May 11, 1954 D. WESTON 2,678,167

MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

Filed July 16, 1951 8 Sheets-Sheet 1

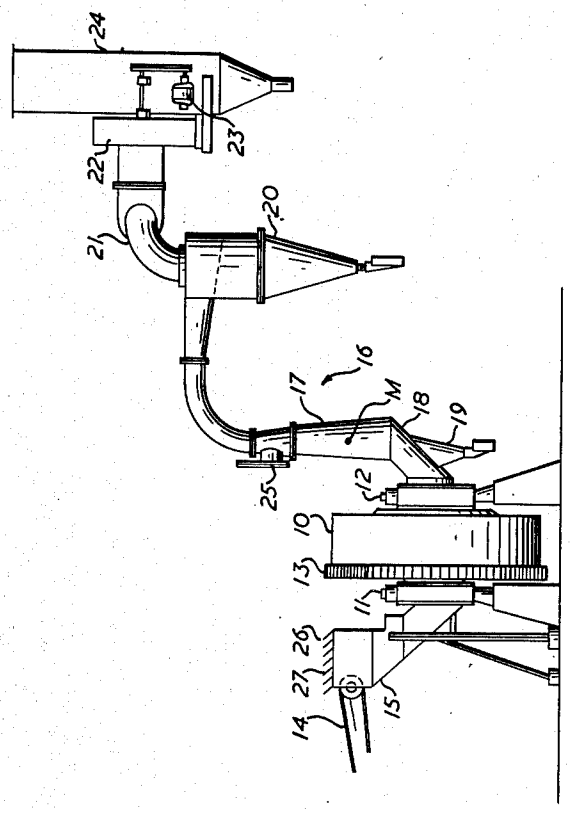


Fig. 1

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MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

Filed July 16, 1951 8 Sheets-Sheet 2

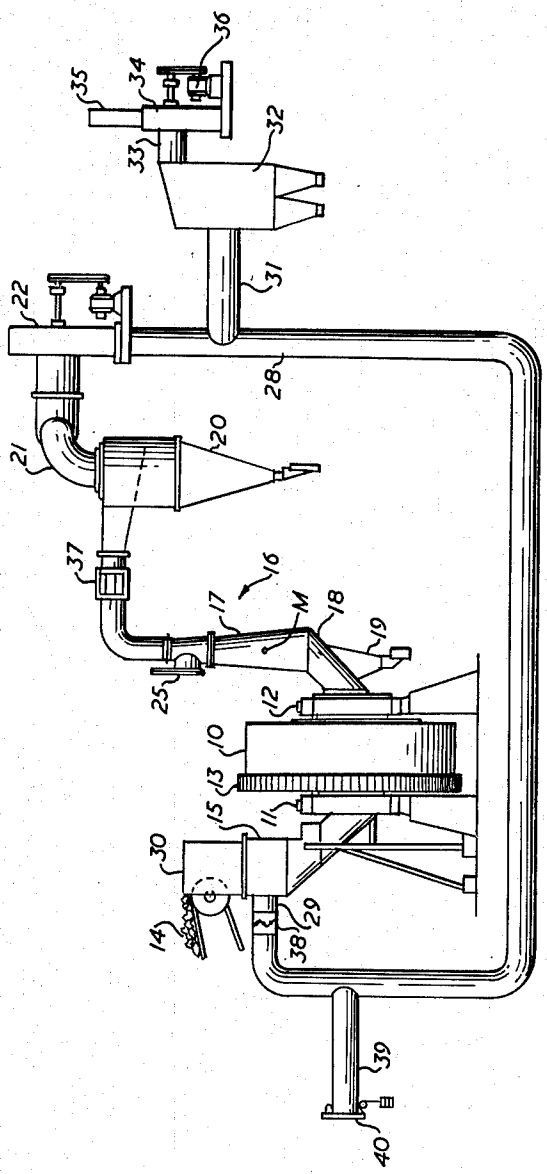


Fig. 2

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MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

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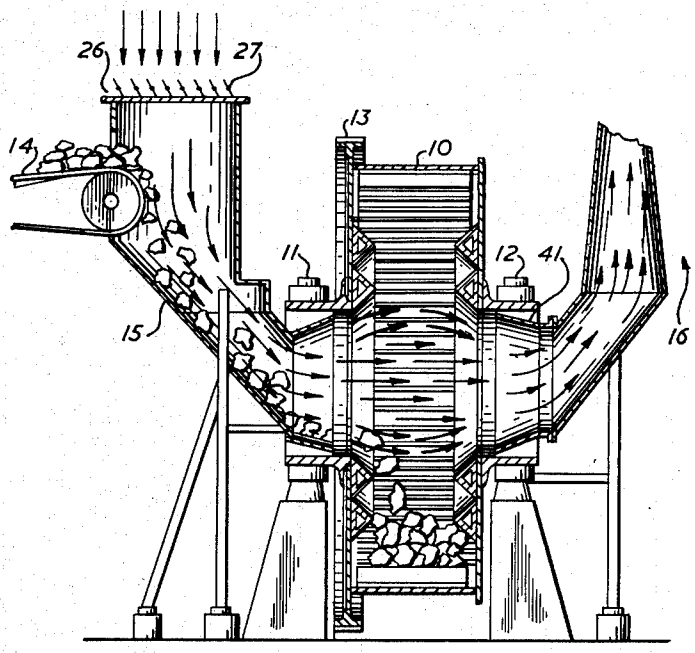


Fig. 3

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MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

