Nov. 14, 1967 E. V. SCHULTE 3,352,498

EXPLOSIVE SHATTERING METHOD AND APPARATUS

Filed Dec. 16, 1965 2 Sheets-Sheet 1

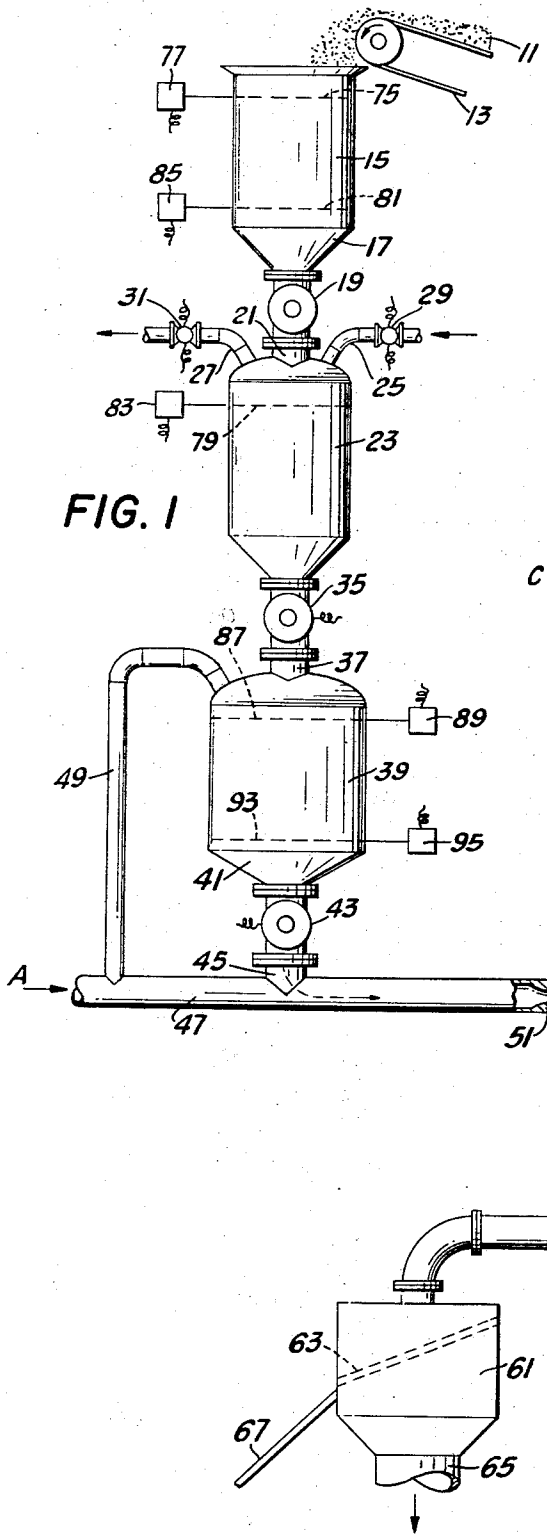


FIG. 1

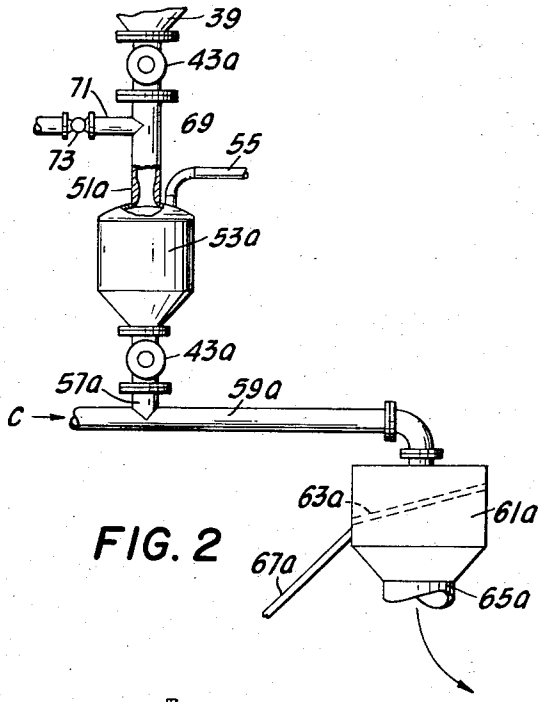


FIG. 2

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EXPLOSIVE SHATTERING METHOD AND APPARATUS

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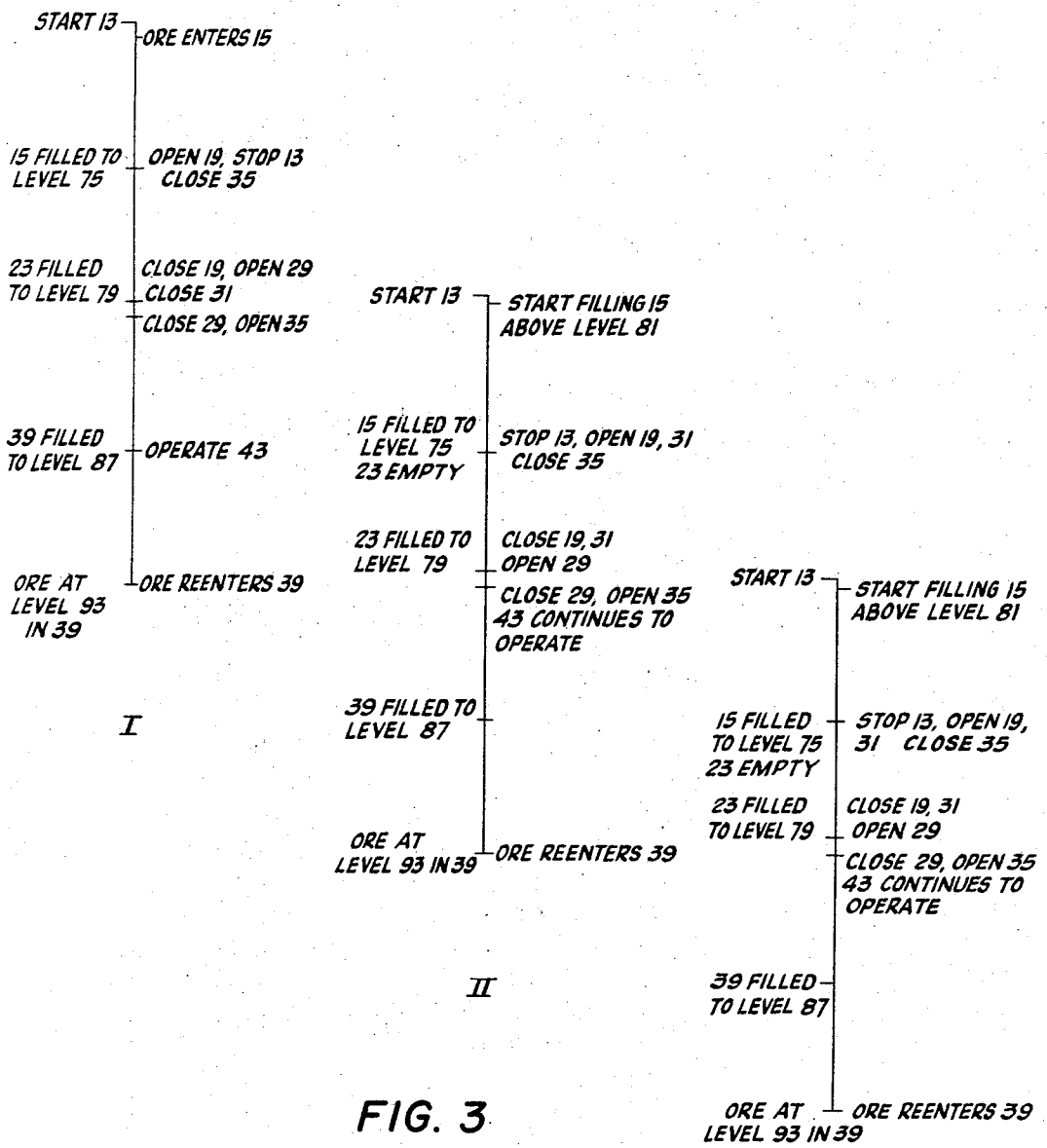


FIG. 3

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United States Patent Office 3,352,498 Patented Nov. 14, 1967

3,352,498

EXPLOSIVE SHATTERING METHOD AND APPARATUS

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Filed Dec. 16, 1965, Ser. No. 514,273
8 Claims. (Cl. 241—1)

The present invention relates to comminution and more particularly to improved method and apparatus for continuously disintegrating materials such as ores and the like.

