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COMMUNICATION BETWEEN WELLS

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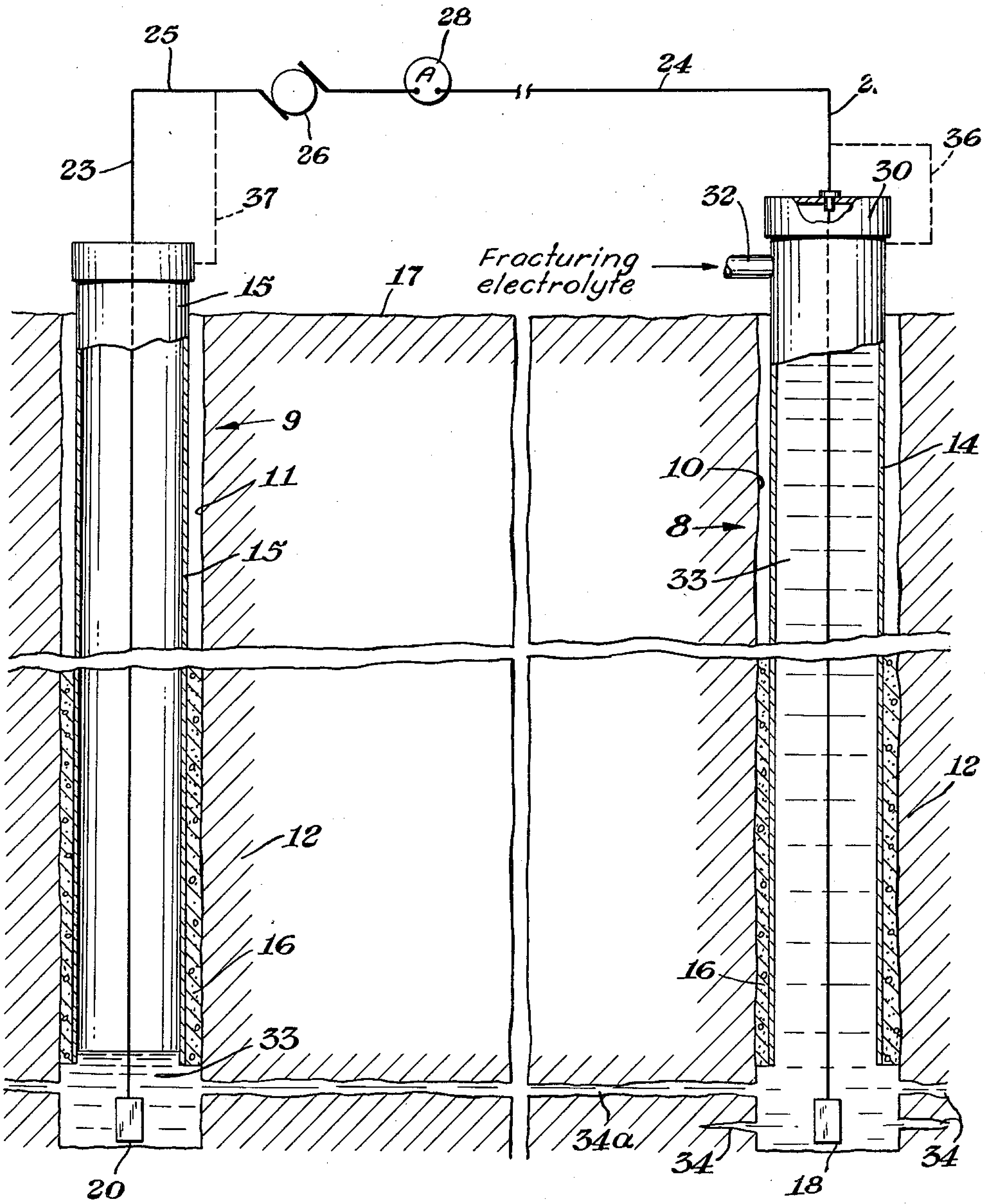

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COMMUNICATION BETWEEN WELLS
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The invention pertains to treatment of subterranean formations penetrated by a plurality of wells. It pertains more particularly to detecting the existence of communication between wells and to the time and extent communication is established through the formation between such wells and a method of improving such communication.

