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METHOD OF ESTABLISHING COMMUNICATION BETWEEN WELLS

Harold E. Staadt, Tulsa, Okla., assignor to The Dow Chemical Company, Midland, Mich., a corporation of Delaware

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This invention relates to a method of obtaining subsurface communication between spaced apart earth wells, and particularly to a method of obtaining said communication through a liquid soluble subsurface formation which extends between said wells.

Such communication is often desired in certain industries, such as subterranean gas storage, solution mining, and certain water flooding operations.

It is known to fracture an earth formation from one well in an attempt to establish communication with a neighboring well. Sometimes the formations adjacent to both wells are fractured in making such attempts. Often, however, communication is not achieved because the fractures so produced from each well do not themselves meet or, if only one well is fractured, the fracture does not extend to or intersect the unfractured well.

Accordingly, a principal object of this invention is to provide an improved method of obtaining subterranean communication between earth wells.

Another object of this invention is to provide an improved method of obtaining communication between spaced apart earth wells through an earth formation which is at least partially liquid soluble.

In accordance with this invention communication is established between cased earth wells which are spaced apart by a predetermined distance, each of which penetrates a particular earth formation, by notching the casing of one well and the adjacent annulus and earth formation in a vertically disposed plane which faces generally towards a second well with which communication is to be obtained, by notching the casing of the second well and the annulus and adjacent earth formation in a horizontally disposed plane which faces and, if extended, would intersect the vertically disposed notch of the other well (or bore hole). The casing of the second well may be circularly notched in a horizontal plane to produce a notch throughout the circumference of the casing; however the preferred method is to orient the notch to face the well which is vertically notched. Both wells are then fractured through the particular formation by pumping liquid under pressure into each well to first break down the formation, and then additional liquid is pumped into each well to enlarge and extend the fractures induced in the formation as it is broken down.

Because the fracture or fractures induced adjacent to one well are vertically disposed while the fractures or fracture induced adjacent to the other well are horizontally disposed, intersection of the fractures of the wells is accomplished with greater certainty than has heretofore been obtainable.

The invention, as well as additional objects and advantages thereof, will best be understood when the following detailed description is read in connection with the accompanying drawing in which:

FIG. 1 is a diagrammatical view showing two spaced apart wells between which communication has been established in accordance with this invention;

FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1; and

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 2.

Referring to the drawing, there is shown a pair of bore holes 10, 12 which penetrate earth formations 14, 16 and

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a more or less liquid soluble formation 18 which may, for example, be a salt (NaCl) formation.

Each of the bore holes or wells 10, 12 terminates in the soluble formation 18 and has the usual casing 20, 22, respectively, disposed therein. The annulus between the casing and well bore wall in each well 10, 12 is filled with cement 24, 26, respectively, as is the space between the bottom of the casing and the bottom of each well bore

The two well bores are spaced apart by the desired distance, about 200 ft. to 400 ft., for example.

The casing 20, 22 of each well is capped at its upper end by a suitable casing head 28, 30. A liquid reservoir 32 is coupled through a valve 34, pump 36, line 38 and valve 40 to the casing head 28. A similar liquid reservoir 42, valve 44, pump 46, line 48 and valve 50 are coupled to the casing head 30.

In addition, a valve 52, 54 is coupled to each of the casing heads 28, 30, respectively.

The casing 20 has a vertically extending slot 56 (about 20 ft. long, for example) disposed near the bottom of the casing string and generally facing the casing 22. A cut or notch 66 similar to the slot 56 extends through the adjacent cement of the annulus between the casing and well bore wall and into the adjacent formation 18 (salt, for example). See FIG. 2, also.

The casing 22 has a series of perforations (58, 60, 62, 64, for example) plus their extensions (see 68 in FIG. 1) disposed along a common horizontal plane and generally facing towards the casing 20. See FIG. 3, also. Alternatively, instead of the perforations 58, 60, 62, 64 a single continuous slot in the casing may be used, the slot (not shown) facing generally towards the casing 20.

The vertically disposed slot 56 and the horizontally disposed perforations 58, 60, 62, 64 plus their extensions 66, 68, respectively, which penetrate through the cement and into the adjacent earth formation are produced by any suitable means, such as are disclosed, for example in U.S. Patent No. 3,066,735, entitled "Hydraulic Jetting Tool," and issued December 4, 1962, to Warren Zingg, where a jet of liquid which contains abrasive materials is directed towards the casing and well bore wall. Perforations are made with the jet held in one position. Slots, such as the slot 56, for example, are made by moving the jet along a linear path as the jet is operated.

After the notching of each well 10, 12 is done, each well is given a formation fracturing treatment. For example, with the valves 34, 40 open, liquid (usually water) is pumped by means of the pump 36 into the casing 20 of the well 10 and the pressure in the well bore and in the vertically oriented notch 66 increased until the formation 18 breaks down, and then liquid is pumped into the formation at a high rate to enlarge and extend the fracture or fractures produced when the formation breaks down.

The well 12 is, usually, but not necessarily, simultaneously with the well 10, given a similar formation fracturing treatment in which liquid from the reservoir 42 is pumped by means of the pump 46, line 48 and opened valves 44, 50 into the casing 22. After the break down of the formation 18 adjacent to the notches 68, liquid is pumped into the fracture to expand and extend it as is well known in the well treating art.

From time to time during the fracturing treatment, it is desirable to shut down the fracturing treatment of one well to observe pressure variations at the well head which indicate that communication has been established between the wells.