The United States Department of Interior, Bureau of Mines, Bulletin No. 402, published by the United States Government Printing Office, 1938 and entitled "Crushing and Grinding," by Mr. John Gross, discusses, particularly at pages 70 et seq., the explosive shattering of ore material preparatory to the recovering of valuable metals from the ore. In pressure shattering, essentially the material to be comminuted is surrounded and impregnated with a gas under pressure, and thereafter the gas pressure is suddenly reduced. Mr. Gross concluded that the resulting breaking down of the material into smaller discrete particles results from several mechanisms: (1) shattering of the large particles by forces from pores and crevices in the particle; (2) shattering of the particles by forces external to the particle; (3) thermal breaking of the structure by high temperature; and (4) breaking of the particles by impact between particles and between particles and the vessel they are in.

While Bulletin No. 402 discusses the application of explosives shattering to a wide variety of materials, the equipment that is described on pages 72 and 74 of the Bulletin for carrying on the process is suitable for a laboratory batch process only, and such apparatus, and the process as well, is unsuited to industrial use. Consequently, the Gross batch process has not become commercially feasible.

The present invention, however, contemplates method and apparatus for the continuous explosive shattering of materials such as ores and the like. The method of the invention includes filling successively a series of vessels with friable material particles to be comminuted and pressurizing the material in one vessel from which it flows at a selected rate into a conduit. A pressurized gas, flowing in the conduit, conveys the particles of material through a velocity-increasing section of the conduit and discharges the material into another vessel wherein the pressure is significantly lower than the pressure in the conduit ahead of the velocity increasing section. The particles of material enter the other vessel and are comminuted by explosive shattering and impact.

For a further understanding of the present invention and for advantages and features thereof, reference may be made to the following description taken in conjunction with the accompanying drawings which show, for the purpose of exemplification, embodiments of the invention.

In the drawings:

FIG. 1 is a schematic arrangement of the equipment suitable for practicing the method of the invention;

FIG. 2 is another schematic arrangement of a portion of the equipment of FIG. 1; and

FIG. 3 is a diagram of related time sequences of operation of the apparatus.

In FIG. 1, ore **11**, or other material that is to be disintegrated, is conveyed by means of a conventional belt conveyor **13** to the upper end of a storage or receiving hopper **15**, and the ore **11** or other material discharges from the conveyor **13** into the hopper **15**. The primary hopper **15** is provided with a conventional conical bottom **17** which connects directly to a conventional type rotary plug valve **19**, or the like, that is adapted for regulating and controlling the flow of ore material from the storage hopper **15**.

The discharge end of the rotary plug valve **19** connects to a conduit **21** leading into another container or primary hopper **23** which is provided with a pair of spaced apart conduits **25, 27**, which are connected to solenoid operated valve closures **29, 31** respectively.

The primary hopper **23** also has a conical bottom **33** that connects directly to another rotary plug valve **35** that is solenoid operated preferably. The rotary plug valve **19** may be manually operated or, as is preferred, it may be operated by solenoid operated in a manner similar to the operation of the rotary plug valve **35**. As shown in FIG. 1, the discharge end of the rotary plug valve **35** is connected to a conduit **37** that leads directly into another container or feed tank **39**.

The feed tank **39** also has a conical bottom **41** that connects to the inlet end of a rotary feeder, or star-wheel feeder, **43**. A suitable type of feeder is disclosed in Patent Nos. 3,178,236 and 3,178,237.

As suggested in FIG. 1, the receiving hopper **15**, the primary hopper **23**, and the feed tank **39**, are preferably arranged in a vertical substantially axially aligned manner beneath the upper or discharge end of the belt conveyor **13**. The rotary feeder **43** discharges into a relatively short vertical conduit **45** that is connected to a horizontal conduit **47** disposed substantially at right angles to the axes of the conduit **45** and hoppers **15, 23** and **39**. Thus, it is evident that the ore material **11** entering the receiving hopper **15** proceeds under the influence of gravity vertically downward through the hoppers **23** and **39** into the horizontal conduit **47** at a rate of flow that is regulated by the plug valves **19, 35** and the rotary feeder **43**.

The horizontal conduit **47** is connected by means of another conduit **49** to the top of the feed tank **39** for a purpose that will become evident hereinafter.

The conduit **47** is connected to a supply of a gaseous fluid that is maintained under a suitable pressure in a vessel (not shown) from which the gaseous fluid flows into the conduit **47** generally in the direction of the arrow A. The right hand end of the horizontal conduit **47**, as seen in FIG. 1, connects to a venturi section **51** that is preferably attached to and communicated directly with another container **53**. The material **11** passing through the venturi section **51** enters the container **53** and is explosively shattered into small particles. Thus, the container **53** serves as a separator for the disintegrated ore material and for the gaseous substance that conveys the ore into the separator. The disintegrated ore material, being heavier than the gaseous substance, gravitates to the lower region of the container **53** and exits therefrom via another rotary feeder **43** which communicates with a short conduit **57** connected to a horizontal conduit **59**. The separated gaseous substance, within the container **53**, exits the container by means of a conduit **55** shown in FIG. 1 connected preferably to the top of the container.

