

June 18, 1963

P. A. H. H. FAHLSTRÖM ETAL

3,094,289

ROCK GRINDING SYSTEM

Filed Jan. 7, 1960

5 Sheets-Sheet 1

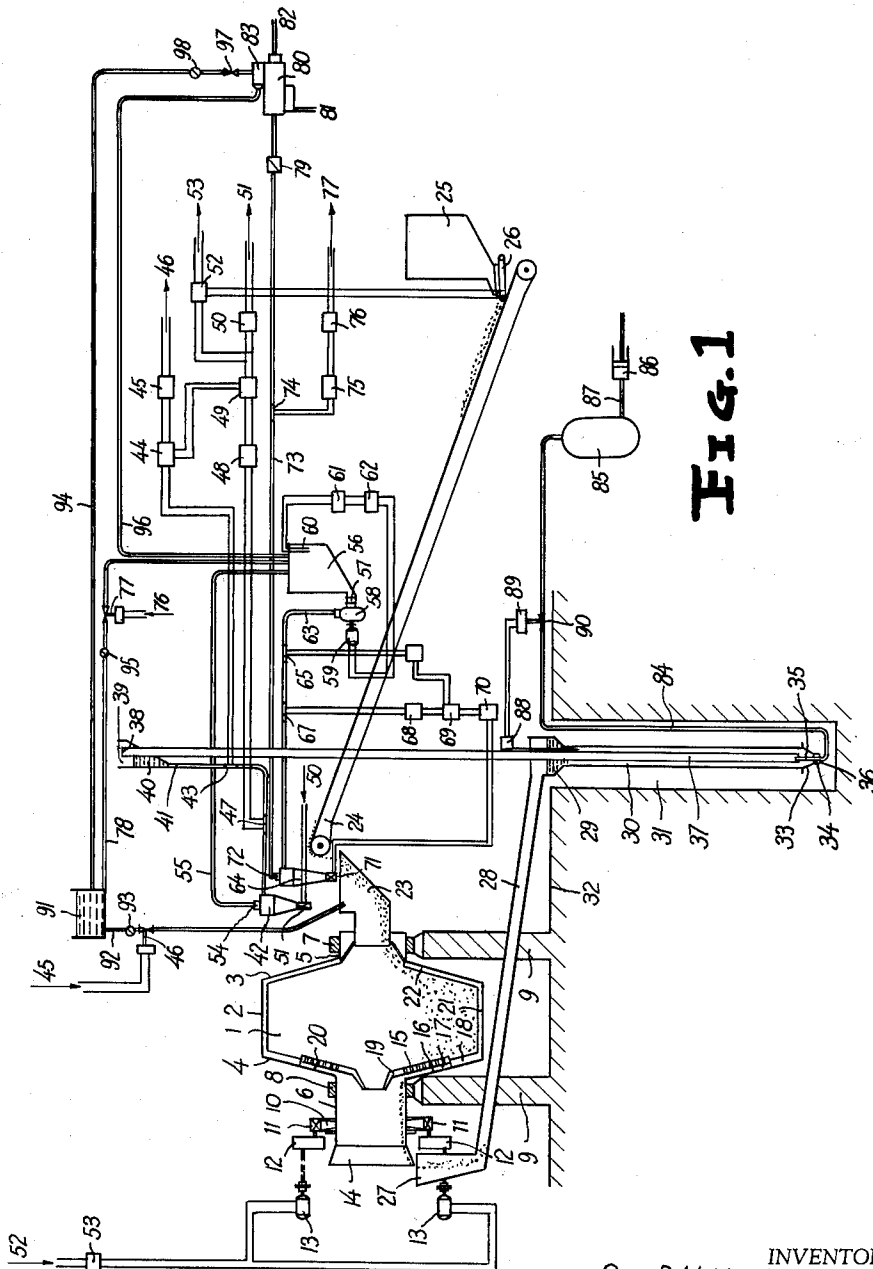


Fig. 1

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5 Sheets-Sheet 2

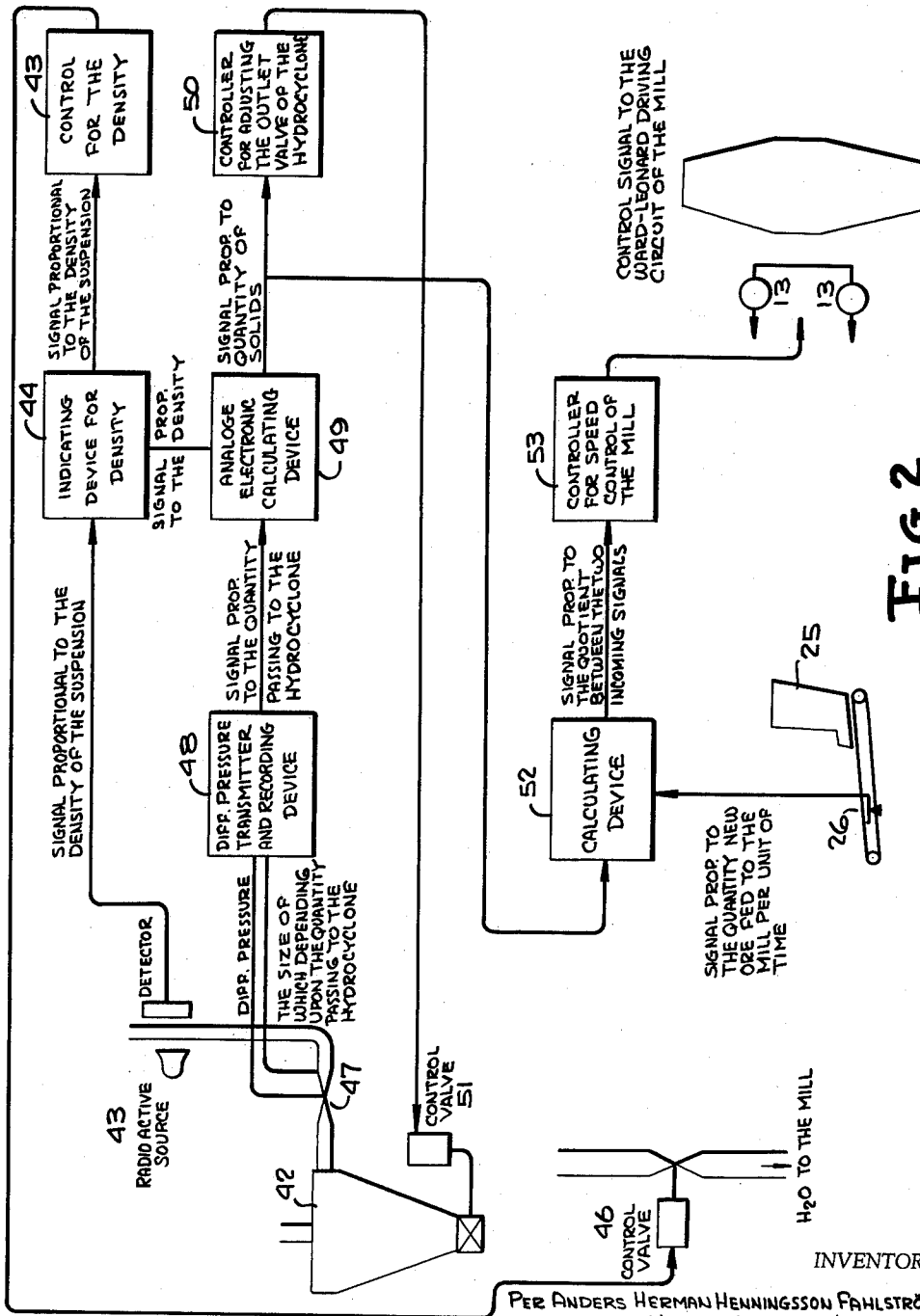


Fig. 2

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5 Sheets-Sheet 3

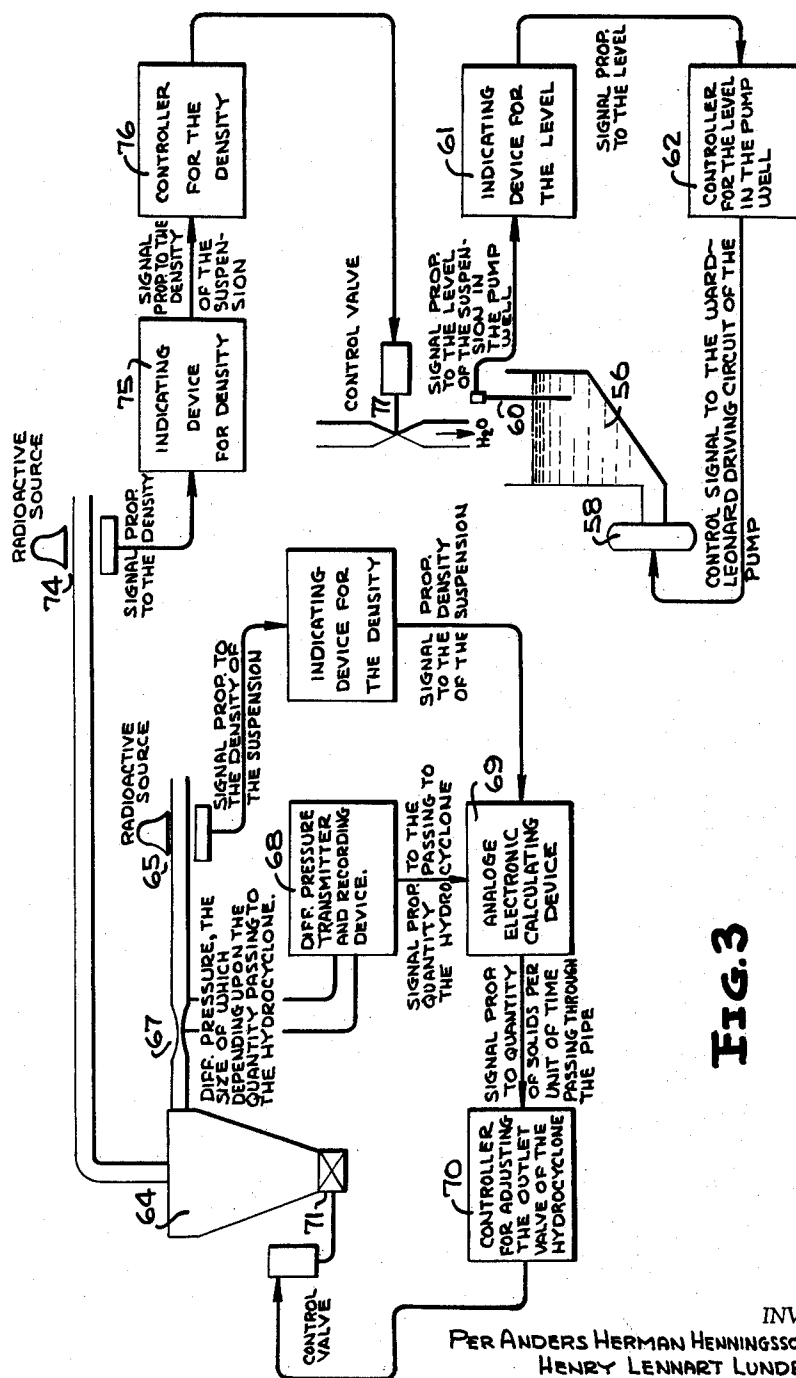


Fig. 3

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5 Sheets-Sheet 4