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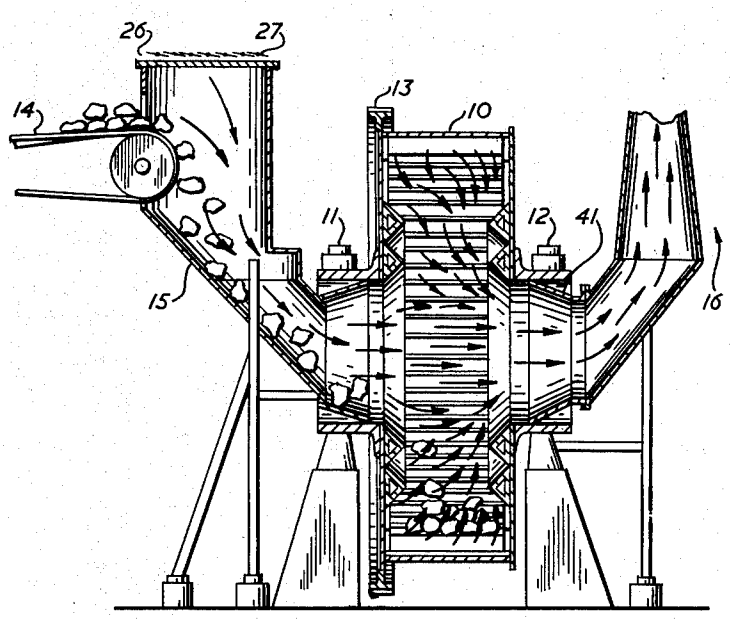


Fig. 4

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MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

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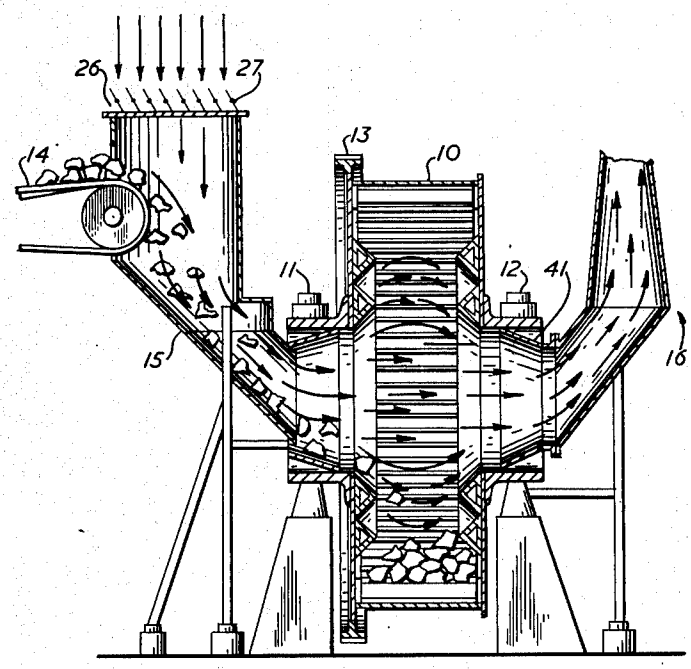


Fig. 5

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MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

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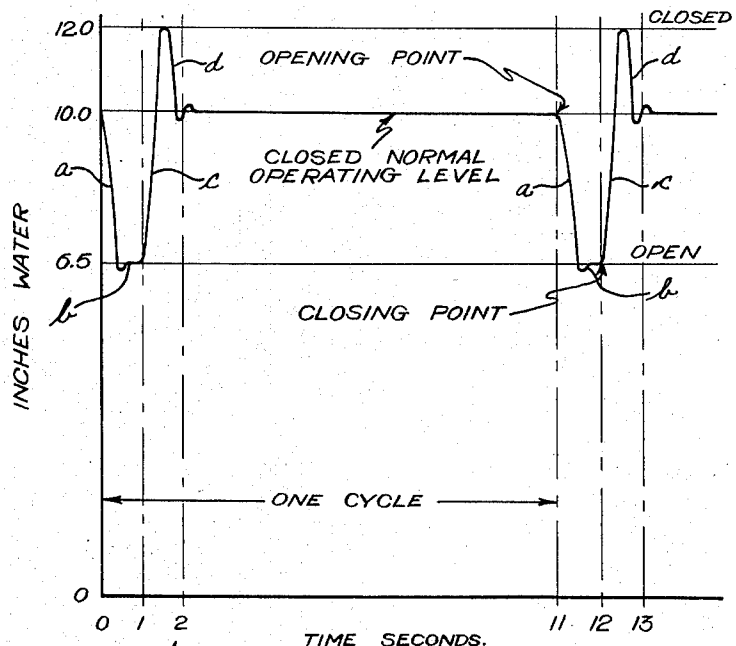


FIG. 6.

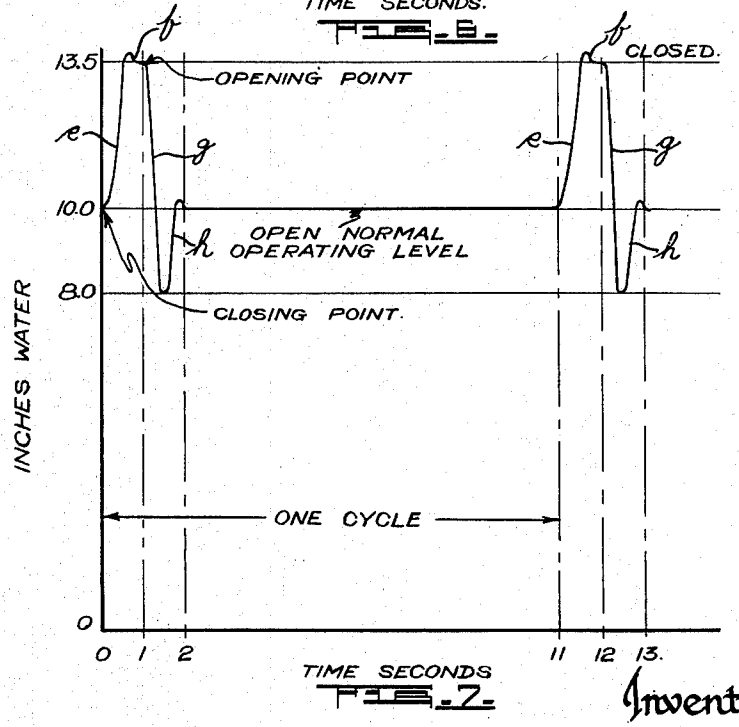


FIG. 7.

