

Sept. 28, 1965

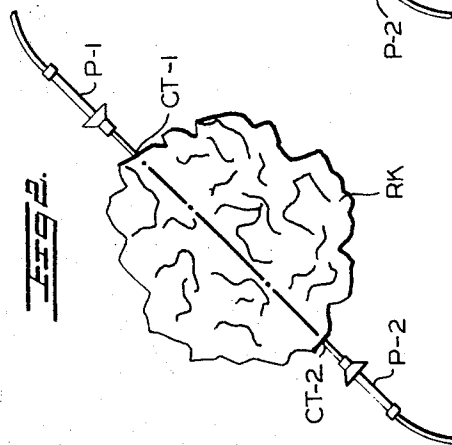
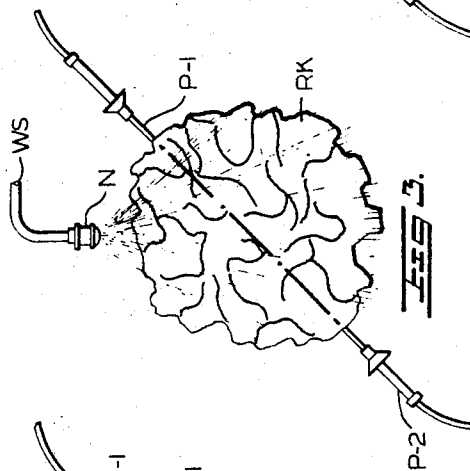
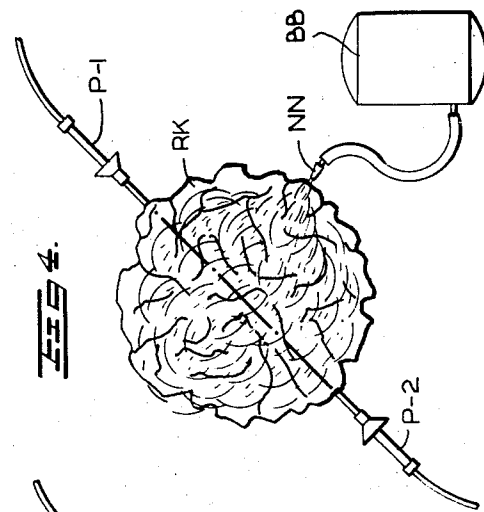
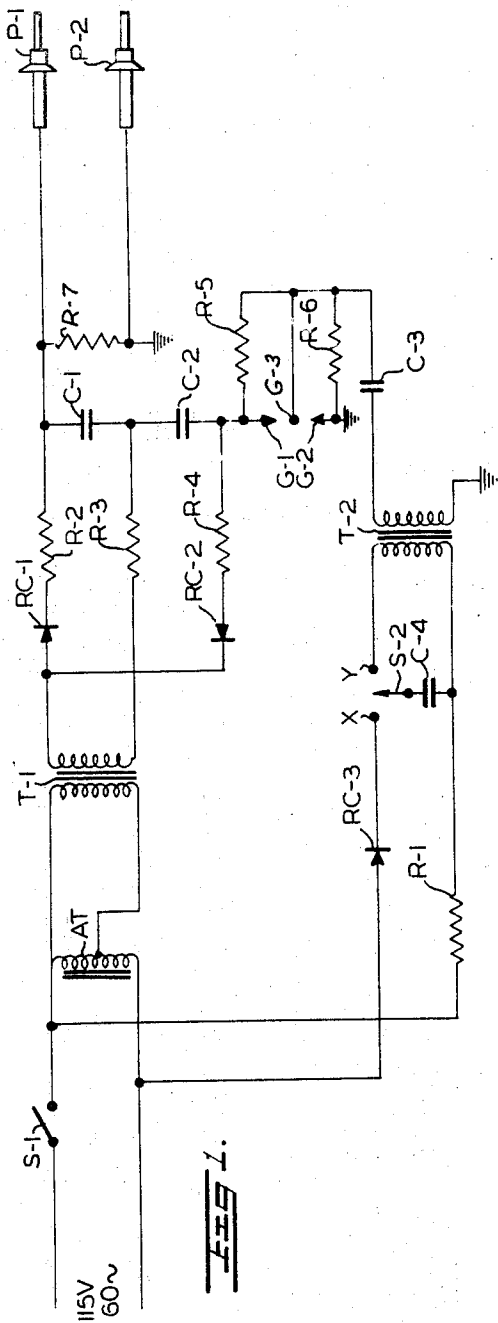
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ELECTROTHERMAL FRAGMENTATION

