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(12) # EUROPEAN PATENT SPECIFICATION

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(54) **Plasma blasting method.**

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US-A- 3 679 007

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Description

This invention relates to a plasma blasting process for fragmenting a substance such as rock and more particularly for hard rock mining.

The traditional method of hard rock mining is a batch process with the following sequence: Holes are drilled in the rock, chemical explosives placed into the holes, and the mine personnel evacuated; then the explosives are detonated, causing a quantity of rock to be separated from the solid rock mass; gases generated by the explosives are then ventilated out before the miners can return.

Over the years many attempts were made to improve efficiency of hard rock mining, by continuously working the ore face, chipping away the rock in smaller chunks. In general, continuous mechanical mining machinery is suitable for softer, more easily workable rock types only.

Electrical methods for hard rock fragmentation were tried by several researchers. One such technique is electrohydraulic crushing which was tested as early as 1905 by Svedberg. He produced colloidal metallic suspensions by capacitor discharge in a liquid as reported by B.K. Parekh, et al. in an article entitled "Novel Comminution Process Uses Electric and Ultrasonic Energy", Mining Engineering, September 1984, pages 1305-1309. The electrohydraulic effect and its potential application in rock fragmentation has been extensively studied by H.K. Kutter and published by the U.S. Bureau of Mines in 1969 (see Report of Investigations 7317 entitled "The Electrohydraulic Effect: Potential Application in Rock Fragmentation"). Additional publications on the electrohydraulic effect can be found in Engineering and Mining Journal, Volume 62 (2) 1961, pages 134 to 140 where an electrohydraulic crusher is described and in Engineering and Mining Journal of February 1970 pages 88 - 89 where a summary of the U.S. Bureau of Mines report mentioned above is given.

Several patents have also been issued in this area which have recognized the importance of electrical discharge in water to generate shock waves. For example, US-A-3,158,207 provides a spark discharge drill operating on this principle. US-A-3,364,708 gives a good overall review of this phenomenon. Also, US-A-3,500,942; US-A-3,583,766 and US-A-3,679,007 relate to drills in which an electric discharge takes place between two electrodes immersed in a fluid such as water, thereby producing a high temperature, high pressure plasma between the electrodes. The expansion of the plasma produces a strong pressure or shock wave which enhances the drilling effect. The main disadvantages of electrohydraulic fracturing are that the pressure pulse is spread out and a large fraction of energy is dissipated in the water (see B.K. Parekh, et al., Supra).

Applicant has now surprisingly found that by delivering electrical energy at at least 100, preferably in excess of 200 megawatts per microsecond until a peak power of at least 3, preferably in excess of 4 gigawatts is reached across the gap of two poles of a coaxial electrode assembly immersed in an electrolyte within a confined area of a substance to be blasted, one can produce a dielectric breakdown of the electrolyte resulting in the formation of plasma within such confined area which creates a pressure sufficient to blast such substance in the manner of a high explosive charge.

The electrolyte could be water or a solution suitable for dielectric breakdown. A preferred solution is that of copper sulphate.

The electrolyte may also be combined with a gelling agent such as bentonite or gelatin in order to make it viscous enough so that it would not run out of the confined area prior to blasting.

The invention will now be disclosed, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of the equipment required for the storage and release of electrical energy for the plasma blasting process in accordance with the present invention;

Figure 2 is a diagram illustrating the rate of energy and the peak power required to break the rock; and

Figure 3 is a diagram of a continuous mining and tunneling machine for plasma blasting.

Referring to Figure 1, the plasma blasting method in accordance with the present invention requires drilling of a hole 10 into the rock face by conventional drilling. A small amount of viscous electrolyte 12, such as copper sulphate, is injected into the hole and a coaxial blasting electrode 14 is inserted in the hole. Electrical energy, typically 300-1000 kilojoules, is delivered into approximately 20-50 grams of the electrolyte under confinement within the hole. Typical dimensions for the hole are about 50 mm diameter and 500 mm depth. These dimensions may change depending on the size of the blasting electrode and the amount of energy input. The diameter of the hole should be such that the blasting electrode would have a close fit and the greater the energy input the deeper the hole would be. The blasting electrode which fits closely into the hole serves two purposes: (1) it carries electrical energy to the electrolyte, (2) it produces the required confinement for the blast by plugging up the hole. Rapid delivery of the electrical energy is important for the development of the desired high peak pressure. Energy is delivered at at least 100 and preferably in excess of 200 megawatts per microsecond until a peak power of at least 3 gigawatts and preferably in excess of 4 gigawatts is reached as illustrated in Figure 2 of the drawings. The peak pressure developed has been found to be in excess of 1 gigapascal, or 10,000 atmospheres which is sufficient to blast hard rock in the manner of a high explosive charge. Applicant has found that if the energy is delivered at less than 100 megawatts per microsecond such as illustrated, for example, by the dotted line in Figure 2, or the peak power is substantially less than 3 gigawatts, insufficient pressure is created to adequately blast the rock, although the amount of energy delivered (area under the curves) is essentially the same.

