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Carley-Macauly et al.

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[54] **ELECTRO-HYDRAULIC CRUSHING APPARATUS**

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[21] Appl. No.: **95,561**

[52] **U.S. Cl.**.....**241/1,** 241/46 R, 241/73

[51] **Int. Cl.**.....**B02c 19/00**

[58] **Field of Search**.....241/1, 46, 46.02, 69, 73, 301

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[57] **ABSTRACT**

Coarse feed material in a liquid medium is allowed or introduced to stratify and the material in the coarse stratum is then subjected to shocks from a spark discharge. Preferably, also, the material in each successively finer stratum is subjected to further shocks by spark discharges at an energy and frequency optimized according to the particle size range in each stratum.

11 Claims, 6 Drawing Figures

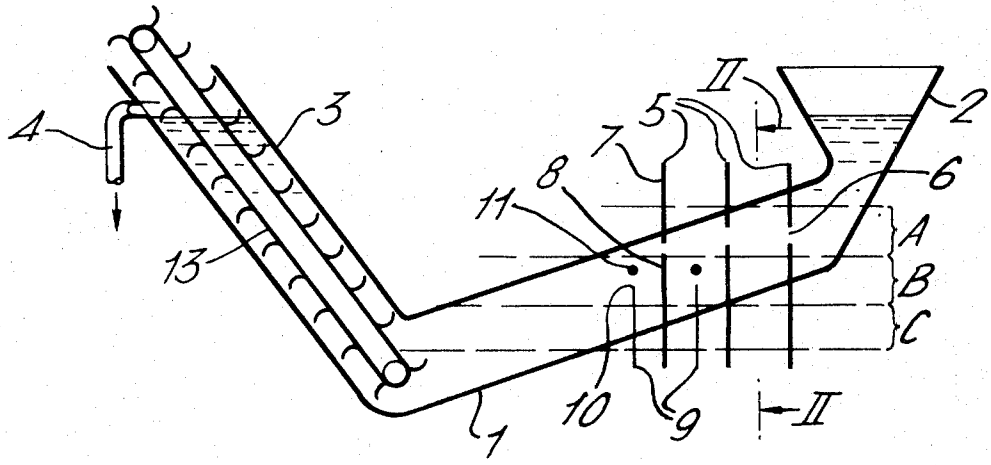


FIG. 1.

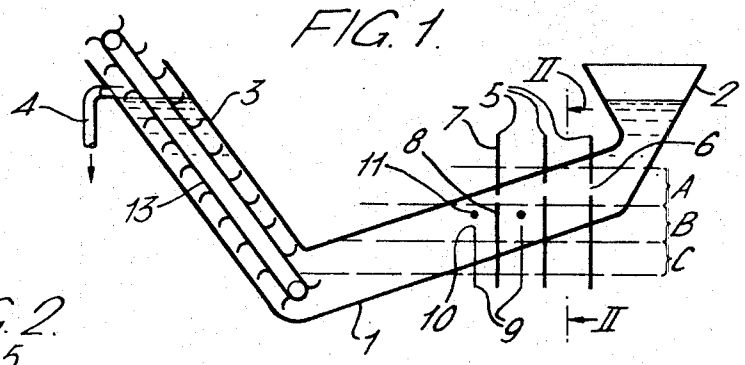


FIG. 2.

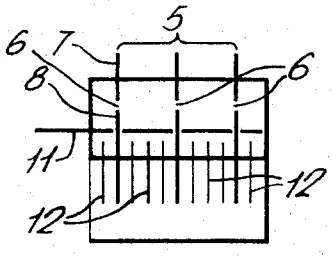


FIG. 3.

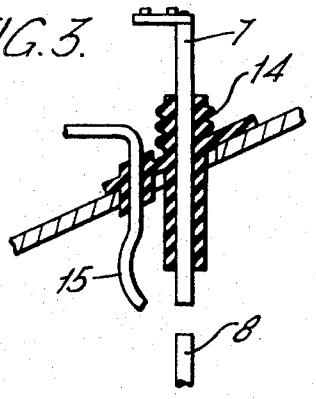


FIG. 4.

