May 18, 1948. L. BALASSA 2,441,613

METHOD AND APPARATUS FOR PULVERIZING AND PROCESSING MATERIALS

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FIG. 1.

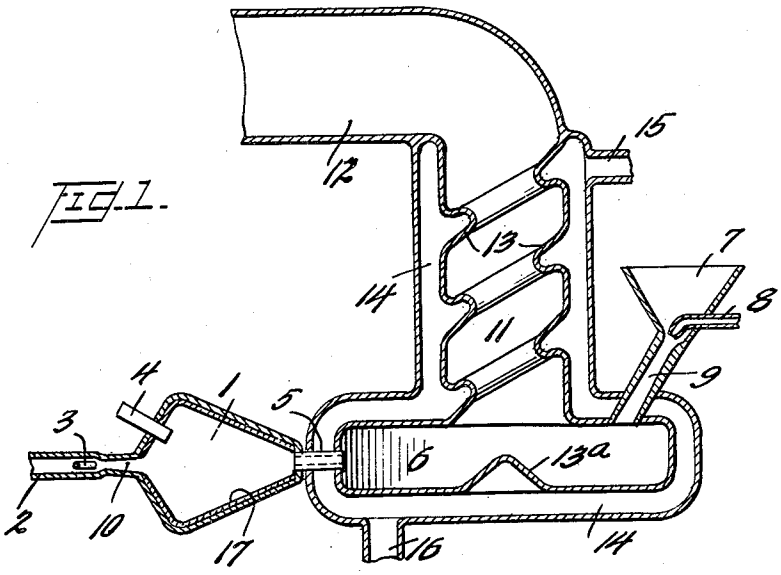
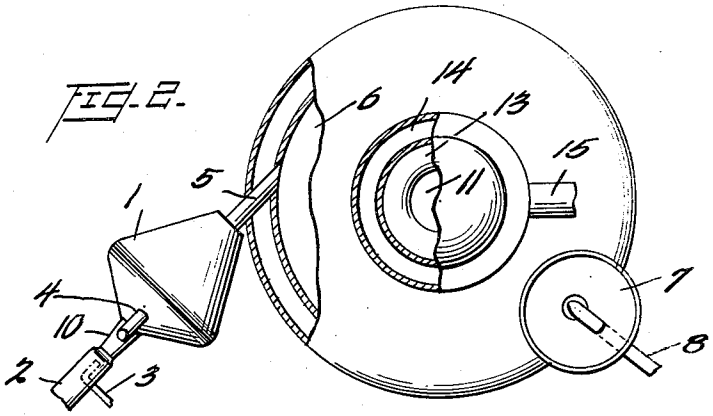


FIG. 2.



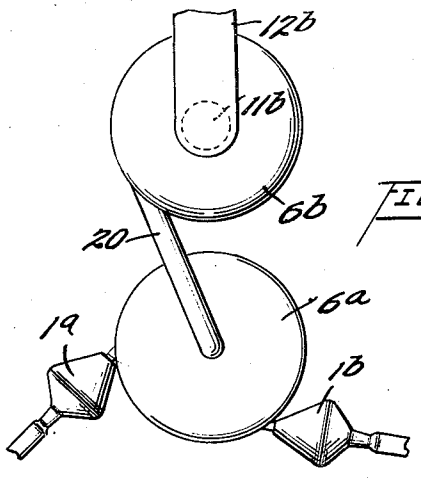


FIG. 3.

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METHOD AND APPARATUS FOR PULVERIZING AND PROCESSING MATERIALS

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8 Claims. (Cl. 23—1)

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My invention relates to a method and apparatus for pulverizing and activating material at high temperatures.

A wide variety of pulverizing methods and apparatus utilizing compressed air, high pressure steam or other similar forms of fluid energy to create a vortex have been proposed and successfully employed. Such pulverizers usually consist of a circular or cylindrical vortex chamber into which the gaseous fluid is injected through one or more jets placed in such a manner as to create a vortex and to maintain the gaseous fluid in a spiralling vortex in the chamber. The material to be treated is introduced into the vortex at its periphery, and the cyclonic or tornado-like vortex of the gases subjects the entrained material to the combined effects of powerful centrifugal forces, as well as of friction and impact, both of the particles on each other and on the walls of the chamber, resulting in the reduction of the particle size of said material to a fine powder. In no case, however, did the prior art contemplate the use of fluids at high temperature, such as above 800° F., or any other change than a reduction in the particle size of the materials being treated.

