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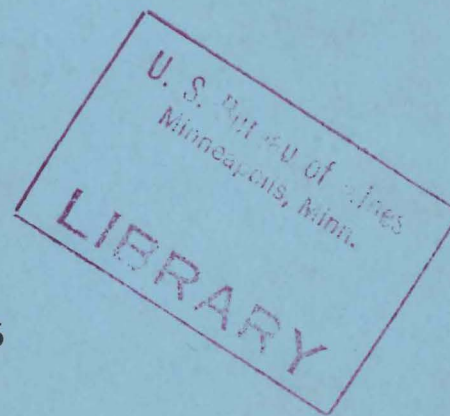
USBM Contract No. S0122069

One Crushing & Grinding -
BIBLIOGRAPHY OF SIZE REDUCTION

Volume 4: Abstracts 2845 to 3999

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USBM Contract Report (Contract No. S0122069)
July 1973

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D. C.

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76-80 (4)



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Equil. conditions in the reaction $\text{CaWO}_4 + \text{HCl} = \text{H}_2\text{WO}_4 + \text{CaCl}_2$ are studied. This reaction is used in scheelite decompn. in heated ball mills. It is found that scheelite decompn. does not require high HCl concns. as previously used.

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The power requirements (I) of a ball mill at different rotating velocities and with 3 different fluids, white spirit, raw linseed oil, and castor oil, have been measured. Reynold's no (Re) has no appreciable influence on the I as long as Re is greater than 15. When the fluid is highly viscous (Re = equals or less than 15) there is a distinct connection between Re and I represented by Newton's no. (Ne), expressed by the equation $Ne = 1.8Re^{-0.21}$.

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Electron diffraction patterns can tell much about a crystal surface, crystal structure, crystal size, orientation, distortion, topography, etc.

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The surface ions of a solid are not arranged in the structure of an ideal crystal lattice, due to polarization of electron cloud and displacement of the ions to minimize unbalanced forces. Displacement distorts the lattice for a depth of about 100 atoms. Tendency for surface ions to become screened, to attempt to form noble gas configuration is cause of distortion.

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Measured the effect of deformation and combined stresses on fracture strength. Tensile properties of several metals notched at various depths and angles studied.

2864. McAdam, D.J., Jr., The technical cohesive strength of metals in terms of the principal stresses, Metals Tech., Tech. Pub. 1782, Dec. 1944.

1. Cohesive strength is not a single valued quantity but is a function of all three principle stresses - thus must be represented by a surface in 3 dimensional figure.

2. Cohesion limit depends on previous mechanical history of the material.

2865. McAdam, D.J., Jr. and Clyne, R.W., The theory of impact testing, Proc. ASTM 38 (2) 112, 1938.

2866. Mumford, A. R. and others, Characteristics of Cloth filters on coal dust - air mixtures, ASME Trans. 62 271-81, 1940.

This paper deals with the installation, operation and maintenance of cloth filters for handling vented air from pulverized coal mills. The experiences of the authors in solving problems in connection with the cloth-bag filter system, as used at the Kips Bay Station of the New York Steam Corporation, are the basis on which the subject is developed. Complete performance tests on a 40 ton mill installation are cited.

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2868. Muscari, Gulielmo, Process for the separation of valuable bran constituents, U.S. Pat. Application A.P.C. 362,659.

2869. Mempel, G., Kinetics of grinding hard materials, Part 5: Fracture energy of the material in ball mills, Chem. Ing. Tech. 37 (11) 1146-53, 1965.

In designing grinding machines, it is most essential to have information on the energy of fracture of the material to be ground. This energy has been determined for various materials with a laboratory mill. The optimum grinding conditions for a given material can be established if knowledge of the details of the energy of fracture is sufficiently accurate. Data for quartz, glass limestone, clinker.

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2871. Mori, Shigejiro and Kawano, Toshio, Relation between the grinding conditions of a test ball mill and the particle-size distributions of the cements, Semento Gijutsu Nenpo 9 194-200, 1955.

A 500 x 300-mm. test ball mill was used in which grinding media are charged at 30% by vol. The effects of the speed of rotation (30-60 r.p.m.), amts. of clinker charge (20,30, and 50% by vol.), and kinds of grinding media on the particle-size distributions of the cements were studied by the air-elutriation method. The particle-size distributions can be expressed by the following exponential formula: $R(x) = e^{-kxn}$, where $R(x)$ is the amt. of particles greater than xn in % by wt.; x is particle diam. in n ; k is a const. The value of n was 0.8-1.2 and increased with decreasing the speed of rotation and with increasing the amts. of clinker charge. The effects of the kind and size of grinding media on the value of n are also reported.

2872. Rumpf, H., Single particle size reduction as a basis for a scientific size reduction technology, Chem. Ing. Tech. 37 (3) 187-202, 1965. Trans: Special Libraries Ass'n.

In assessing a crushing process, the investigation of the individual particle serves as a basis. The principal magnitudes are the type of stress, its intensity and its rate of application, the kind of material, the particle size and shape and the temperature and composition of the surrounding medium. Results are reported for the breaking down of individual particles in the form of glass spheres and irregularly-shaped particles of quartz, limestone, heavy spar (barytes) and cement.

these having been subjected to pressure and impact comminution in various types of test apparatus. From these results, it is possible to set up a programme for optimum mechanical crushing.

2873. Schoenert, K., Ohe, W.v.d., and Rumpf, H., Technical fine grinding with single-grain stressing between two surfaces. Chem. Ingr. Tech. 37 (3) 259-64, 1965.

Test results on the crushing of individual particles show that large peripheral velocities are required for fine grinding with a roller mill. On making trial grindings of a clinker in such a mill designed with this aspect in mind, final surface areas of from 250 to 1000 cm²/g and energy efficiencies of from 70 to 50 cm²/ Joule were achieved.

2874. Behrens, D., The impact crushing of glass spheres and irregularly shaped particles of heavy spar, limestone and quartz sand, Chem. Ing. Tech. 37 (5) 473-83, 1965.

Information on the probability of rupture and on the strength of the individual particles, the resulting particle size distributions and shapes of the fragments, and also on the rupture surface (surface area increase). From this, the specific energy consumption and the energy yield or efficiency in breaking up the individual particle can be determined.

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Deals with fatigue failure of steel parts.

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2881. Ranz, W.E. and Wong, J.B., Impaction of dust and smoke particles, Ind. Eng. Chem. 44 1371-81, 1952.

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2884. Kiesskalt, S., and Dahlhoff, B., Practical importance of two physical effects in comminution, Chem. Ingr. Tech. 37 (3) 277-83, 1965.

A relationship between the rate of crushing and the speed of sound in a solid substance is demonstrated by the vibratory grinding of six crystalline substances. In general, it is not possible effectively to influence the rate of crushing by grinding additives when wet grinding in vibratory mills. The reason lies in the great difference of cracks brought about by impact or blow; the surface-active agent cannot keep up with the fracture front in this type of fissure.

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Strength of mica & Griffith theory. Experiments on tensile failure of mica.

2886. Orowan, E., The increased resistance of thin threads, the Joffe - effect and related phenomena from the viewpoint of the Griffith theory, Z. Phys. 86 195-213, 1933.

Attributes 10-fold strength increase of mica in vacuum measured by Obreimov to high surface energy in vacuum. A vapor has

same effect as the liquid in this regard.

2887. Miller, G., New nitrogen technic assures fine grinding in only one pass, Food Eng. 23 36-37, July, 1957.

This is a method used for grinding agar-agar by chilling it with liquid nitrogen. Developed by Linde Air Products. The material is chilled to its point of maximum brittleness thereby reducing the amount of energy required for fracture. Chief advantage is the efficient grinding of materials which are flexible at ordinary temperatures and which cannot withstand heat. The actual grinding is done by a higher speed hammer mill running at 10,000 r.p.m. This process has excellent possibilities.

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The relationship of the energy of fracture of brittle materials required during grinding to the resultant particle size has been determined on an individual particle in a laboratory ball-mill. The amount of energy supplied to a ball-mill must make due allowance for the energy required for fracture if a high degree of efficiency is to be obtained. A possible method of achieving this is described.

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Presents the mathematics of mill charge movement. Power: no adequate theory, many variables. Use dimensional analysis, experiment. Comminution flow theory valid for single particles, but other effects occur in mills.

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Compares attritor with propellor mixers, Kady mills, and Sigma blade mixers. Found improved dispersion of coating on a continuous basis, with reduction of coating losses, labor and maintenance.

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Determination of particle-size distribution by the sedimentation pipet method of Robineson (C.A. 17, 1924) was found satisfactory on org. fungicides and insecticides by suspending the material in such a medium as 0.25% aq. solution of Nacconol NR. The total solids concentration of the suspension, which should not exceed 3-5%, was determined by optical and polarographic methods. This method was also proved useful in determining the apparent distribution of heterogeneous mixtures. The nature of the diluent used during grinding had some effect on the distribution of the original component of a mixture. Distribution curves can be obtained with as little as 0.05 g. of material and on dusts containing as little as 1% active ingredient.

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Analysis used by McAdam of stresses at base of sharp notches is open to question. In this analysis it was assumed that the stress across notched section is uniform. Assumption has little basis in fact and becomes less valid as deformation before fracture becomes small.

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$$f = Qd \frac{1 - 2m}{3 - 5m}$$

where: f = stress

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Kaolin-type clays were purified. The purified samples were ground for 48 hrs. in a pot mill and then dispersed by shaking a 6.2-g. clay sample with 200 ml. H_2O contg. 0.555g. $Na_4P_2O_7 + 10H_2O$. The method of detn. of the particle-size distribution is reported in C.A. 51, 11950d. The grinding had a considerable effect on the coarser particles. Finer particles are not so much affected. Some agglomeration of finer particles was observed.

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The mathematical basis of particle size analysis of milled particles.

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S. worked with mineral phosphate from Morocco and found that the higher its comminution the higher the change of P_2O_5 in the finished superphosphate.

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of wavy surface. Surface can be active until relieved. Other speculations about surface tension theory.

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Presence of flaws (Griffith's theory) is most probable reason for low strength of metals.

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1. Maximum normal stress (Rankine's theory). Failure when stress on a certain plane reaches maximum regardless of stresses occurring on other planes.
2. Maximum strain (Saint Venant's theory). Failure when strain due to combination of stresses reaches a value equal to that which occurs at failure of a bar subjected to a simple axial test.

3. Maximum shearing stress (Guest's theory).

Failure when maximum shearing stress on some plane through the point reaches a critical test value.

4. Strain energy (Beltrami and Haigh).
5. Strain energy (Von Mises).

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An experimental investigation of a 12-inch glass cyclone has shown that the flow within the cyclone consists primarily of an outer downward spiral and an inner upward spiral of higher velocity. The rotational velocity at any point in the cyclone chamber below the exit duct was found to vary inversely as the square root of the radius. The friction loss in the cyclone varied as the square of the inlet velocity.

Data on the pressure drop with various other internal and external modifications are also reported.

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2913. Alpine AG., Milling process which comprises conducting two gas or liquid streams charged with the material to be ground in opposite directions to promote intensive collision, DBP 814 091, 9/20/51.

2914. Ambler, C.M., Trends in centrifugal separation, Chem. and Met. Eng. 45 256, 1938.

This article reviews sedimentation in liquids in centrifuges.

2915. Anable, Anthony, Closed-circuit fine grinding and what it should accomplish in the cement industry, Rock Products 32 66-72, 1929.

Discusses classification. Compares mill efficiency and work done by tons of size produced by the Rittinger law and by the Kick law. That the classifier determines the capacity, not the mill, is based on examples given.

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This article compares features of several commercial methods of settling separation, giving capacity, cost and performance information for several products.

The use of Stoke's law in "thickening" problems is not recommended because it is based on free fall of the particles whereas physical impact often occurs in the actual case.

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Application of proportional action controller to constant weight feeding system to allow grinding mills to operate at maximum capacity.

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Measurements were made with a Pulfrich photometer. Correlation of particle size, color, concentration with light passage is made.

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Structural details of a continuous, water-cooled ball mill are given.

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2925. Arcuri, Fernando Jr., Optimum velocity of ball mills.
Anais assoc. brasil. quim 13 59-65, 1954 (Pub. 1957).

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1947.

2927. Arnell, J.C., Surface measurements of fine materials by
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terms upon Stoke's law for the motion of spheres through
liquids, Phil. Mag. 22 755-75, 1911.

In the mathematical derivation of the original formula certain
assumptions are made:

1. The discontinuities of the fluid are small compared with
the size of the sphere.
2. The fluid is infinite in extent.
3. The sphere is smooth and rigid.
4. There is no slip at the surface between sphere and fluid.
5. The velocity of the sphere is small.

From the results of several experiments, the author concludes
that slip is an important consideration where very small
particles are involved. The equation

$$v = \frac{2gr^2(s-p)}{9u} \quad 1 + \frac{u}{Br + 2u}$$

is presented to describe the terminal velocity when slip is occurring, B being the coefficient of sliding friction.

2929. Bergstrom, B.H., Sollenberger, C.L., and Mitchell, Will Jr., Energy aspects of single particle crushing I, Trans. AIME 220 367-72, 1961.

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A general description of the machine and process used for cleaning and grinding the wheat so as to retain the maximum of minerals and vitamins. S. claims that there is no food poorer in minerals and vitamins than the fine and, for the most part, chemically bleached flour of today. Wheat cleaned by the Steinmetz process contains the aleurone layer intact, only the fibrous part of the bran having been removed. The whole of this wheat, ground into flour, is used in bread making.

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Materials are dried and ground through the action of a rapidly moving stream of elastic fluid. Three types of mills suitable for materials ranging from 0 to 95% H₂O are described.

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3675, 39 pp., 1942.

A dry pulverizer has been developed that produced superfine sizes; e.g., a coarse muscovite was ground to an average particle size of 2.5 minus.

2933. Sticht, R.C., Grinding of phosphate rock and sulfur, Soc. Chem. Ind. Victoria Proc. 40 297-300, 1940.

Owing to the ease with which it is decomposed by H_2SO_4 , phosphate rock from Nauru and Ocean Island is ground so that only 40-50% passes through 100-mesh; grinding is carried out by jaw crushers, followed by mills of the ring-roll type, operating in closed circuit with air separators. S for agriculture in Australia is ground so that 98.5% passes 100-mesh, while that for rubber-vulcanizing purposes is ground to a fineness of 99.5% through 300-mesh; roller mills are used and the amt. is kept at lower than 5% O_2 content by drawing the air through a coke or oil burner.

2934. Stinherz, A.R., Shape of particles in finely ground powders, Soc. Chem. Ind. J. 65 312-20, 1946.

This paper contains a correlation between three methods for the determination of particle size in the sub-sieve range:

1. Measuring the settling velocity, assuming Stokes' Law.
2. Counting particles of the same weight.
3. Measuring the size of the observed or projected images of the particles in their most stable positions.

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Theory is presented and experimental work on particle size of portland cement, ground quartz and ground glass is presented.

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2936. Svensson, J., and Murkes, J., An empirical relationship between work input and particle size distribution before and after grinding, International Mineral Dressing Congress 37-58 Stockholm, 1957.

2937. Agar, G.E., and Brown, J.H., Can. Min. & Met. Bull. 57 147-51, Feb., 1964.

Review energy theories of size reduction. Conclude that an exponential relation exists, but exponent varies. Search for a "correct" theory is futile and misleading. Bond theory is useful for design. Recommend research on mechanism of fracture.

2938. Altrogge, L., and Schofer, W., The test of milling with the Hiddema system, Die Muhle, Jan. 5, 1952.
Discusses the increased yield of fines with a high differential

in roll surface speed as well as the evaluation of the product character. Differentials in the Hiddema system are from 28 - 30 to 1 as compared with $1\frac{1}{2}$ - $2\frac{1}{2}$ to 1 in conventional grinding. Tests are also reviewed using 8 - 10 to 1 on a conventional mill equipped with variable speed drive for variable differentials.

2939. Last, A.W., Ribotto, J.W., Kennecott Copper Corp.: Milling practice at Utah Copper Division, Milling in America N. Arbiter, Ed., VII Int. Min. Proc. Cong. 375-400, 1964.

2940. Anonymous, Double impeller breakers use dual impact action, Eng. & Min. J. 151 141 only, 1950.
A machine for grinding rock. Minimum size of ground product ranges from $1\frac{1}{4}$ " upwards.

2941. Bergstrom, B.H., and Sollenberger, C.L., Kinetic energy effect in single particle crushing II, Trans. AIME 220 373-9, 1961.

2942. Bond, F.C. and Maxon, W.C., Measured energy input to a bed of particles in a simple crushing device, AIME Tech. Pub. 888, 134-296, 1938.

2943. Burke, S.P., and Plummer, W.B., Suspension of macroscopic

particles in a turbulent gas stream, Ind. Eng. Chem. 20 1200, 1928.

This paper summarizes knowledge of the drag forces acting on macroscopic particles in fluid streams and also presents results from the authors' experiments. The equation

$$R = ksr^2V^2$$

is given for the case of turbulent flow. R is the force in grams acting on particles; s is the density of the fluid; r is the radius of the particle and V, the velocity.

The constant, k, has been determined as 0.00084 when the units of the above equation are in the c.g.s system. For irregular coal or coke particles, the value of k is slightly higher, r being taken as the radius of the sphere of equal volume.

2944. Karpinski, J.M. and Tervo, R.O., Single impact testing of brittle materials, AIME Trans. 229 126-30, 1964.

Describes a machine for rapidly testing many (10,000) grains of material by single impact with a spinning steel vane in vacuum.

2945. Mitchell, Will Jr., Sollenberger, C.L., Kirkland, T.G., and Bergstrom, B.H., Analysis of variables in rod milling, Trans. AIME 199 1001, 1954.

A great deal of data. Graphs show effect of significant variables.

2946. Quittkat, Gotthold, Fine grinding of mineral raw materials in wet drum mills and its application to ore dressing, Z. Erzbergbau u. Metallhüttenw 2 6-14, 1949.

A description and discussion of the field of application and operating conditions for various types of mills.

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2950. Born, M., Thermodynamics of crystals and melting, J.Chem. Phys. 7 591, 1943.

Theoretical development from statistical thermodynamics of the functional relation between melting condition and the temperature and the six strain components on the crystal faces. Melting is considered as violation of the condition c_{44}^{70} that the crystal resist shearing.

Similar criteria are postulated for mechanical fracture of crystals.

2951. Ergun, S., Determination of particle density of crushed porous solids by gas flow method, Anal. Chem. 23 151-6, Jan.1951. As a porous material is broken into smaller pieces, the particle density of the smaller pieces will be greater due to

eliminating of the pores. Increase becomes more marked as particle size approaches size of pores. When pulverized to size of smallest pores, particle density approaches the true density of solid.

Principle problem in measurement is measurement of volume of particles. Paper discusses method of determining volume and hence density by a gas flow method. In this method gas flow rate, pressure drop, and bulk density are measured.

