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FRACTURING METHOD IN SOLUTION MINING

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This invention relates generally to a method of establishing a flow channel between bore holes or wells in a soluble subterranean formation.

It has long been known that soluble formations beneath the earth's surface can be removed by solution mining. The techniques of solution mining are useful for recovering useful salts such as trona or KCl and also the technique has been found useful in establishing underground storage caverns in salt domes for such diverse liquids or liquefied natural gas, liquefied petroleum gases such as propane and butane, liquid ammonia or in some cases gases, as well as other non-solvent (for the formation) liquids and gases.

Depending upon the particular formation, size of the cavern desired, etc., one or more bore holes or wells are drilled into the formation, a casing cemented in and injection tubing and product conduit is provided. A solvent, usually water, is pumped into the formation where the formation is leached out or dissolved in the solvent and the resulting solvent containing dissolved salts is removed via the production conduit to the surface where the salts can be recovered and solvent reused, or if the salt is not to be recovered, e.g., preparation of storage cavern, the saturated solvent can be sent to waste and fresh solvent used. It is also known to force the extension of the cavity laterally by use of a low density nonsolvent on top of the solvent to protect the roof from further attack and to use a higher density nonsolvent beneath the solvent to protect the floor of the cavity.

When it is desired to prepare a solution channel having relatively large horizontal dimensions, it is customary to sink two or more bore holes into the formation and to initiate a horizontal fracture from one of the wells extending to the other wells. Such methods of creating horizontal fractures are known to the art and consist essentially of notching a horizontal opening in the casing in the direction fracture is desired. A fracturing fluid, which can be solvent or non-solvent, is then pumped into the initial well under sufficient pressure to overcome the overburden pressure exerted by the earth, thereby causing the earth to part or fracture. In general, it can be said that for each foot of depth approximately one p.s.i.g. pressure is required to lift the overburden plus some increment to cause the fracture. The exact pressure will, of course, depend on many factors; however, it is within the skill of the art to determine where fracture occurs, usually by a noticeable pressure drop in the injection pressure or by a pressure rise in the target well or wells. It is also known to the art that the ideal location for initiating horizontal fracture is at the interface between different strata of the formation where such strata exist.

In producing flow channels between wells by horizontal fracturing techniques, one serious problem has been faced by the art. If, after the fracture has reached the desired limits, the pressure is substantially reduced, the fracture settles back into place preventing the desired circulation of solvent. If, on the other hand, sufficient pressure is maintained to keep the fracture open until sufficient salt has been dissolved to provide a definite flow channel, the fracture continues to extend beyond the desired limits. Thus, the fracture may extend outside the salt bed to a porous formation which creates a problem of leakage from the solution mining operation or the resulting storage cavern. Also, if there are other caverns in the formation, the fracture will extend into these, providing an undesirable passageway between the new cavern and the old one. If different materials are to be stored in these caverns, then a source of contamination is created.

It is to this undesirable fracture extension that the present invention is directed.

It is, therefore, an object of this invention to provide a method of creating a channel between wells by fracturing without undue extension of the fracture.

Other objects and features of the invention will be obvious to those skilled in the art from the following description.

According to this invention, a horizontal fracture is initiated in a subterranean soluble formation extended between at least two bore holes, a propping agent placed in the fracture, the pressure reduced when the fracture reaches the desired limits of extension and thereafter a solvent for the formation passed between bore holes through the passage created by the fracture and held open by the propping agent.

As is known by the art, any liquid capable of being pumped at high pressures can be utilized as the fracturing fluid. Although a solvent for the formation can be used, preferably the initial fracture will be made with a non-solvent. Thus, suitable fracturing fluids include hydrocarbons such as crude oil, kerosene, light or heavy cycle oils and the like, alcohols and glycols, water and brine or any other organic or inorganic liquid which meets the requirements of being pumpable at the necessary fracturing pressure. In most cases, the preferred fracturing fluid will be water saturated with the material of the formation being fractured. It is within the skill of the art to add thickening agents, fluid loss additives, corrosion inhibitors, bactericides and the like to the fracturing fluid when desired.

Suitable propping agents are any of those propping agents known to the art of fracturing, particularly to the oil well fracturing art. Thus, suitable propping agents include sand, glass beads, resin beads such as polyethylene or other polymeric beads, metallic pellets such as aluminum pellets, walnut hulls and the like. The most desirable materials would be ones that would deform with pressure and not embed in the fracture surface. Thus, the preferred propping agents include resin beads, soft aluminum pellets, walnut hulls and the like.

The propping agent can be added initially with the fracturing fluid, but will preferably not be added until fracture is initiated.

As has been indicated, the method of this invention is applicable to establishing flow channels in subterranean soluble formations, for example, salt domes, sylvite or more commonly KCl in association with NaCl, trona and the like.

As previously stated, this method of forming a flow channel between wells is applicable to two or more wells. However, for simplicity of description, the description of operation will be described wherein only two wells are involved.

Two wells are drilled into the formation to the desired depth at a predetermined distance apart and suitable casing cemented in place. At a predetermined depth, a horizontal fracture is initiated in the first or injection well. As soon as fracture is initiated as determined by momentary pressure drop or increased injection rate, a suitable propping agent is added to the fracturing fluid and injection is continued until the fracture reaches the second or target well as indicated by pressure increase at the target well.

