

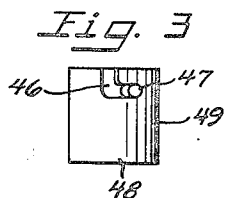
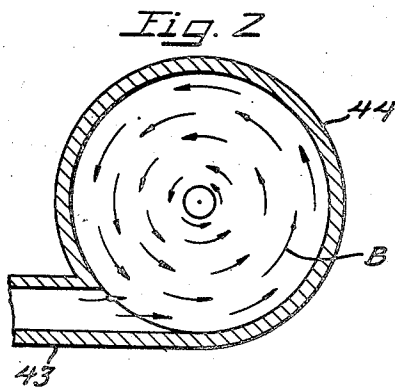
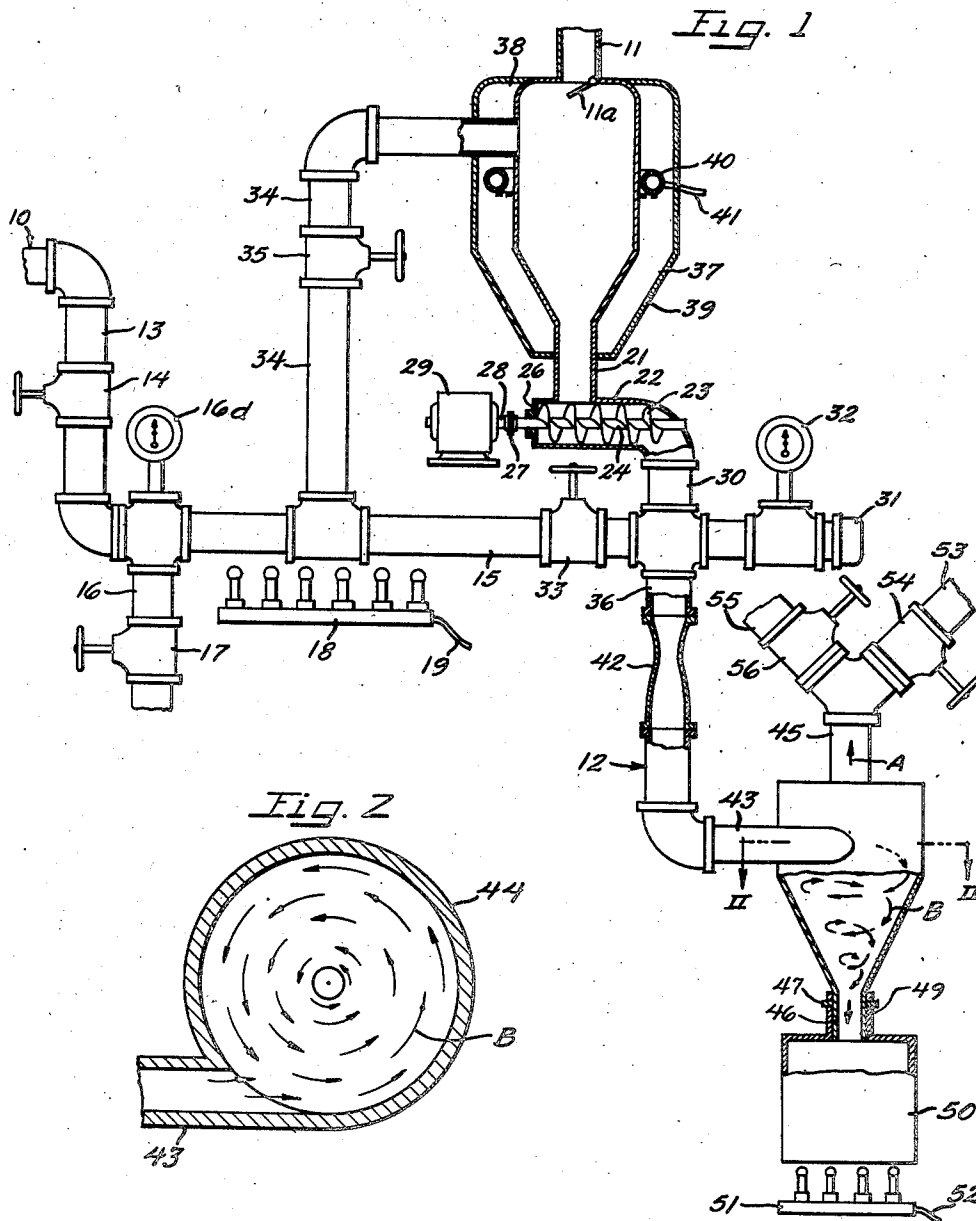
July 18, 1950

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2,515,542

METHOD FOR DISINTEGRATION OF SOLIDS

Filed April 20, 1948



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## UNITED STATES PATENT OFFICE

2,515,542

## METHOD FOR DISINTEGRATION OF SOLIDS

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Application April 20, 1948, Serial No. 22,154

4 Claims. (Cl. 241-1)

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This invention relates to apparatus and methods for the disintegration of coarsely fragmented solid material. More particularly, the invention pertains to methods and apparatus of the type indicated in which a coarsely fragmented solid material to be disintegrated is entrained in a stream of compressed gas and the entraining gas is instantaneously expanded and accelerated to bring about shattering of the entrained granules.

