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Kugelberg et al.

[11] **3,837,583**

[45] **Sept. 24, 1974**

[54] **MULTI-STAGE JET MILL**

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[52] **U.S. Cl.** **241/39,** 241/76, 241/5

[51] **Int. Cl.** **B07b 7/04**

[58] **Field of Search** .... 241/5, 39, 40, 76, 78, 241/152 R

[56] **References Cited**

UNITED STATES PATENTS

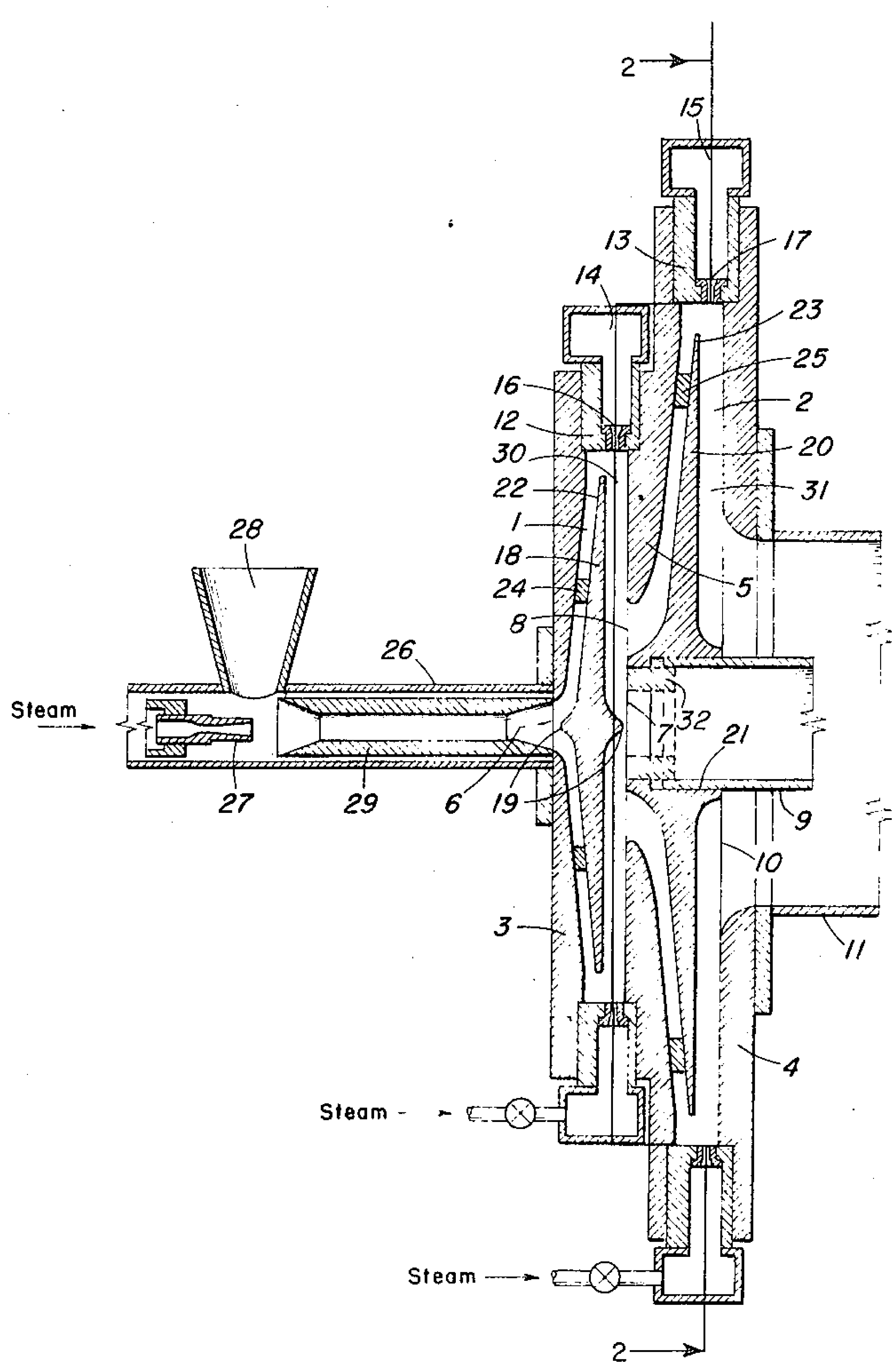
2,032,827	3/1936	Andrews	241/5
2,846,151	8/1958	Wehn et al.	241/39
3,058,673	10/1962	Firing	241/39
3,348,779	10/1967	Andrews	241/39
3,380,665	4/1968	Jester et al.	241/5

Primary Examiner—Roy Lake
Assistant Examiner—R. Daniel Crouse

[57] **ABSTRACT**

An improved multi-stage jet mill is described which may, for example, be used for dry milling pigments.