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MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

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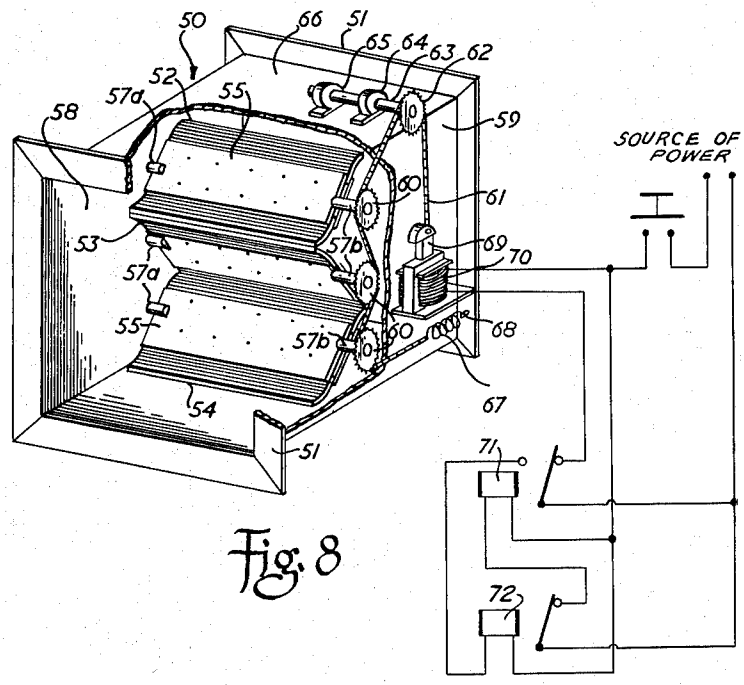


Fig. 8

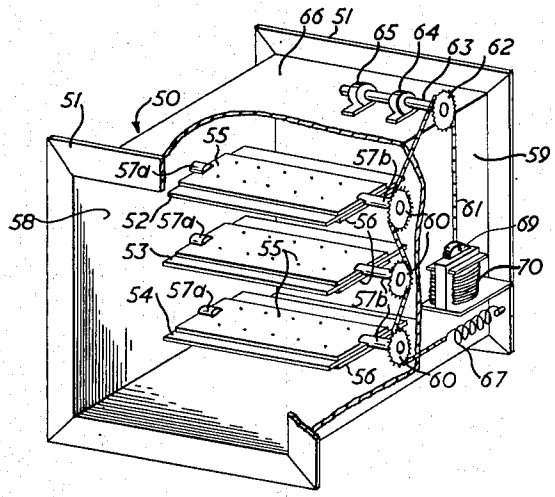


Fig. 9

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MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

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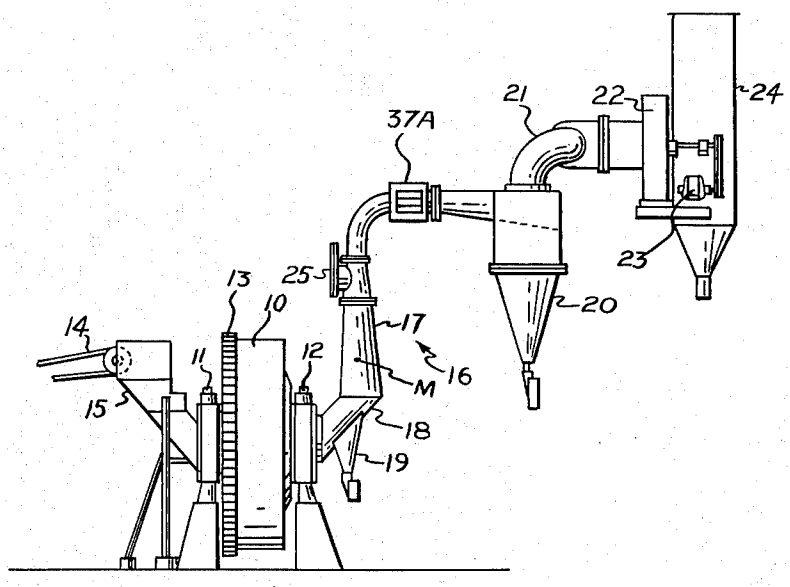


Fig. 10

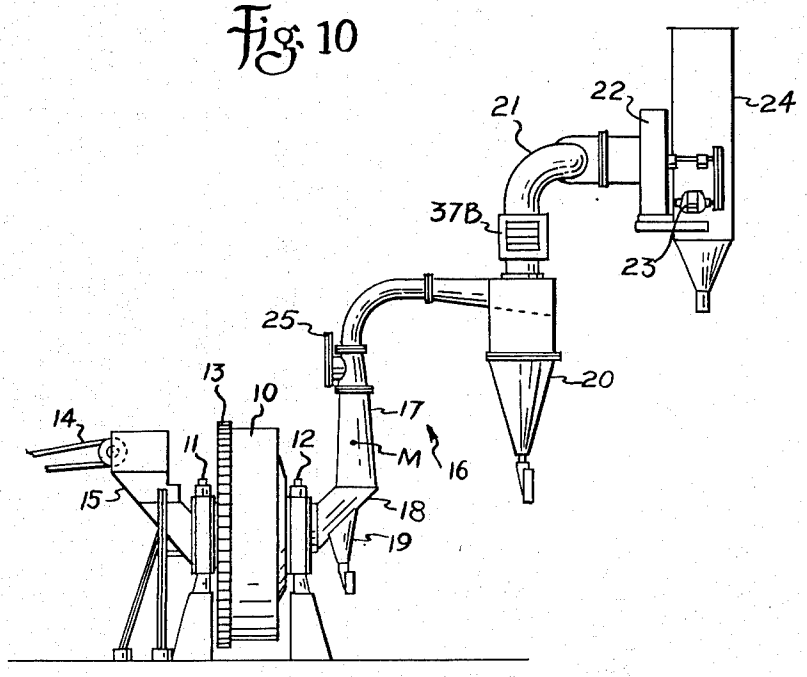


Fig. 11

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Patented May 11, 1954

2,678,167

UNITED STATES PATENT OFFICE

2,678,167

MATERIAL REDUCTION MILLS AND THE OPERATION THEREOF

David Weston, Toronto, Ontario, Canada

Application July 16, 1951, Serial No. 236,906

Claims priority, application Canada June 22, 1951

14 Claims. (Cl. 241—19)

1

This invention relates to material reduction mills, and more particularly it relates to an improvement in mills of the type which is charged through a port surrounding the axis of rotation of the drum and in which product is removed from the mill in a stream of air which is passed across the mill from the inlet port to an outlet port by suitable means situated on the outlet side of the mill.