The horizontal conduit **59** communicates with another container **61** wherein there is a conventional type vibratory screen **63**. A suitable gaseous substance, flowing in conduit **59** generally in the direction of the arrow B conveys the disintegrated particles passing through the rotary feeder **43** into the container **61**, and thereafter the disintegrated material is screened by means of the vibratory screen **63**; particles of the material having a proper size pass through the screen and exit the container **61** via a suitable conduit **65**. Oversized particles, however, gravitate down the inclined vibratory screen **63** and exit the container **61** on a suitable inclined slide or chute **67**; the over-

sized particles are returned to the ore **11** on the belt conveyor **13** and are reprocessed.

The apparatus of FIG. 1 is suitable in most instances for carrying out the method of the present invention to continuously explosively shatter material such as ore and the like, but yet, it is recognized, that there may be instances where another form of apparatus may be more suitable. The apparatus shown in FIG. 2, for example, may be more suitable: (1) where the density of the raw ore particles is high; or (2) where it is desirable for economical reasons to avoid excessive precrushing so that relatively large sized ore particles are used initially; or (3) where it is uneconomical to use a sufficiently high ratio of conveying fluid to ore particles to suspend and carry the ore through the horizontal conduit **47** and venturi section **51**.

FIG. 2 illustrates another arrangement of only the lower portion of the apparatus of FIG. 1; the apparatus above the portion being substantially identical to that shown in FIG. 1. In the arrangement shown in FIG. 2, the material to be disintegrated is already in the feed tank **39**. From the feed tank **39**, the material moves through a rotary feeder **43***a* and thence into a vertical conduit **69** that leads, in a straight vertical line preferably, directly through a venturi section **51***a* that is directly connected to a container or separator **53***a*. It is to be understood that the equipment **43***a*, **51***a*, and **53***a* are in general similar or identical to the equipment units **43**, **51**, and **53** described hereinbefore. Between the venturi section **51***a* and the exit to the rotary feeder **43***a*, there is provided a conduit **71** that communicates with the vertical conduit **69**, and there is provided in the conduit **71** a suitable closure or valve **73**.

The container or separator **53***a* serves the same purpose as the container or separator **53** mentioned hereinbefore and accordingly the disintegrated material or ore exits the bottom of the container **53***a* through a rotary feeder **43***a* that is similar to the rotary feeder **43** shown in FIG. 1. Likewise, the material discharged through the rotary feeder **43***a* enters a short vertical conduit **57***a* and discharges into a horizontal conduit **59***a*. A suitable gaseous substance, flowing in conduit **59***a* generally in the direction of the arrow C, conveys the disintegrated material entering from conduit **57***a* into another container **61***a* wherein there is a vibratory screen **63***a*. Properly sized particles pass through the vibratory screen **63***a*, as explained hereinbefore, and exit the container **61***a* via a suitable conduit **65***a*; whereas, oversized particles exit the container **61***a* via an inclined downwardly extending chute **67***a* and are conveyed thence to the material conveyor **13**. It should be understood that the equipment units **57***a*, **59***a*, **61***a*, **63***a*, **65***a*, and **67***a*, are similar to or identical to the units **57**, **59**, **61**, **63**, **65** and **67** described hereinbefore.

The material to be treated is first subjected to a preliminary crushing to reduce it to a particle size that is convenient to use for further reduction in size. The sizes of the pieces produced in this preliminary step will be determined to some extent by the type of material or ore, and the final treatment to be given the material or ore. Generally, in this preliminary treatment, the pieces may be reduced to a size in the range of from ¼–½ inch. Any suitable type of crusher may be employed for this preliminary treatment.

As carried into practice, the method of the present invention comprises several steps commencing initially with the step of delivering at a desired rate the pretreated material or ore **11** to the receiving hopper **15** by means of the conveyor **13**. While a conventional belt type conveyor has been selected and shown in FIG. 1 for the purpose of exemplification of the invention, it is to be understood that a skip hoist, screw conveyor, or other suitable delivery apparatus may be used if desired.