Solvent would then be injected into the target well without altering the injection rate or pressure in the first (initial) well. This would insure that a new fracture is not created at the target well.

When the pressures in the two wells become substantially equal, the injection at the first well is reduced to zero and the pressure released allowing the formation to settle on the propping agent. Solvent would continue to be injected into the target well and will flow toward the first or injection well through the channel provided by the propping agent and recovered through that well. At the same time, the pressure of the injected solvent, now through the second or target well, will be maintained below the fracturing pressure, thus preventing extension of the fracture.

Since the fresh solvent introduced at the target well dissolves the formation, it becomes less effective as it approaches the initial injection well, and the flow channel will be leached at a greater rate near the well where solvent is introduced. Therefore, once the channel is fully established, it is desirable that the solvent flow be reversed and the fresh solvent be introduced at the first injection well, and the target well becomes the recovery well. This procedure can be reversed many times during the solution mining operation. Even so, if the wells are of sufficient distance apart, the cavern or channel produced may tend to be constricted at a position intermediat the two wells. In this case, it is within the scope of the invention to utilize a nonsolvent of high density to protect the floor of the channel along its lower level from attack and to use a nonsolvent of low density to protect the roof of the channel along its higher levels, thus permitting fresh solvent to attack the soluble material at this area of constriction. It is within the skill of the art to provide these nonsolvents; however, by way of illustration, water saturated with the material of the formation, with or without a heavy salt dissolved therein, could be used as the heavy nonsolvent and a light hydrocarbon such as liquefied petroleum gas, gaseous hydrocarbon such as natural gas, air or nitrogen would serve as the light nonsolvent in conjunction with water solvent.

To further illustrate the invention with relationship to a specific operation, we wish to initiate a flow channel in a subterranean formation of NaCl and KCl. Two wells or bore holes are drilled into the formation, A the initiating or first well and B the target or second well. We find by examining the core that at 1200 feet below the surface the bottom of the KCl rich portion of formation is located, and it is desirable to start our channel at this level. Suitable casing is cemented in and the casing in well A is notched so as to create a horizontal fracture toward well B. After placing a suitable packer, water saturated with NaCl and KCl is pumped into well A. At about 1500 pounds per square inch gauge (p.s.i.g.), fracture is initiated as noted by a drop of pressure to about 1200 p.s.i.g. At this point, aluminum pellets are added to the fracturing fluid and the rate of injection maintained until the fracture reaches well B as detected by an increase of pressure in that well to about 1000 p.s.i.g. At this time, water is pumped into well B while continuing to inject fracturing fluid in well A until the equalization pressure of 1200 p.s.i.g. is reached in well B. At this point, injection in well A is stopped, and the pressure is released. The water injection pressure is maintained in well B until the desired flow rate, say a flow at 50 p.s.i.g., is reached in well A. This rate is maintained by slowly lowering the pressure in well B say down to about 300 p.s.i.g. At this point, the channel is established. From this point on, the direction of water injection will be periodically reversed to leach or dissolve out the KCl. The water enriched with NaCl and KCl is treated by any suitable means to recover KCl. The water freed to KCl but still enriched or saturated with NaCl can then be utilized as the solvent or fresh water can be used as desired.

When more than two wells are employed, the same procedure is employed to the step of reducing pressure in the fracturing well and opening a channel from the target well. From that point, each of the several wells will alternately be utilized as the injection well with the remaining wells serving as recovery wells. It may be necessary to provide pack pressure valves on the wells to control the flow from the producing wells at the same level, thus preventing undue enlargement of the cavern being formed at any particular location. When more than one target well is involved, the fracture will reach each of these wells at different times. It is desirable that the pressure in the first wells reached be maintained until the fracture reaches all of the target wells and that solvent injection be initiated from the target wells to the fracturing wells at about the same time.

Having thus described the invention, we claim:

1. In creating flow channel between bore holes in a subterranean soluble formation, the improvement comprising:

(a) Initiating a horizontal fracture from one of said bore holes, the injection bore hole, in the direction of the remaining bore holes, the target bore holes, by means of injecting a fracturing fluid into the injection bore hole;

(b) Introducing a propping agent into said fracturing fluid after initial break-through and prior to the extension of the initiated fracture reaching the target bore holes;

(c) Introducing solvent for said soluble formation into the target bore holes where said fracture reaches said target bore holes while continuing to inject fracturing fluid into injection bore hole;

(d) Ceasing injection of fracturing fluid and reducing pressure on said injection bore hole while continuing to inject solvent from said target bore holes; and

(e) Lowering the pressure of solvent injection to below the fracturing pressure and recovering solvent from said injection bore hole until flow channel is created.

2. The improvement of claim 1 wherein solvent injection is alternately injected in different bore holes and recovered alternately from different bore holes once the flow channel is completed to enlarge the cavern or channel being formed by solution of soluble formation into the solvent.

3. The improvement of claim 2 wherein said propping agent is deformable under the pressure of the overburden when said fracturing pressure is lowered.

4. The improvement of claim 3 wherein said soluble formation is soluble in water and water is said solvent.

5. The improvement of claim 4 wherein the fracturing fluid is water saturated with respect to said soluble formation.

6. The improvement of claim 5 wherein said soluble formation comprises KCl.

7. The improvement of claim 5 wherein said soluble formation comprises NaCl.

8. The improvement of claim 5 wherein said soluble formation comprises trona.

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