Filed Oct. 19, 1961

3 Sheets-Sheet 1



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ELECTROTHERMAL FRAGMENTATION

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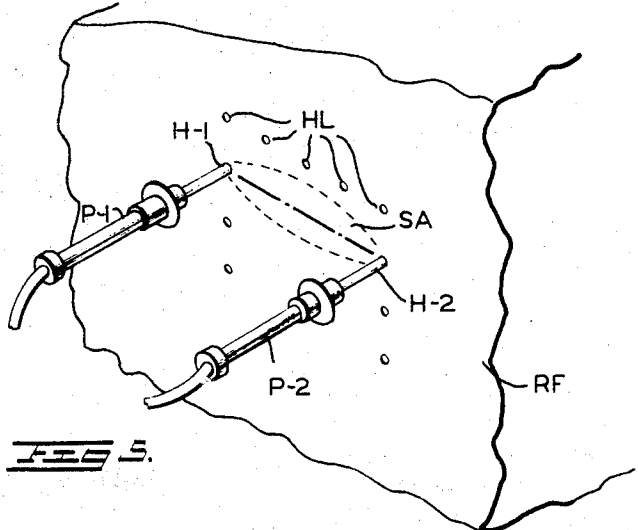


FIG. 5.

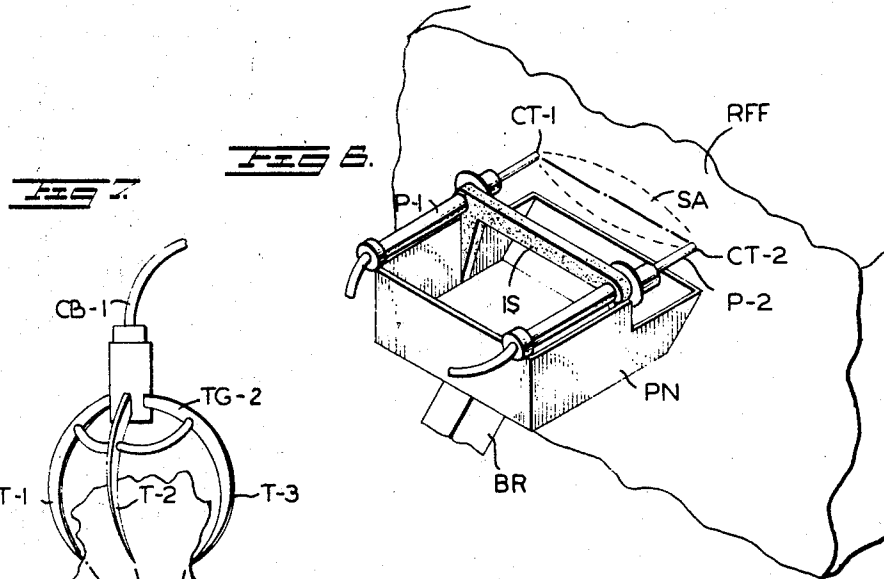


FIG. 6.

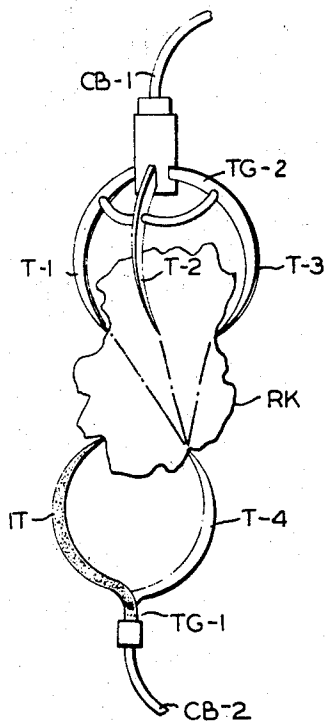


FIG. 7.