In the production of fluids or solubilizable minerals from a subterranean formation yielding such fluids or minerals, two or more wells are frequently employed in a unit operation, one well serving as an input well into which is forced a driving or solubilizing fluid and another well as an output well from which the fluid of the formation or the solubilizable mineral therein is recovered.

Communication is commonly established by a fissure or fracture which intercepts at least two wells. The fissure or fracture may exist naturally or be artificially created by rupturing or breaking apart the rock of the formation by explosive pressures or by hydraulic action within the formation, e.g., as described in U.S. Reissue Patent 23,733.

The existence of a fissure intercepting two or more well-bores in a single formation may not be known. Fissures in the formation may be exceedingly small or an intercepting fissure may be so small in contrast to other such fissures that it permits substantially no passage therethrough. When fracturing to create an intercepting fracture, the time at which there is establishment of such fracture is not readily ascertainable by presently known methods. The enlargement of intercepting fractures, although highly desirable, is not now satisfactorily achieved by known methods.

In the production of petroleum by the employment of input wells into which liquids are forcibly injected to drive the fluid of the formation toward and out of one or more output wells, the communicating channels between the input and the output wells are often inadequate for good production even after fracturing because the fractures produced are in no way guided by the location of wells other than the one through which the fracturing operation is performed. Knowledge of the existence of communicating channels and their subsequent enlargement is highly desirable.

Similarly, in the mining of salt from salt beds by the employment of water to dissolve the salt and to remove it as a brine from the beds, the use of a plurality of wells offers a number of advantages over the use of a single well. However, experience in the use of a plurality of wells in such a manner has shown that the salt tends to dissolve to a large extent only in the vicinity of the input well to create cavities. The channels leading to the output well remain distressingly narrow and inadequate even after long periods of production. Among the reasons for this situation is the fact that the water dissolves salt to the point of saturation shortly after contacting the bed and thereafter is incapable of dissolving more. Therefore, it passes on through the relatively narrow connecting channel to the output well without appreciably enlarging the channel.

Thus, there are shown to exist desiderata in the art of producing a fluid or a solubilizable mineral from a subterranean formation traversed by a plurality of wells, for a more effective method of indicating when there is

establishment of communication between at least two of the wells and of enlarging the communication therebetween after it is established.

These desiderata are met by the effective and relatively simple method of the invention hereinafter described and defined.

The invention is based upon ascertaining the time at which a change occurs in the electrical resistivity of an earth formation traversed by wells due to the entrance into a communication passageway between the wells of an electrolyte and the continued passage of electric current through the passageway to enlarge its cross-section.

The invention is a method of treating a subterranean formation which consists essentially of establishing electric current flow through a formation between wells, along a fissure or fracture therebetween through which an electrolyte is passed, by connecting the wells in series through a current indicator, e.g., a galvanometer or an ammeter and a suitable source of electricity.

In wells which are cased with metal, the casings conveniently serve as electrodes and electrical conductors leading from the source of electricity through the electric current indicator and connected to the tops of the casings. In the absence of metal casing extending to the depths desired, or if otherwise preferred, oppositely charged electrodes may be provided especially by placing a piece or plate of a conducting material at or near the bottom of the wells between which the electric flow is to be established and connecting the conducting pieces through wires leading upwardly to the source of electricity and the current indicator.

The electrolyte may be any conductive fluid medium, such as an aqueous solution of an ionizable substance, e.g., a salt, mineral acid, or soluble metal hydroxide. Natural brines and potable waters containing a substantial amount of dissolved mineral matter are satisfactory as the electrolyte.