Mills in which product is removed in a stream of air as aforesaid have long been known and have recently come into increasing use. An older type mill utilizing this arrangement is illustrated in Taggart (Handbook of Mineral Dressing (1945) Sec. 6, p. 22) while several new developments in this field are described in my co-pending applications Serial No. 749,131, filed May 20, 1947 (now Patent 2,555,171), Serial No. 175,353, filed July 22, 1950, and Serial No. 234,782, filed July 2, 1951, in connection with which the present invention may be used with particular advantage.

There has always been a problem in material reduction mills in connection with the over-grinding of some of the material, that is, in the ability of the system to remove the particles as soon as they are reduced to within the requisite size range. In some cases, due to this over-grinding factor, a portion of the product may be lost because it is either no longer recoverable economically or, by being so finely reduced, has lost the value which it would otherwise retain in its primarily coarse state. In all cases the power consumed in over-grinding represents a waste of energy. For instance, in the case of certain materials, such as asbestos, where it is desirable to reduce the material to its optimum form as an aggregate of primary crystals without breaking up the individual crystals themselves (N. B. in the case of asbestos, the fibre value is basically relative to the crystalline length of the fibres), over-grinding lowers the value of the product and may adversely affect subsequent processing steps to which the material is to be subjected.

The present invention provides a means of controlling over-grinding by the use of a simple novel method and apparatus which may be used in connection with mills employing a current of air for the withdrawing of the product. For convenience of reference hereafter, such mills will be referred to as mills "of the type described."

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Basically, material reduction mills of the type described consist of a drum which is usually, although not always, cylindrical in shape and which generally speaking is mounted for rotation in a vertical plane. The current of air in which the product is withdrawn is normally drawn through the inlet opening which generally surrounds the axis of rotation of the drum at one end thereof and across the drum through the outlet opening where it may proceed through a classifier of one sort or another and a product collector, the whole stream being motivated by a fan or impeller situated at or near the downstream end of the whole arrangement. In passing through the drum, the air current follows the path of least resistance which, generally speaking, means that the relatively high velocity portions of the stream capable of entraining product do not in general pass near the peripheral portions of the mill and thus it is only those particles, the paths of travel whereof happen to intersect the air stream, which are removed. On the other hand, particles of suitable size for removal in the air stream may remain in the mill for a susbtantial time before their paths of travel intersect the air current and such particles will, accordingly, be uselessly further reduced or over-ground.

According to the present invention, the particles of ground material lying in the peripheral regions of the mill are periodically at frequent intervals brought towards the centre of rotation of the mill for entrainment in the current of air by causing a sudden reduction in the air pressure within the drum. As soon as this sudden drop in pressure occurs, the air in the region of the periphery of the drum moves towards the centre thereof and towards the outlet port and, provided the drop in pressure is sudden enough, this movement of air from the peripheral portions of the mill takes place with sufficient velocity to entrain the particles of material in that region which are of a suitable size for removal from the mill. In fact, in one embodiment of the invention wherein a substantial vacuum is created within the drum such movement of air from the peripheral regions of the mill can be made to be sufficiently rapid to carry relatively large size particles into the central portions of the mill and in pilot mill practice particles up to three inches in diameter have been removed from the mill

in this manner. Under normal operating conditions the maximum sized particle which is removed from the mill is ½ to ⅔" in diameter.

The invention and the principles underlying its operation will be more fully understood by reference to the following detailed specification in conjunction with the accompanying drawings which illustrate a number of embodiments thereof.

In the drawings:

Figure 1 is a general side view of a mill of the type described comprising an "open" circuit for air circulation, embodying a feature of the invention and illustrating diagrammatically the general arrangement of components.

Figure 2 is a general side view of a mill of the type described comprising a "closed" circuit for air circulation, illustrating diagrammatically the general arrangement of parts and locations of various features of the invention,

Figure 3 is vertical cross-section taken centrally through the drum of a mill of the type shown in Figure 1 illustrating the normal path of air flow through the drum,

Figure 4 is a similar cross-sectional view to that shown in Figure 3 illustrating the flow of air in the drum upon creation of a substantial vacuum therein,

Figure 5 is a similar cross-section view to that shown in Figure 3 illustrating the flow of air in the drum upon sudden increase of the pressure therein to a value between atmospheric and normal operating pressure during operation according to one embodiment of the process of the invention,

Figure 6 is a graph showing the variation in the level of the water in a manometer during the carrying out of the process of the invention according to one embodiment thereof,

Figure 7 is a graph showing the variation in the level of the water in a manometer during the carrying out of the process of the invention according to another embodiment thereof,

Figure 8 is a projection view, partly cut away, of a suitable form of air control valve means for use in carrying out the process of the invention, the valve being shown in the closed position, and

Figure 9 shows the valve of Figure 8 in the open position.

Figure 10 is a general side view of a mill embodying an alternative form of the invention.

Figure 11 is a general side view of a mill embodying a further alternative form of the invention.

Referring now more particularly to the drawings, the "open" circuit mill illustrated in Figures 1, 3, 4 and 5 comprises the rotatable drum 10 which is mounted for rotation upon hollow trunnions supported by bearings within the bearing housings 11 and 12. The drum 10 is provided with the external gear 13 which meshes with a suitable driving pinion (not shown) by means of which the drum is rotated. Feed material is conveyed to the mill on the conveyor 14 and drops by gravity into the drum 10 through the feed chute 15.

On the outlet side of the mill is an air duct illustrated generally at 16 which, in the mill illustrated, is provided with a classifier portion 17 and an oversize return portion 18. A coarse product collector 19 is mounted below the classifier portion 17, and the portion 18 is arranged at a sufficient angle to the horizontal to ensure that the oversize will flow by gravity back into the drum 10.