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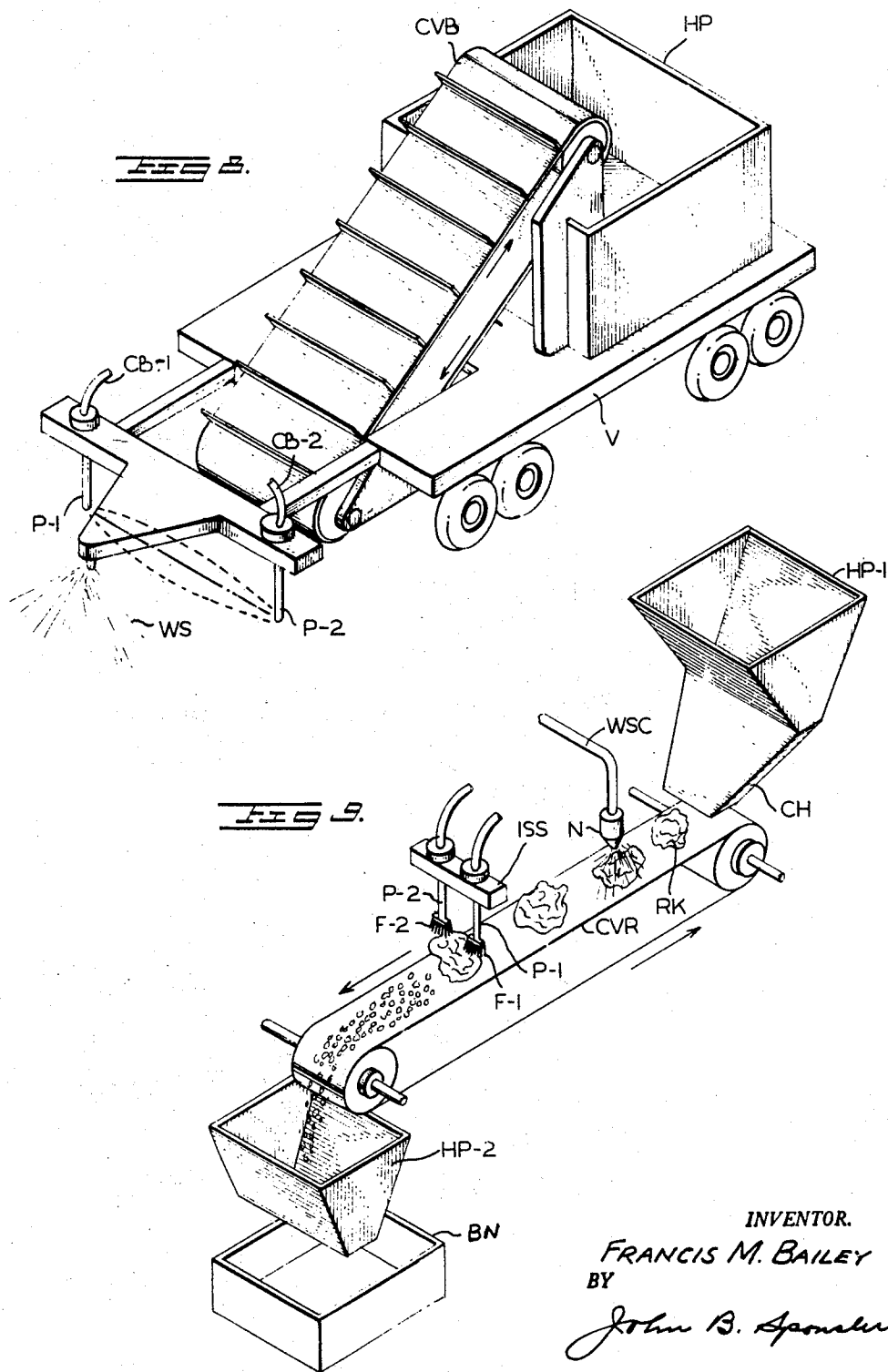
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ELECTROTHERMAL FRAGMENTATION

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3,208,674

ELECTROTHERMAL FRAGMENTATION

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5 Claims. (Cl. 241-1)

This invention relates to the fragmentation of rocks and rock formations by means of electrical energy. More specifically the invention relates to the breaking of rocks by means of a thermal condition set up within the rock as a result of an electrical current flowing through a current conducting channel either occurring naturally, or being formed in the rock body artificially.

