Sudden heat shock (thermal shock) and cooling cycles are used to break large stones into fragments of predetermined size, without conventional heavy and bulky crushing equipment.

11 Claims, 7 Drawing Figures
THERMAL BREAKING OF ROCKS

This application is a continuation-in-part of my co-pending application Ser. No. 97,645, filed December 14, 1970, now abandoned.

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured, used and licensed by or for the Government for governmental purposes without the payment to me of any royalty thereon.

SUMMARY OF THE INVENTION

In military and civilian construction, road building and the like, large stones, boulders, or quarries are often available on the site or nearby. Small broken stone of predetermined size is needed as aggregate for making concrete and other purposes. Large stone crushers are ordinarily too bulky, heavy, and expensive to be brought to the construction site. Hauling of crushed stone from distant crushing plants is time-consuming and expensive.

The present invention provides comparatively lightweight transportable equipment, and a special method of operation, to produce substantial quantities of broken stone on the site by repeated alternating cycles of sudden heat shock and cooling of rocks.

The thermal rock breaker according to the invention is a system which utilizes electrical energy to produce high-temperature, non-piercing hydrogen plasma flames that are projected against the surfaces of large pieces of rock in a chamber, applying a sudden heat shock to the rock surfaces, and cooling the heat-shocked rocks in the chamber with chilled air or other coolant fluid, which causes disintegration or exfoliation of the surface regions of the rocks. The heating and cooling cycle is repeated until the rocks are reduced to fragments of predetermined size. Vibration is applied to the rocks in the chamber to separate the fragmented outer regions of the rocks and expose a fresh surface area to the effects of the next heating and cooling cycle. The precooled air or other coolant fluid is provided by the system for use in the cooling medium for the operating components thereof such as the hydrogen plasma torches which provide the heat shock during the heating portion of the cycle. Electrical energy for operating the heating and cooling equipment is advantageously provided by a power unit such as a turbo generator built into the system.

Depending on the characteristics of the type of rock being processed, the large rock material in the chamber may be advantageously exposed to a preliminary chilling step before the first heat shock is applied.

Cold air is the preferred cooling medium because of its abundance and ready convertibility into a cooling medium by electrical energy; however, another cold inert gas such as cold nitrogen or carbon dioxide may be employed.

A cold liquid coolant such as water may also be used, but is more difficult to apply to the chamber in the cycle, and may not be locally available.

THE DRAWINGS

FIG. 1 illustrates a preferred embodiment of the invention, in perspective.
one or several additional treatment cycles till they too are reduced to the desired small size.

A console 18 is advantageously mounted on one of the supporting legs, illustrated at 16 in FIG. 2 for controlling the movements of chamber sections 3, 4, the alternating heating and chilling cycles, and the vibration, by means of conventional electric motors (not shown) connected to the console and to power unit 7 by conventional circuit wires. As also shown in FIG. 2, coolant supply line 10 and hydrogen supply line 13 pass through or along leg 16 into manifolds which supply the hydrogen plasma torches 11 with hydrogen, and blow pipes 12 with coolant fluid. Console 18 may be operated manually or by remote control.

The hydrogen plasma torches 11, known to those skilled in the art, comprise tungsten electrodes which are in a cooled tube filled with hydrogen. The hydrogen gas passing through the tubes is heated to about 25,000°F and ionized. The diatomic hydrogen is dissociated into atomic form prior to being ionized. The heat of reassociation coupled with the heat released as the gas drops in temperature makes the hydrogen plasma very effective in heating material. The nozzles are selected or set to spread the flames in a heating pattern rather than a piercing pattern. The tubes of the torches may be cooled by circulating pre-cooled air such as that which is used also in the alternate cycles of rock chilling and heating. The hydrogen is advantageously provided from a separate tank (preferable mobile) through tubing 13.

The time and temperature of the flame must be adjusted to avoid a temperature rise in the rocks sufficient to melt them, as distinguished from heat-fissuring.

During chilling, streams of pre-cooled air are directed through blowpipes, as diagrammatically illustrated at 12, and through the spaces between the rocks to chill the surfaces thereof. The cold air may be obtained by drawing atmospheric air through a conventional cooling unit 9 using vapor compression principles or the Joule-Thomson effect. This means of cooling the rock precluded any effect of the Leydenfrost phenomenon occurring on the rock surface. A cold air temperature of about −30°C (−22°F) is suitable but may vary widely, e.g., as low as −100°F. Additional coolant may be drawn from tank 8.

The size of the aggregate depends on the cyclic time periods of heating and chilling, temperatures utilized, and the characteristics of the particular type of rock being broken.

