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METHOD OF WELL COMPLETION

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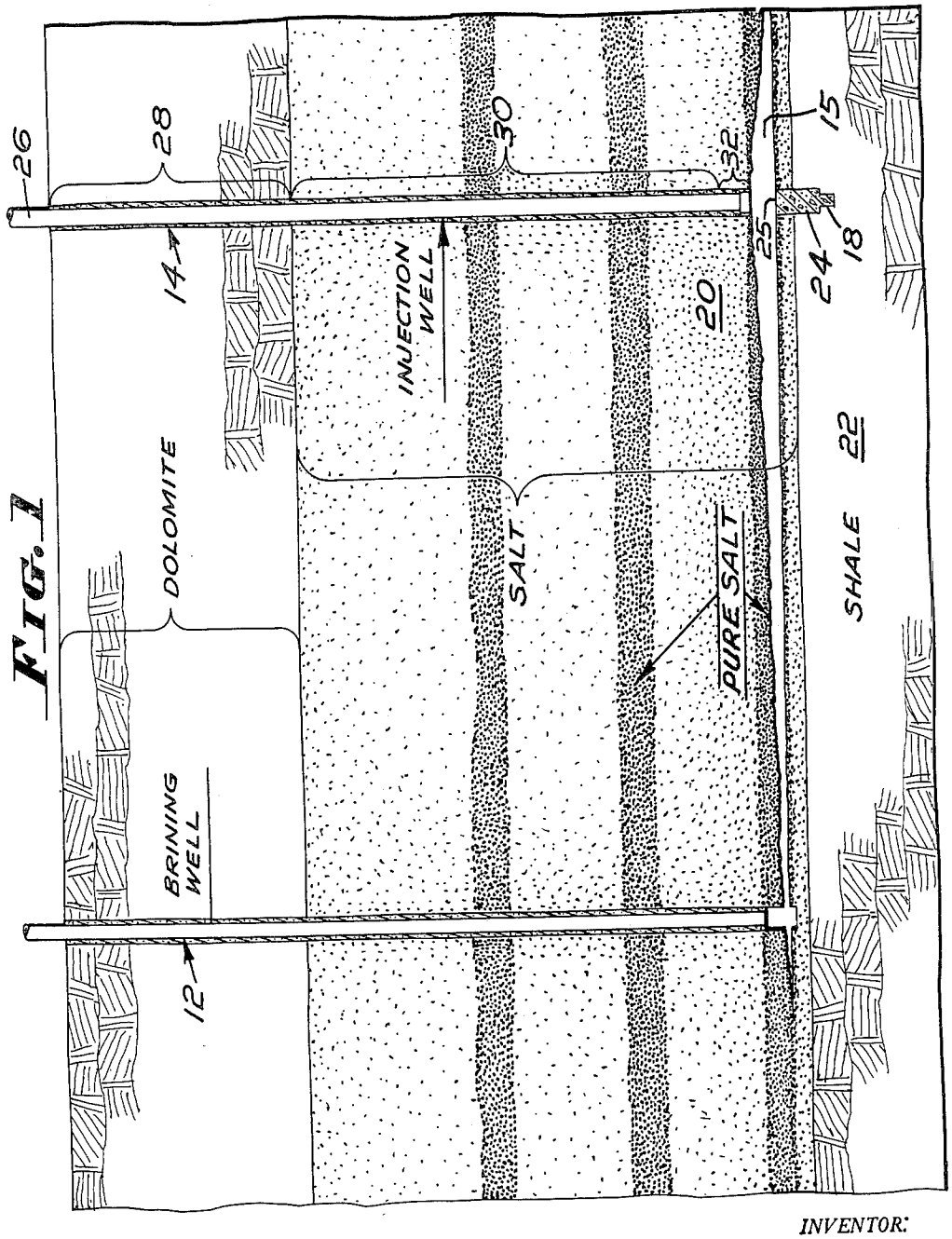