My invention has as an object the utilization of high temperature, high velocity gaseous fluid for pulverizing and reacting with the material at high temperature. A further object is a method by which material suspended in a gaseous medium may be pulverized and calcined simultaneously. Another object is a method and apparatus suitable for simultaneously grinding and reducing oxide ores to metal. A further object is a method and apparatus suitable for the drying of wet mineral pigment pulps, thus avoiding the formation of hard agglomerates which necessitate further grinding. An even further object is a method and apparatus by which materials in solution may be dried in an efficient manner. Other objects will appear hereinafter.

In one form, these objects may be accomplished by the continuous combustion of suitable fluid fuel-air blends in a pressure combustion chamber under uniform pressure. The heat energy in the burned gases is converted into velocity by expansion, and the gases are discharged into a vortex chamber, in such a manner as to create and maintain a high velocity inwardly spiralling vortex. The gases are discharged from the center of the vortex into a reaction chamber, retaining to a large extent both their velocity and their spiral movement. The material to be treated, having a mesh size not greater than ½ inch but

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preferably ¼ inch or finer is introduced into the vortex chamber where the combined effects of the heat, high velocity, centrifugal forces, friction and impact between the particles of the material and the wall of the vortex chamber pulverize said material. The material is subjected to the physical and chemical action of the gases throughout the time of its retention in the grinding chamber and while it is passing through the reaction chamber. The chemical composition of the gases is controlled by suitable adjustments in the fuel-air ratio as well as through the introduction of other substances at any point in the vortex or reaction chamber. The effect obtained by my methods and in my apparatus, in addition to reduction in the particle size, may be that of calcination, drying, oxidation and chemical reduction, depending on the material being treated and on the composition of the gases employed.

Referring to the drawing for a more complete disclosure of the invention,

Figure 1 is a vertical section of an apparatus suitable for the carrying out of my invention;

Figure 2 is a horizontal fragmentary section of the same apparatus;

Figure 3 is a diagrammatic plan view of a modified form.

The apparatus is provided with a combustion chamber 1 that has a heat resistant lining 17. Leading into the chamber 1 is a compressed air inlet pipe 2 connected to the venturi 10 and leading into the mouth of the venturi is a fluid fuel inlet nozzle 3. The combustion chamber 1 is provided with an ignition plug 4 in one of the walls for igniting the fuel. The exit end of the chamber 1 is constricted to form a nozzle 5 which is connected with and tangent to the disc-shaped vortex chamber 6, the latter in turn being connected with and leading into the cylindrical reaction chamber 11 of relatively smaller diameter.

The chamber 11 is provided on its inner side with a spiral baffle 13 extending from the bottom to the top of chamber 11, and is connected at the outlet end with the duct 12 which leads to any suitable collecting or treating apparatus.

For feeding the material to be treated into the apparatus, I provide a hopper 7 with an injector feeder head 9 opening into the vortex chamber 6, a compressed air or steam supply pipe 8 being connected to the feeder head.

The chambers 6 and 11 may be provided with a water or steam jacket 14 having an intake 15 and outlet 16.

The bottom of the vortex chamber is also provided with a baffle 13a.

In the modified form shown in Fig. 3, 1a and 1b are combustion chambers, similar to combustion chamber 1 of Figs. 1 and 2 in structure and arrangement. These chambers lead into the vortex chamber 6a and the products of that chamber are led from the center of the chamber 6a to the periphery of a similar central part of the vortex chamber 6b by the conduit 20. From the vortex chamber 6b, the gases are conducted through the spiral reaction chamber 11b and out the duct 12b, all as in Fig. 1.