Initially, the rotary plug valve **19** is closed and the ore particles fill the receiving hopper **15** to a level such as is indicated at level **75**, whereupon a conventional type level controller **77** is actuated and the belt conveyor apparatus **13** is stopped. At the same time, the rotary plug valve **19** is actuated either manually, by a solenoid device, or other suitable apparatus, so that the ore particles discharge from the receiving hopper and flow into the primary hopper **23**; the rotary plug valve **35**, being also closed initially before the ore particles enter the hopper **23**. The valve **29** is initially closed while the valve **31** is initially open to allow air displaced within the hopper **23** by the ore particles to escape to atmosphere. The valves **29** and **31** are preferably solenoid operated valves.

The ore particles fill the hopper **23** to a convenient level **79** and the level of the ore in the receiving hopper **15** falls to a level **81**. As the ore particles reach both levels **79** and **81**, respective level controllers **83** and **85** become operative. The level controller **83** motivates the closure of the solenoid vent valve **31** and the opening of the solenoid operated pressure control valve **29**. Simultaneously, the level controller **85** motivates the stopped belt conveyor **13** so that it commences to deliver ore to the receiving hopper **15**. Likewise, the level controller **85** simultaneously closes the rotary plug valve **19** and stops the flow of ore particles through it.

Thereafter, a compressible gaseous fluid, such as steam, air, carbon dioxide, nitrogen, argon, ammonia, and the like, or a mixture thereof, that is under a superatmospheric pressure in the range from about 500 to 1000 p.s.i. gauge, is introduced into the primary hopper **23** through the conduit **25**. The same gaseous fluid at substantially the same pressure also flows in the conduits **47**, **49** and fills the feed tank **39** pressurizing it to the same pressure. The rotary feeder **43** at this particular moment is inoperative.

As soon as the pressure stabilizes in the primary hopper **23**, and particularly during the initial steps of the methods of the invention, the rotary plug valve **35** is open and the ore in the pressure primary hopper passes into the feed tank **39**; the ore reaching an initial level at **87**. The pressure is substantially the same in the hopper **23** and the feed tank **39** so that ore freely gravitates from the hopper **23** to the tank **39**. When the ore reaches the level **87** in the tank **39**, another level controller **89** becomes operative and simultaneously closes the rotary plug valve **35**, opens the vent valve **31**, and also motivates the rotary vane feeder **43**. Thereupon, the ore particles, which are under the same gaseous fluid pressure in the feed tank **39** as is in the conduit **47**, discharge from the rotary feeder **43** into the stream of a gaseous fluid flowing in the conduit **47** in the direction of the arrow A, that is toward the venturi section **51**.

The ore level **87** in the feed tank **39** falls as the ore discharges from the tank, and when the ore reaches the level **93**, another level controller **95** becomes operative. The level controller **95** operates to close the rotary plug valve **19**, to close the vent valve **31**, and to open the rotary plug valve **35**.

It should be understood that as soon as the first charge of ore particles leaves the receiving hopper **15**, as described hereinbefore, the conveyor **13** commences to deliver another quantity of ore particles to the hopper **15**. Likewise, as soon as the first quantity of ore leaves the primary hopper **23**, the second quantity of ore in the primary hopper **15** flows via the opened rotary plug valve **19** into the primary hopper **23**. The second quantity of ore particles pass from the primary hopper **23** after being pressurized in the manner the first quantity of ore flows into the feed tank **39**, and the level **93** of ore in the feed tank **39** raises until it reaches the level **87**, when the level operator **89** again becomes operative.

Thus, it is evident that the ore particles between the levels **93** and **87** in the feed tank **39** continually flow from the feed tank **39** into the fluid conducting stream in conduit **47** while ore particles are being fed continually through the receiving hopper **15**, the primary hopper **23**, and into the feed tank **39** through the several rotary plug valves therebetween.

The particles of ore which enter the conduit **47** are suspended in the gaseous fluid therein and conveyed

through the venturi section 51 into the container 53. The pressure of the gaseous fluid on the upstream side of the venturi section 51 is substantially the same as the pressure of the gaseous fluid in the feed tank 39, the primary hopper 23, and in the conduits 25 and 49. But, however, the pressure of the gaseous fluid on the downstream side of the venturi section is less than the pressure on the upstream side. Thus, the ore particles and the gaseous fluid escape from the venturi section exit at a relatively high velocity but at a pressure that is substantially lower than the pressure in conduit 47 in front of the venturi section 51. And so, the particles are, in effect, "jetted" directly into the separator 53 which is maintained at atmospheric pressure in most instances, or, in some cases, at subatmospheric pressure.

Immediately the conveying gaseous fluid and the ore particles enter the separator 53, the volume of the gas increases tremendously due to the great difference in pressure of between a zone just before the entrance to the venturi section 51 and a zone immediately within the container, adjacent the exit of the venturi section. The individual ore particles are thereupon subjected to both external and internal explosive shattering forces which produce a disintegrating or shattering effect on the individual particles.