FIG. 5

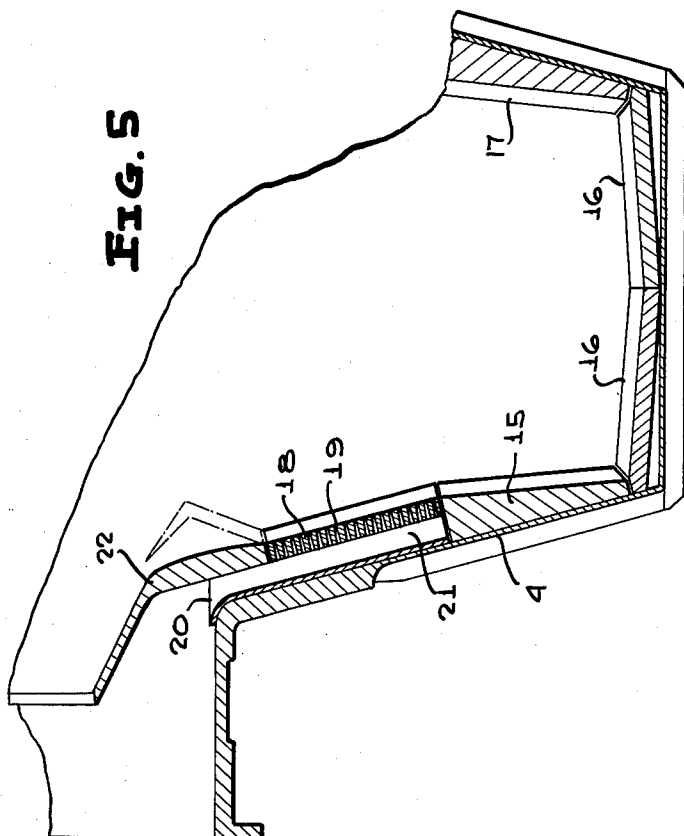
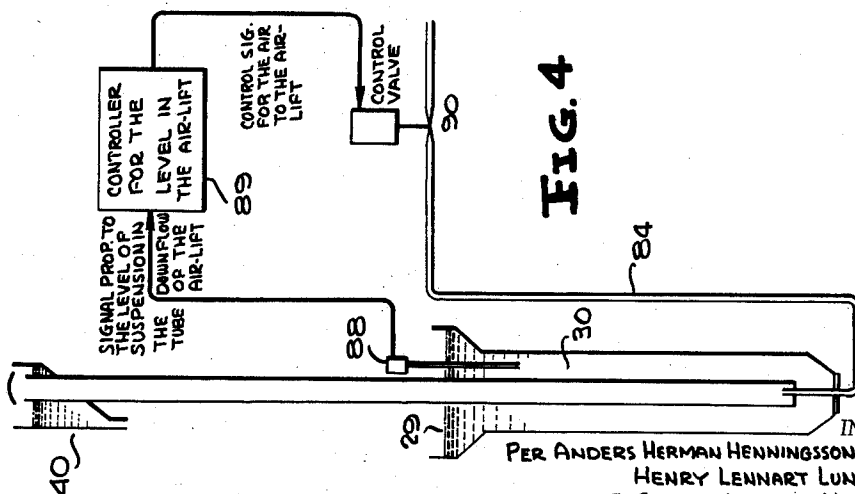


FIG. 4



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5 Sheets-Sheet 5

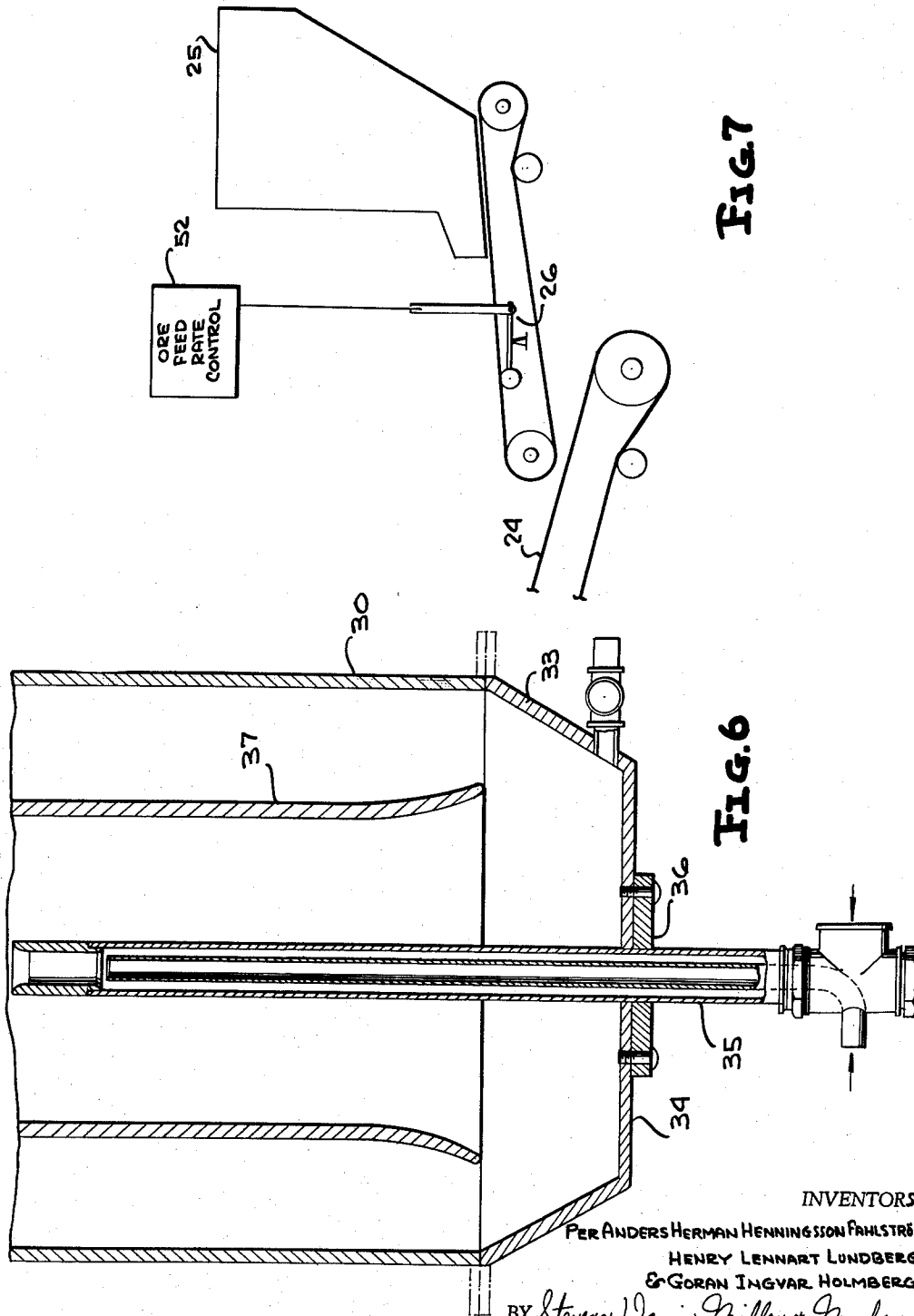


Fig. 7

Fig. 6

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3,094,289

ROCK GRINDING SYSTEM

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Claims priority, application Sweden Oct. 29, 1959