8 Claims, 3 Drawing Figures



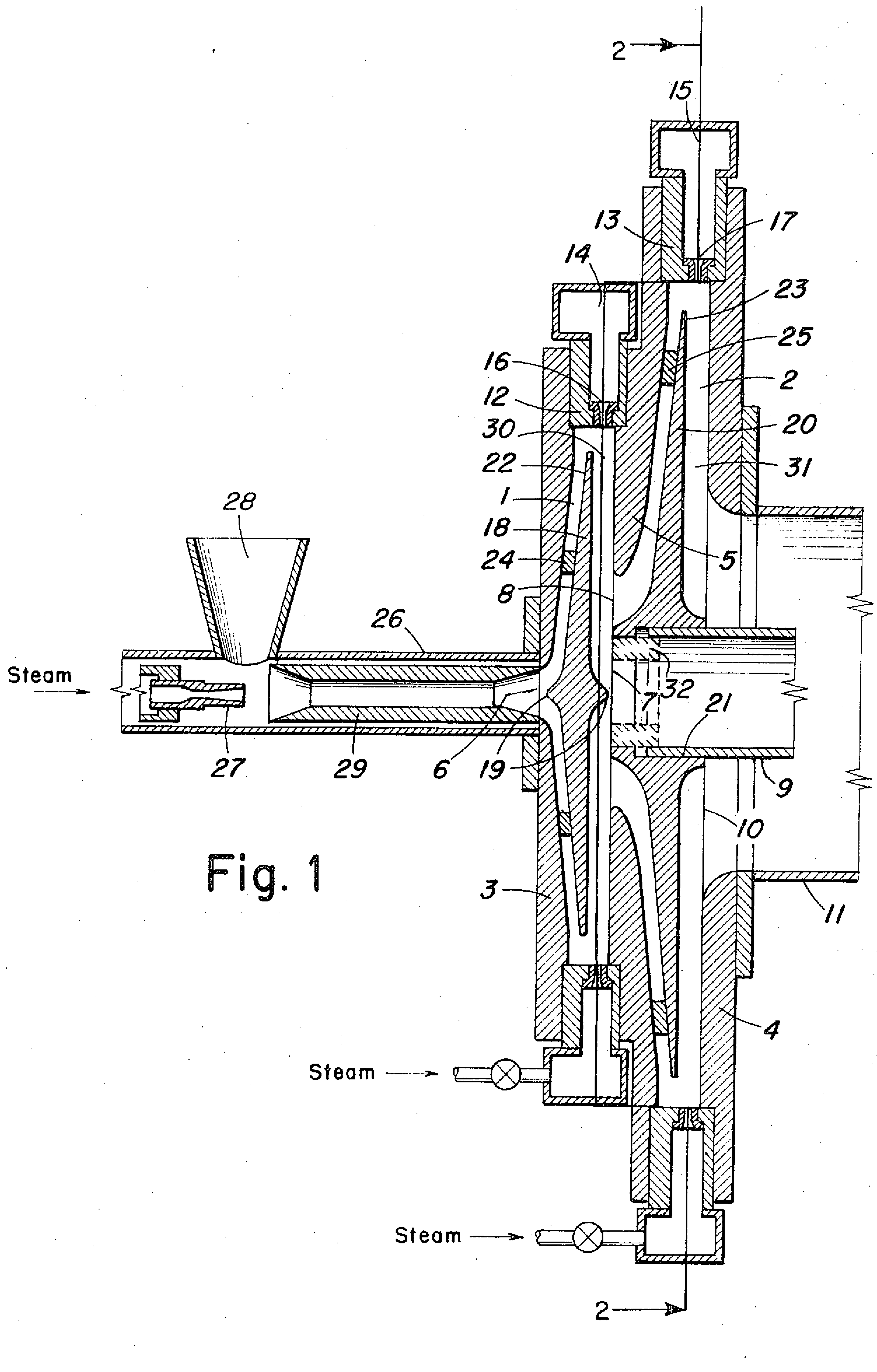