Mathematical equations for final determination are presented.

2952. Margulis, V.S., and Litovka, A.V., Technical and economical characteristics of comminution of ore in ore treatment plants of Krivoi Rog, Gornyi Zhurnal (7) 62-7, 1963.

Flowsheets of ore crushing and comparison of design data with data on output of crushers. Efficiency of crushers and grinders; wear of lining in grinding mills; consumption of material and power required to grind 1 ton of ore; costs of grinding.

2953. DeHoff, R.T., Determination of the geometric properties of aggregates of constant-size particles from counting measurements made on random plane sections, Trans. AIME 230 (4) 764-69, 1964.

Presents a general method for determining the geometric properties of structures composed of particles of identical shape and size. The use of the method requires a knowledge of the qualitative shape of the particles and three simple counting measurements, which are made on a representative plane section taken through the structure. The geometric properties that can be determined quantitatively from counting measurements are size, shape, number, surface area, volume, volume fraction, and surface area per unit volume. See 2954.

2954. DeHoff, R.T., Estimation of particle size distributions from simple counting measurements made on random plane sections. Trans. AIME 233 (1) 25-29, 1965.

A new approach to the measurements of the size distribution

of particle structures imbedded in opaque bodies is developed. The method is based on the assumption of a general two-parameter distribution curve and the estimation of the parameters from three well-known counting measurements made on metallographic sections. The total number of particles in the system is also a product of the analysis. Application of the method with the assumption of the logarithmic-normal distribution function is developed in detail.

2955. Jones, M.P., and Fullard, R.J., Mineral Liberation by thermal decomposition of a carbonate rock, Instn. Min. and Met. Trans. 75 (3) C127-8, 1966.

Conventional crushing breaks through grain boundaries. Thermal decomposition of carbonate matrix rocks liberates CO₂ inside the rock, which may concentrate stress at grain boundaries. A dolomite with 6% apatite gave a sharp liberation when calcined at 900° C and slaked. Cost was 100 times conventional grinding, but efficiencies of subsequent steps could overcome this.

2956. Jones, J.Q., and DeJong, L.C., Homestake-Sapin partners uranium ore processing, Milling in America, N. Arbiter, Ed., VII Int. Min. Proc. Cong. 283-312, 1964.

2957. Johnson, E.B., and Bjorne, C., Milling practice at the Republic mine, Republic, Michigan, Milling in America, N. Arbiter, Ed., VII Int. Min. Proc. Cong. 161-176, 1964.

2958. Dundurs, J., and Sendeckyj, G.P., Edge dislocations inside a circular inclusion, J. Mech. Phys. Solids 13 (3) 141-47, 1965.
2959. Ketter, R.P., Milling practice at the Grace Mine, Milling in America, N. Arbiter, Ed., VII Int. Min. Proc. Cong. 127-49, 1964.
2960. Anon. Classification of methods for determining particle size, Analyst 88 (1044) 156-87, 1963.
2961. Lovell, Harold L., and Rao, P. Dharma, A statistical analysis of attritional scrubbing, VII Int. Min. Proc. Cong., New York, N. Arbiter, Ed., 51-62, 1964.
2962. Rammler, Erich, and Krug, Herbert, Performance characteristics of an impact mill, Freiburger Forschungsh. A90 87-95, 1958.
- The performance characteristics of an impact mill were detd. when crushing a woody brown coal and using 5 different hourly feed rates for each of 3 circumferential velocities. When plotting the sieve analyses on Rosin-Rammler paper, a break in the curves was observed indicating heterogeneity of the Crushed product because the proportion of disintegration owing to impact and attrition varied with the circumferential velocity.

2963. Eisenkolb, F., Possibility of separation of particles of different shapes (in metal powders), Stahl Eisen 84 (12) 734-39, 1964.

The effects of particle shape on technological properties are discussed. The feasibility of separating irregular shapes from spherical ones was investigated by the use of vibratory conveyors, rotating disks, and electrolytic cells.

2964. English, P., and Hiorns, F.J., Measurement of the Specific fracture energy of coal, Instn. Min. and Met. Trans. 75 (3) C87-94, 1966.

2965. Anon., Power measuring device controls materials feeding, Automation 7 80, Feb., 1960.

2966. Anon., Barker mill, Min. & Chem. Eng. Rev. 54 (4) 34-5, 1962.

It is claimed that Barker mill will replace conventional primary rod mill, secondary ball mill, classifier and thickener in many mineral dressing plants; in one operation, mill will reduce $\frac{1}{2}$ in. material to 75% minus 200 mesh, and discharge product at pulp density required for flotation; in recent test, throughput of about 10 tph was obtained with complex silver-lead-zinc sulfide and copper ore from mines at New South Wales. See 4426.

2967. Teel, J.H., Doubling concentrator capacity at Chuquicamata, Chile, Milling in America, N. Arbiter, Ed., VII Int. Min. Proc. Cong. 145-60, 1964.

2968. Anon., Impact breaker for primary and secondary reduction, Engr. 212 662, Oct. 20, 1961.

2969. Eshelby, J.D., Dislocations in viscoelastic materials, Phil. Mag. 6 (68) 953-64, 1961.

An expression is found for the force required to move a dislocation steadily through a viscoelastic medium, in particular Zener's standard linear solid. It is applied to the case of a screw dislocation in iron exhibiting the Snoek effect. Schoeck and Seeger's atomic treatment of the same problem contains an error. When this is corrected the two methods give solutions of the same form.

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Compares open-circuit rod mill with closed circuit single-stage ball mill economics.

2972. Anon., Computers streamline iron ore treating, Can. Chem. Processing 49 (3) 66-71, 1965.

Arnaud Pellets Ltd. plant on St. Lawrence north shore will accept about 4.9 million long tons yearly of iron ore concentrates from Wabash operation; it will slurry feed, grind it in ball mills, filter it, mix it with bentonite (binding agent), pelletize it in balling drums and heat-harden it in large traveling-grate indurating machines; digital process computer will initially monitor and log operations; provision has been made, when process factors are known, to put process under automatic computer control.

2973. Anon., Second look at unit operations - size reduction, Can. Chem. Process 44 78-9, Feb., 1960.

Merely an announcement of some manufacturers.

2974. Anon., Milling plants in Canada, Can. Dept. Mines & Tech. Surveys-Mineral Resources div. List 1-2, 34 pp., Jan. 1957.

Inventory of mills treating industrial minerals; lists record data on size of mill and type of milling process for treatment of asbestos, barite, bentonite, brucite, cement, feldspar, fluorspar, gypsum, iron oxide, lightweight aggregate, magnesian salt, silica, soapstone and talc, sodium sulphate, whitening substitute, and miscellaneous products.

2975. Anon., Milling of Canadian ores, Group of articles on milling practices compiled for occasion of Sixth Commonwealth Mining and Metallurgical Congress, Can. Inst., of Mining and Met., Montreal, 447 pp., 1957.

Covers mineral dressing and testing facilities, general description of milling areas, and list of mills operating or under construction. Articles on milling of gold, silver-cobalt, copper, lead-zinc, uranium, asbestos, iron, and ores of less common minerals. Beneficiation practices in coal mines.

2976. Bassick, Joseph, Supersonic rock crusher demonstrated, Eng. Mining J. 154 (3) 109, 1953.

The mill has a rotor, which is supposed to break rock by ultrasonics. (This appears doubtful).

2977. Anon., Forum on the non-cataracting ball mill, Can. Mining & Metall. Bull. 51 495-504, Aug., 1958; discussion 51 752-3, Dec., 1958.

2978. Anon., 1964 Processing manual and raw materials index, Ceram. Age 80 (10) 10-142, 1964.

Special issue includes tabulations and information on raw materials and equipment for use in production of ceramics, structural clay products, glass, enamelware, refractories, etc., it is in sections on raw materials, particle size reduction, screening and size analysis, weighing and blending, forming,

drying, firing, melting and annealing, finishing, handling, instrumentation and auxiliaries.

2979. Anon., Pulverize ceramic materials with no moving parts, Cer. Ind. 75 56-7, July 1960.

2980. Anon., Systems boosts efficiency of grinding, classifying, Chem. Eng. 70 100+, Oct. 28, 1963.

2981. Anon., Packaged crushing plants made automatic, Chem. & Eng. News 40 86, July 30, 1962.

2982. Frechette, V.D., Ed., Non crystalline solids - symposium, Wiley, New York, 1958.

Several articles on structure of silica, glass properties, relaxation, formation of amorphous layer of normally crystalline material by vapor deposition. Charles on flaw theory of strength, esp. of rubber.

2983. Albus, F.E., Modern fluid energy mill, Chem. Eng. Progr. 60 (6) 102-6, 1964.

More precise control of particle size and narrowing of size distribution range are major advantages for chemical process industries; variables that can be changed and that have effect on end product from fluid energy mill include raw feed size, feed rate, pressure, temperature, viscosity and nozzles; products are in low micron and submicron range.

2984. Anon., Fluid energy mills for sub-sieve pulverizing, Chem. Eng. Progr. 55 108-10, Jan., 1959.

Construction details of a Sturtevant Micronizer and energy requirements for fluid energy mills in general are reviewed. Energy requirement is higher in a jet mill, but so is new surface produced.

2985. Anon., Impact type pulverizing mills making inroads in chemical processing field, Chem. Eng. Prog. 54 134-5, Nov. 1958.

2986. Adamski, T., New two-roll grinding mill, Chem. & Proc. Eng. 45 (7) 343-7, 1964.

Two-roll mill could be made into efficient size-reduction plant if roll speed were increased, but this was always considered impossible due to enormous generation of frictional heat. This difficulty has been overcome by feeding material onto rolls from great height through narrow shaft. Individual particles can then be given high initial velocity, resulting in instantaneous crushing and immediate removal from roll surface. These principles have been applied in design of IBJ mill; experimental results obtained in crushing river sand and bauxite. When operating at higher speeds with a reduction ratio of 3. he found that he could feed up to 50% of the rate theoretically possible by ribbon theory. Williams said that normal practice with larger, slower rolls allowed feeding up to 25-30% of theoretical. This shows that feeding at roll peripheral

velocity does increase production rate even more than claimed.

Idea was first patented by G. Johnston, U.S. Pat. 1 396 712.

2987. Finkin, E., Surface roughness in wear, Wear 6 293-302, July-Aug., 1963.

Surface roughness was investigated by carrying out rotational experiments with sliders on plates for lightly loaded systems of copper on copper and steel on steel. The average maximum surface roughness was measured for lubricated and unlubricated sliding conditions, and compared with the mean wear particle size. The roughness was found to approach a value independent of initial conditions and wear particles were found to have a characteristic shape which varies with the materials; roughly an ellipsoid for copper and a strip or extended plat for 1020 steel.

2988. Anon., Air-stream pulverizers, Comp. Air Mag. 63 22, March, 1958.

2989. Anon., Fahrenwald, A.W., 1933 rock mill, Eng. & Min. J. 163 (5) 83, May, 1962.

Autogenous mill comprises 3 major units--"rock mill", secondary crusher and classifier; coarse rock in ore is employed as crushing media; only steel consumed is from mill lining and from crusher jaw; mill employs quick discharge, low pulp-level principle, and high circulating loads; in variation of system,

grinding may be done in closed circuit with screen instead of classifier.

2990. Forchheimer, O.L., Grit hardness and toughness - their effect on grinding operations, Grinding and Finishing 6 (11) 34-39, 1960.

F. discusses hardness scales, operational and theoretical toughness, and factors that affect the toughness of alumina (crystal size, chemical composition, porosity, grit size, and grain shape).

2991. Anon., Ultrasonics improves grinding economy and quality, Electronics 34 28, June 9, 1961.

2992. Anon., Control of mineral processing, Engineering 214 978-9, Dec. 7, 1962.

2993. Turner, R.R., The aerofall Mill - A promising newcomer (for cement), Rock Products 69 (5) 94-7, 1966.

2994. Cook, N.G.W., Hoek, E., Pretorius, J.P.G., Artlepp, W.D., and Salamon, M.D.G., Rock mechanics applied to study of rock-bursts, J.S. African Inst. Min. and Met. 66 435-528, 1966.

2995. Anon., Memo to management-processing, Eng. & Min. J. 163 (6) 179-96, June 1962.

Thirty-four papers dealing with processes and equipment used for ore separation, crushing and grinding, ore haulage, dust control, flotation, leaching, iron ore sintering, and aluminum ore reduction.

2996. Anon., Gyratory crusher, Engineering 206 984, Dec. 19, 1958.

2997. Gilman, John J., Fracture in solids, Scientific American 202 (2) 94-104, 1960.
Fracture resulting from microscopic cracks is briefly described.

2998. Anon., Studies of abrasive wear resistance, Engineering 191 546-7, April 14, 1961.

2999. Wedderburn, W.M., A review of some abrasion resistant cast materials and their application, J.S. African Inst. Min. and Met. 66 160-64, 1965.

3000. Anon. Properties of crystalline solids, Spec. Tech. Pub. 283, American Soc. for Testing Materials, Philadelphia, 1960.

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3002. Akunov, V.I., Comminution to less than one micron, U.S.S.R. Pat. 110 406, June 25, 1958.

The grinding is accomplished in a gas stream and the classification is accomplished by a combination of centrifugal and mech. forces. The grinding is carried out in a vibrating stream mill having a horizontal chamber and deflectors installed along the periphery which are swept by the contrifugally moving gases.

3003. Anon. Crushing and grinding - a bibliography. Dept. Sci. & Ind. Research, London, 1958. Reprinted by Chem. Pub. Co., New York, 1960.

3004. Anon. Electric ear controls operation of ball mill, Elec. World, 125 188, January 19, 1946.

3005. Batel, W., Critical review of particle-size determination by means of screen analysis, air separation, sedimentation, and the Blaine test, Chem. Ing. Tech. 29 581-9, 1957.

The screen analysis is strongly affected by the operating

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mechanism of the screening equipment, especially when a large portion has a fineness below 60μ . Air sepn. is best for classifying between 30 and 100μ . Sedimentation analysis gives correct values in the range of 1 to 60μ if the particles are dispersed properly. The Blaine test gives a characteristic no., but this no. cannot be taken as a value of the surface, unless an appropriate correction is applied to the Kozeny equation. Many data and 13 references are given.

3006. Bentur, S., Oxidation capacity of nascent surfaces of solids, Bull. Research Council Israel 7A 16-20, 1957.

When nascent surfaces are produced by dehydration (SiO_2 gel) or grinding (quartz, graphite,) the mech. or thermal energy is converted into chem. energy; this gives rise to unusual surface reactivity. Nascent graphite surfaces also reduce KMnO_4 and oxidize TiCl_3 .

3007. Berenbaum, R., Analysis of the shatter breakage of coal using a Matrix Method, J. Inst. Fuel 34 367-74, 1961; 35 346-51, 396-9, 1962.

3008. Bickle, W.H., Fundamental aspects of crushing and grinding in Crushing and Grinding - A Bibliography, Chem. Pub. Co., N.Y. 1-17, 1960.

3009. Birch, J.R., The roller mill, Tech. Education Series, Pamphlet No. 6, The National Joint Industrial Council for the Flour Mill. Industry.

Appendix A-points of seizure and release, 57-61.

Grinding action of rolls, 12-17.

Discussion of surface velocity differential, 23-26.

Design of roll corrugations, 26-30.

Appendix B, smooth rolls for flaking, 61-64.

3010. Blanc, E.C., Crushing, grinding and screening in the Chemical Industries. A Review, *Mechanique, Suppl. Tech. Ind. Chim.* (284 bis) 95-100, 1939.

3011. Boddy, R.G.H.B., Microscope observations of the crushing of coal, *Nature* 151 54, 1943.

When coal dust up to 30 μ thick is crushed under a cover glass, to about 0.1 μ thick, the particles, even of anthracite coal, become translucent. The effects of crushing vary considerably, but in general it seems that coal can behave as a plastic substance.

3012. Bodlaender, Hans W., Air-swept ball mill for the production of coarse and fine carbonaceous material for electrodes, U.S. Pat. 2 815 176, Dec. 3, 1957.

The described app. permits the simultaneous production of coarse and fine material from coke needed for making electrodes

for Al smelting and refining.

3013. Bond, Fred C., Comminution exposure constant by the Third Theory, Trans. AIME 208 Tech. Pub. No. 4648-B (in Mining Eng. 9 1372-7, 1957.)

When P represents the diam. in which 80% of the product passes, F is the size 80% of the feed passes, Wi is the work index, or the kw.-hrs. per short ton required to reduce from theoretically infinite size to 80% passing 100 μ , and W is the kw.-hrs. required per ton, then $W = 10 Wi / \sqrt{P} - 10 Wi / \sqrt{F}$. In crushing and grinding, the larger particles absorb most of the work and protect the smaller neighboring particles from contact with the crushing or grinding media. This paper discusses the evaluation of the exposure differential upon the reduction efficiency and product size distribution.

3014. Bond, Fred C., Grinding-ball size selection, Mining Eng. 10 592-5; Trans. AIME 211, Tech. Pub. 4728-B, 1958.

Empirical and theoretical equations are given for calcg. the proper sizes of balls and rods to be added regularly to tumbling grinding mills. Both equations give similar results. A convenient table of ball and rod wts., vols., and surface areas is given, and tables of the proper ball and rod size distribution for starting up a mill are included. Rough estg. figures for ball and rod wear are given.

3015. Bond, F.C., Measuring surface area in grinding, AIME Min. Tech. TP 1296, March, 1941.

Rittinger theory agrees fairly well with experiment if Gaudin distribution line is extended to grind limit of .7 micron.

3016. Bond, R.L., and Maggs, F.A.P., Particle size and pore structure of finely ground coal chars, Fuel 28 (8) 172-5, 1949. The fine structure of the coal char acts as a molecular sieve penetrable to small molecules but impenetrable to large ones, such as dibutyl phthalate. The immersion of the powdered char in a liquid of sufficiently large molecular volume, therefore, leads to the generation of a wetting energy which is proportional to the external surface area of the particles. The "apertures" of the molecular sieve can be reduced by the action of heat, and a powder heated to a sufficiently high temperature becomes impenetrable to the molecules of all the liquids used in the experiments. Heating to still higher temperatures caused a smoothing of the external surface. These observations permit estimates to be made of the particle size and the surface roughness. The size range of the aperture is quite small and a method of estimating the distribution curve was developed.

3017. Bond, F.C., New theory explains grinding; Bond's Theory, Chem. Eng. 59 242-3, April, 1952.

Bond's theory, the Third Law of Comminution, states that the total work required for crushing and grinding (1) varies

inversely as the square root of the product size, (2) is directly proportional to length of crack tips formed, and (3) directly proportional to square root of surface area formed.

Bond's Equation:

$$wt = \frac{F^{\frac{1}{2}}}{F^{\frac{1}{2}} - P^{\frac{1}{2}}}$$

3018. Bridgman, P.W., Effects of high hydrostatic pressure on the plastic properties of metals, Rev. Mod. Phys. 17 3, 1945.