What actually happens to each particle of ore when it enters the separator is not entirely understood, but it is believed that the comminution that results is derived from one or more of several occurrences. Such occurrences are thought to include: (1) a portion of the carrying fluid may become trapped in crevices, pores, cavities, in the particles and when the ambient pressure is suddenly reduced, the trapped fluid expands with enough force to shatter the particles along natural cleavage lines; or (2) the pressurized carrying fluid envelopes each particle and this envelope of pressurized fluid "explodes" when the pressure is suddenly reduced as in the separator 53, whereby external explosive forces act upon all points of the particle rather than along the cleavage lines or at some particular point on the surface of the particle; or (3) particles acted upon by both the external forces and the internal forces collide and produce impact forces that tend to disrupt the particles; and (4) in the case where the carrying fluid is high pressure (high temperature) steam, the temperature of the particles are raised considerably and the sudden cooling of the particles when they enter the lower pressure in the separator 53, causes thermal shock that fractures the particles.

What actually happens, as explained hereinbefore, may be a combination of these events or some other event not recognized up to the present. The results are graphic and are satisfactory in most instances. Only in a few cases is it necessary to re-run particles a second time.

In many cases, the particles of material distintegrate along natural lines of cleavage and such comminution is referred to herein as "differential shattering."

FIG. 3 illustrates in a graphic form a sequence of events in the operation of the apparatus of FIG. 1 to achieve a substantially continuous explosive shattering of ore material 11. Three phased sequences, I, II and III, are delineated for the purpose of showing the interrelation between the various events that occur during the continuous operation of the apparatus of FIG. 1.

Commencing with sequence, I, the first operation is to start the conveyor mechanism 13 whereby a quantity of material such as ore 11 is delivered to the receiving hopper 15. The ore enters the receiving hopper 15 (there is no ore in the hopper initially) and fills it to the level 75, at which time the rotary plug valve 19 is opened, the conveyor 13 is stopped, and the rotary plug valve 35 is closed. As soon as the rotary plug valve 19 opens, the ore material 11 in hopper 15 gravitates into the primary hopper 23 and, because the plug valve 35 is also closed, the material fills the primary hopper 23 up to the level 79. At this particular moment the rotary plug valve 19 closes and the valve 29 opens allowing the pressurized gaseous fluid to enter the primary hopper 23 and permeate the void spaces therein.

At this particular moment it will be remembered that the conveyor 13 is stopped when the ore particles in the receiving hopper 15 reach level 81. And so, referring to sequence II, as soon as the primary hopper 23 is filled to the level 79 the conveyor 13 is started. Shortly thereafter, the material commences to refill the primary hopper above level 81 and the entire sequence of II has now begun.

Referring again to sequence I, shortly after the level of ore particles in 23 reaches level 79, the valve 29 is closed and the rotary plug valve 35 is opened thereby allowing the ore particles in 23 to gravitate into the feed tank 39. Because the rotary feeder 43 is not yet in operation, the ore particles fill the feed tank 39 to the level 87. Thereafter, the rotary feeder 43 commences to operate and the ore particles discharge from the feed tank 39 through the rotary feeder 43 into the horizontal conduit 47, whereupon they are carried by the pressurized gaseous stream flowing in the direction A toward the venturi section 51.

The ore particles flow continually from the feed tank 39. When the ore reaches a level such as level 93, the ore, which has been previously fed into the primary hopper 23 in accordance with sequence II, now commences to flow through the rotary plug valve 35 into the feed tank 39 at such a rate that the level of the ore particles rises from level 93 to 87.

It should be understood that while the ore particles are gravitating from the primary hopper 23 into the feed tank 39, the rotary feeder 43 continues to operate and material flows continually from the feed tank 39 into the horizontal conduit 47. The rate of flow from the feed tank 39 is proportionately less than the rate of flow of material into the feed tank so that, consequently, the level of the ore particles rises from level 93 to 87 in the feed tank 39.

Referring to sequence III, it will be noted that, when the level of ore in the primary hopper 23 reaches level 79 in sequence II, the belt conveyor 13 is again started and shortly thereafter material flows into the receiving hopper 15 filling it to the level 75 and the sequence III commences.