5 Claims. (Cl. 241—34)

The present invention relates to a method for comminuting rock or other crystalline material in the presence of water to a substantially predetermined particle size and/or pulp density and devices for carrying out the process. The invention especially relates to such particle reduction processes in which the material consisting of an arbitrary mixture of coarse and fine pieces before its comminuting is not subjected to any, or only little crushing, while the essential crushing and comminuting to the desired particle size is effected in a grinding chamber, in which the material without foreign grinding bodies present through the movement of the grinding chamber is brought to act as crushing and grinding bodies and thus crush, grind and comminute themselves.

Said method commonly called rock grinding, has obtained an increased importance for crushing and grinding ores in connection with their concentration, for grinding limestone, raw cement and other crystalline materials. In the process the material to be crushed and ground, for instance ore, which may contain pieces, the edges of which may have a length of up to 20 inches and more, is comminuted to a finely divided product having the particle size required for the common concentration processes. Owing to the fact that the material to be ground is given a falling, rolling, or another mutual movement in the grinding chamber, the different pieces of the material will crush, abrade and comminute each other. Thus, it is characteristic for the method that foreign grinding bodies are not used, which is the case for instance in rod and ball mills, whereas the crushing and grinding bodies required for the reduction are continuously formed from the material itself and are continuously substituted by new bodies. A further feature of the method is to charge the grinding chamber, a material being substantially coarser than that which can suitably be ground in rod or ball mills, whereby the equipment commonly used for the crushing of the material, for instance in jaw and cone crushers, totally or partly is eliminated from the treatment schedule.

It is also known to apply the principle for rock grinding to wet grinding and in this case to carry out the grinding in about the same way as in ball and rod mill grinding with the difference that instead of balls there are used fine grinding bodies and instead of rods coarse grinding bodies of a defined size by screening separated from the grinding charge. Of said processes it is only the last mentioned which hitherto has been more widely applied to in wet grinding, because same is easily adaptable to present art. The first mentioned method which is simply called direct one step rock grinding has in spite of its theoretically obvious advantages compared with other grinding systems hitherto obtained a restricted use, since said method has only been effectively carried out as dry grinding. The dry grinding method has then generally been dependent on the purpose of obtaining the product in a dry state for further treatment.

Direct one step rock grinding is nowadays effected in horizontal, rotating drum mills, the diameter of which generally is twice to four times the cylinder length. The

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material to be ground is generally fed continuously to the mill which at its rotation imparts to the material a movement and brings about a comminution of the product. The size of the ground product is adjusted by increasing or decreasing the rate in feeding the material to the mill. In the grinding operation it is desired continuously from the grinding drum immediately to discharge finely ground particles as soon as they have formed. In the dry grinding type of mills this is carried out by means of a ventilation system connected to the mill, by which system a suitable air volume can be forced through the mill in order to sweep away substantially all particles below the desired particle size, as soon as said particles have been freed. By the stream of air the particles are carried away to a collector, in which from the material of the desired particle size the coarse, not finely ground particles are separated and re-cycled to the mill. Although said system will secure a rapid exhaustion and separation of the fines or finished product, the system requires for its operation an essential additional power consumption. Furthermore, the equipment required for the product circulation is extensive which results in comparatively high installation costs for dry grinding systems.

The possibility of using the principle of dry grinding of ore in one step as a stage of its concentration, especially regarding the most common concentration method, the flotation method, is further restricted by the fact that grinding in the presence of water is an indispensable preliminary step for the concentration. After dry grinding of an ore which is then to be flotated, the finished product must be subjected to a special conditioning step with water and chemicals which process requires additional installation costs as well as an essential power consumption for its operation. To the extent that dry grinding can be employed at all the total efficiency of the installation will therefore decrease. In order to utilize the benefits of rock grinding in one step in concentration of ore, an effective wet grinding method is thus required. The need for this is therefore constantly increasing. The process of direct wet rock grinding of ore in one step having not earlier been commercially practised is due to the fact that several conditions are to be met not only with respect to the mill itself but also with respect to the other devices and their functions belonging to the grinding schedule, which requirements must be fulfilled so that this grinding method compared with grinding in other types of mills and grinding schedules shall give an improved result. These conditions which hitherto have not been fulfilled in a satisfactory way are essentially the following:

The grinding is to be carried out with a higher efficiency in water than in air or in other words, for a certain size reduction in wet grinding the power input must be possible to be made lower than for instance in dry grinding;

Freed particles in the grinding chamber are continuously and immediately after their forming to be discharged from the grinding chamber and separated;

Thus, it must be possible in a controllable and reliable way to circulate the discharged and partly finely ground product with a low expenditure of power;

The grinding shall be possible to carry out under adding ore at a constant rate independently of arbitrary variations in the size of the ore pieces;

The finely ground ore shall be obtained as a suspension with a predetermined particle size and/or density.

Although it has been evident some years ago that mills of about the same type as used in dry grinding with advantage might be used in wet grinding of ore in one step, it has not been possible to carry out said wet grinding,

since not only the mill is essential, but the entire grinding schedule and the way in which said grinding schedule can be controlled.

The present requirements of a wet grinding system are all fulfilled in the present invention which relates to a process and devices for carrying out the process preferably in direct rock grinding in one step of ore together with water at a predetermined particle size and/or density of the suspension formed thereof and its object is to provide an effective, reliable and economical grinding schedule for wet grinding. The process according to the invention comprises the steps of feeding under addition of the water the product (ore) to be ground comprising an arbitrary mixture of coarse and fine pieces, to a grinding chamber at the movement of which the product without foreign grinding bodies present is brought to act as crushing and grinding bodies and thereby to crush and grind themselves, discharging from the grinding chamber a mixture of water, fines and oversize and in one or more steps classifying or screening this product for separating the fines and returning the oversize to the grinding chamber. According to the invention the process comprises the steps of adjusting the addition of water to the mill by means of a density meter adapted to measure the density of the suspension discharged from the grinding chamber in such a manner that the suspension discharged from the mill obtains a predetermined particle size and density, respectively.

The method is furthermore characterized in feeding the ore or material at a substantially constant volumetric rate into a rotating grinding drum, the speed of which is continuously adjustable by changing the r.p.m. of the driving device, continuously measuring the quantity of solids in the pulp discharged from the mill and the feed to the mill and comparing the values obtained with each other, wherein deviations from a predetermined value are used to adjustably actuate the driving device of the mill in such a manner that the r.p.m. of the mill is changed in a direction to counteract said deviation.

The method is further characterized thereof, especially in grinding to a considerable fineness, that separation of not finely ground material in the suspension discharged from the mill is carried out by separation in hydrocyclones in two stages, said suspension being fed to the first cyclone stage, from which the separated fine material is subjected to renewed separation in the second cyclone stage after an addition of water which, controlled by an apparatus measuring the density of the finely ground pulp, separated from the cyclone, is adjusted in such a way that said suspension obtains its predetermined particle size and/or density.

The process is finally characterized in discharging the suspension of the product totally or partly finely ground from the grinding drum through a scooping grate and pumping it to a classifying device by means of compressed air.

According to the invention it has thus been possible to reduce the power consumption for the crushing and grinding by controlling the volume of water added to the mill in relation to the feed in such a manner that the suspension discharged from the mill is given a density which in dependence of the lump size and other properties of the feed is not less than 0.5 and not more than 0.7 times the density of the ore feed. If this requirement is fulfilled, the power consumption for grinding a product to a predetermined size will be lower by wet grinding than by dry grinding, the case being the contrary, if the requirement is not fulfilled. According to the invention it is therefore essential that the volume of water added to the mill is controlled by an apparatus capable of measuring the density of the pulp discharged from the mill and automatically adjusting the volume of water added to the mill, when variations of the feed are detected.