The electrical energy required for the blast is conveniently stored in a capacitor bank 16 which is electrically charged by a suitable D.C. power supply 18. A high current switch 20, such as the one described in US-A-4,897,577, is used to direct typically 500 kiloamperes to the blasting electrode at the time of blast. The switch is triggered by a triggering device 22 which is initiated by a remote trigger 24 through a fiber optic cable or a pneumatic tube to provide perfect electrical isolation for the operator. The capacitor bank is connected to the blasting electrode through an electrical circuit including a coaxial power cable 26 which is designed for minimum inductance and resistance to reduce power losses and ensure rapid discharge of energy (at the above disclosed rate) into the rock for the development of an intense shockwave.

Prior to the blast, the electrode is maintained at ground potential but when the switch is triggered the center lead of the coaxial electrode is raised to the high voltage of the capacitor bank. The electrolyte in the hole then suffers a dielectric breakdown producing a plasma at extremely high temperature and pressure. In this manner, a great amount of energy is transferred within a very short time from the capacitor bank into the small amount of electrolyte in the confined area around the electrode thereby instantaneously transforming this entire finite amount of electrolyte into plasma which must then release this energy by way of a pressure wave, thus resulting in a blast similar to that made by dynamite or other chemical explosives.

The plasma electrode may be equipped with a recoil mechanism to damp out the destructive effect of the blast on the electrode.

Figure 3 is a diagram of a continuous mining and tunneling machine 30 at the back of which is mounted the capacitor bank and associated equipment 32 for triggering a blasting electrode mounted on one or several booms 34 located at the front of the machine. A drilling and blasting head 36 is provided at the end of the boom. The rock blasted from the mine face is collected at the front of the machine onto a conveyor 38 extending to the back of the machine for loading into conventional transport equipment.

Claims

1. A method of fragmenting a substance, which method comprises delivering electrical energy across the gap of two poles of a coaxial electrode assembly (14) immersed in an electrolyte (12) within a confined area (10) of the substance, so as to produce a dielectric breakdown of the electrolyte (12) resulting in the formation of plasma within said confined area (10), characterised in that the electrical energy is delivered at at least 100 megawatts per microsecond until a peak power of at least 3 gigawatts is reached, thereby creating a pressure sufficient to blast said substance in the manner of a high explosive charge.

2. A method according to claim 1, in which the energy is delivered at in excess of 200 megawatts per microsecond.

3. A method according to claim 1 or 2, in which the peak power is in excess of 4 gigawatts.

4. A method according to any preceding claim, in which the electrolyte (12) is a solution of copper sulphate.

5. A method according to any preceding claim, in which the electrolyte (12) is combined with a gelling agent to increase its viscosity.

6. A method according to claim 5, in which the gelling agent is bentonite.

Patentansprüche

1. Verfahren des Fragmentierens einer Substanz, wobei das Verfahren Liefern elektrischer Energie durch den Spalt von zwei Polen einer koaxialen Elektroden-Anordnung (14) umfaßt, welche in ein Elektrolyt (12) eingetaucht ist, innerhalb eines beschränkten Bereiches (10) der Substanz, um somit einen dielektrischen Zusammenbruch des Elektrolytes (12) zu erzeugen, resultierend in der Bildung von Plasma innerhalb des beschränkten Bereiches (10), **dadurch gekennzeichnet,** daß die elektrische Energie mit zumindest 100 Megawatt pro Mikrosekunde geliefert wird, bis eine Spitzenleistung von zumindest 3 Gigawatt erreicht ist, wodurch ein Druck erzeugt wird, welcher ausreicht zum Sprengen der Substanz in der Art einer hochexplosiven Ladung.

2. Verfahren gemäß Anspruch 1, in welchem die Energie mit über 200 Megawatt pro Mikrosekunde geliefert wird.

3. Verfahren gemäß Anspruch 1 oder 2, in welchem die Spitzenleistung über 4 Gigawatt liegt.

4. Verfahren gemäß einem vorangegangenen Anspruch, in welchem das Elektrolyt (12) eine Kupfer-Sulfat-Lösung ist.

5. Verfahren gemäß einem vorangegangenen Anspruch, in welchem das Elektrolyt (12) mit einem Gelierungsmittel kombiniert ist zum Erhöhen seiner Viskosität.