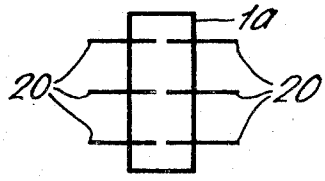
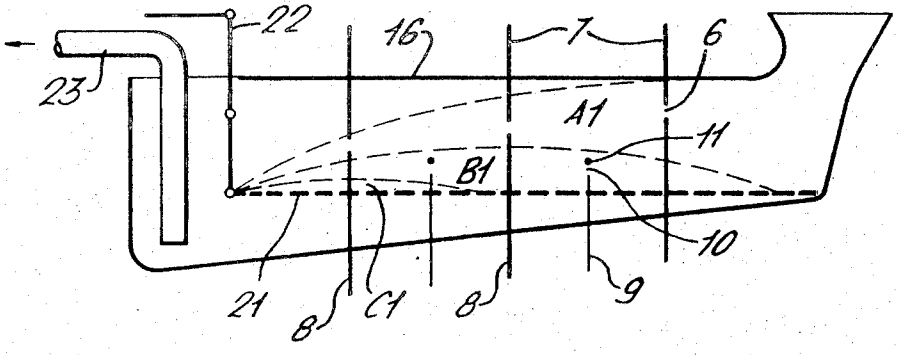


FIG. 5.



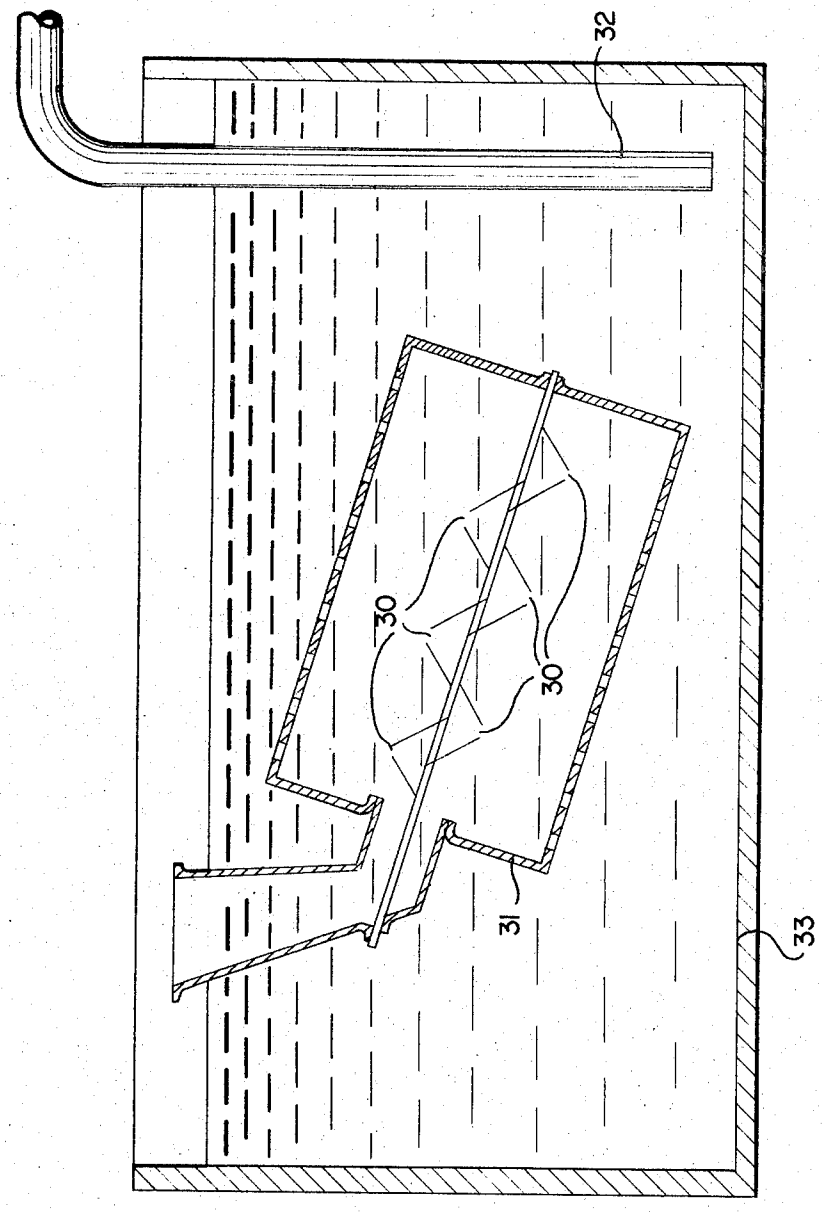


FIG. 6

ELECTRO-HYDRAULIC CRUSHING APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to electro-hydraulic crushing apparatus and is particularly concerned with apparatus for crushing coarse feed materials, e.g. rocks as much as 1 ft. across.

Such material often requires a succession of shocks to initiate break-down and thereafter the broken down material may require to be subjected to further shocks to reduce this size to that of the desired final product.