Operation

Compressed air through the line 2 is forced into combustion chamber 1. Fluid fuel is injected through nozzle 3. The fuel-air mixture is ignited by the glow plug 4. The diameter of nozzle 5 is selected so that a constant pressure of approximately the same magnitude as that of the compressed air is maintained in the combustion chamber. After the combustion chamber becomes sufficiently hot to maintain continuous combustion, the circuit to the glow plug is broken and the fuel air-ratio is adjusted to obtain the desired effect. The high temperature products of combustion are injected, at high velocity, through nozzle 5, into the vortex chamber 6. The fluid entering tangentially, the periphery of the cylindrical vortex chamber creates a spiralling vortex and maintains it at a high rotative speed. Leaving the vortex chamber 6 through the center of the vortex, the fluid enters the reaction chamber 11. Retaining a considerable part of its rotative or spiralling motion the fluid proceeds through the reaction chamber 11 which is equipped with a spiral baffle 13 which aids in maintaining the rotative motion of the fluid. The material to be treated is forced through the injector feeder head 9 into the vortex chamber 6. Under the combined effects of the high heat of the combustion gases, of the centrifugal forces created by the high velocity vortex, of the friction and impact between the particles of the material and of the walls of the vortex chamber, the material is rapidly disintegrated to a fine powder. In the vortex chamber 6 the centrifugal force keeps the larger particles near the periphery of the vortex while the smaller, finely ground particles are carried by the inwardly spiralling gaseous fluid into the reaction chamber. While being pulverized and in the reaction chamber, the material is subjected not only to the physical forces of heat, friction and impact but also to the chemical action of the gaseous fluid. Depending on the fuel-air ratio used in the combustion chamber 1, the gaseous fluid exerts one of the following three effects:

In the case of complete combustion of the fuel, with no excess oxygen present, the effect is usually only that of the heat transmitted by the fluid.

If a high fuel-air ratio is used, leaving an excess of fuel in partial stages of combustion, the effect of the fluid is strongly reducing.

With a low fuel-air ratio, resulting in a fluid containing excess oxygen, the effect will be strongly oxidizing.

After leaving the reaction chamber, the treated material, entrained in the fluid may be precipitated, either in cyclone separators utilizing the vortical energy still remaining or collected by settling in flues, by filtering with cloth, or by magnetic or electrostatic means.

The water and steam jackets 14 around the reaction and vortex chambers serve to protect the walls of the apparatus from the high heat of the gaseous fluid as well as to capture part of the waste heat. The steam produced in the jackets may be used to generate the power necessary for the operation of the process.

It will be seen that my invention is readily adaptable for the treating of materials in a variety of ways hitherto unobtainable in vortex grinding apparatus. By adjusting the fuel-air ratio in the combustion chamber 1, so as to provide air in a slight excess over that theoretically required for the particular fuel used, I am able to obtain temperatures as high as 2500° F. in the vortex chamber. Under these conditions, my invention is particularly suited for the simultaneous grinding and calcination of materials. Under such conditions, I have fed a water wet mineral pigment pulp into the vortex chamber and obtained a product which was dried, finely pulverized and calcined as well.

On adjusting the fuel-air ratio to provide an excess of fuel over that required for the oxygen present, incomplete combustion of the fuel resulted. The gases entering the vortex chamber in this case contained a high percentage of carbon monoxide, some free carbon, hydrogen and methane. The chemical effect of the gases was strongly reducing while the temperature obtained was between 1800° and 2000° F. Under these conditions I am able to reduce iron oxide ore (hematite) to metal.

With the fuel-air ratio adjusted to provide an excess of oxygen in the vortex chamber, I am able to process oxidizable materials like iron sulfide ore, simultaneously grinding and oxidizing same to iron oxide.

In an apparatus constructed and proportioned as shown in Figs. 1 and 2, but having two combustion chambers, as shown in Fig. 3, the volume of the combustion chambers 1 was about 4 gallons each with nozzles 5 of ¼" diameter, the vortex chamber 6 had a diameter of 38" and a height of 3" measured from inside to inside of the base plate and the top at the periphery of the vortex chamber. The reaction chamber 11 had an inside diameter of 24" and a height of ten feet. The injector feeder head 9 had a nozzle with a $\frac{5}{16}$" opening and the venturi opening of ¾" in diameter at its narrowest part.

The following examples describe operating conditions under which satisfactory results have been obtained in accordance with my invention.

Example 1

Air at a pressure of 40 lbs. per square inch was introduced into the combustion chamber. Fuel oil was introduced at first in sufficient amount to obtain complete combustion. After the combustion chamber became sufficiently hot to support combustion, the fuel-air ratio was adjusted to the maximum amount of fuel at which the combustion was still self-supporting. At this point, the gaseous fluid formed by the combustion gases acquired a strongly reducing character. When coarse iron oxide ore, hematite, screened through ⅜" mesh, was supplied to the vortex through the injector feeder, metallic iron having an average particle size of two microns was collected to the magnetic separators.

