Patented Aug. 6, 1940

2,210,545

UNITED STATES PATENT OFFICE

2,210,545

PROCESS OF SEALING OPENINGS IN THE EARTH

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No Drawing. Application November 15, 1939, Serial No. 304,467

10 Claims. (Cl. 166—21)

The present invention relates to an improvement in processes for sealing openings in the earth, particularly when water, gas, or oil are flowing from the same, the invention being specifically applicable to the sealing off of oil wells, gas wells, oil wells from which gas is flowing, and oil wells into which water is irrupting; the grouting of coal mines; stopping water seepage in dams; and when, in the sealing of a well, the water irrupting into the same or other opening contains sulfates and other substances which ordinarily interefere with the proper setting of a cementitious substance which is used to seal the opening, break, or formation.

One of the primary objects of the invention relates to a process of sealing an earth formation, such as for example a subsurface break located at an unascertained distance below the earth's surface, as, for instance, in an oil well or the like, and which break is seriously interfering with the proper operation of the well.

One of the outstanding features of the present invention is the employment for this purpose of a potentially hardenable substance which is capable of congealing or hardening into a solid mass under known conditions, and the addition to said substance of continuously increasing amounts of controlling materials or reagents which thus continuously modify the hardening, setting or congealing time until the latter thus becomes more or less automatically so correlated with the time required for the substance to reach the formation in the well that the substance will there set up or harden despite adverse conditions such as the force of gas or water and agitating or diluent effects.

A specific object of the invention is to force into an oil well, into which water or gas is irrupting, a pumpable slurry of a cementitious material so that the well becomes filled with this material and the slurry begins to discharge into the break or formation where it would ordinarily be washed away or otherwise lost, but with the modification that, as the slurry is being pumped into the well, continuously increasing amounts of, for example, an accelerating material are added to the advancing slurry so that its setting time will continuously be decreased until such a nice balance is established between the setting time and the time required for the slurry to reach the break or formation in the well that the slurry will there set despite any agitation, thus obturating the break or formation and effectively sealing the well.

I have already proposed in my copending applications, Serial Nos. 203,815 and 224,637, the latter of which has now matured into Patent No. 2,191,652, dated February 27, 1940, to pump into an opening in the earth a slurry of calcined gypsum whose setting time has been so adjusted that the slurry will set at about the time that it reached the break or formation in the well, the bedrock under an earth fill dam, or an explosive in a hole. In order to carry out the inventions described in my aforesaid applications, however, it was first necessary to ascertain with a fair degree of accuracy the location of the subsurface break or formation and also to measure or calculate the length of time it would take the slurry to reach the break. If this calculation proved to be inaccurate, then the methods described in my prior applications would sometimes be inadequate to accomplish all of the desired objects.

In accordance with my present invention, however, I improve upon my previous practice by starting out with a potentially hardenable material which in all probability, and as nearly as can be ascertained, will not set or congeal at the time it reaches the break or formation, whereupon I then add to the same, ahead of the pumps, at the pumps, or beyond the pumps which are forcing it into the hole in the ground, such as a well, increasing amounts of accelerating material, so that the setting or congealing time of the material continuously decreases. In other words, let it be assumed, for example, that a well is a mile deep and that a break has occurred at around the 3,000 or 4,000 foot level, but the exact location of the break is in doubt to the extent of about 1,000 feet. In accordance with my previous inventions, I would first have ascertained where the break was and then would have calculated the length of time it would take the setting material which was descending into the well to reach the break, and I would have adjusted the setting time of the material so that it would just about be ready to set when it arrived at the location of the break. This, however, requires rather fine adjustment, which is difficult of accomplishment except by highly trained operators.