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Fig. 1

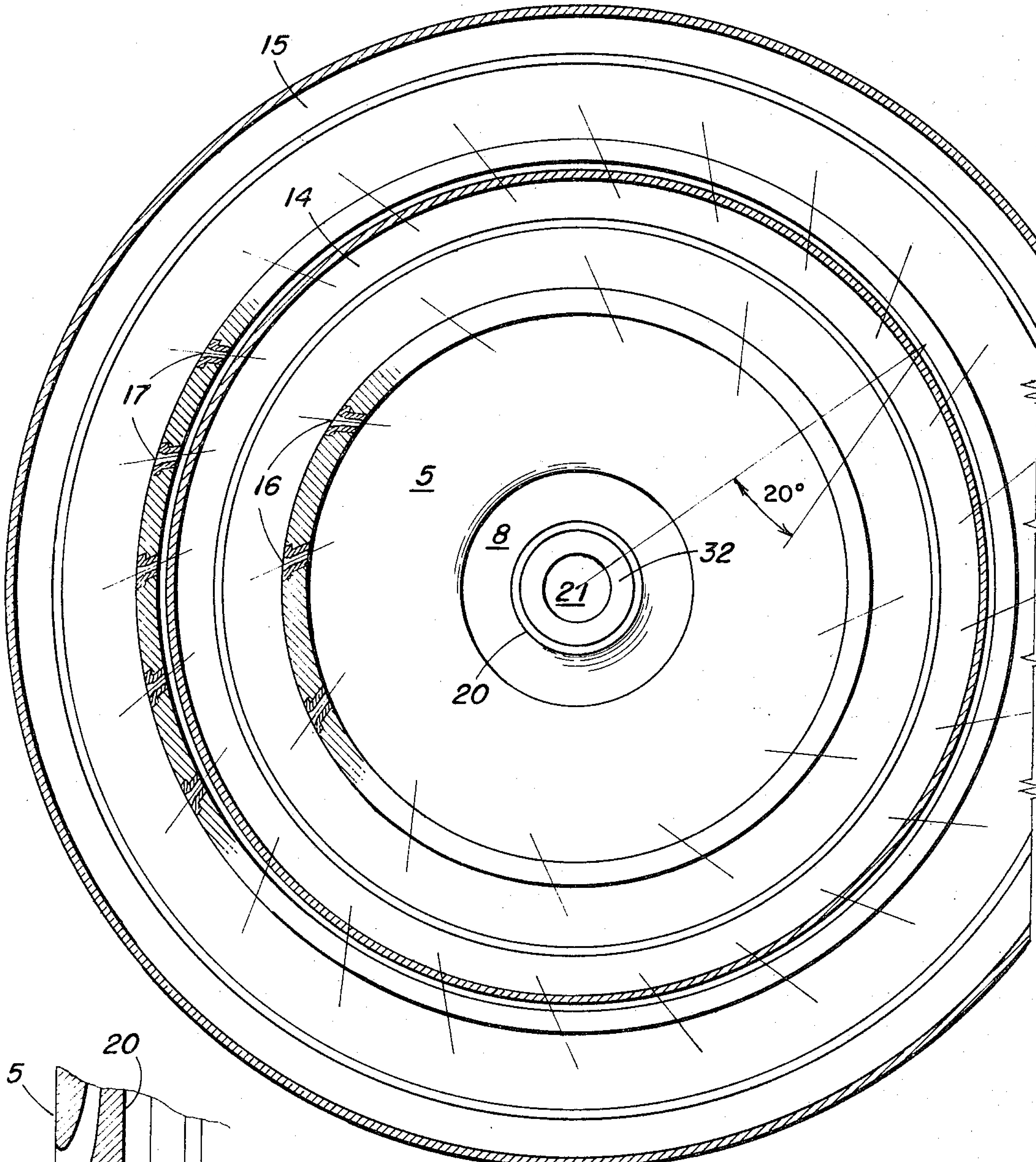

Fig. 2.