Example 2

Using air at a pressure of 40 lbs. per square inch and only the minimum of fuel, with which

continuous combustion could be maintained, a gaseous fluid with highly oxidizing character was obtained. When coarse iron sulfide ore (pyrites) was introduced into the vortex chamber, iron oxide having an average particle size of two microns was collected in the flues.

Example 3

Using air at the pressure of 50 lbs. per square inch and maintaining a fuel-air ratio of 50% excess air calculated on the fuel oil used, a temperature of 2370° F. was obtained in the vortex chamber and maintained throughout the experiment. When ¼" lumps of calcite were fed into the vortex chamber at a rate of 400 lbs. per hour, calcium oxide ground to an average particle size of two microns was recovered in the flues.

Example 4

The conditions of Example 3 were maintained in this experiment. When a 50% solution of ferric sulfate (coquimbite) in water was fed into the vortex chamber, finely pulverized iron oxide was recovered from the centrifugal separator.

Example 5

The conditions of Example 3 were maintained in this experiment, but the apparatus was changed to have the vortex chamber 8 in vertical position, and the reaction chamber 11 in horizontal position. When a mixture of 2 mols of sodium carbonate and one mol of silica was fed into the vortex chamber, fused sodium meta-silicate was obtained from the centrifugal separator.

Example 6

The conditions of Example 3 were maintained in this experiment. When a water wet pulp of acid treated barium sulfate containing 30% water was fed into the vortex chamber, a highly calcined and finely pulverized product of good white color was obtained.

Example 7

The conditions of Example 5 were maintained in this experiment, using hydrogen as fuel. When a 25% solution of sodium hydroxide in water was fed into the vortex chamber, fused sodium hydroxide of around 90% NaOH content was obtained from the centrifugal separator.

Example 8

The conditions of Example 3 were maintained in this experiment. When a mixture of calcium carbonate and silica in equi-molecular proportions was fed into the vortex chamber finely pulverized calcium silicate was obtained from the centrifugal separator.

It is apparent that a great many variations of the above apparatus as to dimensions, types of feeding, etc., are possible within the principles laid down by my invention. The apparatus if desired may be constructed of metal or of suitable ceramic materials. The combustion chambers may be of any suitable design or shape and are preferably lined with fire brick. The nozzle 5 should preferably be of quartz or other similar heat resisting material. The glow plug 4 may be of any of the standard designs used in Diesel engines or it may be substituted by a spark plug or glow wire. In the preferred embodiment of my invention, I have utilized the gaseous fluid obtained through continuous combustion of a fuel-air mixture under pressure. Satisfactory results may be obtained, however, also if the fluid is produced through intermittent combustion or through successive explosions of the fuel-air mixture and irrespective of whether the fuel-air mixture was compressed before ignition or if it was ignited at atmospheric pressure.

While I have disclosed as a preferred embodiment, the use of a fluid fuel-air combustible mixture, other combinations of gases, liquids and solids are within the scope of my invention, where they combine with an exothermic reaction and where the products of the reaction are gases that have a substantially greater volume at the same pressure than the volume introduced into the vortex chamber, thus producing increased velocity in the vortex chamber.

Any of the conventional combustible fuels meeting the above requirements may be employed, such as furnace oil, Diesel oil, kerosene, illuminating, natural and water gas, hydrogen, butane and the like and powdered coal.

The operating pressure in the combustion chamber may range from 30 lbs. per square inch up, depending on the construction of the apparatus. In the type of apparatus disclosed in Figs. 1 and 2, the pressure in the vortex and reaction chambers will usually be near atmospheric but it may reach substantially higher pressures. High pressures are used when the vortex chambers are hooked up in tandem, as shown in Fig. 3, for the gradual stepwise expansion of the gases.

The most useful range of operating temperatures will lie between 1000–1800° C. in the combustion chamber, and between 800–1400° C. in the vortex and reaction chambers, although high temperatures are operative in both chambers.

The speed of the vortex is above 20,000 R. P. M. and preferably about 40,000 R. P. M.

While I prefer to have the vortex chamber in horizontal position, with the reaction chamber in vertical position, the reversal of the relative position of the two chambers does not materially affect the functioning of my apparatus and is within the scope of my invention.