A preferred embodiment of the invention is to connect two wells penetrating a formation in series through an ammeter to a source of electricity and then fracture the formation employing an electrolyte as the fracturing liquid while observing the resulting change in magnitude of the current produced. When thus employed the electrolyte is injected down at least one of the wells until fracturing pressures are attained in the formation and at least one fracture so produced extends to and establishes communication with at least one other well. Such communication may result either from the extension of a fracture from one well extending to and intercepting a second wellbore, or when more than one well is fractured, it may result from the juncture of fractures emanating from more than one well. Communication established in either way is referred to herein, generally, as an intercepting fracture. When such an intercepting fracture is produced, electrolyte enters it, in preference to most other fractures due to the lessened back pressure in the fracture open to the other well and an additional electrical current flow registers on the ammeter at the time electrical contact is made between the wells through the electrolyte. The electrolyte should be reactive with the formation, e.g., hydrochloric acid in a limestone formation or water in a salt formation, to act as a solvent on the faces of the formation exposed along the fracture.

The intercepting fracture becomes filled with electrolyte which, being of higher electrical conductivity than the formation generally, offers sharply decreased resistance to the flow of electric current therethrough. The flow of current is thereby increased through the electrolyte in the intercepting fracture which registers on the ammeter. By thereafter continuing to pass current along the electrolyte loaded communicating fissure or fracture through which the electrical current has been set up, heat is generated which tends to cause crumbling or sloughing of the walls of the fracture, sometimes called rubblizing. The heat is caused both by the resistance offered to the passage of current through the electrolyte in the fracture and to the accelerated chemical action of the electrolyte on the formation due to the rise in temperature.

Instead of employing the electrolyte as the fracturing liquid, if desired any fracturing liquid including those having low electrical conductivity, e.g., oil or emulsions, may be employed as the fracturing fluid and thereafter the electrodes positioned in the well-bores and an electrolyte pumped into the formation as above described.

The invention affords not only a convenient method of ascertaining that communication has been established and for enlarging communicating passageways thereafter, but is inherently selective in its application within the formation because communication will be developed along more direct fractures existing between the wells. Communication having once been established between the wells, the more constricted portions of the more open passageways provided by said more direct fractures thus created will offer more resistance than the less constricted portions thereof thereby heating the more constricted portions of the so more enlarged direct fractures to a higher temperature and thus enlarging them in those places most needed.

A formation to be treated according to the invention, therefore, must be traversed by at least two wells in communication with each other through the formation. The communication, as stated, may exist naturally or be especially created. It is immaterial whether but one well only exists before fracturing and at least one other well be then drilled which traverses a fracture or whether all the wells to be treated be first drilled and the formation then fractured to produce fractures which intercept at least one well other than the one from which the fracture originates.

It is also within the purview of the invention as already indicated to employ wells in excess of two, connecting some of the wells with the electrodes leading to one terminal and connecting one or more other wells to the other terminal of an electrical source and then proceeding in accordance with the practice of the invention. Communication between any two wells having oppositely charged electrodes therein will be readily detectable by change in current flow as registered on the current indicator. Either A.C. or D.C. may be employed, although A.C. is usually employed when available.

The drawing schematically shows an elevation in section of two wells penetrating a formation to be treated in accordance with the invention. In more detail there are shown wells **8** and **9** extending into formation **12** to be treated. Well bores **10** and **11** of wells **8** and **9**, respectively, are cased with casings **14** and **15**, respectively, being held in place by cement **16** some distance above the bottoms of the well bores. Ground level is designated by numeral **17**. Electrode plates **18** and **20** are shown positioned near the bottom of well bores **10** and **11**, respectively, and are connected by conducting wires **22** and **23**, respectively, to surface wires **24** and **25**, respectively, making electrical connection with opposite poles of generator **26**, ammeter **28** being connected in series to wire **24**. Well **8**, which represents the input well for electrolyte **33**, has cap **30** thereon, and is provided with inlet pipe **32** for electrolyte or fracturing fluid. Fractures **34** and **34*a*** are shown extending from the uncased portion of well bore **10** into formation **12**, fracture **34*a*** extending to and intercepting well bore **11**. Electrolyte **33** is shown filling well bore **10**, fracture **34*a***, the lower portion of well bore **11**, and to a limited extent, the other fractures **34**.