I have provided novel apparatus and methods for disintegrating granular solid material involving a number of distinctive features. Thus, I provide a source of expansible fluid held under a pressure such that the fluid can be expanded (at the restricted area mentioned herein below) with a pressure drop of at least 15 pounds per square inch. I continuously discharge the compressed fluid from this source while confining the discharged fluid, as in an elongated conduit, to form a stream of compressed fluid flowing at a velocity less than the critical velocity (critical with reference to the restricted area mentioned herein-below) but, in any event, at least sufficient to entrain or suspend therein a granular solid material to be disintegrated. Having thus established a stream of compressed fluid flowing in an elongated conduit and capable of being expanded with a pressure drop of at least 15 pounds per square inch, I pass this stream of fluid through a restricted area, such as a convergent nozzle, a convergent-divergent nozzle, or a restricted orifice, so as to reduce the fluid pressure practically instantaneously by at least 15 pounds per square inch and to accelerate the fluid to critical velocity. To bring about such reduction of pressure and such acceleration, the entrainment is discharged from the restricted area into an area of relatively low pressure, as by allowing the fluid to escape into the atmosphere, into a large space, into a divergent nozzle or into a conduit of at least the same cross sectional area as conduit upstream of the restricted area. Concurrently and continuously I introduce solid granules (having a maximum dimension not greater than  $\frac{1}{3}$  and preferably not greater than  $\frac{1}{4}$  of the minimum dimension of the restricted area) into the flowing stream of compressed fluid upstream of said restricted area. The amount of solid material introduced into the streaming gas is limited so as not to prevent a pressure drop, at the restricted area, of at least 15 pounds per square inch. In general, less than ten parts (by weight) and preferably not more than four parts of solid should be used for each part of fluid, when the pressure drop amounts to less than 500 pounds per square inch. Then, on passage of the entrainment through said restricted area, the entrained particles are shattered. While limited comminution may be effected upstream of the restricted area, as by

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attrition of solid granules against the walls of the conduit and against each other, it should be understood that, in the operation of the method of the present invention, by far the greatest part of the disintegration brought about is effected at the restricted area.

Thus the disintegrating apparatus of my invention may include a source of expansible fluid; means including a conduit for establishing a controlled, continuous stream of compressed fluid flowing from said source; a closed container for solid granules connected to said source of fluid, to permit said fluid pressure to be propagated into said receptacle; and means for uniformly, continuously, and adjustably feeding solid particles to be disintegrated from said container into said fluid flowing through said conduit. Downstream of the point where the solid particles are fed into the conduit there is located, at the minimum distance required for entrainment or suspension of said solid particles by said flowing fluid, a constriction, such as a convergent nozzle, a convergent-divergent nozzle, or a restricted orifice, the shape of the conduit between the point of feeding and the constriction being such as to minimize the pressure drop upstream of the constriction and to concentrate the pressure drop and the acceleration of the fluid at the constriction. The shape and cross-sectional area of the constriction are such as to allow free passage therethrough of the particles to be shattered. The constricted conduit portion discharges into the atmosphere or into a large space, into a divergent nozzle or into a conduit of as large cross sectional area as the conduit upstream of the constriction. By regulation of the upstream and downstream pressures, a pressure drop of at least 15 pounds per square inch and acceleration to critical velocity may be established across the constriction which is effective to bring about disintegration of fluid-entrained particles passing through the constriction.

The above noted disintegration at the restricted area may possibly be explosive in nature, being brought about by rapid expansion of compressed fluid permeating the solid particles or absorbed thereby. The disintegration may possibly also be brought about by impact and/or attrition as the particles pass through the restricted area at accelerated velocity. Or, the disintegration may be due to both of these two actions. In any event, the disintegration is correlated with the rapid pressure drop and the concurrent rapid acceleration brought about when the entrainment of solid particles in the compressed fluid passes through the restricted area.

In the apparatus of the present invention, the pressure drop and the concurrent acceleration at the restricted area bringing about disintegra-

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tion approach very nearly the same values as the total pressure drop and the total acceleration in the apparatus. Thus, practically all of the total pressure drop and of the total acceleration are concentrated in one area and there utilized to effect disintegration. Hence, according to the present invention a compressed fluid may be efficiently and economically utilized for disintegration of granular solid material.

It should be understood that, in order to bring about a substantial or significant disintegration, it is not sufficient merely to provide a conduit having a convergent nozzle or a restricted orifice and to flow through said conduit an entrainment of solid granules in a compressed gas. Significant or substantial shattering is only effected at a convergent nozzle or a convergent-divergent nozzle, or a restricted orifice when the pressure drop at the orifice or nozzle reaches at least 15 pounds per square inch, and when the gas reaches critical velocity within the nozzle or orifice, and when the ratio of solid to entraining gas is less than 10 to 1 and preferably not greater than 4 to 1.

By the term "critical velocity" I mean the velocity achieved at the section of minimum cross sectional area of the restricted conduit portion when further reduction of the discharge pressure produces no further increase in the weight rate of flow through the restricted conduit portion. The critical velocity may range from 700 to 5000 feet per second, depending upon the upstream conditions, such as pressure, temperature, ratio of solids to gas, the nature of the gas, and the like. In general, critical velocity is not reached unless the upstream pressure is reduced, across the restricted area, by at least about one-half.