The inventors have further found that when new material is fed at a constant rate to a grinding chamber

operating in a closed circuit with classifying devices which return coarse material, by measuring the quantity of returned material and calculating the ratio between said quantity and the quantity of the ore fed to the mill per unit of time and by comparing this value with a predetermined value, it is possible to obtain information of the measures necessary to obtain a maximum operating capacity of the grinding mill. Then it has proved suitable to make said comparison automatically and accordingly to control the r.p.m. of the mill so that a certain predetermined quantity of the charge of material shall be circulated.

Furthermore, the inventors have found that classifying in two stages in cyclones is more advantageous than classifying in either one stage in cyclones or other classifiers or in two stages in other types of apparatus alone or in combination with cyclones. It has now been found that one condition which is necessary for successfully effecting a classifying in two stages is that the pulp is passed from the mill to the first hydrocyclone for recycling to the mill of a decidedly coarse fraction and that the final separation of the fines or finished product is effected in the second cyclone after an automatically adjustable amount of additional water regulated by the desired density of the finely ground pulp.

A still further object of the invention is that by carrying out the process special advantages can be obtained firstly if the grinding drum is provided with a scooping grate which permit rapid discharging of the finely ground particles, the rods of the grates having a spacing which permits discharging the product with a particle size of up to 25 to 30 mms., and secondly if the pulp discharged from the mill is transferred by means of an air-lift to the cyclone in such a manner that the product is discharged by the air-lift into a pressure tank mounted above the primary cyclone which is connected to the pressure tank by a pipe and that the fine material separated in the primary cyclone is passed to a second cyclone by a centrifugal pump.

An embodiment according to the invention shall now be further described with reference to enclosed drawings showing a device for grinding in one stage of lead bearing sandstone ore having a specific gravity of 2.8 with a largest lump size of about 400 mms. to a ground product, 80% of which passes through a 200 mesh screen, the finished ore suspension or pulp having a dilution of 1.5 parts by weight of water on one part by weight of ore, which corresponds to a pulp density of 1.33.

FIGURE 1 is a schematic view of the apparatus for carrying the grinding process in accordance with the invention.

FIGURES 2, 3 and 4 are enlarged fragmentary schematic views showing portions of the apparatus with labels applied thereto.

FIGURES 5 and 6 are enlarged fragmentary sectional views showing in detail specific features of construction of the drum and the air lift.

FIGURE 7 is an enlarged fragmentary schematic view showing the details of the rock weighing device.

In the drawing a mill 1 is shown, consisting of a drum having a substantially horizontal axis of rotation. The drum comprises a cylindrical shell 2 and end closures 3, 4 which are preferably slightly conical, so that the length of the drum increases towards its centre. The grinding drum is provided with two hollow trunnions 5, 6 by means of which it is journaled in two plumber blocks 7, 8, each placed on its foundation 9. The driving mechanism of the mill comprises a gear rim 10 attached to trunnion 6 outside the plumber block 8, and meshing two pinions 11 mechanically connected with the gear boxes 12, the input shafts of which are in turn each connected with a driving motor 13. The motors are preferably electric D.C. motors the rotational speed of which can be regulated continuously, for instance according to the Ward-Leonard system. The Ward-Leonard system, which is a known method of speed control for large D.C.

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motors, comprises a D.C. motor (i.e. the motor the rotational speed of which is to be regulated) the field winding of which is connected in series to a D.C. generator. The output of the generator is regulated by means of the field winding energizing current which is supplied from a separate auxiliary generator, the armature of which is usually mechanically coupled to the main generator. The two D.C. generators are driven by a common A.C. motor. The rotational speed control of the main D.C. motor is accomplished by varying the energizing current supplied to the field winding of the main generator, said energizing current being controlled by means of a rheostat controller connected in series in the circuit. The system provides for a speed control of a very high efficiency within a wide range of r.p.m. and loads. Outside the gear rim 10 the hollow trunnion 6 serving as an overflow for the ground product has an extension ending in a funnel-shaped part 14.

The inner wall of the grinding drum is provided with a steel lining 15, 16, 17 to prevent wear. The end closure at the outlet side of the drum is only partly lined, more specifically at the peripheral part so that the lining 15 terminates in an annular edge surface. From said edge surface an annular plate 18 with grates 19 mounted in a spaced relation to and parallel with the end closure 4 extends towards the centre and as a continuation of the lining 15. In that way there is created a space between the grate and the end closure, which space by means of a number of radially extending partitions 20, serving as scooping members, is divided into a corresponding number of sector-shaped chambers 21. Said partitions 20 also act as wear plates to protect the inner-wall of the end closure 4. Towards the centre the grate terminates in an outlet funnel 22 of solid material. The spacing of the rods of the grate is generally 8-20 mms. The ratio of shell length to diameter of the grinding drum shown is about 1:3 (7 x 22 ft.), but according to the invention the dimensions may vary within a wide range and are not critical for the operation of the mill. Moreover, the power transmission between the mill drum and the motor or motors may be effected in a different way. According to the invention it is not either necessary that the mill drum is journaled on horizontal trunnions but also mills having vertical trunnions and being arranged for rotational or gyratory movement may be employed. Into the hollow trunnion 5 serving as a feed opening issues a feed hopper 23. At the upper part of the feed hopper 23 there is arranged the discharge roll of a conveyor belt 24 for feeding ore to be comminuted from a storage bin 25. Between the bin 25 and the conveyor belt 24 there is mounted a weighing device 26. Below the funnel-shaped part 14 of the hollow discharge trunnion 6 is arranged a collecting box 27, the bottom of which continues into a tube 28 arranged with a slope through the foundation 9. The tube 28 terminates in the inlet funnel 29 of an air-lift. The air-lift consists of a downflow tube 30 placed in a well 31 below the floor 32. At its lower end the downflow tube terminates in a frusto-conical part 33 having a circular bottom plate through a central bore of which there is inserted an air tube 35 adapted to be raised and lowered, a seal between the air tube 35 and the bottom plate 34 being effected by means of a gasket 36. The air tube 35 terminates into a central upflow tube 37 open at the bottom, mounted coaxially of the downflow tube, the lower part of the tube ending at the approximate level of the passage between the downflow tube 30 and the funnel-shaped part 33. The upflow tube extends so far upwards that the pulp expelled through the upper opening 38 of the upflow tube by gravity can be passed to subsequent treating stages. Above the upper end 38 of the upflow tube a splash plate 39 is arranged and a collecting funnel 40, the outlet of which is connected to a pipe 41 which after a vertical stretch extends substantially horizontally and is connected to a hydrocyclone 42. In the vertical part of the pipe 41 a pulp density meter 43 of a

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known type is arranged, suitably based on the principle of gamma radiation. The pulp density measured by this indicator being a function of the percentage of solids and water, respectively, of the pulp, is continuously recorded by a recording member 44. Said member is connected to a regulator 45 which is connected to a control valve 46 for adjustable adding of water into the feed hopper 23 of the mill. On the horizontal part of the pressure pipe 41 a flowmeter 47 is arranged, for instance formed as a venturi pipe, the differential in pressure of which is indicated by means of a recording device 48. The recording device 48 for the flow measuring and the recording member 44 for measuring the pulp density are connected to a calculating and recording device 49 which is adapted from the incoming signals from the recording members 48 and 44 to calculate and record the quantity of solids per unit of time passing through the pipe 41. A regulator 50 is connected to the calculating and recording member 49, said regulator controlling an adjustable valve 51 arranged at the delivery spout of the hydrocyclone 42. The opening of the valve is continuously adjustable by a signal from the regulator 50. The calculating member 49 is further connected to a calculating member 52 which moreover receives a signal from a gauge value transformer of the weighing device 26. The calculating member 52 is capable of determining the quotient between the quantity of solids discharged from the mill and the quantity of new ore fed to the mill (the so-called circulating load). The calculating member 52 is connected to a regulator 53 in the Ward-Leonard circuit of the drive motor (motors). Said regulator 53 is provided with such adjustable time-delay circuits that momentary variations of the measuring signals do not influence the speed control of the mill but only prolonged changes in the circulating load. The hydrocyclone 42 in its upper end has an outlet 54 connected to a pipe 55 which ends into a pump well 56. The hydrocyclone 42 is arranged in such way that the coarse fraction fed through the valve 51 can gravitationally flow into the feed hopper 23. The pump well 56 is by means of a supply pipe 57 connected to a pump 58 which may for instance be a centrifugal pump of known type preferably driven by a variable rotational speed motor 59, preferably a D.C. motor, the r.p.m. of which is controlled according to the Ward-Leonard system. The power of the motor 59 and its revolution are suitably recorded by means of devices known per se which are therefore not to be further described. In the pump well 56 a level sensing means 60 is arranged to sense the level of the pulp in the pump well. The level sensing means 60 is connected to a control member 61 which is in turn connected to a speed control 62 in the Ward-Leonard system of the pump motor 59. From the pump 58 a pressure pipe 63 extends to the jetted tangential inlet of a second hydrocyclone 64. A pulp density meter 65 with recording member 66 as well as a flow member 67 of the same type as the flow meter 47 are arranged in said pressure pipe. The recording member 66 of the pulp density meter 65 and the recording member 68 of the flow meter 67 are connected to a calculating member 69 adapted to calculate and record from the incoming signals from the recording members 66 and 68 the quantity of solid per unit of time passing through the pipe 63. To the calculating and recording member 69 is engaged a regulator part 70 governing an adjustable valve 71 arranged at the bottom spout of the hydrocyclone 64, the opening of the valve being continuously adjustable by an impulse from the regulator 70. The hydrocyclone is arranged in such a manner that the coarse fraction discharged through the valve 71 may gravitationally fall into the inlet funnel 23. The hydrocyclone 64 is at its upper end provided with outlet 72 serving to discharge the finely ground products, said outlet 72 being connected to a pipe 73. In the pipe 73 is connected a pulp density meter 74 of essentially the same type as the meters 43 and 65. The pulp density meter 74 is connected with a recording instrument 75