6. Verfahren gemäß Anspruch 5, in welchem das Gelierungsmittel Bentonit ist.

Revendications

1. Procédé de fragmentation d'une substance, lequel procédé comprend la délivrance d'une énergie électrique à travers l'interstice séparant deux pôles d'un ensemble (14) formant électrode coaxiale immergé dans un électrolyte (12) dans une région confinée (10) de la substance, afin de produire une rupture diélectrique de l'électrolyte (12) résultant en la formation de plasma dans ladite région confinée (10), caractérisé en ce que l'énergie électrique est fournie à au moins 100 mégawatts par microseconde jusqu'à ce qu'une puissance de crête d'au moins 3 gigawatts soit atteinte, créant ainsi une pression suffisante pour abattre par explosion ladite substance à la manière d'une charge hautement explosive.

2. Procédé selon la revendication 1, dans lequel l'énergie est fournie à plus de 200 mégawatts par microseconde,

3. Procédé selon la revendication 1 ou la revendication 2, dans lequel la puissance de crête dépasse 4 gigawatts.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'électrolyte (12) est une solution de sulfate de cuivre.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'électrolyte (12) est combiné à un agent de gélification pour accroître sa viscosité.

6. Procédé selon la revendication 5, dans lequel l'agent gélifiant est de la bentonite.

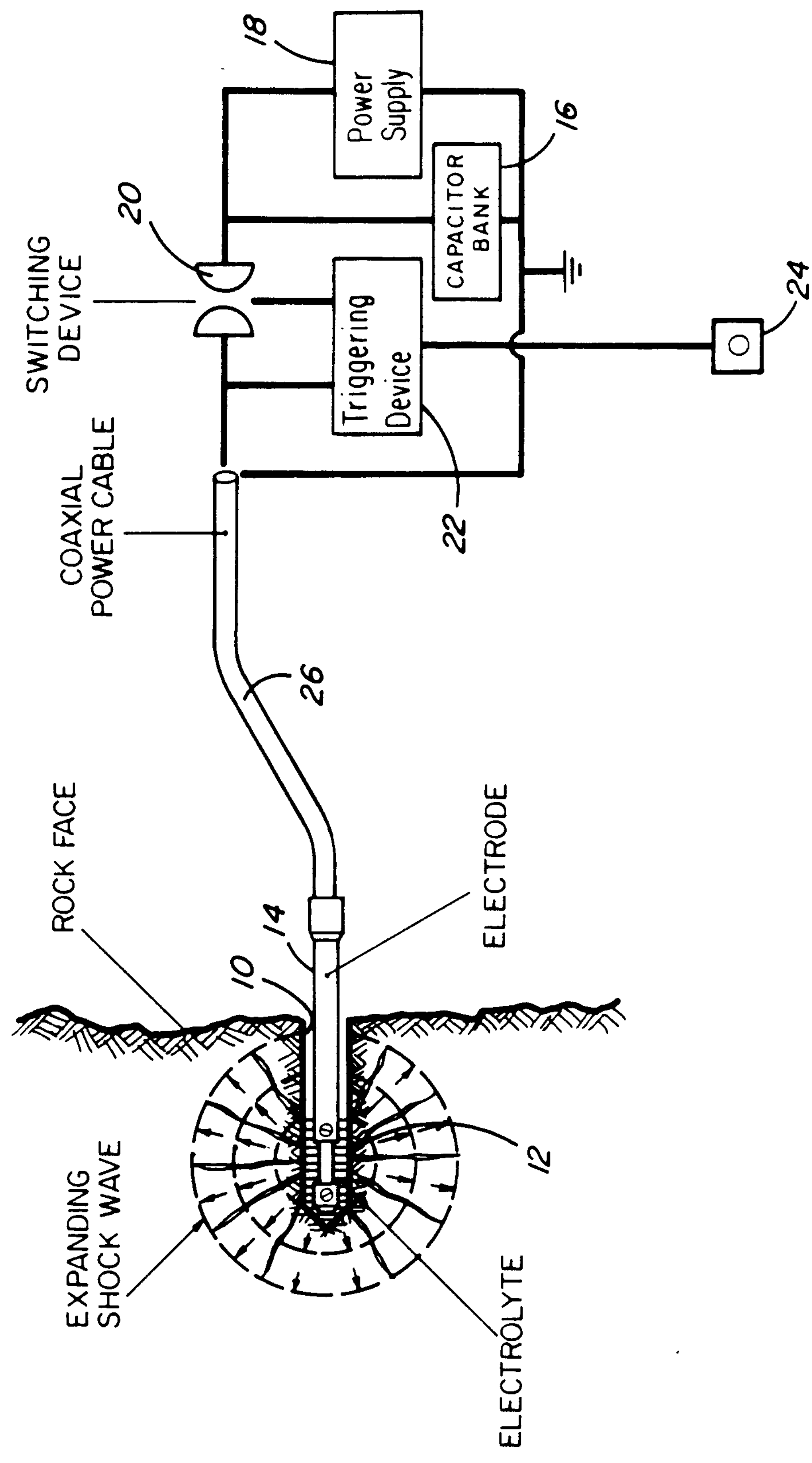
SWITCHING DEVICE
COAXIAL POWER CABLE
ROCK FACE
EXPANDING SHOCK WAVE
ELECTROLYTE
ELECTRODE
Power Supply
CAPACITOR BANK
Triggering Device
10
12
14
16
18
20
22
24
26