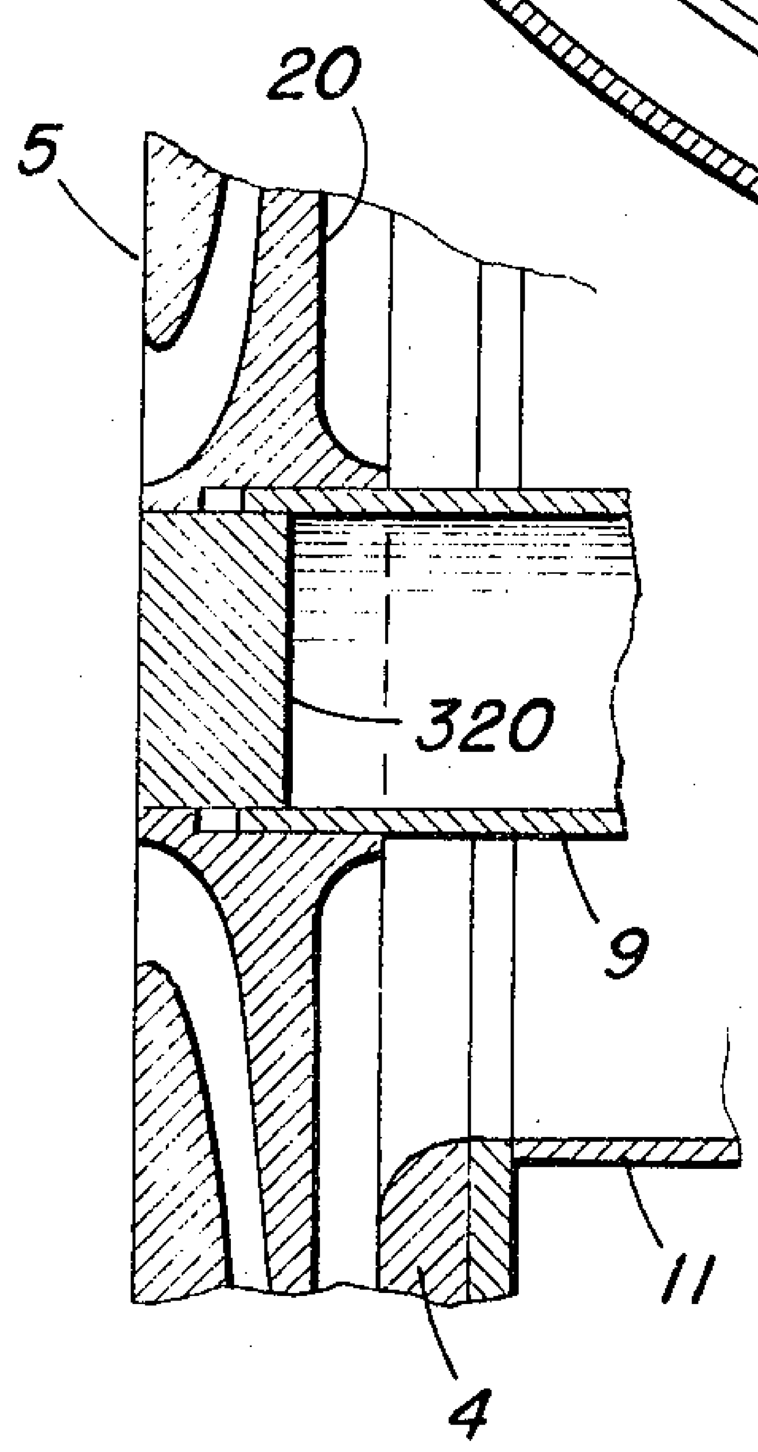

Fig. 3.

MULTI-STAGE JET MILL

BACKGROUND OF THE INVENTION

Each of U.S. Pat. No. 2,032,827 and German Pat. DT-AS No. 1,223,237 describes a jet mill comprising a flat cylindrical milling chamber bounded by two opposed frontal walls. In one of these walls are one or more inlets for the material to be milled; the other of said walls is provided with an outlet for the milled material. The circumference of the chamber is fitted with a number of nozzles arranged at angels to each other for the introduction of streams of gas under pressure into the milling chamber adjacent the periphery thereof. The material to be milled is introduced into the chamber under pressure in such a way that it is caught by the pressurized streams of gas, sometimes referred to as jets, and subjected to rotational movement thereby. In this rotational movement, the material is milled and subsequently carried out of the milling chamber together with the pressurized gas.

It is well known that the milling intensity of such a mill is measured in terms of the ratio of the amounts of pressured gas to amounts of material to be milled, e.g., pigment, and is commonly referred to as the "steam:pigment ratio". The higher the steam:pigment ratio is, the more intense is the milling and the finer should be the milled product.

It is indeed possible to operate these earlier mills at sufficiently high steam:pigment ratios to produce pigments that are satisfactory for many purposes. However, when endeavoring to produce still better pigments there is a definite limit in respect to the capacity of these earlier devices. When the steam:pigment ratio is raised, to insure better grinding, very large volumes of gas are introduced into the mill in proportion to the amount of milled material; and as a consequence the maximum possible pigment thruput is lowered. In addition, at these high milling intensities too large a portion of the milled pigment is of too small particle size. For this reason the material produced has an unfavorable particle size distribution and therefore has poor optical properties.