and this instrument in turn to a regulator 76, which is engaged to a control valve 77 for water placed in a pipe 78, terminating in the pump well 56. At the opening of the pipe 73 a sampler 79 of the type described in my copending application Serial No. 43,381, filed July 18, 1960 is suitably arranged. After the said sampler 79 there are conventional devices 80 for the ore dressing, for instance by flotation. Said devices are provided with members for discharging concentrate 81, for tailings 82 and for returning the middlings to the grinding circuit 83.

The air pipe 35 of the air-lift is by an air pipe 84 connected with a compressed air tank 85 which by a pipe 87 is connected with a compressor 86. In the inlet funnel 29 of the air-lift is mounted a level sensing means 88 arranged continuously to sense the pulp level in the downflow pipe 30. The level sensing means 88 is connected to a control member 89 which is connected to a control valve 90 of the pipe 84.

Said system comprises also feeding devices for water. These devices for instance include a water tank 91 or pressure pipe arranged in such a manner that via the pipe 92 water is passed to the feed hopper 23. The pipe 92 is provided with the aforesaid control valve 46 which is engaged to the control member 45 of the pulp density meter 43, 44, and said pipe 92 is moreover suitably provided with a water flow meter 93. From the water tank 91 also emanates the above mentioned pipe 78 provided with control valve 77, said pipe 78 terminating in the pump well 56. A water flow meter 95 is connected to the pipe 78. Furthermore, a pipe 96 for a diluted suspension of finely ground ore from the ore dressing devices 80 and their devices for re-cycling the return products 83 terminate in the pump well 56. The water tank 91 is connected with the dressing devices, said pipe 94 being provided with a control valve 97 and a water flow meter 98.

The mill operates as follows:

By the conveyor belt 24 is fed to the mill 1 from bins either ore which has been screened in different fractions and then again mixed in a certain ratio or unscreened ore at an approximately constant feed rate, for instance 20 metric tons per hour, which rate is adjusted to a desired value and recorded in the weighing device 26. In this operation the ore has been subjected only to a minor crushing action to break the chunks. The mill 1 is rotated through the motors 13 via the gear boxes 12 and pinions 11 meshing the gear rim 10. The r.p.m. of the mill has now been adjusted in such a manner that it is adapted to the size of the ore feed as well as to the degree of grinding desired, which in the described case corresponds to an r.p.m. of 70% of the critical speed, that is the highest rotary velocity, at which the grinding drum may rotate without the grinding product by the centrifugal force following the drum in its rotation. If the mill is arranged for operation below the critical speed, the r.p.m. of the drum usually is within the range of 50-100% of the critical speed, whereas if the mill is normally intended to operate at an r.p.m. over the critical speed in order to reduce the wear the r.p.m. is adjusted somewhere between 100% and 150% of the critical speed. The ore falls through the feed hopper 23 via the hollow trunnion 5 into the grinding chamber and is set in motion. Simultaneously water is supplied in a controllable volume through the pipe 92 by means of the valve 46. In addition, the oversize material separated in the hydrocyclones 42 and 64 in the form of an aqueous suspension is fed to the feed hopper 23. Owing to the rotation of the mill drum the ore is rolled and is crushing, abrading and comminuting itself. Furthermore, by the motion of the mill a continuous discharge of material takes place through the grate 18 to the scooping chambers 21, in which chambers the material by the rotation of the mill is lifted and then falls through the open space 19 between the outlet funnel 22 and the discharge chambers 21 and therefrom to the discharge trunnion 6. It flows like a

slurry through the opening 14 of the mill trunnion. Depending on the interspace of the grate which generally varies between 8 and 20 mms. the discharged, partly ground product contains particles of up to 25-30 mms. edge size. The mixture of material and water flowing from the mill trunnion falls into the funnel-shaped collecting box 27 and thereafter flows by gravity through the pipe 28 to the inlet funnel 29 of the air-lift. The air-lift operates in such a manner that air is continuously led from the air pressure tank 85 which in turn is fed from the compressor 86 over the pipe 87. The compressor has a larger capacity than that required for the volume of air normally taken from the pipe 84, and therefore the compressor is provided with relief devices in a known manner. Air is blown in through the air tube 35 of the upflow tube 37 of the air lift. The suspension of ore and water conveyed to the inlet funnel 29 of the air lift falls through the downflow tube 30 at the same time as the pulp is caused to flow upwardly in the upflow tube 37 under the influence of the difference between the hydrostatic pressure prevailing in the downflow tube 30 and the hydrostatic pressure of the mixture of suspension and air prevailing in the upflow tube. To have the air lift to operate at maximum efficiency which is essential for the economy of the pumping operation, the inlet pressure of the air and the air volume must be adjusted in such a way that the pressure is just sufficient for the operation of the pump. In the present case this is achieved by means of the aforesaid level sensing means 88 arranged in the inlet funnel 29 of the downflow tube 30, which sensing means 88 is continuously sensing the pulp level in the downflow tube and via the control member 89 controlling the volume of air through the valve 90 in such a way that a constant fluid level is obtained in the downflow tube. If the flow of the suspension discharged from the mill is increasing at a certain setting of the air volume this results in that the pulp level in the downflow tube tends to rise, which is measured by the level sensing means 88 giving a signal to open the valve 90 by means of the control member 89, so that larger air volume is released to the air pipe 35, which results in an increased feed through the air lift. Simultaneously the tapping of air from the air pressure tank 85 is increased which in turn results in an increased delivery of air from the compressor 86. A decrease of the discharge of pulp from the mill at a certain setting of the air volume through the air pipe 35 results in the reverse controlling procedure.

The mixture of suspension and air fed through the upflow tube 37 is deflected at its outlet from the same by the splash plate 39 of the collecting funnel 40, the air being separated and removed while the suspension falls down into the collecting funnel 40 and by gravity flows to the cyclone 42 via the pressure pipe 41. In the cyclone 42 a separation between the coarse and fine material discharged from the mill is effected, the coarse fraction being discharged through the adjustable valve 51 in the apex of the hydrocyclone and thereafter falling into the feed hopper 23, and the fine fraction is conveyed through the top outlet 54 of the cyclone and is subjected to a further classifying. The cyclone 42 has been made with such dimensions that it is capable of separating substantially all material having a particle size >1 mm. as a coarse fraction and a pulp density higher than that of the pulp discharged from the mill, while material having a particle size <1 mm. is discharged through the top outlet 54. For the operation of the cyclone there is required a hydraulic head or pressure of about 5 to 8 meters which is achieved due to the fact that the collecting funnel 40 is arranged at corresponding height over the opening of the inlet pipe 41 of the cyclone. The pulp density meter 43 continuously measures the density of the pulp passing through the pipe 41. If the pulp density meter is of the gamma radiation type, the measuring is based on the absorption of the radioactive radiation passing through the pipe 41. The absorption in-

creases with increasing specific gravity of the suspension in the pipe 41. The measured value of the pulp density is continuously recorded by the recording instrument 44. Owing to the fact that the pulp density meter 43 is mounted on a vertical downflow pipe the incorrect measurements caused by strata in the pipe are negligible which is essential for a good control. The recording member 44 of the pulp density meter is connected to the regulator 45 which is in turn connected to and governs the water valve 46 controlling the feed of clear water to the mill. The desired value of the density of the pulp discharged from the mill is adjusted on the regulator 45, said density being according to the invention within the range of 0.5 to 0.7 times the density of the solid ore. In the example described relating to grinding lead ore having a density of 2.8 it is most suitable aiming at a pulp density of 0.63 times the density of the ore, that is 1.75. Thus, if the volume of water fed to the mill decreases in relation to the ore feed, the percentage of solids in the suspension discharged from the mill will increase which causes an increase of the density of the suspension. Said increase of the density will immediately be recorded by the instrument 44, which via the regulator 45 emits a signal to increase the opening of the valve 46, the water supply being increased and the density of the suspension discharged from the mill being reduced towards the desired value, until same is achieved. If, on the other hand, the water supply in relation to the ore feed should have increased, the density of the suspension discharged from the mill will decrease instead, which is sensed in a corresponding way and causes the reverse controlling procedure. This characteristic of the grinding system is very essential, since even short variations of the density of the suspension adversely affect the grinding capacity of the mill. For at such variations of density the system tends to lose its balance which is difficult to restore. This is perhaps best explained by the fact that the quantity of solids in the suspension discharged from the mill at the described reduction ratio for said ore is generally 10 to 15 times the quantity of fresh ore continuously fed to the mill. Thus, in order to have the system operating satisfactorily it is required that the density of the suspension can be rapidly measured and without any substantial errors which is satisfactorily described in the schedule.