It was mentioned previously that there are numerous gaseous fluids that are suitable for pressurizing and conveying the materials such as ore particles into the separator 53 wherein explosive shattering of the ore particles takes place. In most applications, steam will be found to be suitable and advantageous because it is readily available and is inexpensive to produce. The pressure of the steam in the conduits 25, 47, 49 and in the containers 23, 39 should be sufficiently high so that when the steam and the ore particles entrained therein pass through the pressure reducer 51 and emerge into the separator, there is a very great expansion of the volume of the steam and consequently a significantly more effective explosive shattering of the ore particles.

The conduit 47, in a typical embodiment of the invention, should be so sized that the rate of flow of the ore particles from the feed tank 39 through the rotary feeder 43 and into the conduit 47 will be in the range of 5 to 100 ft./sec., and the ore particles should be of such a size that they will remain in substantial suspension in the pressurized gaseous fluid flowing in the conduit 47.

The pressure reducer 51 may, of course, have many forms such as an adjustable orifice, a fixed size orifice, and adjustable venturi, but, in a preferred embodiment of the invention, a fixed size venturi is preferred. Such a venturi section 51 is indicated in FIG. 1 and would be made from highly erosion resistant material such as silicone carbide, tungsten carbide, precipitation hardened stainless steels of the 440C Class or such erosion resistant

materials might be coated on a base metal such as ordinary steel.

After the explosive shattering has taken place, and such shattering takes place within a zone which is adjacent the exit end of the venturi section **51**, the steam condenses to moisture, and the shattered particles and droplets of moisture gravitate to the bottom of the separator chamber **53**. Gases which are present in the separator chamber **53** are vented into the conduit **55** and conveyed away from the separator apparatus.

The shattered particles are removed from the bottom of the separator **53** through the rotary feeder **43**, and the shattered particles are then screened for size on the vibratory screen arrangement **63**. Whatever particles are oversized and do not pass through the screen, are removed from the chute **67** and are thereafter fed back to the conveyor belt **13** for reprocessing. Proper sized particles, those which pass through the screen **63**, are conducted from the container **61** via the conduit **65** to another convenient location for further processing.

The gases that are vented from the separator **53** by means of conduit **55**, generally contain some fine dust particles of ore, and, accordingly it is desirable to pass such dust-laden gases through the suitable scrubber apparatus (not shown).

While the apparatus shown in FIGS. 1 and 2 utilize a separator **53** that is subjected internally to substantially atmospheric pressure, it is to be understood that in some instances, the pressure within the separator **53** may be subatmospheric. To achieve a subatmospheric pressure condition within the separator **53**, suitable vacuum pump apparatus or other form of exhauster may be connected to the separator in a known manner.

In some instances, the pressure of the gaseous fluid in the vessels **23**, **39** and in the conduit **47** may be in the range of 500 to 3000 pounds per square inch gage, nevertheless, the usual operating range will be, as mentioned hereinbefore, between 500 and 1000 pounds per square inch gage.

Although the invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made only as an example and that various modifications and changes may be made within the scope of the invention as defined by the appended claims.

What is claimed is:

1. The method for continuously comminuting friable material comprising the steps of:

(a) filling a first vessel with a first quantity of friable material;

(b) discharging said first quantity of material into a second vessel;

(c) pressurizing with a gas said second vessel and simultaneously commence refilling said first vessel with a second quantity of said material;

(d) discharging the pressurized first quantity of material from said second vessel into a third vessel whereby, the pressures in said second and third vessels become substantially equal;

(e) terminating the flow of said first quantity of material into said third vessel and simultaneously terminating the flow of said second quantity of material into said first vessel and simultaneously commence discharging said second quantity of material from said first vessel into said second vessel and simultaneously commence discharging the first quantity of material at a selected rate from said third vessel into a conduit wherein flows pressurized gaseous fluid, said material being conveyed in said conduit toward a fourth vessel;

(f) passing said flowing material flowing through a velocity increasing section in said conduit and thereafter discharging into said fourth vessel wherein the pressure is lower than the pressure in said conduit ahead of said section, said material being subjected to the effect of explosive shattering forces and disintegrating the discrete particles of said material;

(g) terminating the discharging of said second quantity of material from said first vessel and simultaneously pressurizing the material in said second vessel;

(h) discharging the pressurized second quantity of material from said second vessel into the third vessel, the pressures in said second and third vessels being substantially equal, and simultaneously commence refilling said first vessel with a third quantity of said material and simultaneously commence discharging said second quantity of material from said second vessel into said third vessel, the remainder of said first quantity of material in said third vessel continuing to selectively discharge from said third vessel into said conduit;

(i) terminating the flow of said third quantity of material into said first vessel and simultaneously commence discharging said third quantity of material into said second vessel;

(j) pressurizing said third quantity of material in said second vessel; and

(k) thereafter continuing said sequence of steps while said material continually discharges into said fourth vessel at a selective rate and is therein comminuted into particles of discrete size.