To give some concept of performance characteristics the following data may serve as an indicator for the apparatus when breaking rocks (e.g., diabase traprock, granite, gneiss, sandstone, shale and limestone, which have melting temperatures of about 1,850° to 2,750°F). To crush about 100 tons per hour, one needs a processing chamber capacity of about 13.5 cubic feet, a time of about 30 seconds, for cycle, a torch flame temperature of 10,000°F, and arc voltage of 440 dc, arc current of 100 amps, hydrogen consumption rate of 80 cubic feet/hour at 25 psi, a precooled air temperature of −100°F, a cyclic air pressure of 3,000 to 5,000 psi, and a fuel consumption rate of 17.4 gallons/hour. The basic vehicle weight is under 4,000 pounds and the equipment weight is less than 5 tons.

Other heat sources, such as radiation or multiburner oxygen, may be substituted for hydrogen plasma with suitable engineering modifications.

Cooling media other than cold air, e.g., cryogenic nitrogen or carbon dioxide may also be used for the practice of my invention, but are presumably less cost effective. Water as the coolant medium effectively cools the hot rocks, but is more difficult to introduce into and eliminate from the chamber in the course of repeated cycles of heating and chilling of the rocks than is the case with a gaseous fluid such as cold air. Effective chilling of the rock surfaces between repeated applications of heat shocks is necessary as otherwise the rocks would melt or soften rather than fissure. Typical thermal softening temperatures for various types of rocks are: Sioux Quartzite 1,740°C; Charcoal Granite 1,230°C; Dresser Basalt 1,150°C. Judicious use of intermittent chilling prevents the rocks from attaining these heating limits. Thus, in the case of Dresser Basalt, a first heat shock may raise the internal temperature to 1,000°C to induce surface heat-fissuring; however, before the next heat shock is applied, the rock is chilled to reduce its internal temperature to about 600°C and less.

From the foregoing description of the principles of my invention and of a preferred embodiment of the same it is evident that modifications and adaptations will readily occur to the expert without departing from the essence and spirit of the invention. I therefore intend to encompass such modifications and adaptations within the scope of my invention, and to this end define the same in the appended claims.

1. Process for thermal breaking of large stones comprising the steps of
   a. placing said stones in a chamber;
   b. applying a sudden heat shock to said stones in said chamber, said heat shock being sufficiently intense to crack at least the surfaces of said stones, but insufficient to melt said stones;
   c. cooling said heat-shocked stones in said chamber;
   d. vibrating said stones in said chamber at least intermittently;
   e. and repeating said heat-shocking, cooling and vibrating until said stones are broken into fragments of predetermined size.

2. Process according to claim 1 wherein said large stones are precooled in said chamber before applying the first heat shock.

3. Process for thermal breaking of large stones comprising the steps of
   a. placing said stones in a chamber;
   b. applying a sudden heat shock to said stones in said chamber, said heat shock being sufficiently intense to crack at least the surfaces of said stones, but insufficient to melt said stones;
   c. cooling said heat-shocked stones in said chamber, whereby a mixture of large and small stone fragments is obtained in said chamber;
   d. separating said small stone fragments from said large stone fragments;
   e. applying another sudden heat shock to said large stone fragments remaining in said chamber, said heat shock being sufficiently intense to crack at least the surfaces of said large stone fragments, but insufficient to melt said stone fragments;
f. cooling said last-named heat-shocked stone fragments in said chamber, whereby a mixture of medium-size and small stone fragments is obtained in said chamber;
g. separating said small stone fragments;
h. and repeating said heat-shocking and cooling of the stone fragments remaining in said chamber until they are reduced to stone fragments of predetermined size.

4. Process according to claim 3 wherein said large stones are precooled in said chamber before applying the first heat shock.

5. Process according to claim 1 wherein said heat shocks are applied in the form of hydrogen plasma.

6. Process according to claim 3 wherein said heat shocks are applied in the form of hydrogen plasma.

7. Process according to claim 1 wherein said cooling is effected by a cold gas.

8. Process according to claim 7 wherein said cold gas is cold air.

9. Process according to claim 3 wherein said cooling is effected by a cold gas.

10. Process according to claim 9 wherein said cold gas is cold air.

11. Process for thermal breaking of large stones comprising the steps of

a. placing said stones in a chamber;
b. precooling said stones in said chamber;
c. applying a sudden heat shock to said stones in said chamber, said heat shock being sufficiently intense to crack at least the surface of said stones, but insufficient to melt said stones;
d. cooling said heat-shocked stones in said chamber;
e. and repeating said heat-shocking and cooling until said stones are broken into fragments of predetermined size.

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