U.S. Pat. No. 3,380,665 discloses milling a material successively in several stages in a jet mill, wherein the material is separated from the gas following each milling stage and prior to conveying it to the next milling stage. In this manner, it is possible to select a relatively low value for the steam:pigment ratio in each stage, and hence high material thruput is possible. In addition, the pigment obtained exhabit improved properties.

However, the disadvantage of this process is the fact that, between the individual milling stages, additional equipment is required for separating the material being milled from the gas and for conveying the milled material anew, under pressure, to the second milling stage. The whole equipment is complicated and expensive, takes much space and requires an increased expenditure in operation and servicing.

SUMMARY OF THE INVENTION

New apparatus has now been discovered for multiple stage jet milling which avoids the above-cited disadvantages. This new apparatus comprises at least two relatively thin cylindrical milling chambers wherein each milling chamber is formed, in a manner known as such, by two opposed parallel-spaced, disc-shaped walls

joined peripherally by a circumferential wall, one or more inlets being provided in one wall for introduction of the material to be milled; and an outlet formed in the opposite wall for discharge of the milled goods, the discharge outlet being arranged centrally of its wall. A plurality of nozzles are arranged in the circumferential wall of each milling chamber for the introduction of pressurized streams of gas into each chamber adjacent the periphery thereof, said jet streams being at an angle and at distance from each other such that the pressurized streams of gas or jets effect rotary movement of the material within the interior of each milling chamber; the device being characterized in that the discharge outlet of at least one of the milling chambers (but not the last milling chamber) comprises, in effect, two discharge openings arranged concentrically with respect to each other and to the milling chamber axis wherein the inner discharge opening comprises a discharge pipe mounted in the discharge opening of the next succeeding milling chamber, and the outer ring-shaped discharge opening is confluent with the inlet opening of said next succeeding milling chamber.

The method of operation of the apparatus according to the invention consists in that the material to be milled is first introduced into a first milling chamber having the two concentric discharge openings described above in which milling chamber the material comes in contact with the pressurized gas jets and is milled. The milled material, mixed with the pressurized gas, is carried by spiral-shaped tracks within the mill into the range of the discharge outlets. Owing to the two concentric discharge outlets a classification of the milled material takes place. Thus, that portion of the milled material having the smaller particle size is discharged directly from the mill, together with a part of the pressurized gas, via the inner discharge opening; and may then be separated from the milling gas in a separating device, for example, a cyclone or a filter. The other portion of the milled material, which comprises relatively coarse particles, is carried with the balance of the pressurized gas through the outer discharge opening of the first mill into the next succeeding milling chamber and is here again milled by additional amounts of pressurized gas jetted into this second milling chamber. The product of the second milling may be discharged from its milling chamber via its discharge outlet in the known manner in a single stream; or it may be subjected to a classification step analogous to the one used when discharging the milled material from the first milling chamber. The individually drawn off portions of milled materials discharged from the two concentric but separate discharge openings may be worked up on separate devices or may be conveyed to a common separating installation.

The invention has in particular the advantage that the milled material is separated into coarse and fine materials within the mill and that the coarse material may be subjected to additional milling in one or more additional milling stages but without further milling of the fine material. The invention thus avoids over-milling by additional milling of an already sufficiently fine-milled material. When the finely milled material and its pressurized milling gas are discharged between successive milling stages, then the volume of the material transported into the next succeeding miller chamber is smaller, thus, effecting a saving of pressurized gas. Thus, it is possible to produce excellent pigments with a relatively low steam:pigment ratio. Another advantage of the invention is the easy upkeep of the device. Furthermore, the material need not be handled between the milling stages in separate working operations.

By selecting the amounts of pressurized gas to be conveyed to the individual milling chambers and the proportions of milled material drawn off from the milling chamber through the inner discharge opening, the device may be readily adapted to prevailing conditions for optimum results.

DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic vertical elevation in section of a two stage mill according to the invention.

FIG. 2 is a schematic plan view of the mill on line 2—2 of FIG. 1; and

FIG. 3 is a fragmentary elevation in section of a solid plug in the central discharge opening of the mill.

PREFERRED EMBODIMENT OF THE INVENTION

According to the invention, the device comprises preferably two milling chambers or milling stages. However, the number of milling stages may be greater than two.