Instead of wires **22** and **23**, coupled to electrodes **18** and **20**, respectively, alternate wires **36** and **37**, shown by dotted lines, may be employed which make direct contact between generator **26** and casings **14** and **15**, respectively, the casings thereby serving as the electrodes and eliminating the need for electrode plates **18** and **20**. If desired, one electrode plate and one casing may be employed as the electrodes, e.g., casing **14** and plate **20**.

To illustrate one mode of practicing the invention: water-soluble salt is to be produced from a natural salt bed extending several miles substantially horizontally at a depth of between 7500 and 8500 feet below the ground surface. Two holes are drilled into the bed at a distance of say about 300 to 400 feet apart. The wells may be then cased to a distance short of the bottom of the hole and the casings connected above ground to a source of electricity through an ammeter, or, if the wells are not cased, special electrodes are placed near the bottom of each hole as illustrated in the drawing to provide a potential through the formation. The potential is of sufficient magnitude to register a flow of current through the formation between the wells. Voltage to provide such potential can be anywhere up to 10,000 volts but is usually not over 2,000 volts and often not over 100–200 volts. The current may be any value sufficiently large to be measurable, e.g., as low as a fraction of a milliampere. Having established a current flow, usually of very small amperage, water is pumped into one of the holes until the pressure produced thereby causes fractures in the formation, at least one fracture intercepting the second hole. The injected water dissolves salt from the formation forming an electrically conductive brine which passes into the second well through the fracture thus formed, thereby providing a current path of definitely less resistance than stray current paths through the formation. The brine in the intercepting fracture passes into the second well thereby contacting the second electrode and allowing more current to flow between the two wells as shown by an increased ammeter reading. The increased current flows thus observed indicates not only that communication is established between the wells through the intervening formation, but also when this has occurred.

If desired, a series of well bores or holes in a more or less linear arrangement may be drilled progressively across the land below which lies a continuous salt bed. The spacing of the well bores depends largely upon the character of the formation, but usually they should not be over 500 to 600 feet apart. By placing electrodes in the well bores, fracturing the bed, and forcing a solvent for the salt into said fracture to produce an electrolyte therein (thereby to complete electric circuits through the fracture between the well bores), and thereafter continuing to pass electric current through said fracture to enlarge it, a continuous tunnel for transporting brine is produced by the dissolution of salt in the bed due to the rise in the temperature of the water as a result of electrical heating. The tunnel thereby becomes a conduit extending for a distance of many miles below the surface.

In formations in which the presence of such electrolytes as mineral acids and aqueous metal hydroxides, e.g., NaOH, are not contaminating to the mineral being produced as, e.g., from oil-bearing formations, such electrolytes may be advantageously employed. In limestone or dolomitic formations, for example, hydrochloric acid would be used. In shale formations e.g., sulfuric acid or fuming sulfuric acid would be used. Similar results would be obtained in other formations employing a suitable electrolyte.

Employing a dilute mineral acid, e.g., hydrochloric acid, or a dilute aqueous solution of a metal hydroxide, e.g., NaOH in the practice of the invention (if the presence thereof in the strata is unobjectionable), like results to those obtained with the brine will be obtained.

To illustrate another mode of practicing the invention, a petroleum producing formation, having at least two wells traversing it, is fractured according to known practice, e.g., that described in U.S. Reissue Patent 23,733. The casings of the wells or electrodes placed near the bottom of the well bores are electrically connected as described above. An electrolyte is then pumped down one of the well bores and forced through a fracture extending to the second well bore to establish electrical contact between the two well bores as indicated by an increase in electrical conductivity in the intervening formation as ascertained in the aforesaid manner. The electrolyte having a solvent action on the formation is thereafter continued to be pumped down the well and along said fracture to effect an enlargement of the fracture produced. Thereafter, a water or gas drive for the production of petroleum from the fractured formation may be employed effectively as a result of the communication thus established between the two well bores.