A distinction should be made between the critical velocity (reached at some point in or at the discharge orifice) and the velocity past the discharge orifice. The critical velocity does not vary, regardless of the form of the conduit, if any, into which discharge is effected. In general, the fluid may be decelerated or accelerated after critical velocity has been reached. Acceleration may be brought about by further reduction of the downstream pressure and by appropriate shaping of the conduit into which discharge is effected. Deceleration may be brought about, for instance, by discharge into the atmosphere. However, whether deceleration or acceleration is effected after the critical velocity has been reached, the weight rate of flow through the restricted area remains constant. For acceleration to super critical velocity, I may discharge into a flaring conduit, such as a De Laval nozzle and, for deceleration, I may discharge into a large space which may be maintained under a partial or complete vacuum.

Attention is directed to the fact that the restricted area herein referred to necessarily has a finite length. Theoretically, a restricted orifice of practically infinitely short length could be constructed, as by the use of a knife edge, but such an orifice would be wholly impractical, as it would be lacking in structural strength and would be worn down very quickly by abrasion due to the solid particles passing therethrough. In the case of a restricted area of finite, even though small, length, critical velocity is probably reached within the restricted area. In any case, the critical velocity can be calculated from data obtained by measuring the pressure and temperature conditions upstream of the re-

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stricted area, by methods known in the art. The critical velocity, however, cannot ordinarily be measured directly. Nor is it necessary to calculate, or to determine experimentally, the exact location where critical velocity is reached. Nevertheless, the fact that critical velocity is reached at least momentarily and the methods for establishing the magnitude of the critical velocity are generally accepted by those skilled in pneumatics.

It will be understood from the foregoing that the critical velocity is correlated with the maximum weight rate of flow through a given restricted area or orifice under given upstream conditions of pressure, temperature and the like. For practical purposes, expansion and concurrent acceleration to critical velocity of gas passing through a restricted area may be considered as being instantaneous. The magnitude of this expansion is generally equal at least to about twice the original volume (a ratio of 0.55 to 1), since otherwise critical velocity will not be reached, but may be greater, depending on the downstream pressure conditions. However, practically instantaneous expansion of the gas to double its original volume bringing about at least momentary flow at critical velocity is not necessarily sufficient to bring about significant or substantial disintegration of a solid entrained in the gas. For this purpose, the ratio of solid to gas (by weight) should be less than 10 to 1 and preferably not greater than 4 to 1. Further, the pressure drop should be at least 15 pounds per square inch, thus excluding operation at low pressure levels where critical velocity may be reached with a pressure drop of less than 15 pounds per square inch. At such low pressure levels, disintegration is markedly reduced, if for no other reason than because of the upper limit for the solid to gas ratio which, at these lower pressure levels, severely limits the through-put of solids through the restricted area, thus reducing the capacity of the apparatus. However, it is possible to employ an upstream gauge pressure of 10 pounds per square inch, when the downstream pressure is at least 5 pounds per square inch below atmospheric, or an upstream gauge pressure of 15 pounds per square inch when the downstream pressure does not exceed atmospheric pressure.

Both critical velocity and a pressure drop of at least 15 pounds per square inch may be obtained by discharging compressed gas through a single open ended tube of uniform cross sectional shape and area. In such a tube the total expansion and acceleration are distributed over the length of the tube, even if critical velocity is reached at the discharge orifice. But, by using a tube having a restricted portion or area, I can, so to speak, dam up the pressure within the tube upstream of the restricted area, so that expansion and acceleration of the gas are both concentrated at the restricted area. Since it is this concentrated expansion and acceleration that brings about disintegration, I can, by my method and apparatus, utilize a compressed gas more easily and more economically for the disintegration of an entrained granular solid material.

It is therefore an important object of the present invention to provide method and apparatus for shattering of granular solids involving an entrainment of said solids in a stream of a compressed gas which is instantaneously expanded and accelerated, the total pressure drop and acceleration of said gas being utilized to

the maximum extent possible for shattering of said granules.

Other and further objects and features of the present invention will become apparent from the following description and appended claims.

The drawing shows, diagrammatically and by way of example, an apparatus according to the present invention adapted for the disintegration of coarsely fragmented solid material. More particularly:

Figure 1 is a side elevational view of the apparatus, with parts broken away and other parts shown in cross section;

Figure 2 is an enlarged cross sectional view taken on the line II—II of Figure 1; and

Figure 3 is an enlarged side elevational view of the connection between the cyclone separator and the receptacle forming parts of the apparatus.

As shown in Figure 1, my apparatus comprises a conduit indicated generally by the reference numeral 10 and adapted to receive steam or other compressed gas from a suitable source (not shown); a conduit 11 for coal or other material to be comminuted; and an outlet indicated generally by the reference numeral 12 for the comminuted material and entraining fluid, such as steam or other gas. Hereinbelow, the apparatus and its operation will be specifically described as utilized for the comminution of coal by the use of steam.

The conduit 10 for the compressed expansible fluid (more particularly, steam) comprises a pressure conduit 13 having a valve 14 therein. This valve 14 forms the main control of the system and, when closed, completely shuts off the flow of gas into the system. The steam conduit 13 is connected to a transverse conduit 15 having a condensate discharge tube 16 provided with a valve 17 as well as with a pressure gauge 16a. Any suitable heating means, such as a bank of burners 18 having a gas supply conduit 19, may be provided for superheating and thus completely drying the steam.