FIG. 1

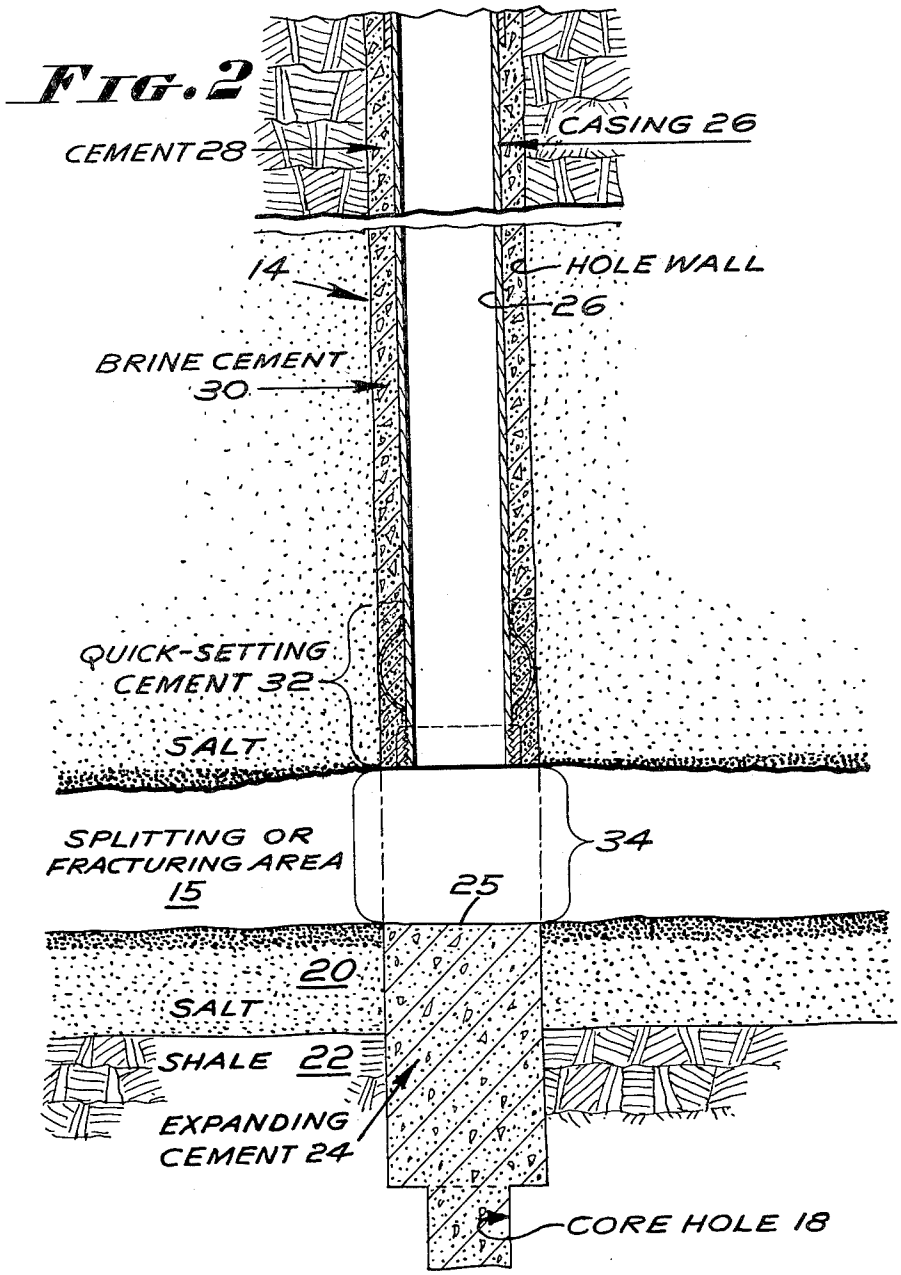
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FIG. 2



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METHOD OF WELL COMPLETION

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7 Claims. (Cl. 262—3)