Amount of plastic deformation which a metal will tolerate without fracture may be increased by application of hydrostatic pressure. (ductibility increased).

Pressure probably forces atoms closer together, thus increasing their atomic forces.

Fracture occurs when sum of these principle stress components reach a critical value.

3019. Bridgman, P.W., Effect of hydrostatic pressure on the fracture of brittle substances, J. Appl. Phys. 18 246-258, February, 1947.

At high pressures the net stress at fracture is compressive. Certain materials lose brittleness and become plastic under pressure. Strength of some materials increases considerably under pressure. Condition of energy release as a factor controlling fracture is emphasized. Griffith conception of fracture as resulting from stress concentration at the ends of microscopic cracks is qualitatively consistent but probably

cannot be carried through quantitatively.

3020. Bridgman, P.W., Flow and fracture, Metals Tech. TP 1782, December, 1944.

When dealing with phenomenon of flow and fracture, the most important of the necessary variables are the external forces acting on various parts of the body. Temperature must remain constant and non-mechanical forces such as magnetic fields must be ineffective for reproduction of stress-flow situation. A necessary condition for fracture is that the total energy of the entire system must decrease in consequence of fracture.

3021. Bridgman, P.W., Considerations on rupture under triaxial stress, Mech. Eng. 61 107-111, Feb. 1939.

Rupture depends on stresses in all three dimensions rather than simple single direction stress. Stress conditions also depend on nature of surface conditions of homogeneity, repetition of stress and general geometric configuration. Use of hydrostatic pressure or tension enables study of three dimensional stress effects.

3022. Bridgman, P.W., Theoretically interesting aspects of high pressure phenomenon, XV: conditions of Rupture, Rev. Mod. Phys. 7 1-35, 1935.

Doubts that the requirement that the molecular cohesive forces be a maximum at critical extension is pertinent. Suggest that

a stability criterion is more pertinent. Conditions of stability difficult to formulate.

3023. Bridgman, P.W., Breaking tests under hydrostatic pressure and conditions of rupture, Phil. Mag. 24 63-80, July, 1912.

3024. Broadbent, S.R., and Calcott, T.B., Coal breakage processes II: A Matrix Representation of Breakage, J. Inst. Fuel 29 528, 1957.

3025. Boerner, H., Problems in connection with the grinding of quicklime, Zement-Kalk-Gips 10 493-8, 1957.

Three main problems in the grinding of quicklime are discussed:

(1) the type of grinding plant in relation to the grindability of the lime, (2) rapid removal from the grinding zone, and (3) preliminary crushing effects on grinding performance.

The introduction of a "slaking value" in analogy with the strength value for cements is proposed.

3026. Borsakoveky, Voldemar, Method of milling grain, U.S. Pat. 2 379 677, July 3, 1945.

3027. Bowden, F. P., and Rideal, E.K., On the electrolytic behavior of thin films, II: The Areas of Catalytically Active Surfaces, Proc. Roy. Soc. A120 80, 1924.

A method of measuring the accessible area of a surface by measurement of the quantity of hydrogen deposited on a cathode surface in order to cause a given change in electrode potential. This method may be used in surface produced vs. energy consumed experiments.

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3029. Boyd, H. Houston, Roll corrugations under the microscope, Bull. of Association of Operative Millers, 1335, Feb., 1944.

Shadowgraphs of corrugations illustrating variability of profile and wear.

3030. Brandtand, Hiedeman, The aggregation of suspended particles in gases by sonic and supersonic waves, Trans. Faraday Soc. 32 1101-1110, 1936.

The process of rapid coagulation by sonic and supersonic waves at frequencies between 5 and 50 K.C. is studied. Photomicrographic and kinematographic observations prove that the process of aggregation takes place in the sound field itself.

The enlargement of the particles was measured by two different methods. The results show that particles may easily increase in size more than a hundred fold under influence of the sound

field. Flowing aerosols may very efficiently be coagulated and precipitated, if sufficiently large sound intensities are used.

3031. Brunauer, S., Emmett, P.H., and Teller, E., Measurement of surface area of fine materials by means of gas adsorption, J. Am. Chem. Soc. 60 309, 1938.

3032. Brunauer, S., Measurement of surface area of fine materials by means of gas adsorptions, The Adsorption of Gases and Vapors, Princeton U. Press, 1944.

3033. Brennan, E.M., and Daniel, A.P., Attrition mill, U.S. Pat. 1 737 183; National Miller, 61, Feb., 1930.

3034. Brown, R.L., Grindability of coal, Progress in Coal Science, D.H. Gangham, Ed., British Coal Utilization Research Assoc. 45 264H, 1953.

3035. Brown, J.H., Gaudin, A.M., and Loeb, C.M., Jr., Intergranular comminution by heating, Min. Eng. 10 490-6; Trans. AIME 212, Tech. Publ. No. 4731-B, 1958.

Two-kg. samples of granite, syenite, isotropic franklinite, taconite, and marble were heated at temps. up to 1000° in a lab. furnace and crushed and sized in lab. equipment. The heating prior to crushing improved the friability and size distribution of the crushed product. The effects noted were

of the nature to be expected if intergranular fracture were occurring as a result of heating. The mechanism appears to be more dependent on phys. changes in the rock at elevated temps. than on chem. changes.

3036. Brown, R.L., Recent advances in mechanics of coal breakage, Brit. Coal Util. Res. Assoc. Monthly Bull. 26 297-302, 1962.

3037. Waeser, Bruno, Characteristics of grinding mills, Chemische Apparatur 28 52-5, 1941.

3038. Burke, Heaton, Effect of shape and density on the free settling of particles at high reynolds numbers, U. of Utah Thesis, August, 1951.

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3040. Calcott, T.G., A matrix analysis of selective breakage processes, Proc. Conf. Science in the Use of Coal, Paper 16, Institute of Fuel, London, 1958.

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3042. Carter, R.J.S., Milling process, U.S. Pat. 2 393 365, Jan. 8, 1946.

3043. Coghill, W.H., Gow, A.M., Campbell, A.B., A laboratory investigation of ball milling, Trans. AIME, Tech. Pub. 327, 1929; Milling Methods 4 51, 1930.

Advances new theory of ball action. Maximum grinding is at 65 per cent of critical speed and greatest efficiency at 50 per cent of critical speed. Gives efficiency of mills of various diameters.

3044. Danser, H.W., and Neuman, E.P., Industrial sonic agglomeration and collection systems, Ind. & Eng. Chem. 41 2439-42, 1939.

This article describes equipment for separating dust or mist from 24,000 cfm of gas containing particles below 10 microns. The sonic wave generator is of a "siren" type using compressed air and a motor driven generator. The article includes a description of performance requirements and construction.

3045. Dean, R.S., and Davis, C.W., Magnetic separation of ores, U.S. Bur. Mines Bull. (425) 321, 1941.

3046. Dedrick, B.W., Grinding power and pressures, National Miller 25, Feb., 1926.

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3049. Earle, Theodore, Method and apparatus for manufacturing grain products, U.S. Pat. 2 366 697, Feb. 25, 1941.

3050. Earle, Theodore, Method of treating cereal grains, U.S. Pat. 2 340 313, Feb. 1, 1944.

3051. Eggerman, U.F., Apparatus for sorting balls of drum mills, U.S.S.R. Pat. 107 147, Aug. 25, 1957.

Within the mill, screens are arranged in such manner that the balls are caught up on them and are discharged inside the mill. The damaged balls are caught in the lowest of the screens which extends outside the mill and discharges the damaged balls outside.

3052. Egorov, A.M., Polishchuk, S.M., and Alekseev, M.V., U.S.S.R. Pat. 107 137, Aug. 25, 1957.

The inside of the ball is made of grog, and this is coated with

a layer having a hardness of not less than 6 Mohs scale, such as pyrophyllite, corundum, mullite, basalt, or diabase. The inside part of the ball is coated with an adhesive slurry, rolled in the powd. material of the outside layer, and finally sintered.

3053. Ellis, J.E., Ray, W.D., and Venables, J., Further work on the matrix analysis of coal breakage processes, Proc. Conf. Science in the Use of Coal, Paper 15, Insti. of Fuel, London, 1958.

3054. Enoksson, B., Influence of solvent movement on sedimentation, Nature 161 934, 1948.

Mathematical analysis of solvent motion which may affect particle size determinations or classification by sedimentation techniques.

3055. Evans, I., The size distribution of run-of-mine-coal, Colliery Eng. 465-9, 508-10, 1962.

3056. Evans, I., Pomeroy, C.D., and Berenbaum, R., The compressive strength of coal, Colliery Eng., 38,75,123,172, 1961.

3057. Evans, I., A contribution to the theory of the size distribution of broken coal, Proc. Conf. Science in the Use of Coal, Paper 14, Inst. of Fuel, London, 1958.

3058. Evans, I., and Pomeroy, C.D., The strength of cubes of coal in uniaxial compression, in Mechanical Properties of Non-Metallic Brittle Materials, Walton, W.H., Ed., Butterworths, London, 5-24, 1958.

3059. Fahlstrom, P.H.:son, Dressing of sulfide ores at the Boliden Mine, Z. Erzbergbau u. Metallhüttenw 8 Beih, B165-76, 1955.

The processes used were as follows: disintegration in an open mill, fine grinding in a rod mill and then a ball mill, rough classification between the rod mill and ball mill with a rake classifier, fine classifying of the finished ground material upon a tray classifier with a high d. slurry. The flotation app. has a countercurrent between slurry and air, considerable cell depth, and very accurate supply of the reagents with reference to the metal content of the tailings. Flotation schedules for individual ore types, the work of pumping, and handling of the tailings were described.

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3061. Francois, August E., Disintegrating cereals, French Pat. 842 192, June 7, 1939.

3062. Fraser, C.F., The air jet method of dehulling seeds,

Can. J. Research 22F (5) 157-162, 1944.

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382, 1949.

Stress for fracture is proportional to logarithm of time.

3064. Friend, O.M., and Friend, S.E., Decortivating wheat by
moistening, heating and agitating in bulk, U.S. Pat. 1 136 597.

3065. Furth, R., Thermodynamical theory of the tensile strength
of isotropic bodies, Proc. Roy. Soc., London A177 217, 1941.

Formula developed connecting tensile strength, F, with melting
energy, Q, Poisson's Constant, m, and Density, D:

$$F = QD \frac{(1-2m)}{(3-5m)}$$

Equation agrees fairly well with experimental measurements.

Thermal movement of atoms causes density fluctuations similar to
structural imperfections.

3066. Gardner, R.P., and Austin, L.G., The use of a radio-
active tracer technique and a computer in the study of the
batch grinding of coal, J. Inst. Fuel 35 173-7, 1962.

3067. Gaudin, A.M., and Meloy, T.P., Model and a comminution
distribution equation for repeated fracture, Trans. AIME 223
243-50, 1962.

3068. Gel'man, A.T., But, A.I., and Berson, S.A., Vibrating ball mill, U.S.S.R. Pat. 107 190, Aug. 25, 1957.

Structural details.

3069. Gilvarry, J.J., Fracture of brittle solids I: Distribution function for fragment size in single fracture (theoretical), J. Appl. Phys. 32 391-9, 1961.

3070. Gilvarry, J.J., and Bergstrom, B.H., Fracture of brittle solids II: Distribution function for fragment size in single fracture (experimental), J. Appl. Phys. 32 400-10, 1961.

3071. Gilvarry, J.J., and Bergstrom, B.H., Fracture of brittle solids III: Experimental results of the distribution of fragment size in single fracture, J. Appl. Phys. 33 3211-13, 1962.

3072. Glathart, J.L., and Preston, F.W., The fatigue modulus of glass, J. App. Phys. 17 189, 1946.

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$$\log t = -\frac{a}{m} + \frac{1}{f_m}$$

3073. Green, H., Industrial rheology and rheological structures, J. Wiley and Sons, New York, 1949.

3074. Griggs, D.T., Rupture on relieve of pressure, J. Geol. 44 541, 1936.

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3075. Grigor'ev, G., and Nikolaichuk, M.L., Apparatus for sorting the charge of balls of ball mills, U.S.S.R. Pat. 106 902, Aug. 25, 1957.

3076. Gugrimoff, A., Research on roll speeds, Northwestern Miller 20-62, October 16, 1935.

3077. Guinier, A., A summary for phys. chemists of results previously published elsewhere, J. Chim. Phys. 40 133-50, 1943. Work on small-angle x-ray scattering by Hosemann and by Kratdy is reviewed (see 2401).

3078. Benedict, C.H., Lake Superior Milling practice, Michigan Coll. of Mining & Tech. Press, 1955.

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3079. Gvozdev, I., Vibration grinding -- a new achievement of the soviet technology, Stroitel. Materialy, Izdeliya i Konstruktsii (5) 6-11, 1955.

At fine grinding, the efficiency and productivity of the mills prevalent in industry (i.e. ball mills) are sharply lowered. The vibro-mills constructed by the Ministry of Building Materials Industry allow grinding a ton of material to 1μ or less and guarantee the uniform grinding of materials with different hardnesses. The fine and ultrafine grinding by the vibro-mills gives new properties to many materials. Application of vibration grinding in the building materials industry and other industries is reviewed. The possibility of using vibration grinding in the chem. industry is noted in particular: for obtaining components with increased sp. surface, for grinding dyes, and in the production of plastics, chem. poisons, etc.

3080. Hamm, F.A., Symposium on fine particles and resolution, Anal. Chem. 21 883-4, July, 1949.

3081. Hamring, Per Emil, Method for hulling oats and like kinds of grain, U.S. Pat. 2 217 112, October 8, 1940.

3082. Hariu, O.H., and Molstad, M.C., Pressure drop in vertical tubes in transport of solids by gases, Ind. Eng. Chem. 41 1148, 1949.

This paper reports experimental results and presents theoretical

considerations of the pressure drop in tubes carrying solids in gases. Direct measurements of the dispersed solids density were made, permitting the average particle velocity, slip velocity, and solids pressure drop to be calculated. Drag correlation for free falling particles in still fluids relates relative velocity of gas and solids to force required to overcome inertia, gravity and solids friction.

3083. Harper, W.R., An exact theory of the coagulation of spherical particles arising from thermal agitation, Trans. Faraday Soc. 32 (8) 1139-1144, 1936.

A theory of the coagulation of particles is presented. The analysis is based on calculating the rate of collision. A sharp effect on collision rate is stated to occur when particles are not spherical.

3084. Harris, C.C., Comminution -- A modified logistic growth function, Nature 197 371, 1963.

3085. Harris, C.C., A study of comminution -- a modified logistic growth function as a model of fine grinding, Cement, Lime and Gravel 38 162-7, 1963.

3086. Hatch, R., Determination of average particle size from the screen analysis of non-uniform particulate substances, J. Franklin Inst. 215 27, 1933.

Better extrapolation of Gaudin - Schuhmann distribution curve is obtained by plotting on log-normal or log-probability paper. Size distribution data obtained by screen analysis cannot be used directly in determining average particle diameter since this data is in terms of weight rather than numbers. Necessary relation between weight and numbers may be determined from log-normal plot of distribution.

3087. Hatch, T., Dust control, present and future design considerations, Mech. Eng. 57 154, 1935.

The article reviews dust control progress from the viewpoint of public health. A theoretical analysis of particle trajectories is also given.

3088. Heilmann, T., The influence of the fineness of cement raw mixes on their burnability, Proc. 3rd Int. Symp. on the Chemistry of Cement, Cement & Concrete Ass'n., London 711-749, 1952.

It is generally known that the finer the raw mix is ground, the lower burning temperature is required. Measured the effect of adding coarse particles of sand or lime to fine-ground materials, also the effect of extra fine fraction. Measured residual free lime, also some microscopic observations. Burning temperatures 1350-1550°C, times 10 min. to 60 min., Done in laboratory gas fired furnace after calcining at 950°C. Silica particle converted to C_2S leaving free lime surrounding, unless the mix has

low lime.

3089. Heiss and Caull., Effect of orientation and shape on the settling velocities of non-isometric particles on a viscous medium, Chem. Eng. Prog. 122-140, Mar., 1952.

3090. Herdan, G., Small particle statistics, Butterworths, London, 2 ed., 1960.

3091. Bond, F.C. and Agthe, Ball coating in grinding, Mining Tech. 4, Tech. Pub. 1160, March, 1940.

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The changes of state of high-molecular substances on crushing is investigated for cellulose. The supermicroscopic image shows a separation into ground fibrils 100 to 750 A. thick, and x-ray investigations show that the crystallized ordered state has disappeared in the fibrils. Water treatment yields the lattice-order, but hydrate cellulose is obtained. Processes in the interior of the ground fibrils are the cause of the decrease of the viscosity if ground. Long grinding produces a curled form of the fibrils and a pelting to lumps without an observable rupture of the fibrils. These interior processes and the increasing of the surface are essential for the changes of the

properties of the ground products.

3093. Hess, K., Sturer, E., and Framm, H., Kolloid Z. 98 148-59, 1942.

3094. Duran, Paul L., Machine for sorting articles of different grades, U.S. Pat. 3 095 090, June 25, 1963.

The machine sorts ore, etc., showing different magnetic, radioactive, optic and like properties.

3095. Hibbs, A.N. et. al., Impact flour milling; centrifugal impact machines, hitherto used for controlling insect infestation; Entoleter, Flour Ind. 19 1626-30+, Dec., 1947.

3096. Hill, T.L., Physical adsorption of gases in capillaries and on small particles (nucleation of condensation), J. Phys. Chem. 54 1186-91, Nov., 1950.

3097. Hiorns, F.J. and Venables, J., Comparison of the fracture of coal and other non-metallic heterogeneous solids, Brit. Coal Util. Res. Assoc. Monthly Bull. 26 265-74, 1962.

3098. Hiorns, F.J., and Venables, J., Controlled fracture of brittle solids, Brit. Coal Util. Res. Assoc. Monthly Bull. 26 77-88, 1962.

3099. Hiorns, F.J., and Venables, J., Propagation of fractures in brittle solids, Brit. Coal Util. Res. Assoc. Monthly Bull. 25 369-406, 1961.

3100. Hollomon, J.H. and Zener, C., Conditions of fracture of steel, Metals Tech., Tech. Pub. 1783, Dec., 1949.

Flow and fracture are dependent upon temperature and rate of strain as well as on applied forces. Relation of stress to temperature and rate of strain is approximately:

$$S = \left[ve \frac{Q}{RT} \right]^r$$

where: S = Stress.
V = Strain rate
T = Temperature
R = Gas constant.
Q = Heat of activation relating strain rate and temperature.
r = Small exponent.

3101. Hoenig, Fundamentals of grinding, V.D.I. Forsch. Geb. Ingenieurw, Suppl. Forschungsheft 378, 1936.

Aim of grinding is the production of new surface. Expenditure of energy depends upon the nature of the stresses (compression, tension bending, etc.). Influence of structure and the manner and regularity of grinding.