Fig. 1

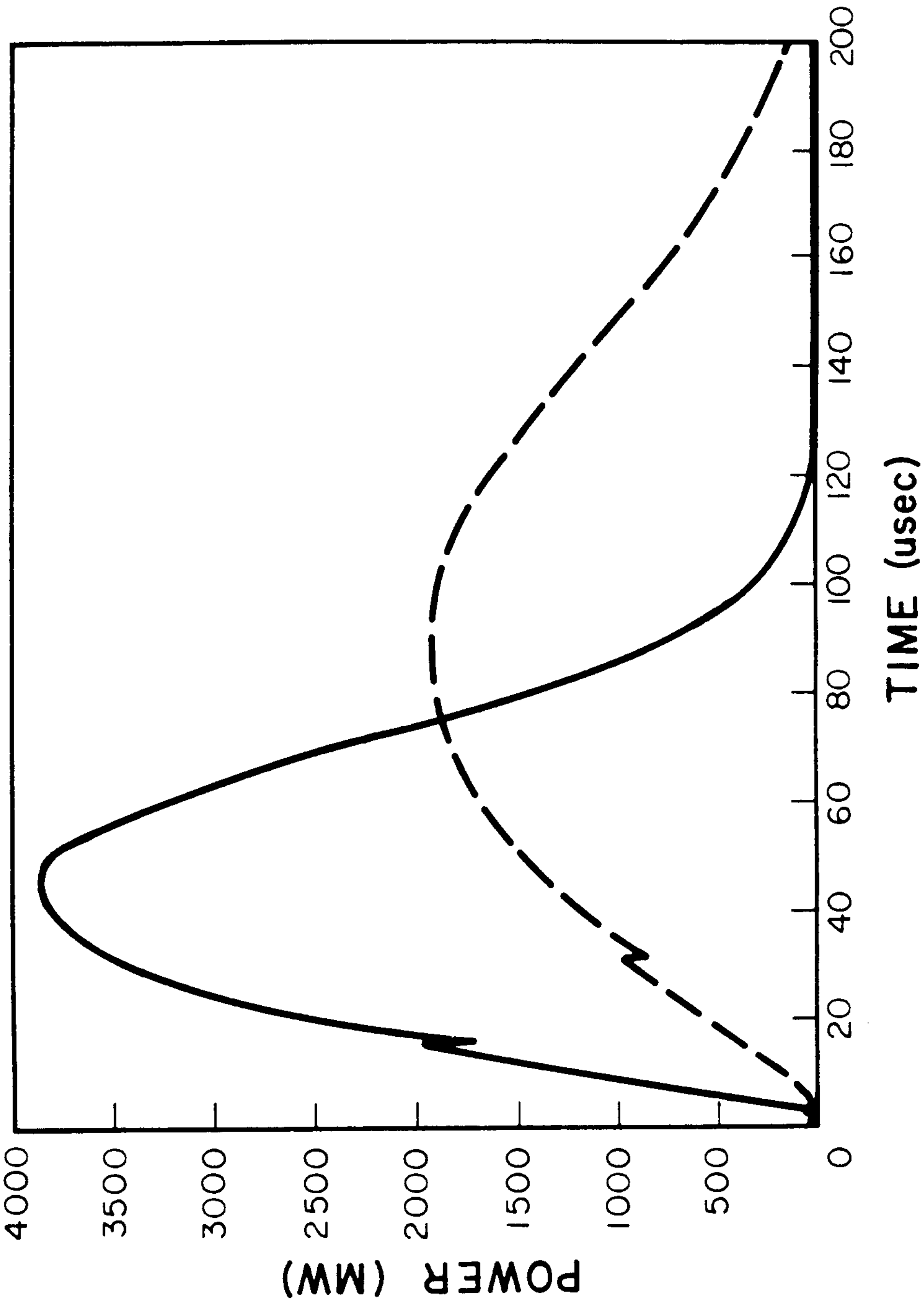
POWER (MW)
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
100
120
140
160
180
200
TIME (usec)