The duct 16 leads into the main products collector 20 which is of the cyclone type, and the duct 21 connects the centre of the collector 20 to the impeller 22 which is driven by the motor 23 and from which air is discharged to atmosphere through the dust collector 24.

The classifier portion 17 is normally provided with the control 25 in the form of an adjustable inlet to the classifier from the atmosphere by adjustment of which the size of the particles withdrawn from the air stream and returned towards the drum may be varied.

The mill thus far described is of generally known construction, and in operation air is drawn into the system through the mouth 26 of the feed chute 15, and is conducted along down the feed chute across the drum 10 through the duct 16 through the cyclone collector 20 by the impeller 22, from which it is discharged to atmosphere through the dust collector 24.

In carrying out one form of the present invention, means are provided across the mouth 26 of the feed chute 15 for quickly shutting off most of the area thereof available for flow of air and suddenly reopening the mouth 26 at frequent periodic intervals during operation of the mill. In Figure 1 these means are illustrated diagrammatically by the shutter 27.

In the closed circuit mill illustrated in Figure 2, the general arrangement of parts of the mill is the same as in the open circuit mill illustrated in Figure 1, and the like parts in Figure 2 are indicated by the same reference numerals used in respect to the description of Figure 1. The main difference in the two mills is that in the closed circuit mill the impeller 22 instead of discharging to atmosphere through a dust collector, discharges into the circuit duct 28 which discharges into the feed chute at 29. The mouth 30 of the feed chute 15 is in this case closed off leaving only sufficient clearance for the discharge of material into the feed chute from the conveyor 14. In addition the by-pass duct 31 is connected to the circuit duct 28 and discharges into the dust collector 32 from which air flows through duct 33 to the auxiliary impeller 34, which discharges to the atmosphere through the exhaust duct 35. The auxiliary impeller is driven by a separate motor 36. Thus far described, the mill illustrated in Figure 2 is of the type which is currently in use and is described in my copending application Serial No. 253,399, filed October 26, 1951.

Apparatus for carrying out two embodiments of the inventive process are illustrated in connection with the mill shown in Figure 2 and these may be used independently or in conjunction with each other, as will be hereinafter described.

In the first place, the air flow control valve 37 is mounted on the duct 16 at a point above the classifier by-pass gate 25 and is provided with a suitable arrangement for opening the valve to establish communication with the atmosphere and then suddenly close the valve again at frequent periodic intervals throughout operation of the mill. During periods of operation between openings and subsequent closings of the air flow control valve 37, the valve itself is in the closed position as shown.

In the second place, an air flow control valve 38 similar to the air flow control valve 37, is situated within the circuit duct 28. The air flow control valve 38 is arranged normally to be in the open position to permit free circulation of

air through the circuit duct 28 and is provided with suitable means for suddenly closing it and then opening it at frequent periodical intervals throughout operation of the mill. In order to prevent undue build-up of back pressure when the air flow control valve 38 is suddenly closed, the circuit duct 28 is provided with the by-pass 39 which is closed at its end by the safety valve arrangement 40. In some cases it may be desirable, in addition, to enclose the end of the by-pass 39 in a dust bag.

In carrying out the process of the invention in a mill of the type illustrated in Figure 2 it may be desirable to include only the air flow control valve 37 or only the air flow control valve 38 and the safety valve 40 in the apparatus. In some cases, however, it is desirable to include both types of air flow control valve in the positions shown and to operate first the one and then the other in timed sequence.

The process of the invention may, of course, be carried out in an open circuit mill of the type illustrated in Figure 1 by using an air flow control valve similar to air flow control valve 37, in a similar position either by itself or in sequence in timed relation to an arrangement such as that shown in Figure 1 at the mouth 26 of the feed chute 15.

It will be appreciated, moreover, that although only one position has been illustrated for each of the components of the apparatus used for carrying out the process of the invention, the effect would be basically the same if the position of each of these components were varied within certain limits. The shutter 27, for instance, might be situated otherwise than as shown in Figure 1, one obvious alternative being to form the mouth of the feed chute in the manner shown in Figure 2. In fact, in many cases, it is advantageous to construct the open-circuit arrangement in this manner because in mills operating in northern climates it may be desired to operate with an open circuit during the summer months when the heating of the plant does not represent an added expense, and to convert to closed circuit operation during the winter months when it is undesirable to waste the latent heat in the circulating gases by exhausting them to the atmosphere.

The air flow control valve 38 shown in Figure 2 would, of course, produce substantially the same result if connected anywhere in the circuit duct 28, between the dust removal duct 31 and the discharge end 29. It is preferred, however, to have the air flow control valve 38 situated as close as conveniently possible to the discharge end 29 because the closer it is to the drum proper, the more sudden is the drop in pressure produced within the drum by sudden closing of the valve.

Similarly, the air flow control valve 37 could be situated at any convenient place between the impeller 22 and the outlet side of the drum. Generally speaking, however, it is more convenient to locate it between the classifier control gate 25 and the main products collector 20. If it is situated below the classifier 17, there is a possibility of relatively large particles, being returned from the classifier to the drum, being deflected in some manner to a position where they might interfere with the proper closing of the valve. On the other hand, the air duct 21, connecting the products collector 20 with the impeller 22, is generally rather inaccessible, and the relatively large volume of the air duct 21 and the main products collector 20 will have a certain damping effect upon the sudden reduction of pressure brought about in the drum 10 by the sudden closing of the air flow control valve 37 after it has been opened. Accordingly, both as a matter of convenience and for the sake of efficient operation, it is preferred to mount the air flow control valve 37 in substantially the position illustrated in Figure 2.