3102. Anon. Meeting fine-grinding requirements with the compartment mill, Concrete (Mill Sec.) 50 214-15, Aug., 1942.

Description of compound combination ball and tube mills.

3103. Hukki, R.T., Fine grinding at supercritical speed. Mining Eng. 10 581-9; Trans. AIME 211, Tech. Publ. 4744-B, 1958. Math. analysis of mill dynamics at supercrit. speeds indicated that mill speed can be increased (1) if the total mass of grinding medium decreases, (2) if the mass of the individual grinding piece increases, and (3) if the coeff. of friction between the outer layer of medium and the mill lining decreases. The coeff. of friction decreases with increasing smoothness of liner surface, increasing roundness of the grinding piece, increasing fineness of material to be ground, decreasing pulp d., and decreasing hardness or abrasiveness of the mineral to be ground. In Helsinki many ores have been ground in a 3 X 3 ft. pilot-plant ball mill at a top speed of 230% of crit. With the same mill, theoretical studies concerning the grinding characteristics of ball mills equipped with a smooth lining have been carried out up to 313% of the crit. speed. In a smaller mill, the grinding characteristics with a variety of grinding media have been investigated at speeds up to 2000% of the crit. In a mill equipped with a smooth lining, the numerical value of the friction factor in the denominator of the crit. speed formula becomes less than 1, indicating that grinding at supercrit. speeds should be possible in such mills.

3104. Hukki, R.T., Sc. D. Thesis, Mass. Inst. Tech. 1943. Size and surface distribution of particles produced by grinding ores.

3105. Hunter, T.G., The principles of granulation, Ind. Chemist 8 404-8, 449-51, 1932.

One of the principle reasons for granulating material is that it is not separated into its component parts upon agitation due to the difference in specific gravities of the components.

3106. Iwanowski, W., and Grabowska, C., Changes in the composition of grains prepared by the method of Steinmetz, Met. Doswiadczalna i Spoleczna 15 42104, 1932.

Mainly cellulose and pectin substances are removed together with the membrane from the grains by the Steinmetz method of milling, while the chief constituents such as starch, protein, and fat remain unaffected.

3107. Jennings, M., Pneumatic conveying in theory and practice, Engineering 150 361, 1940.

This paper presents experimental results relating to the conveying of grain by pneumatic means. The required velocities for carrying various grains in horizontal and vertical pipes are discussed. A velocity of 6 to 7 times the terminal settling velocity will hold all of the solid particles in suspension, although lower velocities can produce satisfactory results by allowing some of the particles to be moved along the bottom of the pipe.

3108. Kahn, N.A., and Imbembo, E.A., Weld. J. 27 1695-1822, 1948.

A study of fracture of metals.

3109. Nobuyoshi, Kayoiuji and Kogure, Ken-ichi, Vortex flow pulverizing in a pipe, Chem. Eng. (Japan) 15 262-6, 1951.

A vortex air pulverizer of closed-circuit type is constructed and its grinding characteristics and mechanisms are investigated with bituminous coal and are compared to those of the ball mill. Results: (1) The grinding efficiency, defined as the increase of surface area per unit energy supplied, is about 4 sq. cm. /kg.m. (2) There exists an optimum amount of charge to obtain the best grinding effect. (3) The value of n in the Rammler equation is about 0.4, which is exceedingly low compared with the value for the ball mill and suggests that the mechanism of grinding is quite different.

3110. Keenan, A.G., The relation between the Brunauer-Emmett-Teller and Langmuir Multilayer Adsorption Equations, J. Chem. Education 25 666, 1948.

Mathematical formulae used in determination of particle surface area by adsorption technique.

3111. Kenny, William J., Energy-new surface relation in the crushing of solids VII! Slow compression crushing of single particles of glass, Univ. Microfilms, Publ. No. 24668, 173 pp. Dissertation Abstr. 18 981-2, 1958.

3112. Kettner, Otto., A combined grain peeling and conditioning process, Muehle 72 1043-6, 1935.

3113. Khan, G.A., Sedova, G.A., and Kurakina, L.A., Grindability of minerals, Gornyi Zhur 124 (5) 23-5, 1950.

The grindability of a number of minerals was studied in a laboratory rod mill. The grindability index is expressed as the ratio of the yield of -200 mesh material in the product to the yield of -200 mesh quartz similarly ground. The indexes for the tested minerals were quartz 1, apatite 1.9, magnetite 3.4, bauxite 3.5, and calcite 5.08.

3114. Kick, F., Das Gesetz der Proportionalen Widerstand and Seine Anwending, Leipzig, 1885.

From consideration of stress-strain diagram the energy of comminution is independent of feed or product size and depends only on reduction rates. Theory sometimes stated as:

(1) Energy required for producing analogous changes of configuration of geometrically similar bodies of equal state varies as the volume or weights of the bodies. (2) For any unit weight of ore particles the energy required to produce any reduction in volume of all the particles in the mass is constant regardless of original size.

3115. Kiperman, S.L., Balandin, A.A., and Davydova, I.R., Effect of vibration milling on the activity of a skeletal

nickel catalyst., Izvest. Akad. Nauk, S.S.S.R., Otdel, Khim. Nauk 1842-4, 1957.

The activity of skeletal Ni catalysts which were first subjected to finer grinding was detd. for the hydrogenation of cyclohexene and the dehydrogenation of iso-PrOH in the liquid phase. The activity of these catalysts is greater than that of catalysts ground by the usual methods. This is attributed to either a change in the micro-roughness of the surface or the presence of internal-diffusion retardation.

3116. Klint, Tage Jensen, Process for the production of flour from grain, U.S. Pat. 2 239 563, April 22, 1941.

3117. Koenig, C.J., Influence of grain-size distribution and fluid-energy reduction on the properties of Lakefield nepheline syenite, Ohio State Univ. Studies, Eng. Expt. Sta. Bull. (156) 29pp., 1955.

Pulverization of nepheline syenite samples by fluid-energy reduction mills without any mech. moving elements yields largest particles only 0.01 the vol. of the largest particles in conventionally ground samples, without an excess of extremely fine particles. Avoidance of extreme fines increases the ease of obtaining high specific gravity casting slips. Fusion of fluid-energy ground samples occurs 2 or 3 cones lower than with conventionally ground. The samples tested have a lower bulk d. than do conventionally ground ones. With 25% flux-content bodies

the fluid- energy ground samples imparted lower drying shrinkages but higher total shrinkages.

3118. Korshunov, B.S., Combined electrochemical and mechanical method for grinding hard alloys, Vestnik Mashinostroeniya 37 (9) 54-6, 1957.

Hard carbide alloys are ground with a 120-grit wheel applied under pressure of 0.2 kg/sq. cm. in the presence of a 25% aq. CuSO_4 soln. Passing of Co into the soln. softens the outside layer of the metal which is more easily attacked by the wheel. Diagrams presented show that applying a pos. current of 80-100 amp. to the alloy speeds the abrasion, but is voltage should not be above 6-8 v., since this leads to electrochem. erosion and lowers the surface quality. Both faster wheel speed and greater feed increase the rate of the metal removal, but the former should not be higher than 1.2-1.5 m./sec. to prevent excessive splashing A.c. has no effect.

3119. Kranz, W., The Humphries Process, Proc. International Conference on Flour and Bread Manufacture, Prague, Sept., 1927.

3120. Krinsky, C., Improved flour milling after preceding chemical peeling of the grain, Proc. First International Conference on Flour and Bread Manufacture, Prague, 76, 1927.

3121. Kuntz, Wm. Jacob., Beater mill, U.S. Pat. 1 742 511,

February, 1930.

3122. Lampitt, L.H. et. al., Pectin studies; the effect of dry grinding, Soc. Chem. Ind. J. 66 157-60, May 1947.

Describes the dry grinding of pectin in a ball mill. The fact that the pectin was depolymerized by the process is mentioned.

3123. Landahl, H.D., and Hermann, R.G., Sampling of liquid aerosols by wires, cylinders and slides, and the efficiency of impaction of the droplets, J. Colloid Science 4 (2) 103-136, 1949.

Measured efficiency of impaction for particles 1 to 50 microns in size.

3124. Langner, P.H., Jr., and Forrester, J.S., The disintegration of bacteria by mechanical means, I: Description and capabilities of a new type of ball mill, J. Immunol 37 133-6, 1939.

A ball mill is described which in grinding dry hemolytic streptococci at low temperature rendered 55% of the total bacterial N sol., in 3 hrs. Similar results were obtained with other organisms. Grinding at room temperature compared favorably with grinding at low temperatures. Also grinding a packed, wet mass of whole organism at room temperature was successful.

3125. Lapple, C.E., and Shepherd, C.B., Calculation of particle

trajectories, Ind. and Eng. Chem. 32 (5) 605-17, 1940.

Equations are developed for calculating the paths of bodies or particles undergoing accelerated motion, taking into account the effect of fluid friction. Available experimental data on particle trajectories show excellent agreement with calculated values. Application to spray cooling, cyclone dust collection, classification sampling and ventilation are presented and discussed.

3126. Lapple, C.E., Fluid and particle mechanics, University of Delaware, March, 1951.

This book presents theory and data on dynamics of particle and fluid motion.

3127. Hudson, W.G., Design of systems for conveying pneumatically, Chem. Met. Eng. 51 147, Feb., 1944.

This article covers design aspects of pneumatic conveying systems, with particular regard to air velocities. Both theoretical and experimental considerations are given. Only particles large enough to have relatively high terminal velocities are discussed.

3128. Lee, Worthy, Decortivating cereals, U.S. Pat. 1 693 847, Dec. 4, 1928.

3129. Legsdin, A., and Schenck, F.L., To rate grinding efficiencies, Eng. Min. J. 150 (4) 88, 1949.

Calculations and graphs enable rating efficiencies of crushing or grinding machinery in terms of new surface area produced per unit of power input.

3130. Lehmann, Hans, and Pralle, Gerhard, Experience with hammer mills in the nonmetallic minerals industries, Tonind.-Ztg. u. Keram. Rundschau 82 459, 1958.

Performance data of hammer mills are given, together with dimensions, power consumption, etc. The grain size distribution of hard limestone, dolomite, basic Bessemer slag, and gypsum are shown before and after milling.

3131. Lenhard, W.B., Improved crushing and grading of pumice; plant of superlite products, Rock Products, 53 82-5, Sept., 1950. A flow sheet showing complete process is given of a new plant at Calepatria, California. Plant uses a newly developed "gyrating screen".

3132. Leva, M., Elutriation of fines from fluidized systems, Chem. Eng. Prog. 47 39-45, Jan., 1951.

This paper presents results of experimental work on elutriation as affected by:

1. Gas velocity.
2. Solute diameter and concentration (fines).
3. Solvent diameter and concentration (coarse).
4. Specific gravity of solid phase.

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5. Mixed density solids.
6. Column height.

3133. Lipov, G.I., Multicomponent vibrating ball mill, U.S.S.R. Pat. 106 903, Aug. 25, 1957.

The individual units of the ball mill are connected by a cascading arrangement.

3134. Lissman, M.A., Dust collection, an analysis of mechanical methods, Chem. Met. Eng. 37 630, 1930.

This article contains a general discussion of mechanical methods of dust collection and a detailed coverage of the performance of the "Multicyclone" separator. Commercial multicyclone separators are reported to have an efficiency above 99% for 5 micron particles. A four inch tube diameter can produce separating forces nearly 700 times gravity.

3135. Lissman, M.A., Jet pulverizing now practical, Chem. Met. Eng. 45 238, 1938.

The Micronizer performs grinding operations by a high-speed jet of air causing violent rotation in a confined bin. The size of product is 5-10 microns.

3136. Ludwik, P., Cleavage boundaries, cold and warm brittleness, Ztsch. Ver. Deut. Ing. 70 379, 1926.

3137. Ludwik, P., The significance of elastic limit, breaking strain and notch strength, Monat. Metallkunde 16 207-12, 1924.

3138. Ludwik, P., and Schev, R., Comparative tension, compression, torsion, and rolling experiments, Stahl and Eisen 45 373, 1925.

3139. Lykken, Wm. H., Grinding and classifying in the subsieve range, Mining Eng. 9 1118-20, 1957.

3140. Murgatroyd, J.B., The mechanism of brittle rupture in glass, J. Soc. Glass Tech. 28 406, 1944.

Stress for fracture is proportional to logarithm of time. Suggestion that Griffith flaws consist of pockets of quasiviscous material surrounded by larger three dimensional aggregates. When pocket material yields to applied stress it no longer carries a load and is equivalent to a hole. Pocket thus acts as a stress concentrator. Time for breakage is due to time for stress on quasi viscous material to relax.

3141. Nakagawa, Yuzo and Matsui, Kunio, Fundamental studies on impact crushing. Relation between net work input to crushing and number of impacts, Kagaku Kogaku 21 810-16, 1957.

Crushing was accomplished by dropping a steel ball on cubic or powdery samples in a steel mortar. From these expts., the authors offered several correlations between net work input and

no. of blows and (or) surface increase.

3142. Nesvizhskii, O.A., Wear-resistant cast iron grinding bodies, Liteinoe Proizvodstvo (1) 5-6, 1958.

Structure and grinding characteristics of white iron with C 2.25-3.20%, Si 0.52-1.95, Mn 0.66-1.70, with and without Cr 0.59-2.5 and Ni 0.21-3.0, cast in sand, centrifugally, and in a vibrating mold were investigated. Centrifugal and vibratory casting interfere with graphite precipitation. The best wear resistance was recorded in unalloyed irons with lower C and Si content.

3143. Nordberg, B., Grinding in closed circuit with air classifiers; Lehigh's Fordwick, Va. Mill, Rock Prod. 53 136-44, Aug., 1950.

This article describes cement production using airswept, integral gear-driven tube mills through which vented air is swept, carrying the product to overhead air classifiers. The classifiers are radial flow type. The air stream carrying the fines from each classifier is drawn through cyclones. The air in the system is cleaned in a bag-type dust arrestor.

3144. Oakley, H.G., Get the best from a ball mill, Ceram. Ind. 55 (5) 59-61, 1950.

A review is given of the 6 variables important in milling; speed of mill, quantity and size of balls, initial size and

quantity of charge, and consistency of load.

3145. Orr, C., and Dallavalle, J.M., Fine particle measurement, Macmillan, New York, 1959.

3146. Orr, C., Fine particles, Scientific Am. 183 50-3, Dec., 1950.

Study of micromeritics. Several electron micrographs are presented, showing particle shape, size and distribution for Kaolinite, Titania, Face Powder, Carbon Particles and Fly Ash.

3147. Paoloni, A., Considerations of granulated and pulverized materials, Corriere Ceram. 19 263-71, 399-407, 1938.

A description of granulometric analysis of and the preparation of very fine powders.

3148. Parker, E.B., Production of Washington Unifine Flour, Bull. of Assoc. of Operative Millers, 1720, Jan., 1949.

Describes rotary mill with cutter bars in rotor and castings. Reports wheat ground to 68 - 84% through 14xx in one pass.

3149. Parsons, A.B., The porphyry coppers, AIME 1933.

3150. Pence, R.O., Grinding zones and effects in break grinding, Nat. Miller, Aug., 1928.

3151. Perov, W.A., and Brand, W.J., *Feinmahlen Der Erze*, V.E.B. Verlag Tech., Berlin 1954, first published in Russian, 1950. Reviews early work on ball motion, filling, energy load, kinetics. Best part is data on Russian practice and experience.

3152. Peterson, W., Influence of flotation agents on particle size in wet grinding, *Metall. Erz.* 38 25-32, 1941.

The effect of such flotation agents as Na oleate, $\text{Na}_2\text{P}_2\text{O}_7$, water glass, NaCN and Na ethyl xanthate on the wet grinding of calspar, quartzite, clay slate, galena and Zn blende was studied. These agents were found to have no special advantage from the standpoint of influence on particle size.

3153. Poncelet, E., Fracture (of glass) III: Speed and duration of fracture, *Verres et Refract.* 3 289, 1949.

Equations are derived from theoretical considerations relating fatigue of glass to stress, and results are compared with data of Baker and Preston. Agreement is good and an apparent anomaly is explained by the concept of a "dangerous fissure," i.e., The first fissure which, under given conditions, attains the critical rate of propagation to cause rupture.

3154. Poncelet, E.F., Nature of strength and failure in brittle solids, *Colloid Chem.* 6 77-88, 1946.

An ideal brittle solid can be visualized as a collection of identical particles held at definite spacings by electrostatic

bonds. The "flaws" assumed by Griffith and others are not essential to fracture. Compressive strength exceeds tensile strength 8 times or more.

3155. Popo, V.S. and Lyashchinskii, B.I., Crushing ferromanganese by electricity, Stal' 17 1098-8, 1957.

When a 2-8-v. current of a 50-kw.-hr. transformer is passed through 2 Cu plates between which lumps of FeMn are placed, the current causes the very thin outside layers of the alloy to peel off, rapidly cominuting it to a fine powder without using any mech. effort and without changing alloy compn. Placing lumps of FeMn directly into the circuit of 100-400-kc. transformer operating at 8500 v. disintegrates them instantaneously. The crusher consists of 2 Cu plates in the vertical position forming a V opening and connected to the current.

3156. Popov, B.A., Vibrational impact mill, U.S.S.R. Pat. 69 984, Dec. 31, 1947.

3157. Powell, H.E., and Preston, F.W., Low tensile strength of glass, J. Am. Ceramic Soc. 28 145, 1945.

3158. Prentice, T.I., Crushing and grinding efficiencies, J. Chem. Met. Mining Soc. (S. Africa) 46 189, 1946.

Subscribes to belief that energy absorbed in grinding is directly proportional to new surface area produced. However, the fact

that deformation of rock up to point of fracture is approximately proportional to volume of the rock does not conform with surface area belief. Suggests that energy required is total of that required to overcome elasticity before fracture and that to supply surface area during fracture. Greater proportion of elastic energy is lost to heat and vibration. Elastic energy requirement constitutes most of the power supplied.

Crushing may be accomplished by:

1. Impact.
2. Shear.
3. Bending.
4. Compression.
5. Tension.

Detailed experimental data and results for these crushing methods given. In discussion of this paper Mr. J. Ellis presents a detailed picture of atomic structure of minerals showing the source of force and energy requirement for elastic, plastic, and fracture actions. Also indicates that total energy is sum of energies for elastic and plastic deformations as well as for actual fracture. Some materials (ductile) which can absorb considerable energy in plastic deformation require large amount of work for fracture. Plastic flow of crystal depends on rate of application of stress, temperature of specimen, relative to melting point, and confining pressures.

3159. Pryor, E.J., Control of the milling process in ball mills, Z. Erzbergbau u. Metallhüttenw 8 Beih. B39-43, 1955.

The factors which influence the grinding process in a ball mill, such as type of construction, effective diam., effective length,

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inclination of the axis, range and distribution of ball sizes, wt. and vol. of ball load, particle size of the charge, and particle size of the discharge are discussed.