SUMMARY OF THE INVENTION

According to the invention coarse feed material in a liquid medium is allowed or induced to stratify and the material in the coarse stratum is then subjected to shocks from a spark discharge. Preferably, also, the material in each successively finer stratum is subjected to further shocks by spark discharges at an energy and frequency optimized according to the particle size range in each stratum.

Apparatus for carrying out the invention comprises means for conveying the material past a succession of spark gaps arranged on a locus substantially coincident with the mean level or position of at least the coarser stratum of the material to be crushed.

More particularly apparatus for carrying out the invention may comprise a closed rectangular section inclined duct and a plurality of banks of vertically arranged pairs of electrodes, the electrodes of each pair extending through the floor and ceiling of the duct respectively and extending towards each other to constitute a spark gap, the gaps of each bank being the same distance from the floor of the duct and the gaps of successive banks being successively further from said floor so as to remain within the coarse stratum.

It will be appreciated that the horizontal distance between the electrodes of each bank will require to be spaced by at least the maximum dimensions of the feed material but double banks, spaced in the direction of feed by at least said maximum dimensions and staggered in the horizontal direction, may be provided.

The electrodes will tend to obstruct the passage of material down the duct but the inclination of the duct is adjusted such that gravity aided by vibrations caused by the spark discharges produces a steady movement of material down the duct and also causes the material to stratify according to particle size, the smallest particles settling to the floor.

In a modification the floor of the duct is perforated to constitute a sieve which separates the lowest stratum (product material) and removes it from the crushing region of the duct.

In another modification a perforated revolving drum preferably with its axis inclined is substituted for the linear ducts described in which case the strata will tend to fold over upon themselves.

The invention includes apparatus for electro-hydraulic crushing comprising a container for the mixture of liquid and material to be crushed, electrodes providing at least one spark gap within the container, and means for conveying fluid separately from the said mixture to the region of the spark gap and for there injecting the fluid into the said mixture.

Preferably the said means for conveying fluid comprises at least one pipeline extending from a source of fluid outside the container to the region of the spark gap. In this way gas (e.g. air) and/or demineralized water or other liquid may be injected into the region of the spark gap to promote sparking.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to enable the nature of the invention to be more readily understood, reference is directed to the accompanying drawing showing by way of example several embodiments thereof. In the drawing:

FIG. 1 is a diagrammatic side elevation of an embodiment of the invention employing an inclined stationary duct,

FIG. 2 is a cross-section on the II—II of FIG. 1,

FIG. 3 is a cross-section of a detail in FIG. 1,

FIG. 4 is a view similar to FIG. 2 of a modified duct,

FIG. 5 is a view similar to FIG. 1 of an embodiment employing an oscillating sieve, and

FIG. 6 is a diagrammatic side elevation of an alternative embodiment of the invention employing an inclined rotatable duct.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 2 the apparatus comprises an inclined duct 1 furnished with a charge hopper 2 at its upper end and an extension 3 extending upwards from its lower end to form a shallow U-shaped configuration, adapted to be flooded with water to the level determined by an overflow pipe 4.

Large pieces of rock, say up to 1 ft. across are fed into the hopper 2 and in the process of operation, as will be hereinafter explained, the rock is crushed and moves down the duct 1. In the process the crushed materials tends to separate according to particle size, the fines moving to the bottom, in a continuously graded formation. For ease of description, however, it is assumed there are three strata A, B and C representing coarse, medium and fine size ranges.

Located in stratum A is a series of banks 5 (FIG. 2) of spark gaps 6. As shown, each bank 5 consists of a number of gaps 6 appropriate to the width of vessel, (3 are shown) formed between the ends of upper and lower electrodes 7 and 8 extending through the ceiling and floor of the duct through suitable insulating bushings (FIG. 3). The lateral spacing between the electrodes of each bank is sufficient to allow the largest rock to be crushed to pass and by making the longitudinal spacing between the banks large enough the electrodes of successive banks may be staggered in relation to each other.

In stratum B is a further series of banks 9 of spark gaps 10 formed between common horizontal electrodes 11 and vertical electrodes 12 extending through the floor of the duct. The electrodes 12 are more closely spaced in accordance with the smaller size of rock particles in stratum B and, if desired, a further series of banks of spark gaps (not shown) similar to the banks 9 of gaps 10 but closer together may be provided in stratum C.

Within the extension 3 is a bucket and chain conveyor 13 for removing the fines which collect at the bottom of duct 1.

As shown in FIG. 3, the electrodes 7 (and with appropriate modification electrodes 11) are mounted in insulating bushings 14 which also provide for the entry

of water feed pipes **15** which direct into the region of each spark gap water of low ion content such as demineralized water.