The theory upon which the process of the present invention operates is illustrated in Figures 3, 4 and 5. The condition of air flow through the drum proper and the adjacent air ducts is, during normal operation of the mill, substantially as shown in Figure 3. The air enters the system through the mouth 26 of the feed chute 15 and follows the course indicated by the arrows, passing through the drum in the form of a somewhat broadened stream, and out into the duct 16 on the outlet side of the mill. At this point it may be mentioned in passing, that, in the mill illustrated in Figures 3, 4 and 5, the coarse products collector 19 which is, of course, optional, has been omitted. It will be evident from a consideration of the flow of air through the drum 10, illustrated by the arrows in Figure 3, that particles within the mill which are of a sufficiently small size to be entrained in the air stream, will only be so entrained for carriage out of the drum if their path of travel within the drum intercepts the air stream. Particles which reach a suitable state of sub-division for entrainment, while they are situated at the periphery of the mill, will remain within the mill until they are carried up to the top and fall into the air stream, or are in some inadvertent manner forced into the air stream. The break-down action of a mill of the type described is very rapid indeed, and the particles above mentioned, which do not immediately enter the air stream on becoming reduced to a suitable size, will be subject to an appreciable amount of over-grinding, even though they remain in the mill for only a few seconds before becoming entrained in the air stream. The present invention causes a removal of particles of suitable size for entrainment from all portions of the mill simultaneously by causing a sudden drop in the air pressure within the drum. When the pressure is thus suddenly reduced, the drum commences to evacuate through the outlet port 41, and the air in the peripheral regions of the drum immediately commences to move inwardly towards the centre of the drum and towards the outlet port 41, substantially in the manner illustrated by the arrows in Figure 4. If the drop in pressure is sharp enough or sudden enough, the air thus moving towards the centre from the peripheral regions of the mill, has sufficient velocity to entrain the particles of reduced material which are of a suitable size for entrainment, and carry them into the air stream passing through the centre of the mill, so that they pass out the outlet port 41 and into the system on the outlet side of the mill, along with all the other particles of suitable size which would normally have been entrained in the air stream without such sudden reduction of pressure. The original conditions of air flow through the drum are restored after each such sudden drop in pressure, and the operation is repeated at frequent predetermined intervals. It has been found in practice, for instance, that a complete cycle of operations every eleven seconds is satisfactory, of which eleven

seconds, about two seconds are required in the production of the pressure pulsation.

There are two general methods of accomplishing the sudden reduction of pressure within the drum referred to above. A restricting influence may, for instance, be suddenly placed in the air stream on the inlet side of the drum, for instance by substantially blocking off the mouth 26 of the inlet chute 15, which suddenly causes the pressure within the drum 10 to drop to a substantially reduced value. The situation within the drum, when the air flow is substantially blocked off at the mouth of the feed chute in this manner, is illustrated in Figure 4. It will be noted that the mouth of the feed chute is not entirely blocked off since, according to the invention, at least some flow of air across the drum must be maintained at all times so that the particles drawn in towards the centre of the drum will be entrained and removed from the mill. In addition, it is not desired highly to evacuate the duct system, because of the possibility of blow-ins and collapsing of the ducts themselves. The restricting influence at the mouth of the feed chute is generally removed one second after it is applied, to allow restoration of the air pressure in the drum. A rather unusual effect can be obtained when carrying out the process according to the manner just described, and that is, that, upon removal of the restricting influence, air will enter the feed chute with a rush, building up a considerable velocity in excess of the velocity which the air stream would have during normal operations. Furthermore, during the period of evacuation of the drum 10, some fairly large pieces of material will be brought towards the centre of the drum. The sudden rush of high velocity air is capable of carrying these large particles which, in operations on a pilot plant scale have been as large as three inches in diameter, into the duct system on the outlet side of the mill. Accordingly, it will be apparent that, by suitable adjustment of the degree of restriction placed across the duct system on the inlet side of the mill and by appropriate control of the speed with which the vacuum thus created is broken, the size of particles capable of being removed in the operation can, to a very large degree, be controlled.

It will be observed from a consideration of Figure 2 that the effect created by closing the air flow control valve 38, in the closed circuit mill, will be substantially the same as the effect created by substantially restricting the mouth of the feed chute in the open circuit mill, illustrated in Figure 1. In the closed circuit, however, the air flow control valve 38 may be shut off completely since sufficient air will continue to pass into the mouth of the feed chute, in the spaces remaining around the end of the conveyor, to maintain the air stream through the drum on a sufficient scale.

The second general method of carrying out the process of the invention involves raising the pressure within the drum 10 to a value between that previously existing and atmospheric, and then suddenly reducing the pressure. This may be accomplished by operation of an air flow control valve 37, 37A or 37B (see Figures 2, 10 and 11). When this is opened, a considerable flow of air passes from the atmosphere into the duct system, and the velocity of the air stream passing through the feed chute drum and duct 16 is considerably diminished. Since the pressure existing within the drum 10 is a function of the velocity of the air flow through the system (the absolute pressure therein being atmospheric minus the resistance to the flow of air of the duct system on the inlet side of the mill) a reduction in velocity of the air flow through the drum, which is caused by an influence on the downstream side thereof, will, in all cases, raise the air pressure in the drum. When the air flow control valve 37 is suddenly closed again, the flow of air rapidly increases, and accordingly the pressure within the drum 10 is suddenly reduced to its previously existing value, with the same effect, although generally on a lesser scale, as the effect already described in connection with Figure 4. Conveniently, the air flow control valve 37 may be operated for a period of one second at ten second intervals. The carrying out of the process of the invention in this manner provides what may be termed a "pulsating effect" within the drum since, every time the air flow control valve 37 is opened, causing in effect a back pressure within the drum 10, the air stream passing therethrough will momentarily be expanded substantially as illustrated by the arrows in Figure 5, thus entraining particles from a much greater volume of the interior of the mill than is the case during normal operations. When the air flow control valve 37 is subsequently closed again, an effect similar to that illustrated in Figure 4 is obtained, withdrawing particles towards the centre of the mill from the peripheral regions of the drum.

The variation of pressure within the system during the carrying out of the process of the invention according to both of the methods outlined above is very well illustrated by placing a manometer lead in the air duct 16 in a position marked "M" on Figures 1 and 2. Time versus manometer reading graphs illustrating the cycle of operations in each case are shown in Figures 6 and 7.