In mining operations where explosives are used for blasting rock formations in order to break up such formations to obtain pieces of ore and other valuable rock deposits frequently large fragments occur that are too large and heavy to handle for loading and removal from the mining area. It has been necessary in instances of this kind to make use of so-called secondary blasting, which requires explosives to be used more than once, necessitating additional safety measures and entailing time consuming operations as well as additional cost. The present invention is concerned with a method and apparatus whereby large fragments of rock produced as a result of primary blasting in a mining operation may be further reduced in size by electrical energy.

The shattering effect of a stroke of natural lightning is well known, and artificial lightning bolts have produced similar destructive forces which appear to be usable in the fragmentation of solids such as rocks, ore deposits and the like. It has been observed, for example, that when high voltage is supplied through point electrodes placed on the surface of a body of rock a current conducting path through the body will occur. It is believed that a thermal break through is produced as a result of current which flows between the electrodes into the body of rock, the current produced causing the path through the rock to heat up and thereby set up internal pressures as a result of temperature differentials along cleavage planes or in areas along the path of the current where the water of crystallization is changed to steam as a result of the heat produced by the electric current. It has been found that rock bodies containing ore that is semiconductive are readily fractured also by the application of electrical energy somewhat in the manner as has been described. However, the fragmentation of rocks of other types and formations is also feasible making use of electrical energy.

It has been found that the frequency and magnitude of the electrical force applied to a rock body largely determine the extent of break through, and it appears that within limits the higher the temperature of the rock body the more readily a current conducting path or channel is formed.

Normally it has been shown that current conducting channels are formed in rock formations by subjecting a body of rock to high voltage at high frequencies (250 kilocycles to 100 megacycles) through two or more probes attached to the surface of the body at spaced-apart locations. The high frequency energy tends to raise the temperature of the rock body thereby causing a breakdown of the dielectric and a consequent reduction in electrical resistance to form conductive channels or

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paths through the rock body. The high frequency energy may be maintained for a period of time until an electrical break through of the channel occurs, or a low frequency source of potential (including direct current) may be superimposed on the channel, or a high voltage pulse may be discharged through the channel that is already formed by the high frequency source. Each of these three methods has been successful in producing an electrical break through of sufficient electrothermal effect to shatter rock bodies substantially.

High frequency apparatus of necessity must be connected to the aforesaid probes by means of costly, coaxial cables, and a control must be provided to adjust the apparatus as the load changes when the current carrying path ruptures in order to safeguard the high frequency generator. Furthermore, the high frequency output (a range from 250 kilocycles to approximately 100 megacycles has been proposed) thereby requiring not only costly and complicated generating apparatus, but also equally costly and complex means for impedance matching and attachment to the load. With high frequency generators of the type referred to above there is also a problem of radio frequency interference in respect to commercial and government radio communications as well as the possibility that explosive detonators in the vicinity of the mining operation may be accidentally exploded.

The present invention is directed to apparatus for fragmentation of rocks and rock formations that does not require high frequency generators, that requires no circuits or arrangements for superimposing one frequency upon another and that presents few, if any, impedance matching problems. While some of the devices pertaining to the invention are unique in their application to electrothermal fragmentation of rocks and the like, the unique method taught in the invention is capable of being performed by conventional electrical apparatus.

It is therefore an object of this invention to provide a simple and effective method for physically disrupting rock formations solely by means of electrical energy.

Another object of the invention is to provide unique devices for the application of electrical energy to the fragmentation of rocks and rock formations.

By experiment it has been shown, as indicated above, that various conditions of rock bodies, e.g., temperature, striation, composition, et cetera, directly relate to the effectiveness of utilizing electrical energy for the fragmentation or physical disruption of rock bodies and the like. Similarly, as also related above, characteristics of the electrical energy applied to rock bodies for purposes of fragmentation, such as frequency, voltage, superimposition of frequencies, et cetera, are equally determinative in the effectiveness of utilizing electrical energy for this purpose. Additionally, however, it has been found that certain factors, heretofore, undisclosed, are even more effective in the fragmentation of rock bodies through the utilization of electrical energy.