On its passage through the pressure pipe 41 to the hydrocyclone 42 the suspension passes through the flow meter 47 formed as a venturi pipe, a pressure head being created which is a function of the volume per unit of time and the density of the suspension flowing through the pipe. This pressure head is recorded in the member 48. From said member a signal is taken which is a function of said pressure head, and furthermore an electric signal is taken from the pulp density meter 44, the strength of the signal being proportional to the pulp density. These signals are transmitted to the calculating member 49 which by means of an analog computer from the incoming signals is capable of calculating the quantity of solids per unit of time through the pipe 41 as well as recording the value obtained. Thus, in the calculating and recording member 49 the quantity of solids continuously discharged from the mill 1 is indicated, for instance in metric tons per hour. The regulator 50 engaged to the member 49 is capable of adjusting the valve 51 of the hydrocyclone 42. This control procedure implies that said control valve is constantly caused to assume a size having a definite proportion to the quantity of solids per unit of time fed through the pipe 41 to the hydrocyclone 42 and in the present case in such a way that the control valve 51 is opened if the quantity of solids increases, whereas if the quantity of solids decreases the valve is closed. In this way a continuous adjustment of the desired ratio of separation of the cyclone is obtained, independent of variations of the incoming quantity of solids. If this quantity increases, the cyclone tends at a constant, unchanged bottom open-

ing to give a coarser fine fraction, whereas if the quantity of solids to the cyclone decreases, there will be obtained a finer fine fraction. According to said control system these variations may be totally eliminated. This results in that an accurate classifying in the second cyclone stage can be obtained. The value of the quantity of solids discharged from the mill recorded in the recording member 49 is also used to control the r.p.m. of the mill. This method will be further described hereinbelow. An essential condition for the classifying to be carried out in the hydrocyclone 42 at a good separation sharpness with respect to the fact that the material fed to the cyclone has a particle size from 25 to 30 mms. down to a few μ , is that the classifying takes place at a high pulp density. This is achieved by the described pump and delivery systems into which no foreign water will pass in an uncontrollable manner which is generally the case when using centrifugal pumps for the pumping.

The suspension essentially freed from >1 mm. particles is continuously fed through the outlet 54 and passes through the pipe 55 to the pump well 56. From the pump well 56 the suspension is sucked into the pump 58. In order that the pump 58 at every moment shall carry away the same quantity as is fed to the pump well 56, the rotary speed of the pump is adjustable. The impulse to the right adjustment of the number of revolutions is obtained from the level sensing means 60, which is continuously sensing the pulp level in the pump well. The regulator cooperating with the level sensing means 60 continuously emits a signal to the speed control 62 of the Ward-Leonard system of the pump motor 59. The device operates in such a way that if, at a certain state of equilibrium between the r.p.m. of the pump and the supplied volume of pulp, the latter for instance decreases and, consequently, the level in the pump well 56 is lowered, this process is immediately detected by the level sensing means 60 which through the control member 61 emits a signal to the speed control 62 to reduce the r.p.m. of the pump 58. In this way the capacity of the pump 58 is reduced and the level tends to rise in the pump well 56. The regulating operation is in principle the same but reversed, if the quantity supplied to the pump well 56 is increased. Therefore, the system is characterized in that the supply to the pump well 56 is at all times in equilibrium with the withdrawal therefrom which renders the pump 58 to operate at the highest possible efficiency independent of variations of the incoming volume. The purpose of the pumping is to force the suspension through the hydrocyclone 64. In said hydrocyclone the final separation between the finely ground and not finely ground particles is carried out of the material discharged from the mill 1 and which has been subjected to a first classifying in the cyclone 42. The second cyclone which does not need to treat the whole quantity of the suspensions discharged from the mill, is thereby made smaller than the first cyclone but requires a higher feed pressure owing to the separation being carried out at a finer grain size.

On its passage through the pressure pipe 63 to the hydrocyclone 64 the suspension flows through the measuring member 67, formed as a venturi tube, a pressure head being created which is a function of the flow rate and the density of the suspension. This pressure head is recorded in the member 68. From this member is taken a signal, the strength of which being a function of said pressure head, and furthermore a signal is taken from the pulp density meter 65, the strength of which is proportional to the density of the suspension. These signals are transmitted to the calculating member 69 which through an analog computer from the input signals is capable of calculating and recording the quantity of solids passing through the pipe 63 per unit of time.

Thus, in the calculating and recording member 69 the quantity of solids continuously fed to the hydrocyclone 64 is indicated, for instance in metric tons per hour. The regulator 70 engaged to the member 69 is capable of ad-

justing the bottom opening 71 of the hydrocyclone. This control procedure implies that said bottom opening 71 is constantly caused to assume a size having a definite relation to the quantity of solids fed through the pipe 63 to the hydrocyclone 64 per unit of time. The operation of the cyclone has the effect that the ratio of separation of the cyclone and in this case the particle size of the fine fraction passing through the top outlet 72 of the cyclone 64 attains a predetermined value, independent of variations of the quantity of material fed to the cyclone. Furthermore, a coarse fraction having a density higher than the suspension is discharged from the mill through the bottom valve of the cyclone.

When, for instance, the quantity of solids per unit of time of the fine fraction discharged from the hydrocyclone 42 and pumped to the hydrocyclone 64 increases, this increase is immediately sensed by the member 69, the regulator 70 adjusting the bottom valve of the cyclone to increase the opening thereof. This results in that a larger quantity of material will be returned to the mill 1 at the same time as the desired particle size of the fine fraction is maintained.

If, on the contrary, the quantity of solids per unit of time of the fine fraction discharged from the hydrocyclone 42 decreases, the control procedure will be reversed so that it is constantly achieved that the ground product obtains its predetermined particle size. To secure this condition it has been found that the described schedule with classifying in two stages is especially appropriate.

In the first cyclone 42 which is relatively insusceptible to variations of the particle size of the incoming material, all coarse particles are separated and the fine fraction is given a particle size distribution which is practically constant during the course of time and the quantity of which may vary, whereas in the second cyclone 64 the particle size and density of the ground product is finally adjusted at the desired value. The separation limits of both cyclones are in this case adjusted in such a manner that they each operate at the highest possible classifying efficiency which is among other things achieved by the density of the suspension in the first cyclone stage being high, whereas in the second stage the density lowered on account of further addition of water.

By the described control of the bottom opening the coarse fractions re-cycled to the mill from the cyclones 42, 64 are given a density which somewhat exceeds the density of the suspension discharged from the mill, and also in this respect the system is automatic, if the opening of the cyclone has been chosen in a suitable manner in relation to the normal variations in the circulating load as well as to the desired separation efficiency of both cyclones.

The finely ground material leaves the cyclone at the top through the opening 72 and has then obtained the desired particle size, in this case 80% below 200 mesh. Therefore, it is withdrawn from the grinding system through the pipe 73. For the subsequent process, for instance a flotation, the ratio of water to solids of the pulp which is a function of the pulp density should be kept within narrow limits. To meet this demand the density of the suspension of finely ground ore coming from the cyclone is continuously measured in the pulp density meter 74, attached to the pipe 73, and the density is recorded by the instrument 75. The desired value of the density of the suspension is adjusted on regulator part 76 belonging to this instrument, in this case 1.33. With these devices the pulp density of the discharged, finely ground product is continuously measured, a deviation from the desired value causing a control measure. For the regulator 76 is engaged to the water control valve 77 of the pipe 78 terminating in the pump well 56. If the finely ground fraction discharged from the cyclone through the aperture 72 is undergoing a change in such a manner that the quantity of solids increase in relation to the volume of water, the density of the suspension increases,

which is immediately sensed by the pulp density meter 74 and recorded in the instrument 75 as well as transmitted to the regulator 76 governing the control valve 77 to increase the aperture so that the supply of water to the pump well 56 increases. This will continue until the value measured by the pulp density meter 74 coincides with the desired value of the regulator 76. The regulation procedure is reversed, if the fine or finished fraction discharged from the cyclone through the aperture 72 obtains a lower solids to water ratio than in normal setting. The control measure will then be the reverse of the described one.