A number of advantages are to be realized from the practice of the invention. Among such advantages are (1) the creation of continuous underground passageways through salt beds or beds of other soluble minerals, which, if desired, can be made to extend from the edge of a salt bed to the farther edge thereof. For example, in the Salina salt bed, which extends beneath several states, water may be injected at intervals, in association with the other steps of the invention, to provide an underground route leading to an output well located in the vicinity of evaporating and refining means. This is a great improvement over pumping the brine to the surface and thence overland long distances to the evaporating and refining means. (2) By the establishment of an electrolytic path in the earth formation between well bores, the electroylte is thereby urged to take the most direct path therebetween in the formation that is possible. In contrast to the common experience of pumping large quantities, often millions of gallons, of solvent into the water-soluble mineral bed and thereby creating only a very small passageway leading to a well having communication therewith, the present invention will enlarge the connecting passageways between the two well bores by the most direct route, and eliminate constrictions in the passageways.

Having described the invention, what is claimed and desired to be protected by Letters Patent is:

1. The method of treating a subterranean formation traversed by two wells consisting of fracturing said formation to produce a fracture which extends from one well to another, positioning an electrode of opposite charge in the formation adjacent to the wellbores in each of said wells traversed thereby, connecting said electrodes to a conductor leading to a source of electricity passing through an electrical current indicator to establish sufficient potential in said formation to register a flow of current on said indicator, injecting an electrolyte down one of said wells under sufficient pressure to cause some of said electrolyte to pass along the fracture connecting the two wells thereby increasing the flow of electricity between the electrodes as indicated on the ammeter, and continuing to pass said electrolyte along said connecting fracture to produce heat to enlarge said fracture.

2. The method of treating a subterranean formation traversed by a plurality of wells having metal casings extending into said formation to a point short of the depth of said wells consisting of connecting the metal casing of at least one of said wells to a terminal of an electric conductor connected to a source of electricity through an ammeter and the metal casing of at least one of the remaining wells to the oppositely charged terminal of the electric conductor, reading the current flow on the ammeter, injecting down at least one of said

wells a liquid electrolyte at pressures sufficient to produce fractures in said formation at least one of said fractures communicating with at least one of the other wells having casing connected to an oppositely charged terminal, forcing electrolyte into the intercepting fracture thus produced to make improved electrical contact therebetween through the formation and increased current flow along said fracture, and reading the increased flow on said ammeter.

3. The method of claim 2 wherein the electrolyte is chemically reactive with the formation, electrical contact established between the wells is continued, and the electrolyte is circulated through the formation along a communicating fracture to enlarge said fracture.

4. The method of making an underground conduit in a stratum of a solubilizable mineral for dissolving and transporting said mineral when in a solubilized state consisting of drilling wells into said stratum not over about 500 to 600 feet apart, progressively along a substantially linear line, placing oppositely charged electrodes leading from a source of electricity through a current indicator into adjacent wells thus drilled and impressing a potential across the formation between the wells, injecting solvent down the wells, having electrodes so placed therein, at fracturing pressures to create a fracture between the adjacent wells, continuing to maintain a potential to insure the flow of electric current, the location and magnitude thereof being ascertained by reference to each of the current indicators across said formation and continuing to pass solvent through the fracture thus created to dissolve mineral along the faces of the fractures thus created and to advance the mineral thus dissolved along connecting fractures in the stratum.

5. The method of treating a formation containing a stratum of water-soluble mineral to produce said mineral consisting of drilling a plurality of holes extending into said mineral stratum, placing negatively charged electrodes in some of the holes and positively charged electrodes in certain other of the holes thus drilled, the electrodes being connected through an outside circuit and in series with an ammeter, pumping down at least one of said holes a solvent for said mineral at sufficient pressure to fracture said mineral stratum, at least one fracture making communication with at least one other hole having an electrode therein of opposite charge, continuing to pump solvent into said formation to dissolve mineral thereby producing an electrolyte, forcing the electrolyte thus produced into contact with the electrode in said other hole to increase the flow of electric current along the fracture, and thereafter continuing to pass current through said electrolyte and out the other hole in communication therewith, said solvent carrying dissolved mineral from the mineral bed.

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