Fig. 2

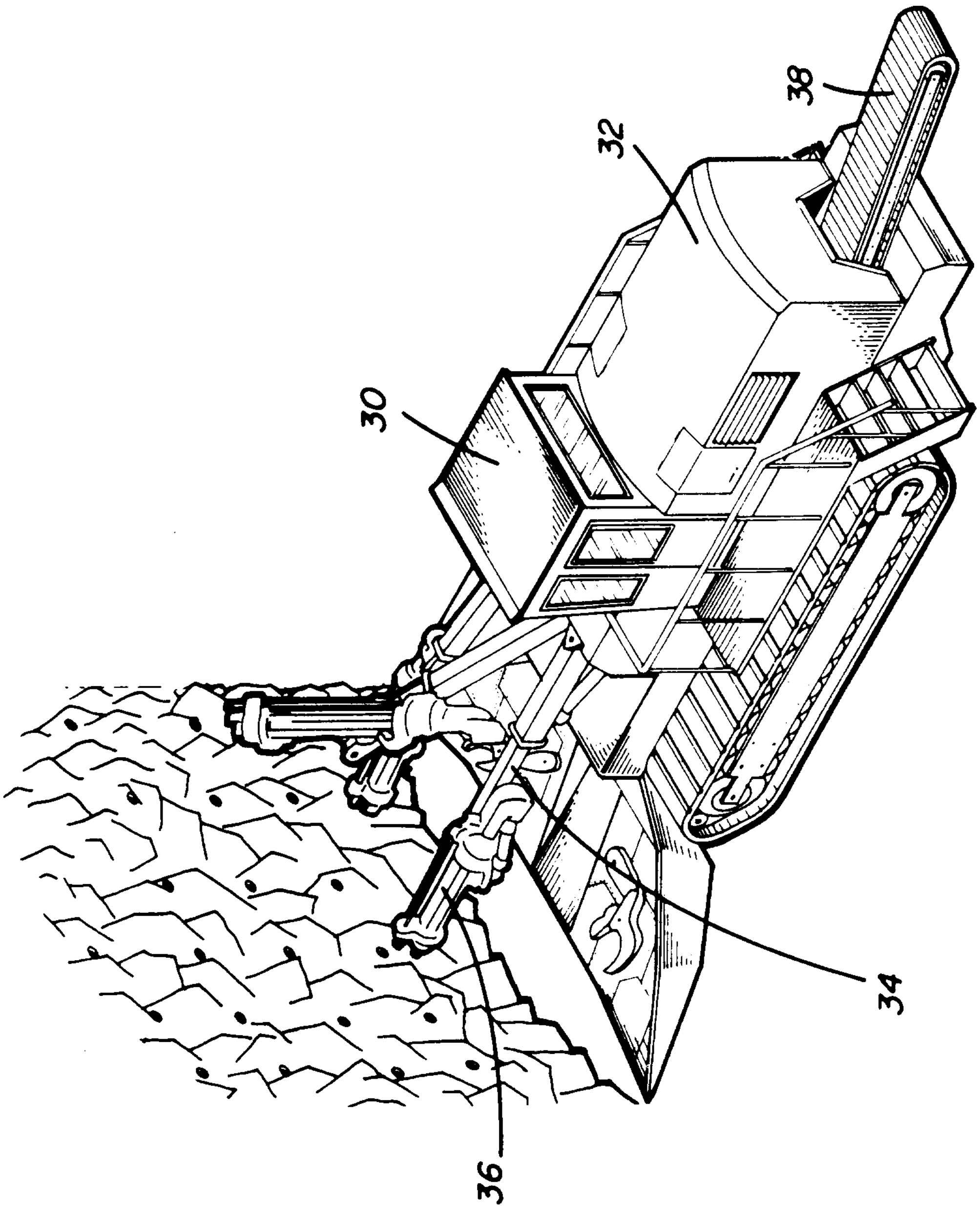

Fig. 3