I now modify this procedure by, for example, making a mixture of calcined gypsum and water to form a pumpable slurry. I start pumping this into the well under pressure by means of well known oil-well-cementing pumps. There will be indicated on the gauges connected with the pumps a certain pressure and, as the slurry reaches the break and is discharged into the

surrounding earth at that point, the back pressure will remain about constant. I then begin to feed into the slurry, either as a dry substance or in solution, set-accelerating materials which have a tendency to increase or accelerate the speed with which the said slurry would set. The pumping is continued all the while and, if the pressure does not rise, larger amounts of accelerating materials are added until the pressure begins to rise, which is a clear indication that setting of the material is taking place. At that time I keep the relative amount of accelerating substance about constant and continue the pumping until the pressure rises so high that it can no longer be accomplished or until the indications are such that I am satisfied that the break or formation has been successfully plugged. The accelerating materials used for this purpose in connection with gypsum, for example, are very well known in the art and usually consist of seed crystals of calcium sulfate dihydrate such as land plaster, ground natural gypsum rock, or metathetically produced seed crystals of calcium sulfate, as, for example, those disclosed in certain patents to Gallagher, No. 1,683,539, and George D. King, Nos. 1,989,641, 2,078,198, 2,078,199 and 2,078,200.

I am not, however, limited to the use of calcined gypsum for carrying out my present invention, as I find that I can accomplish at least comparable results by the use of other setting or cementitious materials such as may be exemplified by Portland cement to which there is being added gradually increasing amounts of a set-accelerating substance as, for instance, a solution of sodium silicate or calcium chloride. Other examples of materials usable for carrying out my present invention are mixtures of magnesium chloride solution with magnesium oxide, such mixtures being sometimes known in the art as Sorel cement. There are also certain phosphate cements which could be used, but the cost of these is probably at the present time too high to make them commercially practicable.

It is also contemplated to use various other combinations of substances, whether cements or not, by which a solid or semi-solid is formed in a formation at a predetermined time and in which the time can be controlled and varied.

There are many operations in which a setting substance is pumped into a well to seal off a cavity therein, to take care of lost circulation, to plug back the well, to control a wild well, or to shut off water or gas, but in which it is impossible to tell in advance the exact time which would be required for the potentially hardenable or setting material to reach the affected point. Under these conditions I may, for instance, start out with a material having a known time of set, say, 30 minutes, 60 minutes, 120 minutes, etc. I may start, for example, by first pumping a column of mud or water into the well. This mud or water, if desired, may be weighted in a known manner as, for instance, by adding thereto finely ground, heavy substances such as barium sulfate, iron oxide, and the like. I continue this pumping until the water or mud reaches the opening or break. I then start following the mud by a column of cementitious material having a set, say, of 120 minutes, to which may or may not be added known weighting materials; and then, as I continue the pumping, I begin to add some known accelerator which speeds up the time of setting. I may feed this in dry, as, for example, when the cement is being mixed with the water as through a hopper, or I may prepare a solution or suspension of the accelerating material and feed it into the pumps or into the potentially hardenable material just beyond the pumps, using for this purpose, if desired, an additional pump whose speed of pumping can be individually controlled. It may also occur sometimes that the material with which I start will accidentally become accelerated as from seed crystals present in the pump or the pipe lines, or hole, or more time might be required to pump into the formation than the predetermined set material would allow, in which case I might even find it advantageous or advisable to use a retarding material to slow up the set. In any event, what I do is to modify the setting time of the material which is being pumped into the well until I have attained a nice balance between the time it requires for the material to reach the break or formation and the time in which the material will set. When this takes place, the material will, of course, set right where I want it to, thus effectively sealing the opening or formation. This is an entirely new concept in the cementing of oil wells and the like.

For most purposes, however, I have found that some form of calcined gypsum is the least expensive and the most desirable material for my purposes. If a great deal of pressure has to be overcome, I may even add to this material weighting agents such as barium sulfate or iron oxide. On the other hand, I might employ a form of calcined gypsum, the very nature of which is so that it has a low consistency, one of these being available on the market and described as "alpha gypsum" in the patent thereon issued to Randel and Dailey, No. 1,901,051. This material is a special form of calcined gypsum which not only has a very low consistency but sets to a solid substance of a strength approximately equal to that of Portland cement. Nevertheless it can be accelerated or retarded with the same ease as ordinary calcined gypsum or plaster of Paris.

Methods for accelerating the set of Sorel cement have also been described in the literature, and I therefore do not wish to be limited in any way by the type of material which I employ for my present purposes.

It will also be self-evident that I can apply the principles of my present invention to those features of my prior invention set forth in my copending application Serial No. 224,637, now matured into patent No. 2,191,652, in which I describe the sealing off of seepage water under an earth fill dam or levee or where I employ the materials for the tamping of an explosive charge such as nitroglycerol or dynamite.