The coal conduit 11 discharges into the upper end of a hopper 20 provided with an outlet conduit 21. For effecting positive feeding of the material to be pulverized from the outlet tube 21, the latter includes a transverse section 22 having a screw 23 rotatably fitted therein. The screw 23 is provided with a spindle 24 rotatably mounted in a suitable bushing 26. The spindle 24 is also coupled, as at 27, with the drive shaft 28 of an electric motor 29. Thus, as the granulated material from the hopper 20 descends into tube 21 and is discharged therefrom, it is picked up by the screw 23 and positively forced into a lower tube section 30 which is a continuation of the tube section 22. This section 30 of the hopper outlet tube leads into the upper side of the transverse steam conduit 15, which is provided with a dead end extension 31, provided, if desired, with a pressure gauge 32 by means of which the pressure in the system may be determined. Preferably the tube 15 is provided, ahead of the inlet of the conduit section 30, with a regulating valve 33 whereby the section 15 of the steam conduit may be entirely closed.

For establishing a condition of pressure equilibrium as between the hopper 20 and the steam conduit 15, an auxiliary steam conduit 34 connects the upper half of the hopper 20 with the steam conduit 15. Preferably this conduit 34 is provided with a shut-off valve 35 which may be regulated in conjunction with the valve 33 to es-

tablish any desired flow condition, and whereby, if desired, the entire flow of steam may be bypassed through the top of the hopper 20 and downwardly to carry the material to be pulverized downwardly through the section 30 of the hopper outlet tube. Such a flow condition is established by entirely closing the valve 33 and opening the valve 35.

The material to be pulverized passes downwardly through the tube section 30 and is fed directly into a depending conduit 36, the details of which are explained more fully hereinbelow.

To make possible the drying of the material to be disintegrated or the driving off of volatile components thereof, or like procedures, the hopper 20 is preferably provided with spaced jacket 37 which may be closed around the upper end of the hopper, as at 38, and which extends downwardly and around the upper end of the outlet tube section 21. The jacket 37 is further provided with outlets 39 at the lower end thereof which allow the escape of gases.

Suitably mounted near the upper end of the chamber formed between the hopper 20 and the jacket 37 is a ring burner 40 connected by conduit 41 to a source of gas. When the ring burner 40 is ignited, the chamber between the hopper 20 and the jacket 37 will attain an elevated temperature whereby the contents of the hopper are heated to bring about drying, volatilization of volatile components or other effects. The products of combustion utilized for heating the hopper 20 escape through the ports 39 in the jacket 37 and may be vented to the atmosphere as shown or may be recirculated in the chamber in any suitable manner.

Thus, the apparatus described provides means whereby granules of the material to be pulverized may first be entrained in a stream of compressed fluid such as superheated steam, and thereafter delivered to the disintegration means described hereinbelow, the inlet for said means being the conduit 36 depending from the transverse steam conduit 15.

If desired, the inlet conduit 11 for the material to be disintegrated may be provided with a valve 11a or any other suitable lock valves permitting the positive feeding of material to the hopper 20 without affecting the pressure prevailing within the system.

As mentioned hereinabove, the material to be disintegrated, having been forced by the screw conveyor 23 into the conduit 15, is entrained in the superheated steam flowing through the conduit 15 and then carried into the conduit 36.

A convergent-divergent nozzle 42 is interposed in the outlet of the steam conduit 15 beyond the section 30 thereof. Any suitable restricted orifice may be utilized instead of the nozzle 42 as long as the desired pressure drop is obtained by passing of the entrained particles therethrough. As the material passes through the conduit section 36 and the nozzle 42, the pressure drop brings about a disintegration thereof, forming a highly comminuted final product. The surfaces of the comminuted particles may be characterized by an active condition, i. e., a condition favoring subsequent chemical or other reaction or modification.

The comminuted mass issuing from the nozzle 42 may be delivered to a conduit section 43 which leads tangentially into separator 44. This separator may be provided with an internal structure of any desired type and functions to deliver the gas component of the mass upwardly into

conduit 45 as indicated by the arrow A and the comminuted particles downwardly in a vortex to the outlet 46 as indicated by the arrows B. The outlet 46 is provided with diametrically opposed, outwardly extending pins 47 which cooperate with bayonet slots 48 in the neck 49 of a coal reservoir 50. This reservoir 50 may be heated by means of a burner arrangement 51 having a gas supply conduit 52 whereby the particles may be maintained free of moisture and the active condition of the particle surfaces may be retained. With the foregoing construction, the removal of the reservoir 50 from the separator is easily effected by mere rotation and downward movement of the reservoir when it has been filled. A more continuous system may be provided in place of the intermittently filled reservoir 50. Further, the comminuted particles may be delivered directly from the restricted orifice into a receiving chamber where the particles may be subjected to further comminution by means of pulsating conditions created by overexpansion at the restricted orifice. Additionally, if desired the particles and entraining steam may be subjected, in said chamber, to a process whereby direct generation of gas is effected. The gas outlet 45 of cyclone separator 44 is preferably forked at its upper end to provide a conduit 53 having a shut-off valve 54 and a conduit 55 having a shut-off valve 56. The conduit 53 opens to the atmosphere when the valve 54 is opened and the valve 56 is closed, thus permitting complete escape of the gas.

The conduit 55 is arranged to connect with apparatus of any suitable construction when the valve 54 is closed and the valve 56 is open, thereby to create a reduced pressure to increase the expansion ratio at the restricted orifice. In this manner the ratio of expansion at the nozzle may be increased to effect a higher degree of comminution.