3160. Swanson, Nels S., Automation in the cement industry, Min. Congr. J. 49 69-72, Apr. 1963.

Describes electrical control of grinders and conveyors with interlocks so one operator can run plant from a control panel. Also controls kiln, with analogue computer control loops to account for timing, lags. Could use digital too. Installations at Calaveras Cement Co., and Dewey Portland Cement Co.

3161. Clauson, C.F., Cement materials, in Industrial Minerals & Rocks, Gillson, J. L. et. al., Eds. AIME, N.Y., 203-31, 3 ed., 1960.

Good process description of cement manufacture.

3164. Callcott, T.G., Tumbling mills and breakage processes, Aust. Inst. Min. Met., 181 1-34, 1957.

Pi-process is assumed: Pi means a constant fraction is broken in each cycle, independent of feed size (zero order). Matrix calculation of results fits data for zinc ore continuous pebble milling, cement clinker in a compound mill and drop-weight grindability tests. Zinc data from Taggart. Cement data is new plant data, but sparse. Drop weight is US Bur Mines RI 3239, 1934. Appendix I contains Matrix derivation.

3165. Bergstrom, B.H., Energy and size distribution aspects of single particle crushing, Proc. Fifth Rock Mechanics Symp., Pergamon Press 155-72, 1963.

3166. Batel, W., Particle size measurement techniques, 2 ed.

3167. Rakowsky, Victor, and Reid, J.R., Process for decortiating grains, U.S. Pat. 2 379 184, June 26, 1945.

3168. Rakowsky, Victor, and Reid, J.R., Process for producing flour, U.S. Pat. 2 358 827, Sept. 26, 1944.

3169. Ram, Atma, and Satya, B. Roy, Wet grinding of mica, Indian Pat. 55 454, Aug. 8, 1957.

Mica is first washed and charged into an edge-runner-type grinding mill. Water is added in small amts. to ensure free vertical movement of the rollers. After grinding, which takes about 8-12 hrs., foreign materials are removed by water flotation and settling. The shiny flakes of mica are screened to different mesh sizes. The recovery of finished products is 70-80% 325-mesh.

3170. Rayleigh, Lord, On vibration of sphere after impact, sonic vibration, Phil. Mag. 11 (6) 283, 1906.

Time during which spheres remain in contact following impact is very long in comparison with the period of lowest mode of

vibration of the spheres. Vibrations may thus be neglected.

3171. Rammner, Erich, and Gloeckner, Erich, Effect of the shape of discharge screens in impact mills on the granulometric composition of the crushed products, Freiburger Forschungsh A73 5-31, 1957.

A systematic study made on a dry brown coal from Niederlaustz, East Germany, with an exptl. Grumbach lab. impact mill showed that: (1) the pulverization (I) increased with increasing speed of rotation (II) and with decreasing throughput (III) for all shapes and arrangements of the discharge screen; (2) the effect of II on I was higher than that of III on I; (3) the effects of II and III on I decrease with decreasing slot openings of the screens; (4) I increases with increasing angle of the screen slots with the plane of the rotor; (5) the difference in I between different angles increases with decreasing II and with increasing III; (6) the factor d/d_s is less than 1 for mills with discharge screens, where d_s is the width of discharge screen slots in mm. and d is I of 0-d mm., which leaves a 10% residue over a square mesh d. mm. wide. It was assumed that these results are applicable to hammer mills in general.

3172. Rammner, E., Theory of simultaneous grinding and drying, Zement 27 703-6, 1938.

It is important to know and control the speed of the drying

gases which will just sustain particles of the desired size. The effect of temperature and kind of gas upon this sustaining speed is given special attention.

3173. Reznik, L.Ya., Budnikov, P.P., Dikerman, N.I., Lovanov, N.I., and Gromov, N.S., U.S.S.R. Pat. 102 715, May 25, 1956. Tech. lignosulfonate from sulfite liquor concentrate and mono- or trisubstituted lignosulfonates are added as grinding aids for ceramic leaning materials.

3174. Riviere, A., Granulometric studies in sedimentation, Bull. Soc. Geol. France 13 409-37, 1943. Sedimentation, suspension, and dispersion of sediments and the techniques of making grain size determination are discussed.

3175. Robinson, H.E., and Martin, S.W., Breaker-type-centrifugal sedimentation of subsieve solid-liquid dispersions, experimental, J. Phys. Chem. 52 854, 1948; 53 860-86, June, 1949.

3176. Roe, Lawrence A., Iron ore beneficiation, Minerals Pub. Co., Lake Bluff, Ill., 1957. Review of process development history & description.

3177. Roller, P.S., Statistical analysis of size distribution of particulate materials with special reference to bimodal frequency distributions; correlation of quartile with statis-

tical values, J. Phys. Chem. 45 241-80, 1941.

Determination of the two parameters of a distribution of pairs of parameters in the case of a bimodal distribution lends to evaluation of statistical constants which properly define a material as to size. These constants are:

1. Surface area per gram.
2. Coefficient of uniformity.
3. Coefficient of regression.
4. Number of particles per gram.

3178. Romankov, P.G., New principles of grinding and mills of new construction, Romomkov. Khim. Prom. 9 17-18, 1946.

The principles of D'Anza mill, internal rupture mill, colloidal mills, and a pneumatic mill are briefly described.

3179. Rosinski, Jan, and Nagamoto, C., Particle trajectories and adherence to cylindrical sticky surfaces, Kolloid Z. Supplement 175 (1) 29-33, 1961.

Effect of blocking by particles already captured. Angle of approach given graphically.

3180. Ross, S., On physical adsorption II: A comparison of methods of estimating surface areas of crystalline solids by gas adsorption, J. Am. Chem. Soc. 70 3830, 1948.

Presentation of the BET and the Gregg (gas adsorption) methods for experimental determination of the surface area of crystals.

3181. Rumpf, H., Basic principles and methods of granulation, I. II., (Tech. Hochschule, Karlsruhe, Ger.). Chem. Ingr. Tech. 30 144-58, 1958.

Granulation covers both comminution and grain-size enlargement. Basic concepts, applications, and properties of granulates are discussed briefly. The phys. principles of size enlargement and the strength of compact-dispersed granulated grains are discussed comprehensively.

3182. Rowland, C.A., Automation of grinding circuits, Pit & Quarry, 56 176-9, 1963.

Closed circuit grinding used to require skill of operator to listen to behavior, only spot-check product size. Pulp density method is inaccurate. Tried control of feed rate by sound level but not sensitive enough. Tried constant power, but media rather than charge mainly affects power. Too many causes of fall in power. Measure recirculating load from elevator power. Measure air power for fines in dry circuits. In wet rake classifier, load measures recycle. There is no satisfactory means to control open-circuit grind, need to measure product size on line, continuous level of charge, computer control of work index. Sound control works better on autogenous mills.

3183. Mitchell, Will Jr., Sollenberger, C.L., Kirkland, T.G., and Bergstrom, B.H., Comparison of overflow and end peripheral discharge mills, Trans. AIME 202 949, 1955.

3184. Anon., Chem. Eng. News 27, 1949.

- p. 246 Mill for grinding plastic materials will grind materials having high moisture or oil content.
- p. 1240 High speed hammer mill developed by Precision Scientific Co. for grinding small samples with variety of hardness.
- p. 1478 Midget mill for custom runs of paints, inks, etc. by Morehouse Industries.
- p. 1552 Laboratory mill for wet or dry grinding to fine state.
- p. 1828 Classifier for general laboratory use, Corr. Co. Type H.
- p. 3077 Rotary pulverizer made by Sturtevant Co. for grinding tailings.

3185. Anon., Exploding grains with compressed air, Chem. and Eng. News. 25 (20) 1462, May 19, 1947.

A short article on the work of Midwest Research Institute in Kansas City on exploding grain by explosive dissociation.

3186. Anon., Fine pulverizer, made by Pulverizing Machinery Co., Chem. and Met. Eng. 52 125, April, 1945; Food Ind. 17 693, June 1945.

Short article describing a fine pulverizer manufactured by Pulverizing Machinery Co. of Summit, N.J. The pulverizer is named the "Mikro-Atomizer" and is designed for the production of fine powders ranging from 1 to 25 microns. The small

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machine required 10-20 HP and will produce 30 lbs. of titanium dioxide per hp. ground to 5 microns or finer.

3187. Walton, W.H. (Editor), Mechanical properties of non-metallic brittle materials, Butterworths, London, 1958.

3188. Anon., Recent developments in mineral dressing, Symposium, Inst. Min. & Metal, London, 1952.

3189. Anon., International mineral processing congress, Inst. of Mining & Metallurgy, 44 Portland Place, London, 1960.

3190. Anon., Progress in mineral dressing, Trans. International Min.Dressing Congress, Stockholm, 1957.

3191. Anon., Fine grinding and stone-dusting, Mech. Handling 29 35-8, Feb. 1942.
Describes the operation of a number of roll mills made by the Bradley Pulverizer Company.

3192. Anon., Germ-containing cereal flour, Brit. Pat. 529 092, Nov. 14, 1940.

3193. Anon., Preliminary study fine pigment dispersion on the Morehouse Mill, Paint Oil & Chem. Rev. 114 12, Dec. 6, 1951.
This article describes the use of a Carborundum mill for

grinding pigments. Discusses the effect of wetting agents and vehicle solids.

3194. Anon., Developments in pulverizer design, Power Plant Eng. 51 101, July, 1947.

Describes the operation of steam pulverizers of the loop and circular varieties. The advantage mechanically of these arrangements is the fact that the only moving part is the worm feed screw which introduces the coal into the pulverizer.

3195. Anon., Fine grinding mica, Rock Prod. 50 92-3, July, 1947.

Descriptive article covering both dry and wet grinding processes used in Spruce Pine N.C. districts. Mica is ground to 3000 mesh by dry process. "Micro-mica" is made by injecting superheated steam into a shallow, circular, grinding chamber which contains a steady flow of mica already ground to 1/8" or smaller. Sizes vary from 1000 mesh (10 to 20 microns) to 3000 mesh (5 to 10 micron size).

3196. Anon., How the Kominuter ball mill got its name, Rock Prod. 49 103, June 1948.

This mill was designed in U.S. and used largely in cement plants. It is self contained closed circuit mill.

3197. Anon., Fifty years of progress; Advances made in processing and machinery, Rock Prod. 49 93-5, June 1946.

3198. Anon., Grinding five sizes in one operation: Thomas-Ville Stone and Lime Co. Flow sheet, Rock Prod. 46 64-6, Oct., 1943.

3199. Anon., Powdered coal, made by puffing, meets turbine needs, Scientific Am. 174 82, Feb., 1946.

Describes a method of puffing coal like breakfast cereals by passing it through a nozzle with steam or air at 100 psia. Puffing occurs due to the sudden expansion of the air or steam trapped in the pores of the coal.

3200. Anon., Cold flour milling, Proc. Fifth.Int. Cong. Refrigeration 112, 1928.

3201. Anon. Disintegration of ores, Texaco Development Corp. Brit. Pat. 777 280, June 19, 1957.

Ore ground to pass 14-mesh is mixed with water or other vaporizable liquids in a 1:2 ratio and then rapidly passed through 800-1000 ft. of a heated $\frac{1}{2}$ -in. pipe to vaporize the solvent and increase the pressure at one end of the pipe greater than 1100 lb./sq.in. The heating pipe is branched at the discharge end and the branches are introduced into the comminution chamber directly opposite to each other, so that the streams discharged are mutually impinging. This breaks the particles of the solid. In the case of molybdenite, the comminuted mineral all passes 200-mesh. The mixt. of steam and solids is

then cooled with water injection, and the slurry of the fine particles is treated in a conventional manner for recovery of its desired constituents. Application to apatite, taconite, and a Zn ore is also described.

3202. Schulman, E.L., Surface area of particle by permeability method, Thesis, Univ. of Minn, 1938.

3203. Takahashi, Rintaro, and Yuize, Takehiko, Chemical pulverization of solids, Brit. Pat. 789 700, Jan. 29, 1958.

Disintegration is described of materials, such as ores, sintered compacts, pottery, porcelain, and concrete, by impregnation with substances which increase in vol. by taking up water. For example, compact, hard unglazed pottery or concrete was immersed in fused CaCl_2 . After penetration, the CaCl_2 was allowed to absorb water forming $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ with accompanying vol. increase. The solid disintegrated on dissolving the CaCl_2 . The process is especially useful in treatment of hard alloys whose main components are carbides, e.g. WC, TiC, BC, MoC, or ZrC, and which contain Co, Ni, or their mixts. as cementing agents. Thus waste tips of a CC-Co alloy were heated in a steam of Cl at $800-50^\circ$ for 30-60 min., quenched in water, and allowed to cool. The material disintegrated into fine granules in 5-6 hrs. The Co had reacted with the Cl to form CoCl_2 , which changed to $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ on taking up water of crystn. The Co and WC are thus recovered for re-use.

3204. Tanaka, Tatsuo, Principles of fineness control in closed-circuit grinding, Zement-Kalk-Gips 10 409-13, 1957.

3205. Timoshenko, Theory of elasticity, 1 ed., McGraw-Hill, N. Y., 1934.

Mathematical analysis of the forces on the boundary of semi-infinite solids for concentrated and distributed conditions, pressure between bodies in contact and the analysis of forces and energy during the impact of spheres. See later edition.

3206. Tranchant, J., Application of a pulverizer-atomizer to ammonium nitrate, Chim. anal. 39 341-4, 1957.

A special app. is described for prepg. crystals or spherical granules of NH_4NO_3 with a particle size in the range 50-100 μ .

3207. Shimel'fenig, V.A., and Rashkov, S.E., Vibratory ball mill, U.S.S.R. Pat. 102 699, May 25, 1956.

3208. Silver, F., Storage and handling of pulverized materials, Mech. Eng. 73 730-4, Sept., 1951. Discussion, 74 245-6, March, 1952.

On the theory of flow of solids and fluids. The information is theoretical in nature.

3209. Simons, E.N., Air separation of powders, Can. Chem. and Process Ind. 31 1121-2, Dec., 1947.

3210. Sinclair, D., and LaMer, V.K., Light scattering as a measure of particle size in aerosols, Chem. Revs. 44 25, 1949. Presents a method of measuring colloid particle size by observation of scattered light.

3211. States, M.N., Turbidity measurements of surface area, Proc. ASTM 39 15, 1939.

3212. Steinmour, H.H., Rate of sedimentation of non-flocculated suspensions of uniform spheres, Ind. Eng. Chem. 36 617-24, 1944. The effect of concentration on the rate of fall of uniform well-dispersed spheres is investigated both theoretically and experimentally. Tests with suspensions of tapioca particles in oil provide empirical solutions of functions of concentration left undetermined by the theoretical analysis.

3213. Vetter, H.W., A small laboratory ball mill, Fette u. Seifen. 47 424, 1940.

A small laboratory ball mill is described which gives the chemist or operator a device whereby practically all materials can be reduced to a granular size as small as 0.001 mm. or to colloidal dimensions in the shortest time. The basic principle of the mill is the use of special construction. The relation between the inner space and the diameter of the balls makes rapid and intensive milling possible.

3214. Vogt, B.G., and White, R.R., Friction in the flow of granular solids in gases through pipes, Ind. Eng. Chem. 40 1731, 1948.

The pressure differentials required to produce steady flow of suspensions of sand, steel shot, clover seed and wheat in air through $\frac{1}{2}$ -inch iron pipe are presented.

3215. Volkova, Z.V., Separation of solids in the gravitational field in mobile and in immobile medium, Zhur. Fiz. Khim. 22 885-94, 1948.

Equations are derived for the degree of separation and the completeness of extn. as functions of the distribution of particle sizes and the quantity $u = f(b, y)$, u being the rate of fall of particle in steady state and y the density of the particle. The equations are tested for separation of mixed powders of galena + quartz and clay + quartz in stationary water, and of the two first named mixtures in a column of rising water. Gravity separation can be used for analyzing powder mixtures.

3216. Wadell, H., The coefficient of resistance as a function of Reynolds number for solids of various shapes, J. Frank. Inst. 217 459-90, 1934.

The usefulness of the degree of true sphericity as an expression for the shape of rock particles is emphasized. The coefficient of resistance as a function of Reynolds number for solids

of different shapes (sphericity values) is then discussed and the significance of the results from the standpoint of sedimentation is noted. A good bibliography is included.

3217. Ward, A.B., and Shellenberger, J.A., Grinding with controlled roll pressures, Bull. Assoc. Operative millers, Aug., 1951/

Using a 7" x 14" roller mill, an experimentation was devised to determine the effects of various roll pressures expressed as lbs. per inch of linear contact on percent fines, input horsepower, particle size distribution and biochemical properties of hard wheat middlings. Percent through 11xx silk flour cloth varied from 29% with a pressure of 12 lbs. /inch of contact to a maximum of 43% through at 64 lbs. /inch of contact and then down to 34% through at 102 lbs. /inch of contact. Horsepower increased as linear function of roll pressure.

3218. Weyl, W.A., Mechanical strength of glass, The Glass Industry 27 17-155, 1946.

Review of literature pertaining to low strength of glass. Considers the mechanical strength of matter from a chemical point of view. Points out the following facts:

Mechanical strength is a structure-sensitive property.

Since flaws are so important it is not possible to corre-

late mechanical strength with average intermolecular forces. At low temperatures strength depends on weakly bonded constituents.

Flaws present in all solids produce stress concentration.

3219. White, H.A., The future of gold metallurgy, J. Chem. Met. Mining Soc. So. Africa 43 135, 1942-43.

Most promising outlook for reduction in cost of gold extraction lies in reduction of cost of fine grinding. Present methods are wasteful of space, power and wear of steel.

1. Space - in tube mills only 3% of balls are striking blows and only $\frac{1}{2}\%$ of area of these balls are effective. Entire surface of only 6 out of 48,000 balls is working at any one time.

2. Efficiencies are in order of 1%.

Suggests further intensified research on fine grinding to focus energy to desired purpose. Notes in this line that;

1. Some materials decrepitate upon application of heat.
2. Tin falls to a powder in sufficient cold.
3. Zinc is turned into fine dust by volatilization.

3220. White, H.J., Charging particles in precipitators, Elect. Eng. 70 682, Aug., 1951.

This article deals in detail with the problem of charging particles in electrostatic precipitators. The unipolar corona discharge is stated to be the best particle charging means

because it is easy to control under industrial field conditions.

3221. Frank W., and Shellenberger, J.A., Continuation of flour granulation studies, Kansas Ag. Exp. Sta., Manhattan, Kansas. A study of conditions effecting granulation of ground product and effects of granulation on quality of product.

3222. Wiegmann, Joachim, and Kranz, Gunter, Observations of the changes in kaolinite by grinding, Silikat, Tech. 8 520-3, 1957.