Each spark gap of each bank **5** is fed from a pulsed high tension supply adapted to dissipate energy of the order of 1,000 joules in a period of about 3 μs across a gap of 6–8 cms at a repetition frequency of about 100 per min. The spark gaps **10** are of lesser dimension, say 4 cm, and the gaps of each bank are fed in parallel from a similar high tension supply adapted to dissipate 200 joules at each gap at 150 per minute. The supply equipment may comprise high voltage capacitors connected through gas filled spark gaps to the electrodes. The capacitor required for each 1,000 joule spark discharge may be, for example, of 1 μF capacity charging to 45 kV from a conventional high voltage D.C. charging circuit. The energies and other parameters quoted in this example are appropriate for crushing a fairly tough rock, say granite, from 6 inches to about ½ inch with the minimum of fines less than ⅛ inch.

It has been advantageous to inject gas into the water in the crusher and feed pipes similar to the water feed pipes **15** may be provided for that purpose. The water feed to the region of the spark gaps is to ensure that the water does not become too highly ionized and cause substantial loss of stored charge before sparking can take place. A gas feed in the same region helps spark initiation and optimum results are obtained by gas and water feed to the gaps. Gas may also be injected so as to flow around the outside of the crushing region to reduce noise and vibration. The gas may be air. Desirably a relatively small quantity of gas is injected into the spark region, for promoting sparking, and there is a rather larger flow around the outside of that region to reduce noise, but avoiding injection of large quantities of gas into the crushing zone immediately around the spark.

In operation, the system is filled with water and the water feed to the pipes **15** is turned on, causing a steady overflow from the pipe **4**. Gas supply to the gas injectors (if provided) is also opened. Rocks are then fed into the hopper **2** and are subject to the crushing action of the spark gaps **6**. Eventually a steady state condition is reached when the duct **1** is full with crushed rock graded from uncrushed rock in the upper stratum A to crushed material in the lower stratum C. This finally crushed material is continuously removed by the conveyor **13** and it will be appreciated that this may be screened, any fraction larger than that required may be fed back to the hopper **2** and any fraction less than that required discarded.

In a modification shown in FIG. **4** the duct **1***a*, corresponding to duct **1** in FIGS. **1** and **2**, is made of sufficient width to pass the uncrushed material and the electrodes **20** in each stratum are positioned in the walls of the duct.

Referring now to the arrangement shown in FIG. **5**, the crushing takes place in a substantially horizontal duct **16** and the material to be crushed is caused to move by means of an oscillating sieve **21** operated by a lever mechanism **22**. The fines which have passed through the sieve **21** are removed by hydraulic suction through an outlet **23**. The steady state condition of the stratified material is such as to produce curved strata A1, B1 and C1 and electrodes similar to those described with reference to FIGS. **1** to **3** are provided as shown. Alternatively, the duct **16** may be of the cross-section exampled in FIG. **4** and electrodes **20** inserted laterally, thus minimizing any design complications which might arise from high voltage electrodes passing through a jigging sieve.

For some crushing duties a single set of spark parameters (voltage energy, etc.) may be close to the optimum over the whole crushing range. In this case there would be little benefit in using several energies, but at each stage along the duct the electrode gaps will be arranged in the region of the largest uncrushed particles at that stage.

According to yet another embodiment of the invention, illustrated in FIG. **6**, the means for conveying the material past a succession of spark gaps **30** comprises a perforate rotatable drum **31** in which the feed material is tumbled and subjected to a series of spark discharges at spark gaps arranged within the drum at positions corresponding to the various strata which develop as the drum rotates, the fine product material being discharged through the perforations and removed by hydraulic suction through outlet **32** as in FIG. **5**. It will be understood that the drum is submerged in a tank **33** of water.

The largest size fraction (i.e. the feed material) will offer the greatest resistance to movement by impressed means such as vibration or rotation. On the other hand the first stage of fracture of the feed (to lumps of, say, half the feed size diameter or less) requires the least total energy. Hence with material of a large feed size it may be desirable to have at least the first stage of crushing (which may not involve many electrode gaps) in an arrangement such as is shown in FIG. **1**, to allow movement of the large material under gravity, before the intermediate product passes to a further crushing region where movement is induced by, for example, oscillatory motion as shown in FIG. **5**, or by rotation.

We have found, in operation of the apparatus of the foregoing examples, that it is advantageous for the material to be crushed to have substantially settled around the electrodes with as dense a packing as can be achieved. In this way, the shock wave acts substantially directly upon solid material and we have found this to result in effective transmission of the crushing shocks to material more remote from the spark gaps than occurs in less densely packed material.