Another apparatus according to the present invention is described in my copending application, Serial No. 762,589, entitled "Comminution device," filed July 22, 1947. Reference is made to this copending application for a complete description of the structure and functioning of this other apparatus.

The operation of the above-described apparatus may be summarized as follows: Solid material, such as coal, in coarsely fragmented form is charged through the conduit 11 and the gas lock 11a into the tank 20. Steam, air, or any other gas under pressure is caused to flow through the conduits 10 and 15 and is introduced through the conduit 34 into the tank 20. The screw conveyor 23 is operated to advance solid material to be comminuted into the stream of gas passing through the conduit 15. The nozzle 42 is so spaced from the discharge opening of the conduit section 30 that the coal or other material discharged into the conduit 15 will be entrained by the gas flowing through the conduit 15 before reaching the nozzle 42. Expansion occurs continuously as the compressed gas in the conduits 15 and 36 passes through the nozzle 42 and causes a shattering of the solid particles. From the nozzle 42 the expanded gas-comminuted solid mixture passes through the conduit 43 into the cyclone or other separator 44 where solids and gas are separated and recovered and discharged through different conduits. As discussed hereinbelow, further comminution of explosively shattered material may be effected in the vortex chamber of a cyclone separator.

When the apparatus is employed for the com-

minution of coal, the operating gauge pressure for the steam, air or other gas in the conduit 15 should be at least 5 pounds per square inch or higher. If upstream gauge pressures of 5 pounds per square inch are used, however, the required downstream pressure will be below atmospheric and the degree of comminution is not so great. Superheated steam at a temperature of between 350° F. and 450° F. is suitably employed for the disintegration of coal. At a preferred operating gauge pressure about 200 pounds per square inch or higher in the conduit 15, the gauge pressure in the conduit 43 may suitably be about 60 pounds per square inch or less.

The velocity of the gas upstream of the constriction 42 may range, for instance, from 10 to 400 feet per second and may reach, at the constriction 42, a magnitude of from 700 to 5000 feet per second. Other velocities, however, will also be operative, as long as a practically instantaneous pressure drop of at least 15 pounds per square inch is effected on passage through the constriction 42.

It should be understood that the extent of comminution is determined, inter alia, by the pressure level of operation, by the difference between the upstream and downstream pressures on the two sides of the nozzle 42, by the ratio of gas to solids passing through the nozzle 42, and by the rate of movement of solids through the nozzle 42. Finer comminution is effected by the maintenance of maximum upstream and minimum downstream pressures, by the use of relatively large amounts of gas as compared to the amount of solids, and by the establishment of rapid flow of solids through the nozzle.

The following experiment will illustrate the effect of various upstream pressures. Illinois coal was pulverized utilizing superheated steam at 400° F. and discharging into atmospheric pressure. The coal was characterized by the following screen analysis:

| U. S. Mesh Screen | Percent Retained |
|-------------------|------------------|
| 16                | 7.5              |
| 20                | 58.3             |
| 30                | 32.0             |
| 40                | 0.9              |
| 60                | 0.1              |
| 80                | 0.1              |
| 100               | 0                |
| 140               | 0                |
| 200               | 0                |
| 270               | 0                |
| 270               | 0                |

The screen analyses of the products obtained at various upstream pressures are tabulated as follows:

| Per Cent Retained on U. S. S. Mesh Screen | Upstream Steam Pressure, lbs./sq. in. gauge |       |      |       |      |      |
|-------------------------------------------|---------------------------------------------|-------|------|-------|------|------|
|                                           | 94                                          | 70    | 50   | 40    | 30   | 20   |
| +16-----                                  | 0                                           | 0     | 0    | 0     | 0    | .1   |
| 16-20-----                                | .1                                          | .2    | .2   | .6    | 3.4  | 9.3  |
| 20-30-----                                | .6                                          | 1.2   | 2.6  | 2.92  | 13.5 | 19.9 |
| 30-40-----                                | 2.5                                         | 4.1   | 7.5  | 8.26  | 16.8 | 19.0 |
| 40-60-----                                | 9.3                                         | 12.4  | 17.5 | 14.48 | 22.5 | 21.3 |
| 60-80-----                                | 9.1                                         | 10.1  | 12.7 | 12.12 | 11.6 | 9.5  |
| 80-100-----                               | 5.8                                         | 6.4   | 6.4  | 6.64  | 4.9  | 3.6  |
| 100-140-----                              | 11.0                                        | 11.74 | 11.5 | 11.12 | 7.3  | 5.5  |
| 140-200-----                              | 13.1                                        | 12.72 | 10.8 | 13.08 | 6.0  | 4.0  |
| 200-270-----                              | 21.5                                        | 19.42 | 9.0  | 9.12  | 4.0  | 3.7  |
| -270-----                                 | 26.3                                        | 20.14 | 21.1 | 21.08 | 7.8  | 5.1  |

The effect of using various amounts of steam for the same amount of coal is illustrated by

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data tabulated hereinbelow and obtained by pulverization of Illinois coal at an initial steam pressure of approximately 85 pounds per square inch gauge, the nozzle being discharged into atmospheric pressure.