For the detn. of kaolinite by x-ray diffraction methods, the effects of mech. deformation under the influence of impacts and pressure on the structure are highly important, because destructions are indicated by changes in the intensities of the basic interference lines. The authors demonstrate how a dry-grinding process (in sintered alumina mortars) affects the (001) lines in the x-ray diagrams of Zettlitz kaolin and two fire-clay minerals. The texture-free samples were prep'd. according to the method of Florke and Saalfeld (C.A. 50, 1455e) by spraying a suspension in a thermoplast soln. The expts. show the rapid decrease in intensity for (001) as a function of the grinding time. Less sensitive are (hkl) interference lines, and especially insensitive is (060) (therefore most suitable for detns. of clay minerals in a given powder sample). For kaolinite especially the range from $d = 4.5 \text{ \AA}$ to $3.7 \text{ \AA}$ is most intensely affected by dry-grinding, and the character of

the interferences becomes gradually more similar to that of fire-clay minerals. Wet-ground samples do not show marked changes in intensity; wet grinding should therefore be exclusively used in all operations for x-ray diffraction test of clay minerals. The approximation of the general character from kaolinite to fire-clay minerals with progressive dry-grinding is also observed in the electron micrographs whereas wet-ground samples do not show any changes of the good crystn. type of the original mineral. Analogous phenomena are observed in the differential-thermal analysis characteristics (cf. Grimshaw, et al., C.A. 40, 6772⁸).

3223. Wilhelm, R.H., and Kwauk, M., Fluidization of solid particles, Chem. Eng. Prog. 44 201, 1948.

Experiments were performed in the fluidization of solid particles by means of air and water in 3-inch and 6-inch columns.

Spherical and uniformly sized particles of sand, glass, silicate catalyst and lead shot ranging in size from 5 mm. to 0.3 mm. were used. Pressure drop, fraction void, and velocity were measured and correlated. Two modes of fluidization, termed particulate and aggregative fluidization, are described and discussed.

3224. Wilson, H.F., and Jackson, M.L., Effect of mineral composition and particle size in dispersants on toxicity of rotenone dusts, J. Econ. Entomol. 39 290-5, 1946.

Results of tests against the pea aphid (*Macrosiphum pisi*) with 14 samples of pyrophyllite (Pyrax) from N. Carolina, 8 samples of talc from Wisconsin, 1 sample of quartz crystals from Arkansas, and with pure Fe_2O_3 , in all of which rotenone was incorporated to 0.25-0.75% are reported. The samples (some were reground) gave 1.007.44 av. particle size by the Fisher subsieve sizer, and 5-25 av. by pipet analysis. Results: Small particles, particularly those of colloidal size, inhibit the toxic value of the rotenone dusts. If the average particle size of the dispersant is too large (60 mesh), the toxic efficiency is greatly reduced. Colloidal particles in many dispersants tend to cover the particles of derris and cube, and prevent them from gaining contact with the insect. The sources of colloidal particles in dispersants are chiefly those rich in ferrous Fe. These are easily fractured to small particle size. Pure quartz proved the best dispersant examined for rotenone but is too abrasive. Pyrax, which is high in quartz, but less abrasive, is an excellent dispersant. It is comparatively free from objectionable forms of Fe. Talc is a good dispersant when few colloidal particles are present. It should be free from excessive amounts of Fe. Ferrous and ferric Fe have no deleterious chemical effect on rotenone.

3225. Wolf, K., Particle classification in uniform spiral-form air streams, *Zement-Kalk-Gips* 3 141-7, 1950.

The operation of the Wolf and Rumpf equipment and factors

affecting the separation of fine dusts into closely sized fractions are discussed. Photographs are given of the fractions produced with various materials. The method has been applied successfully in the manufacture of special cements.

3226. Wooten, L.A., and Brown, C., Surface area measurements by Gas adsorption method enables measurement of very small areas, J. Amer. Chem. Soc. 65 113-8, 1943.

3227. Work, Lincoln T., Size reduction - annual review, Ind. Eng. Chem. 50 481-4, 1958.

3228. Work, L.T., Factors influencing particle size and shape in grinding, Bull. Am. Ceramic Soc. 17 1, 1938.

1. Properties of the product particles which must be measured include:

1. Size of individual particle.

a. Sieve measurement.

b. Microscopic measurement.

c. Sedimentation measurement.

2. Distribution of particle sizes.

3. Evaluation of shape.

II. Nature of the raw material, soft, hard, plastic, brittle.

III. Method of milling - impact, direct compression, attrition.

IV. Classification.

3229. Work, Lincoln, T., An analysis of crushing and pulverizing processes, Am. Soc. Mech. Engrs. RP-55-6, 1933.

Production of surface is characteristic of all types of crushing and pulverizing. Methods of crushing and pulverizing include:

1. Pressure loading of particles.
2. Rapid expansion of material placed in pores of solid.
3. Thermal expansion and rapid quenching.
4. Solution and precipitation grindability factors:
 1. Hardness.
 2. Surface roughness.
 3. Moisture.
 4. Plastic nature.
5. Susceptibility to heat.

Refrigeration is often necessary to control plasticity.

Factors affecting fineness of product.

1. Nature of substance. Ductile material is harder to crush, less dust in non-homogeneous material.
2. Shape of piece. Tension break (non-round particles) produce less dust.
3. Manner of loading. Impact breakage produces minimum of dust.

3230. Ying Fu, Mizushima's method for the determination of the surface area of powders, J. Chem. Phys. 18 899-900, June, 1950. Fu presents a theory to entirely disprove the method presented by Mizushima for the determination of surface area of powders.

The primary question appears to involve the application of duPre's equation (stated to be an equilibrium equation) to a non-equilibrium case.

3231. Zappfe, C.A., The indices of metals, Physics Today 3 9, Sept., 1950.

Existence of micelles of about colloidal size in metals. These probably also exist in rocks.

3232. Zeleny, Richard A., Dissipation of energy in single particle crushing, (Univ. of Minnesota, Minn.). Univ. Microfilms Publ. No. 24682, 103^{pp}; Dissertation Abstr. 18 178, 1958.

3233. Zharovov, V.N., Rotary mill, U.S.S.R. Pat. 92 208, May 25, 1956. Addn. to U.S.S.R. 88 387.

The rotor of the crusher is provided with longitudinal ribs for scraping clean the gap between the rotor and the shell.

3234. Zverelvich, V.V., Effect of grinding conditions on the granulometric composition of a ball-mill product, Gornyi Zhur. 125 (6) 34-7, 1951.

The effect of the following factors were studied; time of grinding; revolutions per minute; water added as % of vol. of mill; solids added as % mill vol.; solid: liquid ratio; const. d. pulp in mill as % of total vol.; vol. occupied by balls as of total vol.; size characteristics of feed; maximum diameter of balls;

and diameter of balls if uniform in size. The maximum diameter of the ground product was affected by any of the variables but the size distribution was harder to change. The size distribution was affected only by the volum of water in the mill, amount balls, and the size characteristics of the balls.

3235. Agar, G.E., and Mular, A.L., Discussion on Mular, Trans. AIME 226 134-7, 1963.

3236. Akao, K., Otsuk, K., and Miyakoshi, H., On friability of coals (in Japanese), Resources Res. Inst. Coal Preparation 13 (67) 380-4, Nov., 1963.

Friability of coals is expressed by straight line on log-log scale paper, which indicates relation between compressive load and average particle size of crushed products; with increase of compressive load, average particle size of coal does not diminish at fixed rate.

3237. Aksenovich, D.A., and Bessonov, N.A., The question of the influence of surface energy on the abrasive wear of crystals, Belorus, Politekh. Inst. im. V.I. Stalina, Sbornik Nauck Trudov (6) 125-30, 1958.

A. and B. theoretically and exptl. discredit Kuznetsov's formula, $A = (\gamma\sigma)/b$, relating frictional work A to vol. of abraded layer γ , surface energy of crystallographic plane of abrasion σ , and interat. distance b. They reason that σ depends on the

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crystallographic plane, whereas their expts. indicate that A is independent of this. The work A as detd. exptl. is much greater than A calcd. from K.'s formula. Reasons for the disagreement between formula and expt. are given.

3238. Prochazka, Svante, Technical and economical considerations of ultrafine grinding, Sklar Keram. 11 (2) 61-64, 1961. Technical and economic factors of different methods of ultrafine grinding are considered for body preparation in different branches of fine ceramics. The grinding parameters of ball mills, vibratory mills, colloid mills, and a new type of the fluid energy mill are compared.

3239. Akunov, V.I., Jet-mills, Elements of the theory and design (in Russ.), Gos. Nauchn. Tekhn. Izd. Mashinostroit, Lit., Moscow, U.S.S.R. 264pp., 1962.

3240. Albus, F.E., There's a jet mill for the job, Drug & Cosmetic Ind. 93 452-4 +, Oct., 1963.

3241. Albus, F., Fluid energy grinding - versatile process tool, Chem. Eng. Prog. 57 (2) 90, 92, 94, Feb., 1961.

Survey of equipment and process; used for grinding hard, heat-sensitive and explosive-type materials; subjects include top particle size, product purity, attritional heat, combination operations, and dehydration.

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3242. Proulx, J., High density media practical shop results, J. Can. Ceram. Soc. 29 (34) 1960.

Conversion from standard to high density ball milling resulted in a 45% increase in output, a 20% decrease in power cost, a 30% decrease in labor per pound of frit milled, and 80% decrease in cost of maintaining pebbles and mill lining, and improved uniformity of frit fineness.

3243. Aleksandrov, B.S., Laboratory vibration mill, Zavodskaya Lab. 24 902, 1958.

A simple lab. mill was constructed. The container had a capacity of 150 cc. and was $\frac{2}{3}$ filled with 8-mm.-diam. steel balls. A 0.25-kw. motor operated the mill and produced 1500 vibrations/min. with an amplitude of 7 mm. The mill was used for grinding salts.

3244. Ames, H.L., and Hemstock, J.M., Forum on Ball mills using steel vs. pebble mills, Can. Min. & Met. Bull 54 (585) 87-99, Jan. 1961.

Major controversial issues relating to grinding and crushing; conversion and expansion of Renable Mines mill to semiautogenous grinding; problems of semiautogenous grinding.

3245. Anderlini, V., and Vivian, H.E., Suppression of steel corrosion in wet grinding mills, Australian J. of Appl. Sci. 12 (1) 87-95, March, 1961.

Steel losses per ton of material ground are generally much higher in wet grinding raw mills than in dry grinding raw or cement mills; this difference is thought to be due to corrosion of steel; experiments have shown that these losses can be reduced considerably by raising the pH of the slurry.

3246. Andreassen, A.H.M., Size reduction and particle size, (Denmark Tech. Univ., Copenhagen). Europaeischen Symp. Zerkleinern, 1., Frankfurt am Main 99-107, 1962.

The validity of Nernst's laws for heterogeneous reactions was proved by soln. of a mineral contg. a wide range of grain sizes in HCl. For a no. of stages during this process, particle size distribution curves were detd. Particle size was reduced proportionally with time. Kick's law and the influence of size redn. by pressure, impact, and (or) grating on the breaking pattern are reviewed. Grating becomes more important with decreasing particle size. Grating expts. yielded linear distributions of the quantities of substance among different sizes if no further grinding of the first produced grains took place.

3247. Andreev, S.E., Laws of crushing and grinding, Gornyi Zhurnal (4) 66-70, April, 1962.

Universal law of crushing and grinding is established according to Rebinder's hypothesis; formulas for approximate determination of amount of work necessary to achieve coarse comminution; analysis of Bond's third theory of comminution.

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3248. Andreev, S.E., Internal friction in ball mill, Gornyi Zhurnal 137 (2) 62-8, Feb., 1961.

Determination of internal friction forces at various speeds of rotation, especially under conditions of supercritical speed; analysis of cascading and continuous regimes in ball mills.

3249. Andreev, S.E., Tovarov, V.V., and Petrov, V.A., Laws of grinding and characteristics of the granulometric composition. Moscow: Gosudarst. Nauch. -Tekh. Izdatel, Lit. po Chernoi i tsvetnoi Met., 1959.

3250. Angerstein, L., Investigation of impact crushing of gas coal and strength of resulting coke, Bergbau Archiv 20 (1-2) 91-125, 1959.

Strength of coke as function of crushing method.

3251. Hannes, Anna, Concentration of iron ores, Ger. Pat. 1 187 202, Feb. 18, 1965.

In a process for the concn. of Fe ores, esp. minette ores, in which the ores are comminuted and the gangue is then sepd. from the hematite and is substantially removed, the ore is heated before comminuting to a temp. at which a molten phase is formed but at which the hematite is not yet decompd., whereupon this state is "frozen in" by rapid cooling.

3252. Arbiter, N. and Bhrany, N., Correlation of product size,

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capacity and power in tumbling mills, Aufbereitungs-Technik 2 (7) 265-72, July, 1961. Translated.

From observed constancy of initial rates of formation of finer sizes in tumbling mills, and exponential dependence of these rates on screen size, familiar weight-size and energy-size relationships of exponential form are developed which lead to definitions of grinding efficiency and grindability.

Appears to be identical to English version #2924.

3253. Arbiter, N., and Harris, C.C., Particle size distribution/time relationships in comminution, Brit. Chem. Eng. 10 (4) 240-7, April, 1965.

Phenomena involved in comminution are too complicated to be represented by methods hitherto attempted; three-dimensional weight-size-time coordinate system is proposed as frame of reference for unifying and interpreting apparently different aspects of comminution theory.

3254. Arbiter, N., and Tate, N.W., Mineral dressing, 1962, Min. Cong. J. 49 60-3, Feb., 1963.

3255. Aresco, S.J., Janus, J.B., and Walker, F.E., Analyses of tippie and delivered samples of coal collected during fiscal 1964, U.S. Bur. Mines, Rept. Invest. 6622 (5) 38, 1965 (Eng.). The U.S. Government bought 5,000,000 tons of coal from which the Bureau analyzed 7112 samples. The results are tabulated. The

analyses are listed according to states, counties, towns, and mines, and include proximate and ultimate analysis, calorific values, free-swelling indexes, ash softening temps., and Hard-grove grindability indexes.

3257. Aronov, M.I., and Morgulis, L.M., Laboratory eccentric vibratory mill for grinding small portions of material, U.S.S.R. Pat. 113 794, Aug. 20, 1958.

3258. Aronov, M.I., Morgulis, L.M., and Kheifets, S.B., Beater mill, U.S.S.R. Pat. 131 605, Sept. 10, 1960.

The mill has an inlet at the bottom and a discharge at the top. Beaters mounted on a series of movable disks match beaters mounted on corresponding stationary disks. The mill has 2 fans, one mounted on the shaft at the level of the discharge port, the other on the central shaft below the feed inlet.

3259. Arrambide and Lezy, P., Grinding granular slag from blast furnaces before use in the preparation of hydraulic concretes, Fr. Pat. 1 257 694, Appl. Feb. 22, 1960.

An app. is described for the activation of slag granules. The presence of 1-3% portland cement avoids the formation of a film of aluminosilica gel which inhibits the hydration reactions of the slag. The mech. strength of the concrete was thus improved.

3260. Radcliffe, Charles S., Apparatus for continuously crushing and selectively discharging solid materials, U.S. Pat. 2 999 649, Sept. 12, 1961.

A mixture of liquid and solids is crushed between the circumferential walls of two rotors.

3261. Ostrus, Aubrey O.T., Aromatic fruit extracts or juices from citrus fruits, Ger. Pat 1 179 085, Oct. 1, 1964; U.S. Appl. Feb. 19, 1960; 6 pp.

The machine for comminuting and sepg. coarse pulp and flavors from the juice and oil contents of citrus fruits is described. Thus, lemons are fed into the machine at the rate of 17.2 kg./min., and enough water spray (113.5 cc./min.) is sprayed in below the cutting disk to envelop the aromatic substances. A raw ext. is obtained having 1% by vol. of volatile oil. The ext. has about 8 times the essential oil content of products of previous processes. An addnl. procedure may be added as the last step. Citric acid soln. may be introduced outside of the sieve at the bottom of the centrifuge bowl, sugar soln. at the middle section, and wash water or stabilizer soln. in the upper part of the bowl. Thirty-nine parts of fluid substances may be added to one part of the raw ext. to produce fruit ice cream or similar products.

3262. Austin, L.G., and Klimpel, R.R., Theory of grinding operations, (Pennsylvania State Univ., University Park). Ind.

Eng. Chem. 56 (11) 18-29, 1964.

The inadequacy of existing grinding laws is discussed and a brief review of fracture is given as a preliminary to newer approaches to the problem. These approaches describe the operation of grinding in general mechanistic terms. The basic concept involved is to split the operation into 2 parameters, the selection function and the distribution function. The selection function represents the fractional amt. of any given size present in the mill which is selected for breakage in a differential increment of grinding. The distribution function represents the primary distribution of a given size on breakage. Exptl. results obtained for the grinding of coal and limestone in a Hardgrove grinding machine and coal in a small ball mill are treated in terms of the above functions.

3263. Avdeev, N.Ya., Grach'yan, A.N., and Dovyborova, L.N., Analytical method for the quantitative evaluation of the effect of surface active compounds on the particle size distribution of cement, *Kolloid. Zh.* 27 (4) 481-4, 1965. (In Russian). The effect of the presence of formic, butyric, caproic, and palmitic acid, and of the sunflower soap during grinding of portland cement was evaluated. The grinding efficiency and the content of fine fractions increase with decreasing no. of carbons.

3265. Avery, H.S., Measurement of wear resistance, Wear-Usure-Verschleiss 4 (6) 427-49, Nov., 1961.

Discussion of various aspects of evaluating wear resistance, with emphasis on abrasion; there being no universal wear test, it is necessary to develop specific tests for surface deterioration with each of them having to pass through 3 stages of establishing reliability, ranking ability and validity; types of abrasion; apparatus and methods for measuring grinding abrasion; laboratory tests and field experience reported.

3266. Avgustinik, A.I., Vigdergauz, V.Sh., Gropyanov, V.M., and Drozdetskava, G.V., Kinetics of wet-grinding of some refractory materials, Poroshkovaya Met., Akad. Nauk Ukr. SSR 3 (2) 3-7, 1963.

The kinetics of grinding were studied in a vibratory mill with EtOH as the liquid medium. The plots, sp. surface S vs. time t , and dS/dt vs. t showed that Ti and Ni pulverized less readily than the more brittle compds. The rate of pulverization const. k was detd. from the slope of the $\log (S_m - S_0)/(S_m - S)$ vs. t plots, where S_m and S_0 are the final and the initial S of the powders. The values of $k \times 10^2$ of the following are given: Ti 0.98; Ni 1.20; NbC 1.94; ZrO_2 2.23; SiC 2.77; ZrC 3.01; and Al_2O_3 3.45. These values were correlated with the mech. and thermal properties of the materials.

3267. Ayers, Joseph W., and Orlemann, Justus K., Non-magnetic finely ground charcoal or calcium carbonate, U.S. Pat. 3 170 764 Feb. 23, 1965, 4 pp.