It appears that the clue to effective utilization of electrical energy for fragmenting rock bodies lies within the interstices of the rock formations. The inclusion in these formations of conductive particles, entrapped globules of the water of crystallization, voids between rock particles or layers and the like has been found to offer a means for improving upon previous attempts in fragmentation or disruption of such formations by electrical energy to an extent not heretofore understood. For ex-

ample, rock formations that have been processed by spraying, immersing, or otherwise treated with water have been found to break into fragments under electrothermal stress from the application of electrical energy far more effectively than those which have not. The use of steam in a similar manner is equally effective. Furthermore, it has been found that when rock formations are so processed, high frequency electrical energy is not normally required, and that very effective fragmentation can be obtained merely by discharging direct current sources, e.g. charged capacitors, through the rock formation. Low frequency alternating current can also be used with comparable effectiveness.

It is believed that rock formations receiving aqueous treatment, as indicated above, more readily form current conducting channels or paths or that the dielectric properties of the rock formation are changed in a manner to more easily produce fractures under the stress of high voltage electrical energy. In other words the present invention provides a means for forming current conducting paths in a rock body without resorting to the heating effect of the high frequency energy for breaking down the dielectric of the rock formation.

It is, therefore, a further object of this invention to provide a method for the fragmentation of rock bodies by electrical energy including pre-treatment by water or steam.

Since many rock formations contain water-soluble salts and the like which reduce the resistance of current carrying channels when treated with water or steam, as described above, it follows that for those formations not so provided, a conductive aqueous solution, such as salt water, may be utilized with equal effectiveness in the manner previously described.

It is therefore a still further object of this invention to provide a method for the fragmentation of rock bodies by electrical energy including pre-treatment by a conductive, aqueous solution.

Another object of this invention is to provide a method for fragmenting rock bodies by electrical energy including pre-treatment of the body by an electrolyte.

Still another of the objects of this invention is the provision of a method for the fragmentation of rock bodies by electrical energy including pre-treatment by a conductive liquid.

A further object of this invention is to provide a method for the fragmentation of rock bodies by electrical energy including the formation of a conductive liquid for the pre-treatment of the rock bodies.

The novel features of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by referring to the following description and the accompanying drawings.

In these drawings:

FIGURE 1 is a circuit diagram of a high voltage source of electrical energy suitable for fragmenting rock bodies according to the present invention.

FIGURE 2 illustrates the application of electrical energy to a rock body, the electrical energy being derived from a source as indicated in FIGURE 1.

FIGURE 3 illustrates the basic principle of the present invention in connection with pre-treating a rock body with a conductive liquid.

FIGURE 4 illustrates diagrammatically the use of steam in the pre-treatment of a rock body according to the present invention.

FIGURE 5 is a diagrammatic view of the application of the teaching of the present invention to a rock face, as in quarrying operations.

FIGURE 6 is a further modification of the device shown in FIGURE 5.

FIGURE 7 illustrates the manner in which contact may be made with irregular rock bodies for the applica-

tion of electrical energy according to the present invention.

FIGURE 8 is an illustration as to the manner in which the teaching of the invention may be applied to fragmentation of rock formations in stripping operations.

FIGURE 9 illustrates an application of the teaching of the present invention to crushing rocks into very small sizes.

Referring now to FIGURE 1 a transformer T-1 is energized through a switch S-1 from a source of 115 volt, 60 cycle alternating current via an autotransformer AT, the output of the transformer T-1 being of the order of 30 kilovolts. In order to obtain still higher voltage the secondary or output of transformer T-1 is fed through the rectifiers RC-1 and RC-2 and the current limiting resistors R-2, R-3 and R-4 to a pair of capacitors C-1 and C-2, which are alternately charged on successive halves of the cycle in parallel, so that their potentials are additive as a result of the series connection illustrated in the circuit of FIGURE 1. Consequently when these capacitors are fully charged, a potential is obtained across them approximately equal to 60 kilovolts, this potential appearing across the resistors R-7, R-6 and R-5 in series and the values of the resistors being chosen so that only a very small percentage of this potential appears across the resistor R-7. The high potential across resistors R-5 and R-6 is also applied across the gaps formed by G-1 and G-3 and by G-2 and G-3; however, these gaps normally are set so that no flashover occurs at the applied potential.