It is desirable that the rate of injection of liquid into the earth formations adjacent to each well be maintained at as high a rate as is practicable with the pumping equipment which is available. Injection rates of from 1 to 100 barrels per minute have been used, for example. High

injection rates, in general, insure that a more rapid extension of the fracture will occur than if lower liquid injection rates are used.

While water has been mentioned as an example of a fracturing liquid, saturated brine is often used as the fracturing fluid until such time as communication between the wells 10, 12 is established. After communication is established, fresh water is pumped into one well and removed from the other well until enough salt (or other water soluble material) is removed to insure sustained communication between the two wells.

Oils, such as petroleum fractions, and crude oils are also satisfactory fracturing liquids. Other satisfactory liquids are acid and other chemical solutions, particularly when the formation being treated is at least partly soluble in such solutions. If an oil or other liquid having no ability to dissolve the formation is used, it is usually preferable to use a propping agent such as sand or other particulate solids as is well known in the fracturing art along with the liquid. The propping agent serves to assure communication through the fracture at such a time as the hydraulic pressure upon the liquid is released. The use of a propping agent is optional when the liquid is a solvent for at least a part of the formation, as communication is gained by dissolution of the formation.

Since the slot and notch 56, 66 at the well 10 is vertically oriented and directed towards the well 12, the fracture 70 produced at the well will be more or less vertically oriented.

Conversely, the fracture 72 emanating from the perforations 58, 60, 62, 64 and their "notched" extensions 68, tends to be horizontally disposed.

With the two fractures being oriented more or less perpendicularly with respect to one another and directed towards one another, intersection of the fractures (and consequently communication between the wells) is much more easily accomplished than if both the fractures were horizontally oriented or both were vertically oriented.

As an example of a pair of wells where communication may be established therebetween in accordance with this invention, the wells are separated from one another by about 400 feet. The wells extend downwardly into a salt zone which is about 100 feet thick, the top of the salt zone being at about 900 feet of depth.

It is desired to fracture the formation and establish communication at the bottom of the salt zone, and the wells are drilled to near the bottom of the salt zone, the casing strings run into the wells and the casing cemented in place.

Notching of one well is vertically oriented and extended about 20 feet in length, from about 975 feet to 995 feet below the surface.

The other well casing is perforated (but could be slit horizontally and the formation notched in a horizontal plane) with multiple perforations in a common horizontal plane at a depth below the surface of about 985 feet. Each so-called perforation extends through the cement in the annulus and into the formation to be fractured, so in effect there is a "notch" communicating with each perforation. The perforations and their "notches" extend generally towards the well 10.

The wells are then given a formation fracturing treatment as heretofore described to achieve the desired vertical and horizontally oriented formation fractures and to establish communications between the two wells.

If the two wells cannot be given formation fracturing treatments simultaneously because of the lack of sufficient treating equipment, it is preferable to first make the vertical fracture and then make the horizontal fracture which communicates to the vertical fracture. The reason for doing the fracturing in this sequence is that vertical fractures usually require less fluid to produce and extend them than do horizontal fractures. Thus, extending the vertical fracture to its maximum practical extent before

making and extending the horizontal fracture saves liquid treating agent which is injected into the formation during the treatments.

While the break down pressures required to induce fractures vary considerably, salt formations (NaCl) generally are rather easy to break down, the usual break down pressure being about 1 pound per foot of overburden depth. After break down of the formation the pressure at which liquid is injected into the formation usually drops by a substantial amount as is well known in the formation fracturing art.

While the invention has been principally described in connection with the establishing of communications between spaced apart wells through a salt formation, the method of the invention is equally applicable to the establishment of communication through formations of other types which are penetrated by spaced apart well bores. Further the invention may be practiced in uncased formations, such as in formations below the cased portion of a borehole, or in sections of a borehole which otherwise are uncased. When the invention is practiced in an uncased section the formation is notched in a similar fashion as if casing were present and the remaining steps are followed as if casing were present.

What is claimed is:

1. A method of establishing subsurface communication between first and second earth wells which are spaced apart by a predetermined distance, each of which penetrates a particular earth formation, comprising notching said formation of said first well along a predetermined depth range and in a vertically disposed plane which extends generally towards said second well with which communication is to be established, notching said formation of said second well in a horizontally disposed plane which, if extended, would intersect, the vertically disposed notch of said first well, and hydraulically fracturing said particular earth formation from both wells through said notches until said fractures meet.

2. A method in accordance with claim 1, wherein said wells are fractured simultaneously.

3. A method in accordance with claim 1, wherein the hydraulic fracturing is done first from the well having said vertically disposed notch.

4. A method in accordance with claim 1, wherein said particular formation is at least partially liquid soluble.

5. A method in accordance with claim 1, wherein said particular formation is water soluble.

6. A method in accordance with claim 1, wherein said particular formation is principally composed of sodium chloride.

7. A method in accordance with claim 1, wherein a brine solution is the treating agent used in hydraulically fracturing said particular formation.

8. A method in accordance with claim 1, wherein the treating agent injection rate during said hydraulic fracturing is between 1 and 100 barrels per minute.

9. A method in accordance with claim 1, wherein the horizontally disposed notch is directed toward said well having a vertically disposed notch.

10. A method in accordance with claim 1, wherein a particulate solid propping agent is used with said treating agent used in hydraulically fracturing said particular formation.

11. A method in accordance with claim 1, wherein said first and second wells are cased through said particular earth formation and notching said casing and adjacent annulus and thence said formation in said first and second wells.

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