To prevent the formation of magnetic ferrites during grinding in a steel ball mill with steel balls of an aq. slurry of a material, e.g., charcoal, CaCO_3 , that tends to make the slurry alk., there is added to the slurry an acidic agent in amts. sufficient to lower the pH below 8. In an example, a 40% aq. slurry of dense walnut-shell charcoal was ground with steel balls in a steel ball mill for 5 hr. at 150°F. Without addn. of an acidic agent, the dried ground charcoal contd. 5.86% Fe_2O_3 ; under the same conditions, except that H_3PO_4 in the amt. of 0.408% of the wt. of the charcoal was added, the dried ground charcoal contd. 2.46% Fe_2O_3 , none of which was magnetic. The ground charcoal was suitable for use in phonographic record molding compns.

3268. Azarov, A.L., and Prishchenko, V.I., Comparative data on performance of elongated grinding mills, Gornyi Zhurnal (7) 69-70, July 1962.

Experience with reconstruction of ball mills and rod mills in copper and nickel ore treatment plants; increase of volume of mill by 22% resulted in increase of efficiency under conditions of controlled classification up to 17.8%.

3269. Dotson, J.M., Extending range of jet mills, Ind. & Eng. Chem. 54 (2) 62-5, Feb. 1962.

Fluid-energy or jet mills are used where fine particle sizes are required; work reported here shows that efficiency of jet mills is influenced by size, type and operating variables and that it is reasonable to consider some types for uses other than fine grinding; experiments with commercially available mills and Hardinge conical type ball mill.

3270. Badeev, Yu. S., and Fonyakov, I.A., Application of hydrocyclone in the flow sheet of additional grinding of intermediate products, Tsvetnye Metally 28 (6) 5-7, 1955.

Beneficiation of multimetallic ore, in which galena is intergrown with sphalerite and pyrrhotite, is discussed. A hydrocyclone was installed ahead of a ball mill, and was fed with control flotation concentrate and with 1st cleaning cells tailings. Regrinding of the hydrocyclone sands increased Pb extn. into Pb-Cu concentrate and decreased Pb content of the tailings.

3271. Baibulatova, S.G., Naumova, A.T., Biochemical characteristics of flour obtained by various grinding methods, Tr. Vses. Nauchn.-Issled. Inst. Zerna i Produktov ego Pererabotki (43) 21-43, 1963.

Grinding flour by various methods increases the yield of the free intermediate protein fraction. The saccharifying capacity of the flour was increased by passing twice through a hammermill.

A jet mill decreased the protein content and gluten yield but did not change the gluten quality. Vibration grinding had a neg. effect on gluten and bread-baking qualities. The highest yield of intermediate protein was obtained (while maintaining the quality of gluten) by a double treatment in a hammermill.

3272. Downie, C.C., Modern dust collectors, Food 2 248-50, 1933.

A general informational discussion on development work on Electrostatic Separators, especially as can be used for flour milling industry.

3273. Draper, N., and Lynch, A.J., An analysis of multi-stage comminution and cyclone classification circuits, Proc. Aust. Inst. Min. Met. 213, 1965.

3274. Barcicka, A., Waksmundzki, A., and Sznajder, R., The optimum disintegration of phosphorites from Annopol for the flotation process, Przemysl Chem. 35 207-11, 1956.

The phosphorites (I) under discussion contain SiO_2 , CaCO_3 , bound K_2O , FeO , and are assocd. with zircon, dysthene, stauro-lite, tourmaline, and rutile. These I were ground and sepd. by aid of heavy liquids, such as CHBr_2 . By microscopic analysis it was established which of the numerous methods would lead to the best sepn. of I from the gang. The best sepn. was obtained if the grinding was to 0.1 mm. These findings were

verified by chem. analyses. In the preflotation treatment it is possible to enrich the material up to 32% P_2O_5 . Influence of some parameters upon the trend of the flotation of phosphorites from Annapol by using tall oil as collector. Barcicki, J., Waksmundzki, A., and Szczypa, J., Ibid. 212-16.--In the form of graphs are presented the changes introduced into the flotation of I of less than 0.2 mm. grain size, if the amt. of petroleum is varied, the manner of adding it, the d. of the flotation suspension, the pH of the bath, and the addn. of water glass as depressing agent. On the basis of these graphs a recipe is presented which gives the best flotation results. Application of a cationic collector in the flotation of phosphorites, Barcicka, A., Barcicki, J., Waksmundzki, A., Ibid. 217-21.-- The same I were flotated by using dodecylamine (II) as collector, and it was found that a cationic collector such as II-HCl used alone, offers no advantages over the use of an anionic collector, with the exception of the removal of SiO_2 , which proceeds very smoothly, if II.HCl is used. These results were obtained at 27° and pH values of 6, 7.5, and 9. Enrichment of annapol phosphorites by flotation, Waksmundzki, A., Barcicki, J., and Barcicka, A., Ibid. 221-5.-- Ground I in grain sizes from 0.2 down to 0.02 mm., from which in a preliminary treatment the slimes were removed, were subjected to multistep flotations; some methods used an anionic collected exclusively, while others used anionic and cationic collectors alternately (tall oil, petroleum, II.HCl). The various

fractions obtained were collected on sieves, and then analyzed with respect to P_2O_5 . The highest P_2O_5 content was found in the grain sizes below 0.1 mm. It is economically feasible to prep. concentrates contg. 25% P_2O_5 ; a preliminary removal of SiO_2 and slimes is definitely of advantage, as the expenses incurred are made up by a higher concn. of P_2O_5 in the final product. The gang removal should be undertaken with the original mineral, after it had been ground to 0.1-0.2 mm.; if anionic collectors are used exclusively, the P_2O_5 in the wastes remains below 2%.

3275. Bard, Albert F., and Johnsen, Arthur M., Hard iron-base grinding balls containing abrasive particles, U.S. Pat.

3 061 209, 10/30/1962. 2 pp.

Hard, tough grinding balls are produced by mixing powd. Fe with 10% by vol. fine Al_2O_3 , compacting the mixt., sintering the compacts in coke at 2000°F. or higher, forging them while hot to rough spheres with a few blows, reheating in coke, and hardening them by heat treatment. The Rockwell C hardness of such balls was 61-4.

3276. Bard, Albert L., and Weed, Waune B., Heat treatment of rods for grinding mills, U.S. Pat. 3 170 641 (Cl. 241-184), 2/23/1965, Appl. 10/16/1961; 4 pp.

High-C steel rods 3-4 in. in diam. and 10-16 ft. long such as are used for grinding ores, are hardened to at least 50 Rockwell C while maintaining max. deviation of 1/8 in. in straight-

ness in 5-ft. lengths, by quenching with suitably directed conical sheets of H_2O while the rods, from a furnace at 1450-1600°F., are passed lengthwise through a machine in which they are rotated and kept straight by rollers and springs. Rods so hardened with straightness maintained, after 720 hrs. use in grinding ore, lost 33.8% in wt., while rods which were hardened only to the degree permissible for conventional machine straightening lost 47.1% in wt. after 720 hrs. of similar service.

3277. Barkan, H.E., Wear of materials - design failure, Electro-Technol. 68 (1) 95-102, July, 1961.

Study of basic concepts of wear of materials, based on results obtained from observation of wear in metals; types of wear, theory; surface interaction; predictability; materials combinations; surface finish; hardness; surface irregularities; abrasion effects; high-temperature effects; corrosion effects, lubrication.

3278. Barron, Gordon, and Mitchell, John, Particle size reduction of dyes and pigments, Brit. Pat. 956 515, 4/29/64, 4 pp. Pulverizable solids, esp. dyes and pigments, are reduced to a very small particle size by rapid stirring with grinding elements, such as sand, glass beads, Al_2O_3 , or SiO_2 , and an org. liquid of surface tension less than 40 dynes/cm. at 20°. The org. liquid may be miscible or immiscible with H_2O and should have no solvent action on the pulverizable solid. Thus 35

parts Cu phthalocyanine contg. 4.1% Cl was added to 110 parts $C_6H_3Cl_3$ with stirring at 1800 r.p.m. The 400 parts sand (0.35-0.5 min.) was added and stirring continued for 60 min. at 20°. The sand was removed by screening and the $C_6H_3Cl_3$ by steam distn. After filtration, the pigment was washed and dried. The product had a surface area of 60 m.²/g. and was easily incorporated into alkyd paint media with little flocculation. The process is also suitable for azo and dioxazine-type pigments.

3279. Barskii, M.D., Levchenko, P.V., and Dolganov, E.A., Effect of pulverization during classification on effectiveness of the process, *Izv. Vysshikh Uchebn. Zavedenii, Khim. i Khim. Tekhnol.* 7 (5) 858-61, 1964 (Russ); cf. *ibid.* (3) 501-04.

In air classification of a friable material, such as rosin, fracture of particles affects the apparent efficiency of the sepn. process. In the equation for calcg. sepn. efficiency, the factor i_M is a coeff. of pulverizability related to the percent of material, larger than the screen opening which is pulverized in the classification process.

3280. Barta, R., and Bruthans, Zd., Thermographic study of activation by vibration grinding, *Silikaty* 6 (1) 9-15, 1962. A differential thermal analysis was made on the effect of vibration grinding on quartz and dolomite. Quartz sand contg. more than 99% SiO_2 was 1st ground in a ball mill. The largest

possible sp. surface, about 12,000 sq. cm./g., was obtained after 14 hrs. of grinding. Further grinding was carried out in a vibration mill. After 4 hrs., the sp. surface rose above 12,000 sq. cm./g., and after 10 hrs. above 20,000 sq. cm.g. Samples for differential thermal analysis were taken during the course of the grinding. The deflection caused by quartz decreased more than the corresponding increase of its sp. surface. Similar changes occurred during grinding in a ball mill to a sp. surface of greater than 8000 sq. cm./g. Any mech. grinding causes defects of the quartz lattice with subsequent increase of its reactivity. The types of these defects are investigated. Pure dolomite was ground in a ball mill and a fraction with a sp. surface of 100 sq. cm./g. was sepd. This fraction was ground in a vibration mill for 170 min.; in the 1st case, the sp. surface increased to about 4200 sq. cm/g., in the 2nd case to about 8200 sq. cm./g. All 3 samples were subjected to differential thermal analysis. With the increased fineness, the endothermal deflection due to the decompn. of MgCO_3 was shifted from 785° to 777° and further to 750° . The deflection of a coarse sample with a sp. surface of 8200 sq. cm./g. is deeper than that of CaCO_3 , but after a 180-min. grinding of a 8200 sq. cm./g. sample, the deflection is about the same as that of CaCO_3 . The temp. difference between the max. rose from 107° to 146° . In this case also, the grinding causes defects of crystal lattice, probably by making possible the incorporation of MgCO_3 into the crystal lattice of CaCO_3 . This change is

irreversible since thermal analyses made directly after the grinding, after 24 hrs., and after 7 days, gave identical results.

3281. Barta, Rudolf, and Bruthans, Zdenek, Effect of grinding on the structure of crystalline substances investigated by differential thermal analysis, Proc. Conf. Silicate Ind., 6th Budapest 17-28, 1961, (Pub. 1963).

In the case of quartz sand, rock gypsum, and dolomite, grinding brought disturbances and changes in the crystal lattice. The effects of grinding in the ball mill and in the vibratory mill proved similar.

3282. Barwell, F.T., Report on papers on wear presented at Institution of Mech. Eng. Conference, Wear-Usure-Verschleiss 1 (5) 418-45, April, 1958.

Summary of papers of conference on lubrication and wear, Oct. 1957, arranged by Institution of Mechanical Engineers, London.

3283. Barwell, F.T., Techniques for surface examination and their contribution to our knowledge of friction and wear, Lubrication Eng. 14 391-7, 1958.

A review with 11 references.

3284. Batel, W., Comminution in pin-type mills, Chem. Ing. Tech. 32 448-53, 1960.

Experiment and theory show that size reduction is mainly the result of one impact only, while air movement in the mill has no effect. Conclusions regarding construction are given.

3285. Batel, W., Influence of adsorption layers on the milling process, Intern. Congr. Surface - active substances, 3rd, Cologne, 1960 2 493-7 (Pub. 1961).

The tensile strength S of a homogeneous substance is $S = \sqrt{4E\sigma\rho/\pi\lambda r_0}$, where E is the modulus of elasticity, λ the length of the crack, r_0 the range of the mol. cohesive forces, ρ the radius of the torn surface, σ the sp. surface energy. σ is greatest in a vacuum; when adsorption occurs, σ decreases. Adsorbed water vapor reduces σ more than does N . Agglomeration during milling reduces milling speed. It can be avoided by fast adsorption of gas on the fresh tear surfaces, thus reducing the cohesive forces between adsorbed layers and sufficient surface cond. of the milled goods. Wet machine milling with highly polar liquids (water) or with steam is most successful.

3286. Batel, W., Experiments on tube, vibrating, and pin mills, TVF 30 . 346-55, 1959. (In German).

The known laws of similarity for input power were verified with the help of pilot tests by using a tube mill with interchangeable drums of 0.3-0.9 m. diam. The throughput at equal rates of pulverization increased with the 2.5 power of the drum diam.

It still has not been possible to find corresponding relations for the degree of pulverization. Air streams in the grinding space exert an influence, esp. with finely ground products, by improving the material transport and thereby the pulverization; but local air movements impair the size reduction by removal of the fine particles from the grinding media. The best charging ratio is about 85% of the spaces between grinding media. The wear of the grinding medium was almost independent of the tube diam. In vibrating mills, the degree of pulverization increased with the amplitude and the acceleration. The periodical air movements removing the material from the grinding media diminish the rate of pulverization. In pin mills, no high fineness can be attained because the fine particles are surrounded by air. By varying the atm., not only the boundary energy of the particles and therewith the strength, but also the grinding process is affected. The degree of pulverization was about equal in a pin mill at 760 mm. pressure and in vacuo. Test with x-rays showed improved results in the vibrating mill, but inferior results in the tube mill.

3287. Batel, W., Comminution in vibrating mills II! Effect of gas atmosphere on the comminution process in vibratory and tube mills, Chem. Ing. Tech. 30 651-60, 1958.

A diagram of the exptl. arrangement and photographs of the charge are presented. Exptl. data for operation with air, N, O, and H over a pressure range of 0.005-760 mm. Hg are given in

numerous graphs. Gas turbulence phenomena are shown in the photographs.

3288. Batel, W., Comminution in vibratory mills, Chem. Ing. Tech. 30 567-72, 1958.

Motion pictures were used to elucidate the grinding process in a spring-mounted vibrating mill. The ground material is distributed in an aerosol-like manner and is subjected to impact by collisions and blows. The swinging rhythm imparted to the grinding balls results in air streams or puffs which carry fines from the grinding zones.

3289. Bateman, J.B., et. al., Determination of particle size and concentration from spectrophotometric transmission, J. Colloid Sci. 14 308-29, June, 1959.

3290. Bauer, W.G., Recycle compensation-basic improvement for closed circuit systems, Pit & Quarry 53 (1) 100-3, July 1960. Closed-circuit systems of external classifier type in which recycle oversize-stream is measured so that primary mill feed can be manually or automatically adjusted to compensate for its flow variations; design is described and shown in drawings.

3291. Baumert, Paul A.F., Grinding of iron ores and ceramic raw materials, Ger. Pat. 1 035 177, 7/31/58.

Fe ores or ceramic raw materials are transformed into voluminous

products of small grain size by repeated impingement in the presence of moisture, e.g. by treatment in a molding-sand centrifuge.

3292. Beaubaire, J., Beneficiation of iron ore gets modernized tryout, Chem. Eng. 71 (12) 156-8, 1964.

Empire Iron Mining Co. complex near Palmer, Mich. is operating above its rated capacity of 1,200,000 tons/yr of high-grade iron pellets for blast furnaces in Great Lakes area; operations include crushing and autogenous grinding of iron ore, screening, magnetic separation of iron, concentration in coppers, mixing with bentonite, and pelletizing.

3293. Bond, F.C., Confirmation of the third theory, AIME, TP 59B32, AIME Trans., 217, 1960.

Lab. ball mill data on 15 different ores is presented.

3294. Behrens, D., New developments in impact mills for fine grinding, Aufbereitungs-Technik 5 (5) 259-70, May 1964.

For better evaluation and comparison, impact fine grinding mills have been classified into 3 basic design characteristics- posture of rotor, material's main path through grinding zone, adjustment and control of fineness during operation; features of newer machines include greater fineness, better control of fineness and autogenous grinding; 9 impact mills are discussed, 5 of them new; some characteristic grinding and fineness results;

new classifier provides accurate size cuts in subsieve range.
Same as 3295.

3295. Behrens, Dieter, New developments in impact mills for the production of fine and ultrafine powders, Europaeischen Symp. Zerkleinern, 1., Frankfurt am Main 474-502, 1962.

3297. Behrens, D., Survey of recent developments in crushing and grinding techniques, Staub. 20 (4) 101-8, 1960.
Methods of crushing and grinding, by use of crushers, ball, tube, vibration, and hammer mills are described and discussed.
83 refs.

3298. Beinarts, J., and Kalnins, A., Mechanical and chemical treatment of birchwood in the presence of small amounts of sulfuric acid, Latvijas PSR Zinatnu Akad. Vestis, Kim. Ser. (3) 329-36, 1964. (Russ.)

The behavior of birchwood sawdust was studied during grinding in the presence or absence of H_2SO_4 . Under equal conditions of grinding in a vibratory mill, the mols. of xylan are most easily destroyed. The presence of 0.05 mole $H_2SO_4 \cdot H_2O$ per wt. unit of oven dry wood intensifies the mech. effect on the polysaccharides in the solid phase. The degradation of polysaccharides continues at room temp. even after vibratory grinding, with concurrent activation of the heterolytic destruction

of polysaccharide macromols. This process is accelerated when the temp. increases to 80°. The amt. of H₂O-sol. degradation products of cellulose and xylan depends not only on the amount of acid, but also on the intensity of the mech. action. Mech-anochem. treatment of wood helps to improve the sugar yield even when using small amts. of H₂SO₄·H₂O. The practical possibility of a quant. conversion of birch polysaccharides into readily hydrolyzable carbohydrates by vibratory grinding in the presence of small amts. of acid (1-0.5 mole H₂SO₄/wt. unit of abs. dry wood) is demonstrated.

3299. Beinarts, J., and Odincovs, P., Grinding sprucewood and sprucewood lignocellulose in a ball mill, *Gidrolizn. i Lesokhim. Prom.* 15 (2) 9-11, 1962.

Spruce sawdust (I) and spruce lignocellulose (II) were ground in ball mills with balls of 50 and 25 mm. diam. At equal initial particle size, the comminution rate of II was higher than that of I. An increase in the moisture content of I and II reduced the milling efficiency, and more so for 25-mm. than for 50-mm balls.