The 115 volt, 60 cycle alternating current source is also connected through switch S-1 and a rectifier RC-3 to charge a capacitor C-4 via a limiting resistor R-1 under control of a switch S-2 so that when the switch S-2 is thrown to contact X the capacitor is charged and when the switch S-2 is thrown to contact Y the capacitor is discharged through the primary of a step-up transformer T-2. When capacitor C-4 is discharged in this manner the secondary of the transformer T-2 supplies a high voltage pulse through the capacitor C-3 of sufficient magnitude to break down the gap formed by G-2 and G-3, and as a result the high potential of the capacitors C-1 and C-2 in series overcomes the gap formed by G-1 and G-3 so that the total potential of the capacitors is applied across the resistor R-7 and to the probes P-1 and P-2. In the manner described high voltage direct current pulses are supplied to the probes P-1 and P-2.

Using the electrical pulse generator described above, a rock body RK as shown in FIGURE 2 may be fragmented by applying the probes P-1 and P-2, respectively, to contact positions CT-1 and CT-2 on the surface of the rock body. Ordinarily a single high voltage pulse may not be sufficient to fragment the rock body; however, repeated pulses may be delivered until an electrical current carrying channel is developed along the "dot-dash" line indicated in FIGURE 2 between the contact positions CT-1 and CT-2. This current carrying channel normally occurs through the rock body although there may be occasional "flash-overs" on the rock surface.

As previously discussed, the formation of a current carrying channel through the rock body is necessary in order to generate sufficient heat within the rock body to bring about disruption of the rock's structure. In ore bearing rock formations conductive paths may already be formed or partially formed due to the semi-conductive properties of the ore deposits; however, in most rock formations it has been found that the rate of forming a current carrying channel is greatly enhanced, if not altogether made possible, by the introduction of conductive liquids into the interior of the rock thereby lowering the resistance of one or more paths along the interstices of the rock formation. The conductive liquids may be tap water, salt water, a copper sulphate solution or any type of electrolyte, aqueous or otherwise.

The conductive liquid may be sprayed or poured upon

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the rock body as in FIGURE 3 wherein a nozzle N provides a spray of water or electrolyte from a source WS with which the rock RK is pre-treated prior to a high voltage pulse being injected into the rock body via the probes P-1 and P-2. The rock body may be immersed in the conductive fluid, or it may be subjected to a spray of steam, as indicated in FIGURE 4, from a tank BB via a nozzle NN. It is to be noted that while steam per se is not a conductive agent, as with pure water, many rock bodies contain salts or other water soluble substances, which in combination with water or steam produce conductive liquids or the equivalents. Since it is desired to have a current carrying channel form within the rock body in order to set up the stresses that bring about fragmentation rather than make the surface of the rock body more conductive, it is necessary to insure that the surface of each rock body treated with conductive fluid becomes dry before the high voltage impulse is applied via the probes P-1 and P-2. With most aqueous fluids normal evaporation is sufficient for this purpose; however, forced drying of the rock body by moving air or otherwise may be employed.

FIGURE 5 illustrates the manner in which the teaching of the invention may be utilized to "scale off" fragments from a rock face. Holes HL of relatively small diameter are drilled into a rock face RF above the area that is to be fragmented and a conductive liquid is injected into them. The probes P-1 and P-2 from the high voltage impulse device described in FIGURE 1 are then inserted into similar holes H-1 and H-2, respectively, so that when the high voltage pulse is applied a conductive path is formed internally of the rock formation between the tips of the probes. The area SA (see dotted lines in FIGURE 5) substantially will have absorbed the injected conductive liquid so that the electrical break down and consequent disruption of the rock face will occur in that area.

FIGURE 6 illustrates a further modification of the arrangement shown in FIGURE 5. According to FIGURE 6 the rock face RFF is sprayed by a conductive liquid, some of which is absorbed by the rock face. Since the surface of the rock face will evaporate the liquid more rapidly than the interior, some of the liquid will remain to assist in forming current conductive paths internally, as previously explained. A pan PN supported by a movable ramp BR, which may be carried on the boom of a crane or shovel, is provided with a pair of probes P-1 and P-2 separated by an insulating arm IS mounted on the pan. The probes P-1 and P-2 in this instance are arranged to have points or pointed tips so that the pan PN can be forced against the rock face RFF thereby forcing the tips into the face at points CT-1 and CT-2, for example, thereafter a high voltage pulse is provided to the probes. In this manner a rock face may be chipped away more rapidly in small areas such as SA (see dotted lines of FIGURE 6).