| Per Cent Retained on U. S. S. Mesh Screens | 0.725 lb. steam per lb. coal |         | 0.629 Up-stream per lb. coal |         | 0.283 Up-stream per lb. coal |         |
|--------------------------------------------|------------------------------|---------|------------------------------|---------|------------------------------|---------|
|                                            | Feed                         | Product | Feed                         | Product | Feed                         | Product |
| +16.....                                   | 17.4                         | 0.8     | 17.6                         | 0.6     | 18.2                         | 1.5     |
| 16-20.....                                 | 13.0                         | 1.6     | 13.6                         | 2.9     | 14.7                         | 3.9     |
| 20-30.....                                 | 11.6                         | 3.4     | 13.9                         | 4.4     | 14.3                         | 8.0     |
| 30-40.....                                 | 11.5                         | 6.6     | 12.3                         | 7.4     | 13.0                         | 10.7    |
| 40-60.....                                 | 14.8                         | 13.8    | 15.3                         | 14.7    | 15.8                         | 19.1    |
| 60-80.....                                 | 7.5                          | 9.8     | 7.7                          | 11.5    | 7.7                          | 12.5    |
| 80-100.....                                | 2.7                          | 7.8     | 3.2                          | 6.1     | 3.6                          | 4.7     |
| 100-140.....                               | 5.0                          | 15.0    | 4.8                          | 14.2    | 3.7                          | 13.5    |
| 140-200.....                               | 3.7                          | 11.4    | 2.9                          | 11.2    | 2.0                          | 7.8     |
| 200-270.....                               | 2.2                          | 6.8     | 1.7                          | 7.2     | 1.6                          | 4.8     |
| -270.....                                  | 9.2                          | 20.8    | 5.2                          | 18.3    | 3.3                          | 11.9    |

The applicability of the present method to the disintegration of a number of solid materials is indicated by data tabulated hereinbelow:

| Per Cent Retained on U. S. S. Mesh Screen | Limestone |         | Sand  |         | Bone Char |         |
|-------------------------------------------|-----------|---------|-------|---------|-----------|---------|
|                                           | Feed      | Product | Feed  | Product | Feed      | Product |
| +16.....                                  | 42.4      | 8.8     | 0.35  | 0.0     | 0.1       | 0.0     |
| 16-20.....                                | 31.5      | 13.4    | 0.35  | 0.0     | 0.7       | 0.0     |
| 20-30.....                                | 17.8      | 11.7    | 4.40  | 1.3     | 10.5      | 0.3     |
| 30-40.....                                | 5.5       | 9.7     | 37.25 | 19.05   | 43.5      | 2.0     |
| 40-60.....                                | 1.4       | 10.4    | 46.35 | 39.6    | 6.7       | 22.5    |
| 60-80.....                                | .2        | 4.3     | 8.45  | 14.25   | 10.0      | 17.1    |
| 80-100.....                               | .2        | 3.3     | 1.60  | 6.0     | 6.3       | 7.4     |
| 100-140.....                              | .2        | 4.8     | .05   | 8.15    | 9.7       | 17.3    |
| 140-200.....                              | .2        | 6.9     | .0    | 4.10    | 5.5       | 12.5    |
| 200-270.....                              | .1        | 10.2    | .0    | 1.85    | 2.5       | 8.0     |
| -270.....                                 | .2        | 15.4    | .0    | 5.05    | 4.1       | 12.8    |

| Per Cent Retained on U. S. S. Mesh Screen | Limestone |         | Coke Breeze |         |
|-------------------------------------------|-----------|---------|-------------|---------|
|                                           | Feed      | Product | Feed        | Product |
| +16.....                                  | 88.3      | 40.8    | 19.4        | 8.0     |
| 16-20.....                                | 8.4       | 16.4    | 14.7        | 8.0     |
| 20-30.....                                | 2.2       | 10.4    | 13.5        | 9.2     |
| 30-40.....                                | 0.4       | 7.6     | 11.7        | 10.1    |
| 40-60.....                                | 0.1       | 6.8     | 14.8        | 15.6    |
| 60-80.....                                | 0         | 2.6     | 8.7         | 11.1    |
| 80-100.....                               | 0         | 1.6     | 3.1         | 5.1     |
| 100-140.....                              | 0         | 2.6     | 3.9         | 10.1    |
| 140-200.....                              | 0         | 1.8     | 2.4         | 7.0     |
| 200-270.....                              | 0         | 1.5     | 1.0         | 3.3     |
| -270.....                                 | 0         | 6.4     | 5.7         | 11.8    |

|                  | Upstream Pressure | Downstream Pressure | Gas    |
|------------------|-------------------|---------------------|--------|
| Limestone.....   | P. s. i. 70       | P. s. i. 15         | Steam. |
| Sand.....        | 75                | 3                   | Do.    |
| Bone Char.....   | 69.5              | 5.5                 | Do.    |
| Limestone.....   | 35                | 0                   | Air.   |
| Coke Breeze..... | 83.5              | 3.0                 | Steam. |

Experimental data are tabulated hereinbelow showing that flash pulverized material can be further comminuted by having the nozzle 42 discharge the streaming entrainment of disintegrated coal or the like directly and tangentially into a vortex chamber such, for instance, as a cyclone separator. Reference is made to the said copending application, Serial No. 762,589, for further means and methods for comminution by means of a flash pulverizing device directly and tangentially discharging into a vortex chamber having an annular or cylindrical inner wall surface.

