein a fluid is injected into the formation through a first well bore and connate earth fluids are withdrawn through a second well bore spaced apart therefrom, a method of repairing the formation when a channel therein permits direct fluid communication between the well bores, comprising:

forming a fluid having an apparent viscosity of at least 30 centipoises, a water loss of no more than 20 cc. API, and a radioactivity of at least 0.1 millicurie per 42-gallon barrel of a radioactive material having a half life at least equal to the estimated time for a fluid interface to traverse the earth formation between said well bores through said channel;

positioning a radioactivity detector in the second well bore in the vicinity of the intersection of the channel and said second well bore;

pumping a quantity of said fluid into said channel through said first well bore ahead of a cementitious mixture including an organic colloidal water loss additive sufficient to reduce the water loss of the cementitious mixture to no more than 60 cc. API, and concomitantly withdrawing fluids from said second well bore;

measuring the quantity of said fluid and of said cementitious mixture pumped into said channel, the volume of said fluid pumped into said channel being at least equal to the volume of liquid in the well bore between the earth's surface and the level of the channel opening into said first well bore;

with said detector, detecting the intrusion of said fluid into said second well bore;

after detection of said fluid, pumping an additional quantity of said cementitious mixture into said channel substantially equal to the volume of said fluid to displace said fluid from said channel; and

preventing egress from said second well bore of further amounts of fluid and placing said first well bore, said channel, and said second well bore under hydraulic pressure until said cementitious mixture has hardened.

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STEPHEN J. NOVOSAD, *Primary Examiner.*