2. The invention set forth in claim **1** including:

(a) screening said discrete particles and separating oversized material particles from sized particles; and

(b) recirculating said oversized particles to said first vessel for re-shattering.

3. The invention set forth in claim **1** wherein:

(a) the pressure of fluid flowing in said conduit is within the range of about 500 to 3000 pounds per square inch gage.

4. The invention set forth in claim **1** wherein:

(a) the gaseous fluid flowing in said conduit is steam.

5. Apparatus for continuously comminuting friable material comprising:

(a) a first vessel for containing a first quantity of friable material;

(b) means for discharging said first quantity of material into a second vessel;

(c) means for pressurizing with a gas said second vessel and means for commencing the simultaneously refilling of said first vessel with a second quantity of said material;

(d) means for discharging the pressurized first quantity of material from said second vessel into a third vessel whereby, the pressures in said second and third vessels become substantially equal;

(e) means for terminating the flow of said first quantity of material into said third vessel and means for simultaneously terminating the flow of said second quantity of material into said first vessel and means for simultaneously commencing discharging said second quantity of material from said first vessel into said second vessel and means for simultaneously commencing discharging the first quantity of material at a selected rate from said third vessel into a conduit wherein flows pressurized gaseous fluid, said material being conveyed in said conduit toward a fourth vessel;

(f) a velocity increasing section in said conduit through which said material flows and thereafter discharges into said fourth vessel wherein the pressure is lower than the pressure in said conduit ahead of said section, said material being subjected to the effect of explosive shattering forces and disintegrating the discrete particles of said material;

(g) means for terminating the discharging of said second quantity of material from said first vessel and means for simultaneously pressurizing the material in said second vessel;

(h) means for discharging the pressurized second quan-

tity of material from said second vessel into the third vessel, the pressures in said second and third vessels being substantially equal, and means for simultaneously commencing refilling said first vessel with a third quantity of said material and means for simultaneously commencing discharging said second quantity of materials from said second vessel into said third vessel, the remainder of said first quantity of material in said third vessel continuing to selectively discharge from said third vessel into said conduit;

(i) means for terminating the flow of said third quantity of material into said first vessel and means for simultaneously commencing discharging said third quantity of material into said second vessel;

(j) means for pressurizing said third quantity of material in said second vessel and

(k) thereafter continuing said sequence of steps while said material continually discharges into said fourth vessel at a selective rate and is therein comminuted into particles of discrete size.

6. The invention set forth in claim 5 including:

(a) means to screen said discrete particles and separate oversized material particles from sized particles; and

(b) means to recirculate said oversized particles to said first vessel for re-shattering.

7. Apparatus for the continuous explosive shattering of ore particles comprising:

(a) a first hopper for receiving a supply of said ore particles;

(b) means for maintaining the supply of ore in said first hopper between predetermined upper and lower levels;

(c) a second hopper for periodically receiving ore from said first hopper;

(d) a third hopper for periodically receiving ore from said second hopper;

(e) a first conduit wherein pressurized steam flows;

(f) a second conduit communicating said first conduit and said third hopper whereby the ore therein is pressurized to the same pressure that is in said first conduit;

(g) means for pressurizing the ore in said second hopper to substantially the pressure in said third hopper;

(h) means between said first and second hoppers to

control the flow of ore therebetween and to maintain pressure within said second hopper;

(i) means between said second and third hoppers to control the flow of ore therebetween and to maintain pressure within said third hopper while said second hopper is being reloaded;

(j) a rotary vane feeder between said third hopper and said first conduit to regulate the flow of ore at a continuous rate between said third hopper and said first conduit;

(k) means to release the pressure in said second hopper preparatory to receiving ore from said first hopper;

(l) a velocity increasing venturi section in said first conduit connected to

(m) an expansion container for receiving the ore particles entrained in the pressurized gas flowing in said first conduit and through said venturi section, and wherein said ore particles are explosively shattered, the pressure in said expansion container being substantially lower than the pressure of the gas in said first conduit ahead of said venturi section.

8. The invention set forth in claim 7 including:

(a) a second rotary vane feeder connected to said fourth hopper to regulate the flow of explosively shattered ore particels at a continuous rate between said fourth hopper;

(b) a fifth hopper wherein there is a vibratory screen to sift and segregate said ore particles according to a preselected scale of sizes; and

(c) means for returning oversized ore particles to said first hopper.

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