The data tabulated hereinbelow were obtained by modifying the apparatus of the drawing as follows. In one instance, a filter bag (suitably

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backed up to withstand the gas pressure) was mounted upon the discharge end of the nozzle 42, so that any possible comminution due to impact at the elbow leading into the conduit 43 or due to attrition and/or impact within the separator 44 would be eliminated, the product issuing from the nozzle 42 being caught and retained within the filter bag.

In the other instance, the conduits 30 and 36 and the nozzle 42 were arranged in the horizontal plane of the conduit 15. The nozzle 42 was connected tangentially to a cyclone separator.

The material comminuted in these two modified forms of apparatus was Illinois coal having the following screen analysis:

| Screen Size  | Percent Retained |
|--------------|------------------|
| +16.....     | 21.4             |
| 16-20.....   | 12.4             |
| 20-30.....   | 8.8              |
| 30-40.....   | 12.0             |
| 40-60.....   | 12.4             |
| 60-80.....   | 7.6              |
| 80-100.....  | 3.0              |
| 100-140..... | 6.4              |
| 140-200..... | 4.2              |
| 200-270..... | 3.0              |
| -270.....    | 8.6              |

Comminution was conducted with steam at an up-stream gauge pressure of about 70 pounds per square inch and a down-stream gauge pressure of about 5 to 8 pounds per square inch. The screen analyses of the products are tabulated as follows:

| Screen Size  | Percent Product Retained |              |
|--------------|--------------------------|--------------|
|              | Without Cyclone          | With Cyclone |
| +16.....     | 4.8                      | 1.4          |
| 16-20.....   | 5.2                      | 3.0          |
| 20-30.....   | 6.4                      | 4.8          |
| 30-40.....   | 7.6                      | 7.2          |
| 40-60.....   | 12.6                     | 11.8         |
| 60-80.....   | 7.6                      | 7.6          |
| 80-100.....  | 4.8                      | 4.8          |
| 100-140..... | 11.2                     | 12.0         |
| 140-200..... | 9.6                      | 6.6          |
| 200-270..... | 9.2                      | 14.2         |
| -270.....    | 21.0                     | 25.6         |

The above-disclosed specific apparatus and methods have been disclosed only by way of examples. It should be understood that many details of construction and procedure may be varied within a wide range without departing from the principles of this invention. Thus, any suitable means may be employed, in place of the tank 20 and conveyor 23, to introduce the solid granules to be comminuted into the conduit 15, including means for forcing the material to be disintegrated directly into the conduit 15 against the pressure prevailing in the latter. The nozzle 42 may discharge, if desired, into the atmosphere; in other words, the length of the conduit 43, including the divergent portion of the nozzle, may be reduced to zero. The nozzle 42 may discharge directly and tangentially into a vortex chamber wherein further comminution is effected by vortical movement under the influence of the kinetic energy of the suspending gas, or the disintegrated material issuing from the nozzle may be separated from the suspending gas without such further comminution. If desired, the solid material may have been permeated with a gas under pressure before being introduced into

the compressed fluid in the conduit 15. It is therefore not my purpose to limit the patent granted on this invention otherwise than necessitated by the scope of the appended claims.

I claim as my invention:

1. The method of disintegrating a granular fluid-permeable material which comprises providing a source of compressed fluid capable of being expanded with a pressure drop of at least 15 pounds per square inch; continuously and uninterruptedly discharging compressed fluid from said source while confining the discharged fluid to establish a stream of compressed fluid flowing uninterruptedly and continuously from said source to and past a discharge point spaced from said source; concurrently, continuously and uninterruptedly introducing said granular material into said stream ahead of said discharge point for acceleration and suspension of said granules by said fluid ahead of said discharge point; and at said discharge point establishing and continuously and uninterruptedly maintaining a sharp fluid pressure gradient, the pressure of said granule-suspending fluid being instantaneously reduced as said granule-suspending fluid continuously and uninterruptedly flows past said discharge point; said stream of compressed fluid having a substantially uniform cross sectional area upstream of said discharge point and being sharply constricted only at said discharge point whereby the total fluid pressure drop in said stream is concentrated at said discharge point; the drop in fluid pressure at said discharge point being continuously and uninterruptedly maintained at a value of at least 15 pounds per square inch and the fluid pressure immediately downstream of said discharge point being reduced at least to an extent where further downstream pressure reduction will not bring about a substantially increased weight rate of flow past said discharge point; said granular material being introduced into said stream in an amount less than 4 parts by weight for each part of fluid when said pressure drop amounts to less than 500 pounds per square inch and in the form of granules having a maximum dimension not greater than one-third of the minimum dimension of said stream at said discharge point; each of said suspended granules being carried in suspension by said streaming compressed fluid along a substantially straight path to and past said discharge point and there further accelerated and subjected to said instantaneous drop in fluid pressure whereby all said granules are disintegrated in the same manner.