The present invention has found wide application in the sealing off of wild wells, particularly when large quantities of water irrupt thereinto or if they blow out with gas. My present process can be used very effectively, without waste of material, and with a much greater certainty of success than the prior processes involving the use of Portland cement which, as is well known, requires a comparatively long time to set.

One of the particular advantages of calcined gypsum for the present purposes lies in the fact that this material will set even though violently in motion and even though gas or water is irrupting into it, which, therefore, distinguishes the calcined calcium sulfate from the other known cements, most of which require a state of quies-

cence in order to set and which will not set if disturbed or agitated.

However, by the use of sodium silicate or calcium chloride I can speed up the setting of Portland cement sufficiently for my purposes, and I therefore wish to have Portland cement, so accelerated, considered as a further specific embodiment of my present invention. In employing the term "formation" I use it in the sense in which it is generally understood by those familiar with earth-boring or oil-well drilling operations, and may include sand, gravel, porous limestone or sandstone, fissure, crack or cave; in other words anything into which oil, water, drilling-mud or the like may escape from the drilled hole or from which something may enter into the drilled hole.

Saving for myself such equivalents as will occur to those skilled in the art, and without in any way limiting my invention to the particular instrumentalities for carrying it into effect, I claim:

1. The process of sealing a formation in the earth which comprises forcing into it a potentially hardenable substance containing a controlling material affecting its time of hardening, and as the forcing continues adding further and increasing quantities of said controlling material until a time of hardening is reached which is in accordance with the conditions encountered and which is such that the substance will harden in such a manner as to seal up the formation.

2. The process of sealing a formation in the earth, located below the earth's surface and the exact location of which is unascertained, which comprises forcing into said formation a setting substance while feeding into the flow of said substance in increasing amounts a controlling reagent having the power of changing the setting time of the substance so as gradually to decrease said setting time until the latter is so related to the time of travel of the substance to the formation that it will set up and harden at about the location of the formation.

3. The process of sealing a formation located below the earth's surface in a well or similar opening in the earth, the location of which formation is not definitely ascertained, which comprises producing a slurry of calcined gypsum having a known setting time and forcing said slurry into the well while gradually reducing the setting time of the calcined gypsum being thus forced until its setting time has become so correlated with the time of arrival of the slurry at the locaton of the formation that it will there set up into a hard mass.

4. The process of sealing off an earth formation in an oil well which comprises preparing a slurry of calcined gypsum having a known setting time, pumping said slurry into the well until it reaches the formation and passes into it; then, as the pumping continues, gradually accelerating the setting time of the slurry by the addition of an accelerator until said time is so correlated to the time of travel of the slurry that the latter will just about set when it arrives at or near the formation.

5. The process of sealing a subsurface break in an opening in the earth which comprises preparing a mixture of water, and a substance capable of hardening after a certain time, to form a pumpable mixture; pumping said mixture into the opening in a continuous stream until it fills the opening and begins flowing out of the opening into the break therein, and then beginning to add a set-accelerating substance to the mixture and continuing the pumping while continuously adding increasing quantities of accelerating substance to the mixture until pumping becomes too difficult to continue, this being occasioned by the hardening of the material in or about the break and in the opening between the break and the surface of the earth.

6. The process of claim 5 when the substance capable of hardening is a form of calcined gypsum.

7. The process of claim 5 when the substance capable of hardening is calcined gypsum and the accelerating substance is added to the mixture during the pumping operation.

8. The process of sealing off an oil well from which gas is escaping which comprises forcing into the well a slurry of calcined gypsum, and as the forcing continues gradually accelerating the setting time of the slurry being forced into the well until the said setting time is so co-ordinated with the gas-pressure conditions that the slurry will set sufficiently fast, despite the agitation thereof by the gas, to seal the well.

9. The process of sealing off an oil well from which gas is escaping which comprises forcing into the well a potentially hardenable substance, and as the forcing continues gradually accelerating the hardening time of the substance being forced into the well until the said hardening time is so co-ordinated with the gas-pressure conditions that the substance will harden sufficiently fast, despite the agitation thereof by the gas, to seal the well.

10. The process of sealing a formation in the earth which comprises forcing into it a potentially hardenable substance and, as the forcing continues, adding gradually increasing amounts of substances affecting the rate of hardening of the material until a time of hardening is reached which is in accordance with the conditions encountered.

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