This invention relates to the mining of liquid-soluble minerals from underground strata, and more particularly to the solution mining of salt. It is well known that soluble mineral deposits may be recovered by the drilling of wells into the mineral strata, fracturing the strata to open a passageway from one well to another and then circulating a mineral solvent through the opened underground system. Such a system of interconnected wells and cavities is referred to as a gallery. It is also well known in the art that the solution mining of salt has particular difficulties due primarily to the fact that when water is pumped into a well drilled into a salt formation the fresh water will tend to rise and the brine saturated water remains near the bottom of the cavity. As a result the formed cavity develops primarily upwardly and only secondarily laterally. This condition is further developed by reason of the insoluble impurities in the salt deposit falling out of the brine solution and forming a semi-porous insoluble blanket on the floor and to some degree, the walls of the cavity. It is of course obvious that in order to obtain any worthwhile amount of salt under these circumstances it is necessary to drill the well to the bottom of the salt strata and even then a great deal of the deposit will be wasted. Because of the aforesaid conditions it was a natural development to utilize the gallery system for solution mining of salt, and this is discussed in a number of letters patents, examples of which are Patents 1,960,932 to Tracy, 2,847,202 to Pullen and 2,850,270 to Hanson.

It is a primary object of the present invention to provide an improved method for "completing" a well driven into and through an underground strata of mineral to be recovered by the dissolution mining process.

A specific object of the present invention is to provide an improved method of sealing off a well that has been driven through a salt bed and into the strata therebelow so that the subsequent fracturing or splitting operation will be limited to within the salt bed while still being confined to the lower level thereof.

Another object is to provide an improved method for sealing the well in relation to the strata above and below the bed to be mined, by means of an improved concrete sheath and seal.

Still another object of the invention is to so locate and complete drilled wells which are to be interconnected so as to secure improved results in the mining operation by more efficient use of the liquid solvent circulated through the gallery system.

Other objects and advantages of the invention will appear in the specification hereinafter and in the drawings wherein:

FIG. 1 is a diagrammatic vertical sectional view taken through strata including a salt bed to be mined by circulation of water through an injection well and fractured strata to the production well;

FIG. 2 is a fragmentary sectional view, on enlarged scale, taken as indicated at II—II of FIG. 1, showing the lower portion of the completed well in more detail.

Referring now to FIG. 1, a target well **12**, and injection well **14** have been drilled into a salt strata and an underground connection has been effected as by splitting and uplifting the salt bed as indicated at **15**, thereby establishing a gallery for the purpose of solution mining through interconnected wells. In accordance with my

improved method, the injection well **14** is drilled and completed as follows:

I prefer to use a rotary drill for sinking the hole because I believe it allows a better bond between the wall rock and the cement sheath which is provided around the well casing, as will be described hereinbelow, by lessening the possible number of air and water entrapment voids created by a rough wall and eliminates a major portion of the detrital slough which is created by running casing in a rough-walled hole. Such slough rock will tend to follow the casing down the hole and will often form partial or total blockages in the annulus between the hole wall and casing. Usually a 12" to 15" diameter hole is desirable and the hole **14** will be started with the appropriate rotary bit. As it is desirable to have accurate knowledge of the location of the bottom of the salt strata and the composition of both the salt strata and the adjacent rock formation, when a point approximately 50 feet above the calculated "top of salt" is reached, we may use a 6½" core bit to core through all the major salt stratum and into enough of the underlying strata to determine its exact nature. Alternatively, it would be less accurate but also less expensive if the normal hole were continued and logged by some geophysical means such as gamma ray logging.

I have found that improved cavity and gallery formation is obtained by confining the well-interconnecting split to the salt strata. This is because the rock formations underlying salt deposits, although not necessarily soluble, are in general, much more permeable horizontally than the salt. An uplift in these planes would allow considerable and possibly total loss of injection fluid. Accordingly, when the above mentioned coring is finished, the hole is drilled on down approximately three feet into the rock underlying the salt and the hole is then plugged back, preferably with a suitable expanding cement **24**, to a point about two feet above bottom of salt, as indicated at **25**. This will effectively seal off the hole from the underlying rock. The casing **26** is then run into the hole and set to within about two feet of the top of the plug as shown in FIG. 2. The dimensions given are representative only. The specific measurements will depend upon the actual rock and salt conditions found at each particular well site. I select a zone within the lower portion of the salt strata which is as pure and as free of insolubles as possible. The lower tensile strength of the pure salt and the greater solubility thereof will aid in the splitting of the bed and subsequent wash-through operations. In any case the gap between the end of the casing and the plug in the hole bottom will be kept as small as practicable because this will be the point of application of the splitting fluid pressure. The point of application of the splitting and uplifting pressure is confined to as small a vertical portion of the hole as possible because this reduces the possibility of causing multiple horizontal fractures within the same salt bed. If two or more independent partings occur, the volume of fluid required to complete a fracture to the point of intersection with the target well will be greatly increased, and proper development of the cavity during mining may be impaired. Given a small wall area exposed to splitting pressure, salt deposits may be horizontally split and uplifted much more satisfactorily than most rock formations because of the low tensile strength of the salt and because its bed planes generally run evenly horizontal.