In order to extend the processing time of materials that are difficult to oxidize or reduce, the reaction chamber may be lengthened to any extent necessary to obtain a retention time sufficient for the completion of the reaction in question. Both the vortex and the reaction chamber may be equipped with jets suitable for the injection of air, steam or other gases to modify the quality of the product obtained.

By coupling two or more vortex chambers, as shown in Fig. 3, in such a manner as to force the fluid leaving the center of the first vortex chamber into the rim of the second and repeating this process any desired number of times until the pressure of the gases drops to atmosphere pressure, it is possible to provide a step-wise expansion of the combustion gases generated in the combustion chamber. At any desired stage of this process the volume velocity or composition of the gases may be increased or otherwise changed through the introduction of gases generated in additional combustion chambers.

If desired, the direction of the reaction may be changed from oxidation to reduction or vice versa by changing the composition of the gases at various stages. For instance, calcining in the first stage with a slight excess of air and then in the second stage introducing a reducing gas like methane or ethyl alcohol, which after exhausting the excess oxygen provides a strong reducing atmosphere.

My invention has the following advantages over the prior art:

1. It provides for a more efficient use of fluid energy. I obtain about the same grinding effect with a compressed air supply of 40 lbs. pressure to the fuel-air blend, as the prior art would obtain at around 250 lbs. pressure with air alone. This is due to the increased volume of the gases of combustion at the high operating temperature of my apparatus.

2. It utilizes high heat gaseous vortex for pulverizing and for effecting simultaneously one or more physical and chemical processes at temperatures beyond the reach of prior art.

3. It provides the conditions which make it possible to pulverize materials and simultaneously effect physical and chemical changes such as calcination, oxidation, reduction and chemical combination of two or more materials.

4. It makes it possible to control the composition and the temperature of the gaseous fluid during the process, through changes in the fuel-air ratio or through introduction of air, steam or other fluid at any desired stage of the process or by increasing the circulation of the liquid in the jackets. In other words, when the hot gases of combustion flow through the nozzle 5 into the grinding chamber 6, applicant derives the same benefit from the drop in pressure from that in the combustion chamber to a pressure only slightly above atmospheric which exists in the grinding chamber that is realized in the prior art, but, in addition, the drop in temperature converts a large proportion of the heat in the gases into kinetic energy, which is expended in increasing the velocity of the gases in the grinding chamber.

It will be seen from the above examples that there may be provided procedures and methods of construction which vary considerably but which yet embody the fundamental and novel concepts of my invention.

Since certain changes in the construction of my apparatus and in carrying out my processes, which embody the invention, may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the accompanying drawing shall serve merely as illustration and not limiting in any sense.

I claim:

1. A method of pulverizing solid material and simultaneously chemically reacting said material at high temperatures comprising the steps of leading a combustible mixture into a combustion chamber and burning the same under conditions which create high temperatures and pressures in said chamber, leading the combustion gases from said combustion chamber through a narrow passageway to a circular vortex chamber and introducing the combustion gases from said passageway tangentially into said circular vortex chamber at high temperatures and pressures, the gases moving at high speeds spirally in said vortex chamber, while concurrently introducing solid material to be processed into said gases in said vortex chamber at a pressure in excess of the pressure in said vortex chamber, simultaneously cooling the vortex chamber and introducing the gases into a reaction chamber which conducts the material and gases through a prolonged path in the reaction chamber whereby slowing down of the gases is effected and causes substantial completion of said reaction.

2. A method of pulverizing solid material and simultaneously chemically reacting said material at high temperatures comprising the steps of leading a combustible mixture into a combustion chamber and burning the same under conditions which create high temperatures and pressures in said chamber, leading the combustion gases from said combustion chamber through a narrow passageway to a circular vortex chamber and introducing the combustion gases from said passageway tangentially into said circular vortex chamber at high temperatures and pressures, the gases moving at high speeds spirally in said vortex chamber, while concurrently introducing solid material to be processed into said gases in said vortex chamber at a pressure in excess of the pressure in said vortex chamber, introducing the gases into a reaction chamber which conducts the material and gases through a prolonged path in the reaction chamber whereby slowing down of the gases is effected and causes substantial completion of said reaction, and simultaneously cooling the vortex chamber and the reaction chamber.