There are several reasons for the dilution or the density of the pulp discharged from the cyclone 64 through the aperture 72 being varied. The density of said suspension is determined by the density of the fine-granular suspension discharged from the hydrocyclone 42 through the aperture 54 as well as by the separation rate in the hydrocyclone 64, which is determined by the setting of the bottom aperture in relation to the quantity of material fed. The density of the finely ground product is furthermore determined by the density of the quantity of the return material which is passed through the pipe 96 to the grinding circuit into the pump well 56. From the concentration circuits a varying quantity of return material is normally re-cycled, the return material consisting of a mixture of water and partly concentrated ore which requires renewed treatment in grinding as well as flotation. Said return material is discharged in the concentration circuit 80 through the device 83 and is conveyed to the pump well 56 through the pipe 96. The quantity of the material as well as the volume of water of said return material varies within broad limits depending on the nature of the ore and the way in which the flotation process itself is carried out. The water following the return material is used as dilution water in the suspension at its treatment in the hydrocyclone 64. In the fine classifying which is desired there is obtained an improved separation, if water is added to the suspension, as stated above. Instead of adding only clear water, in this way already utilized water is used in the process. The volume of water following the return material through the pipe 96 is, however, generally not sufficient for the suspension of finely ground material discharged from the cyclone to obtain a sufficiently high percentage of water, and therefore it is necessary also to supply the pump well 56 with clear water, the quantity of which being automatically controlled by the valve 77 in the manner described. In order to carry out all these regulating functions in a satisfactory way, it is necessary that the capacity of the pump is adjustable so that the rate of withdrawal pulp by the pump is the same as the delivery to the pump. This is noted to emphasize that the cyclone pump is made with variable capacity, which is in the present case attained by the fact that the pump motor has been given a variable rotary speed.

At the outlet of the pipe 73 the suspension of finely ground particles and water passes through the sampler 79 adapted continuously to sampling small quantities of the finely ground ore. Said sample can, if desired, be continuously classified, changes of the screen tests being recorded and used to control the r.p.m. of the mill (for instance according to United States patent application Ser. No. 748,514). This can be effected in such a manner that the sample taken at a rate of for instance 10 kgs. per hour is continuously classified in a sieving machine with mesh apertures adapted clearly to show the particle size of the ground product. In the present example a revolving screen having three woven sieves of 0.1, 0.06 and 0.044 mm. aperture is used. The weight of the fractions retained on the sieves are weighed continuously on recording balances, the value of the sieve analysis thus obtained being used to control the r.p.m. of the mill.

It has been described above how the regulation of the

grinding product is continuously controlled in a grinding scheme to a predetermined sieve analysis and predetermined degree of dilution, in which scheme there are important variations of quantities of material and volumes of water. The method described and the devices for the circulation and classifying of the ore in the hydrocyclones are especially suitable for said regulation. Since the detention period in the cyclone devices used and the auxiliary equipment is 2 to 4 minutes, a change in the operation conditions of the mill will be very rapidly manifested in the composition of the finely ground product. On the other hand, this therefore necessitates effecting regulation functions automatically since in such a system the manual handling will be too time-consuming to have the system operating in a satisfactorily manner. By the invention there have been achieved very simple automatic devices as well as low operating costs for the circulation of the material. The purpose of the regulation methods now described in the first hand is to equalize and neutralize the effect of minor changes of the composition of the finished product especially in the circulating load and volume of water. According to the invention a further factor, that is the r.p.m. of the mill, which may be if desired governed by impulses based on the circulating load can be introduced as a regulating factor to enable a predetermined sieve analysis of the ground product also at very strong variations of the grinding properties of the ore.

In grinding of a certain type of ore with constant feeding of new ore to the tumbling mill of a certain r.p.m., for instance 70% of the critical speed, the grinding and screening system will automatically operate in balance. In the mill a crushing and grinding charge of totally or partly disconnected bodies of a certain composition is formed, which gives the material discharged from the mill a certain particle size in so far as the density of the suspension discharged from the mill is kept within the range given. However, if the grinding properties of the ore are changed, for instance if in the feeding the ore attains another size-distribution, density, fragility, etc., this will manifest itself in a change of the circulating load.

The calculating member 52 continuously estimates the ratio between the quantity of solids discharged from the mill and the quantity of fresh ore fed to the mill (circulating load) from the signals emitted from the calculating member 49 of the pulp flow meter 49 and the gage value transformer of the weighing device 26. At balance in the system said member 52 shows in the present case a value of the circulating load which is for instance 10 times the quantity of the ore fed per unit of time. An increase of the quantity of the material discharged from the mill is immediately measured and recorded in the calculating member 49. Initially this results in that the regulator 50 adjusts the bottom aperture 51 of the hydrocyclone 42, so that a larger quantity of material corresponding to the increase is returned to the mill 1. If the increase is very sudden, the bottom valve 51 is not always capable of discharging the total additional quantity of the material, but a certain part thereof is passed also to the hydrocyclone 64, the bottom aperture 71 of which is also increased by regulation in a manner earlier described, so that the finely ground product discharged from the cyclone 64 is maintained at the predetermined composition. However, if the increase is of considerable duration, for instance dependent on changed grinding conditions in the mill 1, the quantity of the material discharged from the mill will successively increase according as an increased quantity of material is re-cycled from the cyclones 42, 64, from which it is evident that the grinding conditions of the mill 1 have been changed, in this case towards lower grinding capacity. It is possible to neutralize such a change by reducing the feed of new ore to the mill 1. Such a reduction, however, is also causing a decrease of the finely ground ore delivered from the system, and since the process following the grinding for its most economical

operation requires that the feed of ore is constant, this regulation method is less suitable. Instead of that the information and the changes of the quantity of the material discharged from the mill can be used to control the r.p.m. of the mill. From the member 52 a signal is transmitted to the regulator 53 in the Ward-Leonard system for the drive motor or motors 13 of the mill 1 and then re-adjust the number of revolutions of the mill.

If the circulating load calculated in the member 52 increases in relation to the adjusted desired value a signal from the regulator 53 is transmitted to the drive motor or motors 13 for adjusting of the r.p.m. of the mill according to a predetermined program. In the present example this program implies a reduction of the r.p.m. of the mill, if the circulating load increases, and an increase of the r.p.m., if the circulating load is reduced which among other things results in a certain time delay so that only changes of long duration but not of short duration are recorded in the circulating load, and also that the regulation of the r.p.m. is carried out in several smaller intervals. This results in a charge which is capable of finely reducing more effectively which in turn results in a reduced circulating load, so that said charge approaches the desired value of the system and automatically will be restored to said value. The case is the reverse if the circulating load decreases which shows that the grinding tends to become finer than desired. At a constant feed of ore this will be compensated according to the program by an increase of the r.p.m. by means of the regulator 53 and the drive motor 13.

According to the invention also other regulating programs than the described one can be used. The program is then dictated by the crushing and grinding properties of the ore or material. The essential matter of the regulation operation described is that in combination with the dilution control and the classifying process earlier described, said operation enables a complete control of the reduction operation which has not been possible earlier.

Some further essential features of the invention will be pointed out below.

In wet rock grinding it is important that the finely ground particles are immediately discharged from the mill. This is most suitably accomplished, if the mill is provided with a scooping grate. It is also desirable to make these grates wider than in mills for scooping in ball or rod mill grinding. By this method it is rendered possible very rapidly to discharge the material from the mill. However, this has the result that the product discharged from the mill will contain bodies of up to 20 to 30 mms. edge length. Furthermore, the suspension discharged from the mill is relatively viscous on account of the consistency the pulp has within the optimal density range. The separation of the finely ground product and the re-cycling of not finely ground product to the mill which in common ball or rod mill grinding does not result in any special difficulties, requires in rock grinding special devices. For instance in ball mill grinding the partly ground pulp discharged from the mill drum is permitted to flow by gravity to a mechanical classifier, in which coarse, not finely ground particles are left and by a raking mechanism or a screw feeder are scraped towards the feed end of the mill, and then said coarse fraction by means of for instance a conveyor or by a lifting scoop is transported to the mill. Said system cannot be adapted in the present mills, since the diameter of the mill is too large to permit such an arrangement. In order to solve the problem it has been earlier tried either to place a classifier below the mill and by means of a chain-bucket elevator to lift the coarse material into feed trunnion of the mill, or there has been chosen a method by means of a chain-bucket elevator to lift the total quantity of the material and water discharged from the mill to classifiers placed above the centre line of the mill wheel in such a way that the coarse material fraction can gravitationally fall into the mill trunnion. As the cir-