FIGURE 7 shows the manner in which individual rocks may be fragmented using the teaching of the invention. After pre-treatment with a conductive liquid and drying a rock RK has applied to it the tongs TG-1 and TG-2 so that current carrying paths may be formed internally of the rock RK between the tips of the tongs T-1, T-2 and T-3 and the tang T-4 (as indicated by the dash-dot lines of FIGURE 7), the tongs TG-1 having an insulating tang IT for mechanical support. The high voltage impulse in this instance is supplied to the cables CB-1 and CB-2 in the same manner that has previously been explained for the probes P-1 and P-2, respectively. The tongs of each of the tongs may be spring urged to close upon the rock so that operating personnel may stand clear when the high voltage impulse is delivered.

A unique adaptation of the invention is illustrated in FIGURE 8; namely, a vehicle capable of performing strip mining operations. A wheeled or tracked vehicle V

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is provided with an extension carrying a yoke supporting the electrodes or probes P-1 and P-2, respectively, having cables CB-1 and CB-2 connected to a high voltage impulse source (not shown). A means is also provided in the nature of a spray WS for distributing a conductive liquid in the path of the vehicle. The vehicle moves slowly over the area to be "stripped," and may be self-propelled or pushed by a tractor or the like. The rate of travel of the vehicle V is such that the conductive liquid will seep into the pores of the rock formation via gravity thereby tending to set up current carrying channels in the sub surface of the rock as the probes P-1 and P-2 progress, recurring high voltage impulses being supplied to them, so that fragments will be broken loose substantially from an area as indicated by dotted lines and picked up by a continuously moving conveyor CVB and deposited in a hopper HP.

A form of electrical rock-crusher is illustrated in FIGURE 9. Here a conveyor belt CVR moves continuously to deliver rocks RK from a hopper HP-1 to a nozzle N which sprays conductive liquid from a pipe WSC upon the rocks. Thereafter the rock progresses to be contacted by flexible fingers F-1 and F-2, respectively, attached to the probes P-1 and P-2, which are connected by cables to a high voltage impulse source such as that described in connection with FIGURE 1, above. Forced air drying (not shown) may be employed to dry the surface of the rocks before contacting the fingers F-1 and F-2; however, normal evaporation ordinarily will provide a dry rock surface so that surface "flash-overs" occur only infrequently as the high voltage impulses are applied by the fingers F-1 and F-2. Consequently the current carrying paths formed in the rocks as a result of being treated with the conductive liquid form the major paths of current discharge, and the rocks RK are fragmented, as previously described, the fragments being carried by the conveyor CVB into another hopper HP-2 and delivered into a bin BN.

While this invention has been explained and described with the aid of a particular embodiment thereof, it will be understood that the invention is not limited thereby and that many modifications will occur to those skilled in the art. It is therefore contemplated by the appended claims to cover all such modifications as fall within the scope and spirit of the invention.

What is claimed is:

1. A method for fragmenting a rock by electrical energy comprising the steps of introducing steam into the interstices of the rock, attaching electrodes to the surface of the rock, and applying electrical potential across the electrodes.

2. A method for fragmenting a rock by electrical energy comprising the steps of introducing a conductive fluid into the interstices of the rock, attaching electrodes to the surface of the rock, and applying a high voltage direct current impulse across the electrodes.

3. A method for fragmenting a rock by electrical energy comprising the steps of introducing a conductive fluid into the interstices of the rock, attaching electrodes to the surface of the rock, and applying high voltage direct current across the electrodes.

4. A method for fragmenting a rock by electrical energy comprising the steps of spraying the rock with a conductive fluid, allowing the fluid to seep into the interstices of the rock, drying the surface of the rock, attaching electrodes to the surface of the rock, and applying electrical potential across the electrodes.

5. A method for fragmenting a rock by electrical energy comprising the steps of immersing the rock in a conductive fluid, allowing the fluid to seep into the interstices of the rock, removing the rock from the conductive fluid, drying the surface of the rock, attaching electrodes to the surface of the rock, and applying electrical potential across the electrodes.

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