A preferred form of the device according to the invention is characterized in that the front wall of at least one of the milling chambers has a single material inlet arranged centrally and coaxially thereof; its rear wall has a material discharge outlet comprising concentric inner and outer discharge openings wherein the inner discharge opening outlet is confluent with a discharge pipe mounted in the material discharge outlet of the next succeeding milling chamber; and a distributing device is provided within the milling chamber for deflecting the inflowing material. Furthermore, an advantageous modification of the mill comprises a construction wherein at least two successive milling chambers are arranged coaxially in a manner such that they have a common wall, i.e., the rear wall of a preceeding milling chamber and the front wall of the next succeeding milling chamber are formed as one separating wall for both milling chambers. The advantages of this construction lie in the fact that the mill is built in a particularly simple manner and is characterized by a particularly compact, stable and space-saving construction.

A further modification of the device according to the invention consists in making the diameter of the next succeeding milling chamber or at least one of the next succeeding milling chambers larger or smaller than the diameter of the preceeding milling chamber. This modification has the advantage that even in those instances in which the amount of pressurized gas conveyed to the next succeeding milling chamber is greater or smaller than the volume of gas exhausted, axially, from the preceeding milling chamber, equal ratios prevail in both milling chambers. Furthermore, there is often an advantage if the addition of pressurized gas can be controlled separately in each milling chamber.

Moreover, in many cases, it is sufficient if the inner end of the discharge pipe that forms, in effect, an extension of inner discharge opening of the two concentric discharge openings, is constructed so as to be substantially flush with the rear wall of the first milling chamber, and under certain circumstances, it may be advantageous to have the inner end of the discharge pipe arranged to extend into the first milling chamber beyond the plane of its rear wall so that, in effect, the inner discharge opening is within the milling chamber itself. By this construction, the separating effect in the stream of milled materials being discharged from the mill is additionally improved.

A further advantageous modification of the device, according to the invention, consists in making the inner discharge opening of at least one of the milling chambers variable in size. Thus, as indicated by the dotted lines in the drawing, an insert comprising a sleeve **32** of relatively small inner diameter may be inserted into the inner end of the aforesaid discharge pipe thereby reducing the size of its opening; or the insert may be a solid plug **320** by which the discharge opening is completely closed. By these modifications the mill can be adapted to prevailing operating conditions without great expense.

Further, by providing suitable profiles to the peripheral edge of the inner discharge opening and/or the outer discharge opening the shape of the openings may be varied such that the direction of the stream of milled material and the separating effect of the discharge outlet of the milling chamber may be improved decisively. In this respect it is quite possible to determine the best profiles in each case by tests. The simple construction of the device, according to the invention, facilitates the replacement of individual parts, if this should be necessary owing to wear and tear, or if the characteristic of the mill is to be modified.

While each milling chamber of the multi-stage mill of this invention may be a unit complete in itself and held in juxta position to neighboring units by suitable fastening means a preferred construction is that shown in the drawing wherein the multi-stage milling device comprises two relatively thin cylindrical milling chambers **1** and **2** respectively integrally joined by a common wall. Thus, the milling chamber **1** sometimes referred to as the first or front milling chamber, has front wall **3**. Milling chamber **2** sometimes referred to as the back or next succeeding milling chamber has a rear wall **4**. The rear wall of the milling chamber **1** and the front wall of the next succeeding milling chamber **2** constitute a common separating wall **5**. An inlet **6** is provided in the front wall **3** of the two stage mill axially and centrally thereof for introducing the material to be milled. The discharge outlet of milling chamber **1** consists of an inner circular discharge opening **7** and a concentric outer ring-shaped discharge opening **8**. The inner discharge opening **7** of milling chamber **1** is confluent with a discharge pipe **9** which is mounted within the discharge outlet of the next succeeding milling chamber and constitutes, in effect, an extension of the inner discharge opening for conducting milled material directly out of the mill into a separating device [not shown]. The outer concentric ring-shaped discharge opening **8** of the first milling stage serves also as the material inlet of the second milling chamber or stage, the discharge outlet of which comprises an opening **10** in the rear wall of the second chamber, said opening having an extension in the form of a sleeve **11** which concentrically surrounds the aforesaid discharge pipe **9** and exhausts milled material to a second separating device [not shown]. The front and rear walls of the respective milling chambers **1** and **2** are held in spaced parallel relationship by circumferential walls **12** and **13**, respectively, provided with annular manifolds **14** and **15**, respectively, which are separately fitted each with a gas inlet pipe having a gas control valve; and a plurality of nozzles **16** and **17**, respectively, for the introduction of pressurized gas into the respective milling chambers **1** and **2**. A distributing device **18** is provided in the milling chamber **1**, said distributing device **18** having the shape of a solid disc tapered in thickness from its central axis to its periphery and provided at its center with nipple-like projections **19** extending from both sides thereof. A distributing device **20**, also substantially disc-shaped, is provided in the seond stage milling chamber. This disc is also thicker at its center than at its periphery and has a bore hole **21** at its center in which the discharge pipe **9** is secured. The disc-shaped distributing devices **18** and **20** are shaped in such a way that their front faces **22** and **23**, respectively, are substantially parallel to the inner faces of the front walls **3** and **5** of the milling chambers **1** and **2** and are fixedly connected to the aforesaid walls **3** and **5** by means of several webs **24** and **25**, respectively.