culating load in rock grinding is often up to 10 to 15 times the quantity of the ore fed, the quantity of the material which shall be transported by said chain-bucket elevator will be very large and also expensive with regard to installation and maintenance. Furthermore, a chain-bucket elevator has the disadvantage that by certain relations between the particle size of the solids and the percentage of water the material will sediment in the buckets, which results in said buckets totally or partly being incapable to transport. It has not been possible by known, rotating centrifugal pumps successfully to pump the suspension discharged from the mill to a classifier situated above the mill, partly due to the coarse particle size and partly due to the pulp density being too high with respect to the general purpose of a centrifugal pump. This has caused a substantial wear of the pump, irregular speed and, accordingly, unsatisfactory operation conditions. The use of an air lift to raise the suspension discharged from the mill, containing even very large ore particles at a low percentage of water, affords many advantages and makes it possible for the grinding scheme described to operate effectively. A correctly dimensioned air lift is operating very regularly and is capable at a constant efficiency to raise a pulp, the quantity of which varies for instance as 5:1. The operation of the airlift is not disturbed by relatively coarse bodies fed to the lift. The air lift does not contain any moving parts and shows an insignificant wear and is therefore very reliable. Finally the air lift, in any case in the grinding of complex sulfide ores, has the advantage that the ore in the grinding is subjected to a vigorous airing which promotes the subsequent flotation. The air lift is suitably installed in a well which is to be blasted in connection with the building of the mill hall. In certain cases it is possible to simplify the construction of the pump as far as the downflow tube 30 not being placed in a well but directly as a hole in the ground. In this case the inlet air tube 35 is placed within the downflow tube and suitably at the wall of the tube and ending through a bend of the upflow tube 37. In certain case it is suitable to arrange the air lift in two or several stages, each of which raising the pulp half or less parts of the way. This has the advantage that the immersion depth below the ground surface needs not to be large. In order that the air lift shall operate with the highest possible efficiency the compressed air shall not be compressed to a higher pressure than is required for the air just to be forced into the upflow or raise tube. In the starting period and in certain instances it is therefore desirable to supply air of a pressure higher than is suitably accomplished by a separate compressor. For air lifts intended for mills having diameters up to 10 metres, an air pressure of about 28 p.s.i. gage (2 kgs./sq. cm.) is required, if the air lifts are made in two stages. Thereby a level difference is obtained between the collecting funnel 40 and the hydrocyclone 42 of about 5 to 6 metres, which generally is satisfactory for the operation of the hydrocyclone. The compressed air from piston compressors generally contains a minor quantity of oil which can adversely affect the subsequent flotation of the finely ground suspension, and therefore an oil filter should be inserted between the compressor 86 and the compressed air tank 85. An air cooler for the compressed air is not generally necessary.

In the classification in hydrocyclones in two stages special advantages are also attained. Due to the fact that the suspension discharged from the mill is classified in a hydrocyclone, in any case a primary separation of the coarse fraction, a very reliable and simple device for the classification has been obtained. It is earlier known to use cyclones for classifying fine granular material. It has now been rendered possible successfully to carry out also a classification of a material which has been previously considered as being possible only to be separated in mechanical classifiers. In the present case a mechanical classifier should have the dimensions 4 x 10 mm. which is

now substituted by a cyclone of 600 mm. diameter. In fine grinding it is suitable to carry out a subsequent classification in a further, somewhat smaller cyclone, since the coarsest fraction has been withdrawn and returned to the mill. This suspension is then totally freed from coarse particles which may have an abrading effect on a rotating pump so that the pumping to the second hydrocyclone stage is advantageously carried out by means of such type of pump. The fine separation in the second cyclone generally requires a higher inlet pressure to the cyclone in the second stage than in the first stage. If the entire classifying operation should be carried out in one cyclone, there should be required for said cyclone an inlet pressure as high as for the second cyclone which means that the total quantity of the pulp of higher density and containing very coarse material must be pumped at a higher pressure which would essentially reduce the economy of the pumping operation. Thus, in the present invention the pumping to the separate hydrocyclone stages has been adjusted in such a manner that this part of the installation obtains the highest possible efficiency.

If the ore is not desired to be ground as finely as required for flotation which is the case for instance in iron ore dressing, it is suitable to carry the classification in only one step in the hydrocyclone 42. In this case it is suitable for the control of the dilution or density of the finely ground pulp discharged through the top opening 54 of the hydrocyclone, to mix the suspension with a variable volume of water in a mixing vessel, said addition being controlled by a pulp density meter which also can be made automatically adjustable in the same manner as earlier described. However, it is also possible to make this control of the volume of water in the air lift, if special measures are taken to measure the added volume of clear water which then suitably takes place in the inlet funnel 29 of the air lift. If the added quantity of clear water is measured and recorded, the effect of said quantity on the density of the suspension measured in the pipe 41 can be compensated by a special calculating member. The measuring instruments 44, 48 and 49 which measure, record and control the quantity of the material discharged from the mill are, however, not affected by the addition of water in the air lift 29.

In grinding to especially coarse particle size of the finely ground product, other separating members than hydrocyclones, for instance screens may be preferred and then such screens are substituted for said cyclones 42 and 64. In this case the regulation according to the invention is facilitated to continuously measuring the density of the material in the pumping and measuring of the circulating load, the operation of the mill being controlled in a similar way as earlier described. In this case the control sieves corresponding to the cyclones are suitably arranged in such way that the coarse, not finely ground product separated by the sieves by gravity can be recycled to the feed hopper 23.

In the above example grinding of ore in grate mills has been described, since same are the most effective ones in wet grinding. In certain cases, for instance if the material tends to clog the grates, traverse type mills are to be preferred. In such case the ground product discharged from the mill will be finer than in grinding in grate mills so that there is less advantage in using an air lift. Therefore, in such cases it may be suitable to substitute a rotary pump for the air lift feeding the cyclone 42 directly. The operation of said pump is then controlled in an analogous manner as described for the pump 58 connected to the second hydrocyclone, whereas the control of the operation of the cyclone, measuring of amounts and density of pulp are effected in a similar way as described for air lift pumping.

Having now described the invention, what we claim as new and desire to secure by Letters Patent, is:

1. A device for comminuting a material consisting of solid pieces of preferably crystalline structure, for instance

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ore, to a water suspension of finely ground material having a substantially predetermined density, comprising a rotatable grinding drum provided with feeding devices for material to be ground and devices for discharging a pulp comprising finely and partly finely ground material and also with a driving device, in which grinding drum the grinding material without the presence of foreign grinding bodies is caused to act as grinding bodies and crush and grind itself, a pipe with a control valve for adjustably adding water to the grinding drum, devices for separation of the pulp comprising finely or partly finely ground material from coarse pieces of the material subjected to grinding, devices for conveying the pulp comprising finely and partly finely ground material discharged from the grinding drum, a flow meter for measuring the rate of flow of the pulp, a density meter, means conveying said pulp through said flow meter and said density meter, means controlled by said flow meter and density meter to separate the finely ground material from the partly ground material to a predetermined ratio of separation independent of variations of the incoming quantity of solids and return the pulp comprising partly finely ground material to the grinding drum for furnishing a closed grinding circuit, and a regulating member which is adapted to be actuated by said density meter for governing the control valve to increase the addition of water to the grinding drum when measuring a pulp density above a predetermined value and for reducing the addition of water to the grinding drum when measuring a pulp density below said predetermined valve.

2. A device as claimed in claim 1, and means including said flow meter for continuously measuring the quantity of solids per unit of time discharged from the grinding drum, devices for comparison of said value with the quantity of grinding material fed into the grinding drum, and means controlled by said last-named means and last-named devices to regulate the number of revolutions per minute of the grinding mill motor.

3. A device for comminuting a material consisting of solid pieces of preferably crystalline structure, for instance ore, to a water suspension of finely ground material having a substantially predetermined density, comprising a rotatable grinding drum provided with feeding devices for material to be ground and devices for discharging a pulp comprising finely and partly finely ground material and also with a driving device, in which grinding drum the grinding material without the presence of foreign grinding bodies is caused to act as grinding bodies and crush and

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grind itself, a pipe with a control valve for adjustably adding water to the grinding drum, a grate arranged at the discharge end of the grinding drum with radial lifters for separation of said pulp comprising finely and partly finely ground material from coarse pieces of the material subjected to grinding, devices for conveying said pulp comprising finely and partly finely ground material discharged from the grinding drum, to two subsequent hydrocyclones arranged in series for repeated treatment of the pulp discharged from the grinding drum to separate and discharge the pulp comprising finely ground material and return the pulp comprising partly finely ground material to the grinding drum for furnishing a closed grinding circuit, devices for regulating the bottom apertures of the cyclones, a device for continuously measuring the density and a device for measuring the quantity of solids in the suspension fed to the respective hydrocyclones, a device for measuring the density of finely ground pulp separated from the second hydrocyclone and a device adapted to be actuated by signals from the last mentioned device for the operation of a control valve, engaged to a water pipe connecting the second hydrocyclone for regulating the water supply to the second hydrocyclone.

4. A device as claimed in claim 3, comprising a variable capacity pump arranged between the first hydrocyclone and the inlet of the second hydrocyclone.

5. A device as claimed in claim 3, in which the means for passing the pulp comprising finely and partly finely material discharged from the grinding drum to the hydrocyclones consists of an air lift pumping the pulp to an equalizing container mounted above the first hydrocyclone and that between said container and the first hydrocyclone placed under said container a downcomer is arranged to convey the pulp by gravity to said first hydrocyclone.

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