3. A method of pulverizing solid material and simultaneously chemically reacting said material at high temperatures comprising the steps of leading a combustible mixture into a combustion chamber and burning the same under conditions which create high temperatures and pressures in said chamber, leading the combustion gases from said combustion chamber through a narrow passageway to a circular vortex chamber and introducing the combustion gases from said passageway tangentially into said circular vortex chamber at high temperatures and pressures, the gases moving at high speeds spirally in said vortex chamber, while concurrently introducing solid material to be processed into said gases in said vortex chamber at a pressure in excess of the pressure in said vortex chamber, simultaneously cooling the vortex chamber and introducing the gases into a reaction chamber which conducts the material and gases through a spiral path in the reaction chamber whereby slowing down of the gases is effected and causes substantial completion of said reaction.

4. A method of pulverizing solid material and simultaneously chemically reacting said material at high temperatures comprising the steps of leading a combustible mixture into a combustion chamber and burning the same under conditions which create high temperatures and pressures in said chamber, leading the combustion gases from said combustion chamber through a narrow passageway while simultaneously cooling said passageway at a point adjacent to its connection to said vortex chamber and introducing the combustion gases from said passageway tangentially into a circular vortex chamber at high temperatures and pressures, the gases moving at high speeds spirally in said vortex chamber, while concurrently introducing solid material to be processed into said gases in said vortex chamber at a pressure in excess of the pressure in said vortex chamber, simultaneously cooling the vortex chamber and introducing the gases into a reaction chamber which conducts the material and gases through a prolonged path in the reaction chamber whereby slowing down of the gases is effected and causes substantial completion of said reaction.

5. An apparatus for pulverizing solid material and simultaneously chemically reacting said material at high temperatures, comprising a combustion chamber, a relatively shallow circular vortex chamber, means connecting the combus-

tion chamber with the vortex chamber including at least one nozzle angularly connected to the periphery of the vortex chamber, a fuel inlet for said combustion chamber, ignition means in said combustion chamber, an inlet into said vortex chamber in proximity to its circumference for the admission of solid comminuted material, a jacket surrounding said vortex chamber, a reaction chamber axially mounted as to said vortex chamber and axially communicating therewith, said reaction chamber being constructed to provide an elongated path of flow for the mixture of gas and solid particles and to prevent direct straight line flow therethrough.

6. An apparatus for pulverizing solid material and simultaneously chemically reacting said material at high temperatures, comprising a combustion chamber, a relatively shallow circular vortex chamber, means connecting the combustion chamber with the vortex chamber including at least one nozzle angularly connected to the periphery of the vortex chamber, a fuel inlet for said combustion chamber, ignition means in said combustion chamber, an inlet into said vortex chamber in proximity to its circumference for the admission of solid comminuted material, a jacket surrounding said vortex chamber, a reaction chamber, means mounting said reaction chamber above and axially aligned as to said vortex chamber and axially communicating therewith, said reaction chamber being constructed to provide an elongated path of flow for the mixture of gas and solid particles and to prevent direct straight line flow therethrough.

7. An apparatus for pulverizing solid material and simultaneously chemically reacting said material at high temperatures, comprising a combustion chamber, a relatively shallow circular vortex chamber, means connecting the combustion chamber with the vortex chamber including at least one nozzle angularly connected to the periphery of the vortex chamber, a fuel inlet for said combustion chamber, ignition means in said combustion chamber, an inlet into said vortex chamber in proximity to its circumference for the admission of solid comminuted material, a jacket surrounding said vortex chamber, a reaction chamber axially mounted as to said vortex chamber and axially communicating therewith, said reaction chamber being constructed to provide a spiral path of flow for the mixture of gas and solid particles and to prevent direct line flow therethrough.

8. An apparatus for pulverizing solid material and simultaneously chemically reacting said material at high temperatures, comprising a combustion chamber, a relatively shallow circular vortex chamber, means connecting the combustion chamber with the vortex chamber including a plurality of nozzles angularly connected to the periphery of the vortex chamber, a fuel inlet for said combustion chamber, ignition means in said combustion chamber, an inlet into said vortex chamber in proximity to its circumference for the admission of solid comminuted material, a jacket surrounding said vortex chamber, a reaction chamber axially mounted as to said vortex chamber and axially communicating therewith, said reaction chamber being constructed to provide a spiral path of flow for the mixture of gas and solid particles and to prevent direct straight line flow therethrough, and a second jacket surrounding said reaction chamber.

LADISLAUS BALASSA.

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