For introducing the material to be milled into the mill, a tubular housing **26** is mounted on the front wall of the first milling chamber in axial alignment with its central opening **6**; and a nozzle **27** is provided in the entrance end of the housing **26** for introducing a carrier gas. Opening laterally into the housing **26** substantially opposite the nozzle **27** is a funnel **28** for introducing the material to be milled. In addition, a sleeve **29** with a venturi type bore hole is secured in housing **26** between the funnel opening **28** and the front wall **3** of the first milling chamber.

The operation of the multi-stage mill is as follows: the material to be milled, e.g., calcined titanium dioxide, is introduced into the funnel opening **28** and is carried along by the carrier gas, e.g., a steam jet entering through nozzle **27**, into the venturi-shaped bore hole of the sleeve **29** whereby the steam:pigment mixture is homogenized and enters the first milling chamber **1**. There it is directed by the distributing device **18** to the circumferencial wall **12** where it comes in contact with the presurrized gas entering through the nozzles **16**. From thence the material enters the zone **30** between the fixed distributing device **18** and the common separating wall **5** of the two stage mill where it is milled. The milled material then passes into the discharge area of milling chamber **1**. At this point a classification of the milled material takes place. The finer particles, together with part of the pressurized gas, enter the area of the inner discharge opening **7** and are discharged out of the mill via discharge pipe **9** to a separating device [not shown], e.g., a cyclone or a filter. The coarser milled particles travel, with the balance of the pressurized gas, through the outer ring-shaped discharge opening **8** into the second milling chamber **2** in which they are directed, by the fixed distributing device **20**, to the circumferential wall **13**. Here they come in contact with the pressurized gas issuing from the nozzles **17** and are thereby subjected to a second milling within the zone **31** between the distributing device **20** and the back wall **4** of the second stage. Finally, this part of the milled material together with the pressurized gas passes via the outlet **10** and discharge sleeve **11** into a separating device [not shown].

As pressurized gas, steam or any other suitable gas may be employed. The same pressurized gas may be introduced into all the milling chambers or else differnt types of pressurized gas may be used in each milling chamber.

EXAMPLE

A two stage mill was used as shown in the drawing, having two milling chambers or stages with the following dimensions:

The first milling chamber **1** had a diameter of 50.8 cm, the second milling chamber **2** had a diameter of 76.2 cm. The disc-shaped distributing device **18** of the first chamber and a diameter of 45.5 cm; and at the edge it was 0.3 cm thick and its thickness increased toward the axis in such a way that front and back sides of the disc formed an angle of 5° with each other. At its center and on opposite sides thereof were nipple-like projections **19** at which point the disc had a maximum thickness of 6.6 cm. Furthermore, the distributing disc was fixed by six cross-pieces **24** to the front wall **3** in such a way that the distance between the inner surface of the front wall **3** and the front face **22** of the distributing device **18** was 1.2 cm. The zone **30** formed between the rear face of this distributing device and the common separating wall **5** had a depth of 2.3 cm. Twelve gas nozzles **16** are arranged in the circumferential wall **12** in such a way that their axis extend in a plane at right angles to the axis of the milling chamber and at acute angles to the radius of the milling chamber.

The milling chamber **1** had an inner discharge opening **7** having a diameter of 10.2 cm and an outer ring-shaped discharge opening **8** having an outer diameter of **20.2** cm and a width of 4.4 cm.