In Figure 6 the manometer reading is plotted against time during the operation of the process of the invention according to the embodiment wherein the pressure within the drum is first raised to a pressure between its previously existing pressure and atmospheric pressure, and is then suddenly reduced, the apparatus used in this case being an open circuit mill of the type shown in Figure 10 but having air flow control valve 37A similar to air flow control valve 37 situated in the position as illustrated in Figure 2.

Referring to the graph in Figure 6 it will be seen that with the air flow control valve closed during normal operation, the manometer reading is ten inches of water. As soon as the control valve is opened the pressure within the system at the point at which the manometer is situated (and hence also the pressure within the closely adjacent drum 10), rapidly increases, the increase in pressure being represented by a fall in the manometer reading from ten inches to about 6.5 inches, or in all a total of 3.5 inches of water, this increase in pressure being represented by the portion of the curve marked *a*. The pressure rapidly levels off at 6.5 inches as shown by the portion *b* of the curve.

As soon as the air flow control valve is suddenly closed, there is a sudden drop in pressure within the drum represented by the portion *c* on the curve. It will be observed that the pressure drops by an amount corresponding to about 5.5 inches of water in approximately half a second, conditions then rapidly return, following the generally sinusoidal curve *d*, to the previous

pressure represented by a manometer reading of ten inches of water.

During the portion of the cycle of operations represented by the curve *a*, air flow conditions within the drum will generally correspond to conditions illustrated in Figure 5. During the portion of the cycle of operations represented by the portion of the curve marked *c*, however, the conditions of air flow within the drum will correspond to the conditions indicated in Figure 4. There will, of course, be an additional slight pulsating effect during the levelling off of the pressure represented by the portion of the curve marked *d*.

In Figure 7 the manometer readings have been plotted against time during the operation of a mill of the type illustrated in Figure 1, equipped with means for substantially suddenly restricting the inflow of air through the feed chute 15 as illustrated diagrammatically on Figure 1, by the shutter 27.

It will be observed that, with the shutter 27 open, the manometer reading is ten inches of water; however, when the shutter 27 is suddenly closed, the manometer reading rapidly rises to 13.5 inches of water as illustrated by the portion *e* of the curve on the graph, where it rapidly levels off at 13.5 as illustrated by the portion *b* of the curve. The sudden rise in manometer reading represented by the portion *e* represents a sudden drop in pressure within the drum of approximately 3.5 inches of water. As soon as the shutter 27 is opened, the pressure within the drum rapidly rises as indicated by the portion *g* of the curve, the manometer reading falling from 13.5 inches to a minimum of 8 inches, following which the original pressure is rapidly restored according to the usual sinusoidal type of curve represented by the portion *h*.

Thus it will be appreciated that, during that part of the cycle of operations represented by the portion of the curve *e*, conditions within the drum will substantially correspond to the condition illustrated by Figure 4, while, during the portion of the cycle of operations represented by the curve *g*, conditions will generally correspond to those indicated in Figure 5, with the exception, as previously mentioned, that the incoming stream of air builds up a considerably increased velocity depending upon the extent of the sudden increase in pressure brought about by opening the shutter. There is, of course, a further slight period during which conditions are somewhat similar to those illustrated in Figure 4 during the levelling off of the pressure during the portion of the cycle of operations indicated by the portion of the curve *h*.

Although there are many types of air flow control valves which could be used satisfactorily according to the invention, it has been found that the air flow control valve illustrated in Figure 9 is satisfactory. As illustrated, the valve is mounted in a short length of duct 50 which may suitably be mounted by means of the flanges 51 over an opening in the duct system on the outlet side of the mill in a position similar to that of the air flow control valve 37 in Figure 2. If the valve is mounted in position similar to the air flow control valve 38 illustrated in Figure 2, however, the valve may be mounted directly within the circuit duct 28. The air flow control valve illustrated in Figures 8 and 9 consists of three fairly heavy rubber diaphragms 52, 53 and 54, which are mounted between the rigid mounting plates 55 and 56, leaving a marginal strip of the rubber diaphragms 52, 53 and 54 free on either side. The three diaphragms thus assembled are provided with the spindles 57*a* which are mounted for rotation in the wall 58 of the duct 50, and the spindles 57*b* which pass through the opposite wall 59 through suitable openings within which they are freely rotatable. The spindles 57*b* are provided with the sprockets 60 which are adapted to mesh with the chain 61 in the manner illustrated. An idler sprocket 62 is mounted on the spindle 63 which is rotatable within the brackets 64 and 65 which are secured to the top 66 of the duct 50. The sprockets 60 and the idler sprocket 62 are arranged in generally the same plane.

A tension spring 67 is secured at one end to the flange 51 of the duct 50 at 68, while the other end of the spring 67 is secured to the chain 61 which latter is threaded around the sprockets 60 in the manner shown, over the idler sprocket 62, to connect at its other end to the movable core 69 of the solenoid 70 which is connected electrically to suitable means for causing opening and closing of the circuit at predetermined intervals of time. Many such suitable arrangements are known, and the one which it is preferred to use in connection with the valve illustrated, consists essentially of a time-delay relay 71 for opening the valve and a second time-delay relay 72 arranged to commence its time cycle upon actuation of the relay 71, to close the valve at a predetermined interval after it has been opened by the relay 71.

The valve illustrated in Figures 8 and 9 is arranged normally to be in a closed position as illustrated in Figure 8. When current is supplied to the solenoid 70 the core 69 is lowered, pulling the chain 61 downwardly against the influence of the spring 67, causing the apparatus to assume the open position as illustrated in Figure 9. When current is cut off from the solenoid 70 the spring 67 re-asserts itself, pulling the chain 61 in the opposite direction and causing it to resume the position illustrated in Figure 8.

The valve arrangement illustrated in Figures 8 and 9 has a number of advantages. In the first place, in opening and closing the valve, the diaphragms being centrally mounted, impose practically no load on the actuating means. The flexible edges on the diaphragms effectively seal the valve in its closed position, but are straightened out in the open position as illustrated in Figure 9, presenting very little resistance to the flow of air. The solenoid type of actuation illustrated is very simple and dependable and will operate satisfactorily over extended periods of time and requires very little maintenance.