After the core hole **18** and main hole **14** have been plugged back and the casing set, the next step is to establish a cement sheath around the outside of the casing to fill the annular space between the casing and the hole wall. The cement sheath serves to reinforce the casing, insulate the casing against corrosive influences such as ground

waters which in many locations often contain considerable amounts of hydrogen sulphide and ammonia together with other corrosive salts, and to seal off the hole above the lower end of the casing against possible vertical fracturing when the splitting pressure is introduced, and against vertical escape of injection fluid alongside the casing during wash-through operations.

In order to obtain the best possible sealing effect it is desirable to have the cement sheath devoid of any cracks or fissures and to have the sheath bonded to the surrounding rock. I have found the following improved method of cementing the well to provide an excellent finished sheath. The cement is placed by pumping it into the casing and the cement reaching the bottom of the well will be forced upwardly around the outside of the casing. Since the material first pumped into the casing will be that which ultimately fills the space between the casing and the wall rock around the upper sector of the well as indicated at **28**, the first cement injected into the casing is preferably regular Portland cement mixed with fresh water. The fresh water cement is followed by a batch of brine-based cement which will provide an improved sheathing of the lower end of the casing in the salt strata as indicated at **30**, because water-based cements will not bond with "salts" whereas the brine based cement will bond with the beds of salt and anhydrite. Fine granulated salt is mixed with the brine based cement in proper amounts depending on rock temperatures, the temperature of the brine at the mixing point and the ground water conditions immediately above the salt sections, to maintain the brine in the saturated state. At the final stage of cementing, 2% by weight of calcium chloride is added to the cement which will sheath the lower-most end of the casing as indicated at **32**, so as to cause this portion of the cement to set-up and harden before the major portion of the cement above it. As soon as the calcium chloride containing portion of the cement sheath has set the cement in and under the end of the casing is drilled out down to the expanded cement plug **24** in the hole bottom and an expansion reamer is used to remove the rest of the concrete from around the hole wall, from the bottom point of the casing to the top of the plug, thus leaving the salt wall exposed over this area as indicated at **34**. This is the point to be subjected to splitting pressure.

Alternatively, before cementing, water, gravel or other material may be placed in the hole bottom to form a pad or spacer. This pad will keep the cement from filling the entire gap between the casing and the bottom plug and, when removed after cementing is completed, will leave the desired area of the salt wall exposed. Of course any known method may be used to expose desired areas of the salt deposit to the splitting media by perforating the cement sheath or the sheath and casing.

The use of the quick setting cement mixture at the lower portion of the well provides two important advantages. First, by permitting the cement at the bottom of the casing to be drilled out as described, while the rest of the cement sheath is still plastic or semi-liquid, the sheath is not subject to vibration cracks which often result when the sheath has hardened before the drilling-in takes place. This is prevented by the hardened lower portion of the cement backing up the still plastic sheath. Secondly, a considerable amount of waiting time, and the attendant rigging and personnel cost, is saved.

I claim:

1. The method of completing a well driven through overburden into a salt deposit overlying a non-salt deposit, said method comprising backplugging the well with expanding cement to the elevation of the bottom of the salt area to be subsequently split, running a casing into the well to the top of said area, pumping water-based cement into said casing in a quantity sufficient to fill the space between the casing and said overburden, then pumping into said casing a supply of brine-based cement sufficient to fill the space between the casing and the upper portion of the salt deposit above said area, then pumping into said casing a supply of calcium chloride containing cement sufficient to fill the remainder of the space between the casing and the salt deposit, and then after said calcium chloride containing cement is set and before the balance of said cement is set reaming out the cement at the splitting area to expose the salt strata thereat.