2. The method of disintegrating a granular fluid-permeable material which comprises providing a source of compressed fluid capable of being expanded with a pressure drop of at least 15 pounds per square inch; continuously and uninterruptedly discharging compressed fluid from said source while confining the discharged fluid to establish a stream of compressed fluid flowing uninterruptedly and continuously from said source to and past a discharge point spaced from said source; concurrently, continuously and uninterruptedly introducing said granular material into said stream ahead of said discharge point for acceleration and suspension of said granules by said fluid ahead of said discharge point; and at said discharge point establishing and continuously and uninterruptedly maintaining a sharp fluid pressure gradient, the pressure of said granule-suspending fluid being instantaneously reduced as said granule-suspending fluid

continuously and uninterruptedly flows past said discharge point; said stream of compressed fluid having a substantially uniform cross sectional area upstream of said discharge point and being sharply constricted only at said discharge point whereby the total fluid pressure drop in said stream is concentrated at said discharge point; the drop in fluid pressure at said discharge point being continuously and uninterruptedly maintained at a value of at least 15 pounds per square inch and the fluid pressure immediately downstream of said discharge point being reduced at least to an extent where further downstream pressure reduction will not bring about a substantially increased weight rate of flow past said discharge point; said fluid flowing ahead of said discharge point at a velocity of from 10 to 400 feet per second and being instantaneously accelerated at said discharge point to a velocity of from 700 to 5000 feet per second; said granular material being introduced into said stream in an amount less than 4 parts by weight for each part of fluid when said pressure drop amounts to less than 500 pounds per square inch and in the form of granules having a maximum dimension not greater than one-third of the minimum dimension of said stream at said discharge point; each of said suspended granules being carried in suspension by said streaming compressed fluid along a substantially straight path to and past said discharge point and there further accelerated and subjected to said instantaneous drop in fluid pressure whereby all said granules are disintegrated in the same manner.

3. The method of disintegrating a granular fluid-permeable material which comprises providing a source of compressed fluid capable of being expanded with a pressure drop of at least 15 pounds per square inch; enclosing said material in a confined space; thereafter admitting said fluid into said confined space; continuously and uninterruptedly discharging compressed fluid from said source while confining the discharged fluid to establish a stream of confined fluid flowing uninterruptedly and continuously along a substantially straight path from said source to and past a discharge point spaced from said source; concurrently, continuously and uninterruptedly transferring said granular material along a confined path from said space into said stream ahead of said discharge point for acceleration and suspension of said granules by said fluid ahead of said discharge point, said granular material being maintained under balanced fluid pressure during said transfer by said admission of fluid into said confined space; and at said discharge point establishing and continuously and uninterruptedly maintaining a sharp fluid pressure gradient, the pressure of said granule-suspending fluid being instantaneously reduced as said granule-suspending fluid continuously and uninterruptedly flows past said discharge point; said stream of compressed fluid having a substantially uniform cross sectional area upstream of said discharge point and being sharply constricted only at said discharge point whereby the total fluid pressure drop in said stream is concentrated at said discharge point; the drop in fluid pressure at said discharge point being continuously and uninterruptedly maintained at a value of at least 15 pounds per square inch and the fluid pressure immediately downstream of said discharge point being reduced at least to an extent where further downstream pressure reduction will not bring about a sub-

stantially increased weight rate of flow past said discharge point; said granular material being introduced into said stream in an amount less than 4 parts by weight for each part of fluid when said pressure drop amounts to less than 500 pounds per square inch and in the form of granules having a maximum dimension not greater than one-third of the minimum dimension of said stream at said discharge point; each of said suspended granules being carried in suspension by said streaming compressed fluid along a substantially straight path to and past said discharge point and there further accelerated and subjected to said instantaneous drop in fluid pressure whereby all said granules are disintegrated in the same manner.

4. The method of disintegrating a granular fluid-permeable material which comprises providing a source of compressed fluid capable of being expanded with a pressure drop of at least 15 pounds per square inch; enclosing said material in a confined space; thereafter admitting said fluid into said confined space; continuously and uninterruptedly discharging compressed fluid from said source while confining the discharged fluid to establish a stream of confined fluid flowing uninterruptedly and continuously along a substantially straight path from said source to and past a discharge point spaced from said source; concurrently, continuously and uninterruptedly transferring said granular material along a confined path from said space into said stream ahead of said discharge point for acceleration and suspension of said granules by said fluid ahead of said discharge point, said granular material being maintained under balanced fluid pressure during said transfer by said admission of fluid into said confined space; and at said discharge point establishing and continuously and uninterruptedly maintaining a sharp fluid pressure gradient, the pressure of said granule-suspending fluid being instantaneously reduced as said granule-suspending fluid continuously and uninterruptedly flows past said discharge point; said stream of compressed fluid having a substantially uniform cross sectional area upstream of said discharge point and being sharply constricted only at said discharge point whereby the total fluid pressure drop in said stream is concentrated at said discharge point; the drop in fluid pressure at said discharge point being continuously and uninterruptedly maintained at a value of at least 15 pounds per square inch and the fluid

pressure immediately downstream of said discharge point being reduced at least to an extent where further downstream pressure reduction will not bring about a substantially increased weight rate of flow past said discharge point; said fluid flowing ahead of said discharge point at a velocity of from 10 to 400 feet per second and being instantaneously accelerated at said discharge point to a velocity of from 700 to 5000 feet per second; said granular material being introduced into said stream in an amount less than 4 parts by weight for each part of fluid when said pressure drop amounts to less than 500 pounds per square inch and in the form of granules having a maximum dimension not greater than one-third of the minimum dimension of said stream at said discharge point; each of said suspended granules being carried in suspension by said streaming compressed fluid along a substantially straight path to and past said discharge point and there further accelerated and subjected to said instantaneous drop in fluid pressure whereby all said granules are disintegrated in the same manner.

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