The improvement in efficiency effected by the process and apparatus of the present invention is illustrated in the following example taken from actual operations on a pilot mill scale.

Example

Asbestos bearing ore was reduced in a test open circuit mill 2 feet long and having a nominal diameter of 5 feet. The mill was equipped with an air flow control valve similar to that shown in Figures 8 and 9 and situated between the classifier by-pass gate and the main products collector in a manner similar to the air flow control valve 37 illustrated in Figure 2. Use was made of a ball charge in accordance with the teachings of my aforementioned copending application Serial No. 234,782, filed July 16, 1951.

A sample of ore was divided into two aliquot portions, one of which was run through the mill

in the normal manner using a normal steady flow of air throughout while the other aliquot portion was run through the mill operating according to the invention. In the latter case the air flow control valve was opened for one second at eleven second intervals through the test run. Comparative results of the two runs are tabulated as follows:

Air Current	Percent Fibre[1] Recovered from Original Ore on 20 Mesh Screen	Percent of Individual Fibre Size Recovered				Relative Value at Following Figures			
		+½"	−½" +¼"	−¼" +10M	−10M	+½"	−½" +¼"	−¼" +10M	−10M
						$15.00	$7.00	$3.00	$0.50
Normal	2.30	4.9	50.7	24.2	20.2	1.69	8.65	1.67	0.23
Pulsation	2.41	10.4	55.3	21.9	12.4	3.77	9.31	1.65	0.15

[1] This figure is an actual percentage of the original ore representing what is termed in the asbestos industry as "test fibre." Test fibre is the fibre which is recovered on cleaning the mill product of both dust and granular rock particles on a Tyler standard 20 mesh screen.

The tabular results above speak for themselves and indicate clearly the reduction in over-grinding brought about by use of the present invention. It will be noted for instance that the percentage of plus half inch fibre recovered is more than doubled. Using the scale of relative values current in the asbestos industry, the total relative value of fibre recovered using the process and apparatus of the present invention is increased from $12.24 to $14.88 representing an improvement of about 21½%.

The process and apparatus of the invention may be used to advantage to obtain an improved result and to a large extent overcove over-grinding problems in connection with the comminution of materials in the processing of which over-grinding is a problem, the above example being illustrative only of the improved result achieved in the reduction of asbestos ore which has always been recognized as presenting one of the most difficult problems in connection with over-grinding.

What I claim as my invention is:

1. In a material reduction mill having a rotating drum, a feed port surrounding the axis of rotation at one end of the drum, and an outlet port at the other end of the drum; said mill being of the type in which feed is introduced through the feed port and product is withdrawn through the outlet port by means of a current of air drawn through an air circuit including said feed port and said drum and said outlet port by suitable means on the outlet side of the mill; means for producing a sudden reduction of air pressure within the drum, and actuating means arranged to actuate the pressure reduction means at frequent predetermined intervals during operation of the mill.

2. A new method for operating a material reduction mill of the type having a rotating drum, a feed port leading to the drum, and an outlet port leading from the drum, said method comprising continuously feeding material to be reduced through said inlet port, drawing a current of air through said feed port by continuously withdrawing air from the outlet port, said current of air being maintained at least in part throughout the operation of the mill, withdrawing reduced material from said drum through said outlet port by means of said current of air, and imparting substantially continuous pulsation to the air within the drum by frequently creating a sudden reduction of air pressure within the drum and then restoring the air pressure.

3. The method defined in claim 2 in which the sudden reduction of air pressure in the drum is brought about by raising the air pressure within the drum to a value between the pressure of the atmosphere and the pressure previously existing in the drum and then suddenly reducing the pressure in the drum to its previously existing value.

4. The method defined in claim 2 in which the sudden reduction of air pressure in the drum is brought about by suddenly restricting the current of air by application thereto of a restricting influence at a point before it enters the drum.

5. The method defined in claim 2 in which the sudden reduction of air pressure in the drum is brought about by introducing a supply of air into said current of air after it leaves the drum to raise the air pressure in the drum, and then suddenly cutting off said supply of air.

6. The method defined in claim 4 in which said current of air flows in open circuit and the restricting influence is applied across the mouth of the inlet port of the mill materially suddenly to reduce the effective area thereof avialable for flow of air.

7. The method defined in claim 4 in which the said current of air flows through a closed circuit and the restricting influence is applied to the air in said closed circuit substantially closing the latter off at a point shortly before the point of delivery of air to said drum.

8. The combination defined in claim 1 in which said means for producing a sudden reduction of air pressure within the drum is situated on the inlet side of the mill.

9. The combination defined in claim 1 in which the said means for producing a sudden reduction of air pressure within the drum is situated on the outlet side of the mill.

10. The combination defined in claim 8 in which the air is circulated through the mill in open circuit and said means for producing a sudden reduction of air pressure within the drum comprises means for suddenly blocking off a substantial portion of the mouth of the inlet port of the mill to suddenly restrict the flow of air through said inlet port at frequent predetermined intervals during operation of said mill.

11. The combination defined in claim 9 in which said current of air is circulated through the mill in closed circuit and said means for producing a sudden reduction of air pressure within the drum comprises means for substantially blocking the air flow in said closed circuit at a point near the point of delivery of air to said drum, suddenly substantially to prevent delivery of air to said drum through said closed circuit to said drum at frequent predetermined intervals during operation of said mill.

12. The combination defined in claim 11 in which safety valve means are provided in said closed circuit on the upstream side of said means for substantially blocking off the air flow in said

closed circuit to prevent an undue build-up of air pressure in said closed circuit.

13. The combination defined in claim 1 in which said current of air is circulated through the mill in open circuit and said means for producing a sudden reduction of air pressure within the drum comprises air valve means controlling communication between said air stream on the outlet side of the mill and the atmosphere, said actuating means being arranged to open said valve to increase the pressure within the drum and then suddenly to close said valve whereby suddenly to reduce the pressure in the drum at frequent predetermined intervals during operation of the mill.

14. The combination defined in claim 13 wherein the open circuit includes a classifier downstream of said mill and said air valve means is situated downstream of said classifier.

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