The distributing device **20** of the second milling chamber had a diameter of 70.8 cm and was 0.4 cm thick at its circumference and this thickness increased towards the mill axis so that front and back sides of the distributing device formed an angle of 5°. The distance between the front face of the distributing device **20** and the back face of the common separating wall **5** was 1.2 cm; and the distance between the back face of the distributing device **20** and the inside of the back wall **4** was 2.4 cm. The distributing device **20** had a bore hole **21** through which passed the discharge pipe **9** of the inner discharge opening **7**. Adjacent the bore hole the distributing device **20** was thickened by profile insets up to 8.3 cm. The projecting nipple **19** on the rear face of the distributing device **18** and the entrance to the discharge pipe **9** of inner discharge opening **7** were located in a common plane with the front face of the separating wall **5**. The distributing device **20** was fixed to the mill housing with aid of six cross-pieces **25** in such a way that these cross-pieces comprised parts of screw connections for joining the front wall **3** and the separating wall **5** to each other simultaneously. By this arrangement a simple dismantling of the mill is possible. Twenty-four gas nozzles **17** arranged in the circumferential wall **13** sent pressurized gas into the second milling chamber, the arrangement being analogous to that of gas nozzles **16**. By means of additional screw connections the front of back wall **4** was secured to the separating wall **5**. Located centrally in the back wall **4** of the second milling stage was a discharge sleeve **11** having an inner diameter of 32.8 cm which sleeve, like discharge pipe **9**, led to a cyclone [not shown].

The venturi-shaped sleeve **29**, which serves for introducing the material to be milled into the first milling chamber, had a length of 25.5 cm and at its narrowest part a diameter of 2.5 cm. 2000 kg/hr titanium dioxide pigment were conveyed to the two **2** stage mill in the form of a suspension in 600 kg/hr steam. By means of the gas nozzles **16** 1400 kg/hr steam were blown into the first milling chamber. 350 kg/hr pigment together with about 500 kg/hr steam were discharged from the first milling stage via the inner discharge opening **7** and its discharge pipe extension **9**; the balance of the material was milled once more in the second milling chamber wherein 2600 kg/hr steam were blown in through the gas nozzles **17**; subsequently, this suspension was removed from the mill through the discharge sleeve **11**. Both pigment fractions were separated in separate cyclones.

The quality of the pigment obtained was judged according to the "gloss-haze" which was determined according to the method described in "Farbe u. Lack" 74 (1968), pg. 160. The product recovered from the milling chamber **1** through pipe **9** had a gloss-haze value of 225; the product recovered from the milling chamber **2** had a gloss-haze value of 260.

When the same pigment was milled in a conventional jet mill the milled product has a gloss-haze value of 400, the higher number, according to this test, being indicative of poorer quality.

We claim:

1. A multi-stage jet mill comprising at least two relatively thin cylindrical milling chambers, each comprising spaced opposed front and rear walls held in spaced parallel relationship by a circumferential wall including an annular manifold, the front wall of each chamber having an inlet for material to be milled, the inlet of the first of two successive milling chambers being coaxial with the axis of the mill, and the rear wall of each chamber having an outlet arranged centrally thereof for discharging the milled material from the respective chambers, a plurality of jet nozzles arranged circumferentially in the circumferential wall of each chamber in communication with its respective manifold, means to supply pressurized gas to said manifolds for introducing pressurized gas by way of said jet nozzles into each milling chamber adjacent the periphery thereof, said jet nozzle axes arranged tangentially with respect to a concentric circle inwardly of the circumferential wall of its respective chamber so as to set up a circular movement of the material being milled within each milling chamber, the material discharge outlet of the first of two successive milling chambers comprising concentrically arranged inner and outer discharge openings coaxial with the axis of said mill for classifying the material discharged from said first chamber the said inner discharge opening of said first milling chamber outlet being constructed and arranged to discharge a relatively finely ground portion of the milled material from said first milling chamber directly out of said multistage mill, and the said outer discharge opening of said first milling chamber outlet being constructed and arranged to discharge a relatively coarse portion of the milled material from said first milling chamber into the next succeeding milling chamber of said mill.

2. A multi-stage mill according to claim **1**, characterized in that it comprises two successive milling chambers.

3. A multi-stage mill according to claim **1**, wherein the diameter of a succeeding milling chamber is different than the diameter of a preceeding milling chamber.

4. A multi-stage mill according to claim **1**, wherein said gas supply means is provided with valve means arranged to separately control the pressure of the gas supplied to the jets of each milling chamber.

5. A multi-stage mill according to claim **1**, wherein a discharge pipe is arranged to form a coaxial extension of the inner discharge opening of said first milling chamber.

6. A multi-stage mill according to claim **5**, wherein an insert in the form of a sleeve is provided in the discharge pipe for varying the size of the discharge opening.

7. A multi-stage mill according to claim **6**, wherein the insert is a solid plug whereby the discharge opening is closed.

8. A multi-stage mill according to claim **1**, wherein a material distributing plate is arranged within each of said milling chambers substantially opposite its inlet for deflecting the inflowing material outwardly radially in each chamber.

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