We claim:

1. Electro-hydraulic crushing apparatus comprising:

a container defining a chamber for confining a body of liquid;

means for introducing material into the body of liquid in said chamber whereby the material to be crushed is positioned within said body of liquid;

electrode means for producing a spark discharge within the body of liquid in said chamber, the gap of said electrode means being located in the chamber so as to be positioned within a body of material being crushed when said material is present in the body of liquid in said chamber, said gap being located in the upper region of said container whereby the gap will be in the body of a relatively coarse stratum of said material being crushed;

said chamber comprising a closed rectangular section inclined duct:

and said electrode means comprising electrodes arranged in a plurality of banks of vertically arranged pairs of electrodes, the electrodes of each pair extending through the floor and ceiling of the duct respectively and extending towards each other to constitute a spark gap, the gaps of each bank being the same distance from the floor of the duct and the gaps of successive banks being successively further from said floor so as to remain within the coarse stratum.

2. Apparatus as claimed in claim 1, wherein the duct is inclined downwardly from inlet to outlet, whereby the action of gravity and vibrations caused by the spark discharges produce a steady movement of material down the duct and also cause the material to stratify according to particle size, the smallest particles settling to the floor.

3. Apparatus as claimed in claim 2, wherein the floor of the duct is perforated to constitute a sieve through which the lowest stratum passes and is removed from the crushing region of the duct.

4. Electro-hydraulic crushing apparatus comprising:

a container defining a chamber for confining a body of liquid;

means for introducing material into the body of liquid in said chamber whereby the material to be crushed is positioned within said body of liquid;

electrode means for producing a spark discharge within the body of liquid in said chamber, the gap of said electrode means being located in the chamber so as to be positioned within a body of material being crushed when said material is present in the body of liquid in said chamber, said gap being located in the upper region of said container whereby the gap will be in the body of a relatively coarse stratum of said material being crushed;

said container comprising a rotatable drum with its axis inclined;

and means for rotating the drum, whereby the strata will tend to fold over upon themselves as the drum rotates, the electrodes being located to define spark gaps substantially coincident with the means positioned of at least the coarser folded stratum of the material to be crushed.

5. Electro-hydraulic crushing apparatus comprising:

a container defining a chamber for confining a body of liquid;

means for introducing material into the body of liquid in said chamber whereby the material to be crushed is positioned within said body of liquid;

electrode means for producing a spark discharge within the body of liquid in said chamber, the gap of said electrode means being located in the chamber so as to be positioned within a body of material being crushed when said material is present in the body of liquid in said chamber, said gap being located in the upper region of said container whereby the gap will be in the body of a relatively coarse stratum of said material being crushed;

and means for conveying fluid separately from the said mixture to the region of the spark gap and for there injecting the fluid into the said mixture.

6. Apparatus as claimed in claim 5, wherein the said means for conveying fluid comprises at least one pipeline extending from a source of fluid outside the container to the region of the spark gap.

7. A method of electro-hydraulic crushing comprising:

introducing coarse feed material to be crushed into a body of liquid to provide a body of material being crushed in the liquid body;

stratifying the body of material being crushed in the body of liquid into relatively coarse and relatively fine strata, each stratum being defined by upper and lower limits; and

subjecting the feed material, in the coarse stratum, to shocks by spark discharge, the shocks being imparted at least at one locus within the coarse stratum of the body of the material being crushed and within the liquid body, said locus being substantially midway between the upper and lower limits of said coarse stratum.

8. A method according to claim 7 wherein the material being crushed is subjected, in at least one finer stratum to further shocks by spark discharge, said further shocks being imparted at least at one locus within the body of the material being crushed and within the liquid body.

9. A method according to claim 8 wherein said further shocks are imparted in each successively finer stratum of material being crushed.

10. A method according to claim 7 wherein stratification of the material being crushed is at least partially induced.

11. Apparatus for electro-hydraulic crushing comprising:

a container defining a chamber for confining a body of liquid;

means for introducing material to be crushed into the body of liquid in said chamber whereby the material to be crushed is positioned within said body of liquid;

electrode means for producing a spark discharge within the body of liquid in said chamber, the gap of said electrode means being located in the chamber so as to be positioned within a body of material being crushed when said material is present in the body of liquid in said chamber, said gap being located in the upper region of said container in the body of a relatively coarse stratum of said material being crushed at a locus substantially midway between the upper and lower limits of said coarse stratum.

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