2. The method of completing a well driven through overburden into a salt deposit and an underlying non-salt deposit, said method comprising backplugging the well with expanding cement to the elevation of the bottom of the salt section to be fractured, running a casing into the well to the top of said section, pumping unset cement into said casing in a quantity sufficient to fill the space between the casing and said overburden, then pumping into said casing a supply of brine-based cement sufficient to fill the space between the casing and the upper portion of the salt deposit above said section, then pumping into said casing a supply of calcium chloride containing brine-based cement sufficient to fill the remainder of the space between the casing and the salt deposit, and then reaming out the cement at the area to be split to expose the salt strata thereat.

3. In a method of completing a well driven through overburden into a salt deposit for solution mining thereof, the steps of backplugging the well with expanding cement to the elevation of the bottom of a salt area to be fractured, running a casing into the well to the top of said area, pumping unset cement into said casing in a quantity sufficient to fill the space between the casing and said overburden and the upper portion of said salt deposit, then pumping into said casing a supply of cement containing calcium chloride sufficient to fill the remainder of the space between the casing and the salt deposit, and then after said calcium chloride containing cement is set and before the balance of said cement is set reaming out the cement at the area to be fractured to expose the salt strata thereat.

4. The method of mining a subterranean soluble salt deposit lying above a non-salt strata, which method includes driving a well through said soluble salt deposit and into the strata therebelow, plugging back the well to a point above the elevation of said non-salt strata and within a relatively pure salt layer, inserting a casing into said well which is of smaller diameter than the well and to a point just above the plug at the well bottom, forcibly introducing a quantity of cement through said casing sufficient to fill the annular space around the casing upwardly from said plug, in which the cement last introduced is quicker setting than the previously introduced cement, cutting away the quick setting cement immediately above said plug to expose a small vertical portion of the salt deposit when the quick setting cement has hardened and while the cement thereabove is still in plastic condition, and then applying a splitting and uplifting pressure within said casing after all of the cement has hardened, preparatory to introduction of a salt solvent fluid into the split area.

5. The method of mining a subterranean soluble salt deposit, which method includes

(*a*) driving a well through said soluble salt deposit and into the strata therebelow,

(*b*) sealing the bottom of the well by plugging back the well to a level within the region of the soluble salt deposit,

(*c*) inserting a casing into said well which is of smaller diameter than the well and to a point just above the plug in the well bottom,

(*d*) sealing between the casing and well by forcibly introducing cement through said casing to seal between the casing and the well upwardly from said plug,

(*e*) cutting away the cement to expose a small vertical portion of said soluble salt deposit in an

area thereof between said plug and the bottom of the casing after the plug and at least a lowermost portion of the cement around the casing has hardened and without disturbing the stated seals at areas either above or below the exposed portion,

(*f*) then applying a splitting and uplifting pressure to said salt deposit at said exposed portion thereof so that such force is confined solely at the exposed region, preparatory to introduction of a salt solvent fluid into the split area.

6. The method according to claim 5 wherein the introduction of cement is controlled so that

(*a*) the cement last introduced is quicker setting than the previously introduced cement so that the quick setting cement is disposed within the region of and extends upwardly from the plug,

(*b*) said salt deposit being exposed after the quick setting cement has hardened but while the cement thereabove is still in plastic condition,

(*c*) the splitting and uplifting force being applied after all the cement has hardened.

7. The method of solution mining salt which includes the steps of

(*a*) driving a well through a soluble salt deposit and into underlying strata,

(*b*) sealing the well by introducing cement into said well to form (*a*) a solid plug upwardly from the well bottom to a point within said soluble salt deposit and (*b*) a casing-embracing shell above said plug and extending upwardly through at least a substantial extent of the salt deposit,

(*c*) cutting away the cement to expose a small vertical area of the salt deposit just above the plug after the plug and at least a lowermost portion of said shell has hardened and without disturbing the seal in areas either above or below the exposed portion, whereby the plug and shell are discontinuous only at said exposed portion,

(*d*) and thereafter applying a splitting and uplifting force within the well so as to be confined in its application solely to the exposed portion of the salt deposit to the exclusion of regions above and below said portions.

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