3301. Beke, Bela, The grinding process and its equilibrium state, (Central Res. Inst., Budapest, Hung.), *Rev. Mater. Construct. Trav. Publ. C*, (558) 73-82; (559) 115-21, 1962; cf. Holmes, *Trans. Inst. Chem. Engrs. (London)* 35 125-56, 1957. The theories of Rittinger, Kick, and Bond for calcg. the energy

of comminution, based as they are on a single grain dimension, neglect particle size distribution. The theories of Charles, Holmes, and Schuhmann consider this factor, but result in the low energy values for late phases of the crushing process. For detg. the energy, B. proposes a calcd. grain dimension $\chi_e = \bar{\chi}/v$, where $\bar{\chi}$ is the grain size, characteristic of the aggregate, (36.8% of the residue), and v is $f(n)$, for which a table is given. The granulometric parameter (n) increases in the early stages of grinding as production of fines results in greater particle size uniformity, but reaches a limit and decreases as agglomeration takes place and size equil. develops.

3303. Bellwinkel, A., Developments in ball mill construction, Symposium Zerkleinern, 373-84, 1962; Aufbereitungs-Tech. 3 (9) 389-94, Sept., 1962.

Ball mills 3.8 m. in diam. and 12 m. in length are used for dry grinding of cement and similar products in open or closed circuit; short ball mills up to 3.8 m. in diam. and 1000 kw are used in closed circuit with bucket elevator, for simultaneous grinding and drying of cement raw material and minerals; in ore processing, wet milling demands shorter ball mills up to 4 m. in diam. with 1000 kw, operated in closed circuit. Same as 3302.

3304. Belyaev, G.I., and Levchenko, N.V., Zavedenii, Khim. i Khim. Tekhnol, (5) 87-91, 1958.

Kinetic curves relating the sp. surface (s), the vol. wt. (γ),

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and the sp. vol. (v) to the duration of milling of the sand in the vibratory mill show that a remarkable increase of s occurs during the 1st 60 min. when sand is milled. There exists a close relation between v and s which permits the production control of s of many materials. An increase in the dispersion of sand remarkably accelerates the solid phase reaction between SiO_2 and Na_2CO_3 . An increase in s of the sand accelerates the process of silicate formation occurring at low temps. The dispersion of sand and of the charge as a whole has a significant influence on the rate of glass formation and complete baking of the enamel charges and permits shortening the baking time by 30-35%. Steel disks covered with enamel prep'd. from charges milled in vibratory mills and also from charges with milled sand are distinguished by a high luster, smoothness, and brightness of the surface; this is apparently related to the decrease in the loss of F , B_2O_3 , and alkali owing to volatilization during baking.

3305. Belyaev, I.I., Automatic process of grinding nepheline-slime burden at Volkhovsk aluminum plant, Tsvetnye Metally (1) 53-9, Jan. 1962.

Automatic control of wet grinding is based on determination of density of pulp by pick-up of noise signal; scheme of installation; diagram.

3306. Conley, Robert F., Rapid particle-size analysis of ceramic clays by packing-volume technique. J. Am. Ceram. Soc.

46 (1) 1-5, 1963.

Particle-size distributions for 20 to 0.2μ clays were calculated by sediment-volume measurements. Stokes' law holds with (1) uniform shape, (2) moderately broad distribution, and (3) low particle charge. Nonaqueous sedimentation can be employed. Charged particles create additional forces, particularly in polar liquids, and correction factors must be used. Good correlation occurs between mass-measuring techniques and packing-volume measurements for systems where 1 and 2 are valid. Non-uniform shape distribution can be computed if the non-uniformity is dependent on particle size and not random. Deviation isopleths may be formulated from statistical data. Their use gives $\pm 3\%$ correlation with classical methods. General operational techniques are given for improving accuracy and time requirements.

3307. Bennett, M.J.S., and Wild, J.D., Tonnage and density control in the Quemont grinding circuit, Can. Min. & Met. Bull. 52 683-7, Nov., 1959.

3308. Benning, Calvin J., Ball milling apparatus, U.S. Pat. 3 060 006, 10/23/62, 3 pp.

3309. Berdyshev, K.A., and Smirnov, B.I., Automatic control of two-stage wet-grinding cycle. U.S.S.R. Pat. 129 568, 7/1/1960. The density of the classifier overflow in the 1st stage is adjusted in relation to the circulating load of the 2nd stage.

3310. Bereza, V.Sh., Electroacoustical method of automatic control of load of ball mills, Teploenergetika 9 (2) 70-2, 1962. Influence of disturbances on amplitude and frequency of noise emf is employed as signal for automatic control of grinding process in mill.

3311. Bereza, V.Sh., Statistical estimation of automatic control of milling in ball mill, Avtomatika i Telemekhanika 20 (2) 150-60 Feb., 1959; English trans. in Automation & Remote Control 20 (2) 144-53, Feb., 1959.

Accidental fineness errors are shown to follow normal distribution law in automatic control of milling, and high-peak law in hand control of milling; use of mean square error to calculate automatic control of milling system.

3312. Bereza, V.Sh., Electro-acoustic method of automatic control and charge regulation for ball mills by means of milled material, Teploenergetika 5 (9) 19-26, Sept., 1958.

Study of useful signal in noise of operating mill; description of various schemes of electroacoustical devices and of automatic control of milling process.

3313. Berezin, B.V., Dependence between size of openings of hammer mill grate and maximum size of product particles, Gornyi Zhurnal 132 (8) 30-3, Aug., 1957.

3314. Bergstrom, B.H., Energy and size distribution aspects of single particle crushing, Minnesota Univ. School Mines & Met-Symposium on Rock Mechanics, 5th-Proc., 155-72, May 1962.

When single crushing event is considered, whether it takes place within crusher or grinding mill, circumstances necessarily approximate those of single particle crushing; although correlations of commercial data yield satisfactory equations for design purposes, it is essential to understand single particle crushing events before completely unified crushing theory can be developed.

3315. Bergstrom, B.H., Electrohydraulic crusher, Eng. & Mining J. 162 (2) 134, 136, 138, 140, Feb., 1961.

Soviet comminution device which harnesses forces which result when electric spark occurs within liquid; these forces are said to be created by spark transmitted through liquid and cavitation impact, which results when liquid refills void created when spark is extinguished; high pressures, amounting to several hundred atmospheres break up rocks within vicinity of spark; method appears to be inefficient.

3316. Bergstrom. B.H., Crabtree, D.D. and Sollenberger, C.L., Feed size effects in single particle crushing, Trans. AIME 226 (4) 433-41, Dec., 1963.

Experimental data for several natural minerals on load required for fracture of single specimens over very wide size range;

experimental results are compared with published data, such as for coal specimens from 30 μ to 64 in. in size; correclations of specific energy (per unit mass) required for fracture with specimen size are given as functions of specimen shape and experimentally observed load-size relationships; correlations are discussed with reference to comminution theory.

3317. Bergstrom. J.H., Permanente Cement Co. doubles capacity at Cushenbury, Rock Prod. 66 68-74, May, 1963.

3318. Bergstrom, J.H., Three-in-one spells versatile, Rock Prod. 65 60-4, Nov., 1962.

3320. Bernstrom, Bernard, Grinding iron ore in wet autogenous mill, Trans. AIME 223 (3) 304-11, Sept., 1962.

Twenty-two ft diam. 7-ft long, wet autogenous grinding mill was installed in new Cretaceous plant of Jones & Laughlin Steel Corp. to prepare crude iron ore for concentration in spirals and flotation cells. Flowsheet, operating, and metallurgical results have been obtained, including capacity, horsepower. Operating problems and comparison of pilot plant results with those obtained in commercial operation.

3321. Bernutat, P., Wear of grinding media and liner plates, Zement-Kalk-Gips 17 (9) 397-400, 1964.

Effect of mill diameter on wear of balls and plates in small

mills in which these components are subject to impact loads was studied; figures in grinding ball abrasive wear are critically examined and comparisons made between different mills.

3322. Bernutat, P., Heat balance of grinding plants, *Aufbereitungs-Technik* 5 (5) 254-8, 1964.

Equations are derived for drawing up heat balance for recycling mills with bucket elevators as well as for compound mills, from which allocation of grinding heat to possible heat output items and different temperatures of material to be ground can be calculated; mill with diam of 3.0 m and 11.75 m in length is shown.

3323. Bernutat, P., Nomograph for approximate calculation of tube mills, *Zement-Kalk-Gips* 12 (2) 65-7, 1959.

Determination of dimensions of mill depends on hourly throughput, degree of filling, bulk density of grinding media, specific throughput, and ratio of internal length of mill to internal diameter of grinding chamber; equations derived by use of these factors; nomograph shown contains these factors and enables rapid determination of dimensions.

3324. Berry, C.E., and Kamack, H.J., Surface activity in fine dry grinding, *Proc. Intern. Congr. Surface Activity*, 2nd, London 4 196-202, 1957.

The effect of agglomeration of small particles, size of grinding

balls, and size of ball mills for dry grinding are discussed. Attrition appears to be the chief mechanism of fine dry grinding in a ball mill. Grinding of ilmenite with naphthenic acid as the surface-treating agent was studied.

3325. Beushausen, W., Fine grinding with mechanically driven impact machines, Chem. Ing. Tech. 31 (9) 553-60, 1959.

Impact grinding is particularly suited to selective grinding of structurally inhomogeneous substances; general distinction between impact grinding and other types of mechanical operation; operating range of various tasks; effect of machine velocity on particle size; effect of flowing carrier medium on fineness.

3326. Beushausen, Walter, Fine crushing and air separation, Chem. Tech. (Berlin) 11 190-200, 1959.

A general discussion of the development and construction of pulverizers, with a study of various Alpine machines for use in pigments.

3327. Beyer, G., The influence of dispersing agents on grinding in ball mills, Rudy (Prague) 12 (7-8) 296-8, 1964.

On the basis of theoretical and exptl. studies the following conclusions are reached: (1) Grinding in ball mills can be improved by addn. of dispersing agents. (2) Each raw material requires a specific agent. (3) The grinding operation can be affected by the presence of another mineral.

3328. Beyer, Gerhard, Comminution and classification of potassium minerals, Freiburger Forschungsh. A291 25-47, 1963.

In the planning of industrial installations, the mineral recovery and prepn. stages must be selected with classification in mind, inasmuch as excessive fineness of the product is undesirable. Equipment presently used includes impact crushers, hammer mills, and rolls, for an av. output of 300 tons/hr., to yield grain sizes around 80 mm. For intermediate and fine grinding, impact and hammer type mills are employed, with and without screen bars, for unit outputs to 200 tons/hr., screening to 20 mm. In size sepn., roller screens and Briart screens are used, as well as grizzlies, with vibrating screens, trommels, and shakers for the fine sizes, for outputs to 15 tons/sq. m. Various arrangements of these types are compared for effectiveness. Straight screens inclined at 40-5° gave excellent results and a simple overall layout.

3329. Beyer, G., Effect of liquid additives on disintegration of rock in a ball mill, Celostatni Konf. Rudn. Hornictvi Upravnictvi, Prague 41-52, 1962.

The disintegration rate of quartz (1-4 mm. grain size) with the moisture content accurately controlled was studied in a lab. ball mill. The following substances were used as liquid additives: (1) CCl_4 (nonpolar), (2) H_2O (polar), and (3) stearylamine acetate (I) (polar). The I was added in concns. of 25, 50, 100, and 200 g./ton. The optimum concn. of I was 50-100

g./ton. The effect on the disintegration rate (after 40 min. of grinding) of various substances was different. CCl_4 decreased the disintegration rate. If the disintegration rate with H_2O as additive is taken as 1, then the disintegration rate with CCl_4 is 0.6, and that with I 1.4.

3330. Bhrany, U.N., and Brown, J.H., Particle-size measurement and control, Trans. AIME 223 (3) 248-54, 1962.

Size distribution of finely crushed quartz was determined by several methods and critical comparison of data was made; experimental results showed that different sizes may be indicated for one material depending on method of analysis used; conversion factors by which size measurements obtained by various methods can be expressed in terms of screen sizes are presented as one method for correlating results.

3331. Bialas Jan, and Placzek, Joachim, Dry grinding of sulphurous products, Freiburger Forschungsh. A255 221-4, 1962.

Trial runs carried out in a small ball mill connected to an air separator showed that dry material contg. 17-37% S can be ground to 0.1 mm. without the danger of explosions.

3332. Bickle, W.H., Powder production by fine milling, in Powders in Industry, Soc. of Chem. Ind. (14) 3-22, 1961.

3333. Biele Gustav, and Willmer, Theo K., Laboratory pulveri-

zing mill, Ger. Pat. 1 009 828, 6/6/57.

3334. Bikerman, J.J., The criterion of fracture, Soc. Plastics Engrs. Trans. 4 (4) 290-4, 1964.

Dupre's theory (Ann. Chim. Phys. (4) 7 245, (1866) that work of rupture is equal to the increase of surface energy is not correct e.g. because the surface area during rupture of liquids almost always, and during rupture of solid often, decreases rather than increases. Work is needed for deformation to rupture, not for rupture. Since Griffiths' criterion is based on Dupre's idea, and is therefore also incorrect, another hypothesis is suggested, namely, that a crack propagates when the decrease of strain energy around the "crit. domain" is greater than the increase required for an elastic deformation of the "crit. domain" to the breaking point. The advantages of the new concept are: (1) continuity between macro- and micro-effects; (2) avoidance of surface energy, which cannot be measured for solids; (3) accounting for the heat effect; (4) reasonable explanation of the unexpectedly high values of the "surface energy" (usually 10^4 - 10^7 ergs./cm.²).

3335. Binkevich, V.A., et. al., Performance of rod mills and ball mills during first and second stages of comminution, Gorny Zhurnal (1) 65-7, Jan. 1962.

Data on crushing of iron ore in Krivoi Rog basin and evaluation of efficiency of applied flowsheets.

3336. Bishin, B.M., Dhar, R.N., and Mandal, S.S., Indian mica: effect of grinding on differential thermal analysis, Central Glass Ceram. Res. Inst., Bull. (India) 8 15-22, 1961.

Irrespective of particle-size, the dehydroxylation peaks of dry ground Indian ruby and green micas appeared at 840 and 872°, resp. Redn. in particle-size caused the gradual growth of a secondary exothermic peak at ~365 and 300° for ruby and green mica, resp., together with a regular decrease in the dehydroxylation peak. This was attributed to the adhesion of OH⁻ to the broken bonds produced by fracture of the mica crystallites during grinding.

3337. Bitzer, E.C., For finer feed to wet mills-new high-speed crusher, Eng. & Min. J. 166 (3) 92-5, 1965.

Gyradisc crusher has extended dry reduction well into range now occupied by wet rod-milling; with new design of crushing cavity and new crushing principle, Nordberg Gyradisc crusher should prove to be substantial cost-cutter in mining industry; operating features and possibility of application to mining industry.

3338. Blanc, E.C., Terminology and neologisms in field of crushing, Rev. de l'Industrie Minerale 46 (5) 461-4, 1964. Definition of 7 french terms designating types of crushing.

3339. Blanc, E.C., Development of single toggle crusher, Aufbereitungstechnik 5 (5) 238-41, 1964.

Six principal ways of articulating single toggle crushers and characteristics of each; operation, limitations and disadvantages

of single toggle and double toggle crushers; method of calculating range of applications of both machines.

3340. Blanc, E.C., Development, design and application of rod mills, Europaeisches Symposion "Zerkleinern", Frankfurt/M-1, 101; Aufbereitungs-Technik 3 (3) 89-128, 1962.

3341. Blanc, E.C., Primary feeder crushers with two toothed rolls, Revue de l'Industrie Minerale 40 (9) 686-92, 1958.

Hadfields crusher is direct descendant of Edison crusher; it comprises rolls with dimensions 6 ft x 5 ft (1.80 m x 1.50 m), driven by two electric motors of 200 hp at 185 rpm; it can maintain capacity of 450 tons/hr of iron ore; toothed-roll crushers require less maintenance; they can handle ore in sticky condition, but they are not suitable for handling very hard rock or abrasive material.

3342. Blanc, E.C., Lucas, R., and Zagury, M., Industrial results of the fine grinding of iron ores for an agglomeration process, Europaeischen Symp. Zerkleinern, I., Frankfurt am Main 310-22, 1962. (in French).

Lorraine iron ore contains particles up to 250 mm. and is not abrasive. Hammer mills are used to reduce the size of the feed to less than 100 mm. The first pass gives 70-80% less than 10 mm. Internal screens remove all material less than 40 mm. from the mill. The final product is removed by an external

screen and the fraction between 10 and 40 mm. is recycled. This process is claimed to give less dust (less than 0.1 mm.) in the product and to reduce the wear on the hammers by a factor 4. The capacity of a hammer mill with 36 mm steel hammers of 80 kg. each is 600-800 tons/hr. This process cannot handle more abrasive ores.

3344. Blaskett, K.S., and Woodcock, J.R., Ore dressing-developments in Australia, 1962, Min. & Chem, Eng. Rev. 55 (7) 26-33 1963; 30-43, 1963.

New equipment and circuits added during 1962.

3345. Blazek, A., and Pribyl, M., Edge mills for wet grinding, Stavivo 38 92-4, 1960.

After a report on the function and purpose of edge mills, the authors describe two types of mills, manufactured in Czechoslovakia.

3346. Blekhman, I.I., Vibrating ball mill, U.S.S.R. Pat. 125 117, 12/29/59.

Structural details of the mill are given.

3347. Blumkina, G.V. et. al., Automation in ore concentration plants, Congr. Intern. Prepn. Minerais, 6^e, Cannes, France 862-79, 1963. (Pub. 1964)(Fr).

The design of transmitting, measuring, and regulating means for concn. plants was studied. A detector, MT 6 type, including

a highly reactive oscillating circuit, prevents the recurrent stops caused by the passage of metallic bodies through crushers. Combined with an extractor, it actuates the removal of the metallic body. The automation of flotation processes requires the automatic control of the supply of reagents. In a 1st method, the regulating parameter is the tonnage of the feed or the solids content of the pulp, and induction transmitters are combined with integrating balances and pulp and solids flowmeters. The rate of flow of the solids may be measured with a piezometric flowmeter system. In a 2nd method, the regulating parameter is the residual ionic concn. of the reagent in the pulp. Na_2S is added to the pulp as a sulfurizing or depressing agent, and the concn. is measured potentiometrically by means of a Ag electrode.

3348. Blyakh, G.I., Automatic control of particle-size distribution during concentration of copper ores, Dobycha i Obogashch. Rud Tsvetn. Met., Nauchn.-Tekh. Sub. 1964 (8) 25-8, 1964.

Suspension elec. cond., which depends on the content of solid particles, was used to control the particle-size distribution of a pulp. The granulometer was completely automated and controlled by a cyclic command app. In the granulometer, particles of each size were radially pptd. in a column of pure water from the upper layer of the polydisperse pulp; this gave distinct fractional sepn. and decreased crowding during pptn. Error in detn. of the 200-mesh class content was 0.8% for a

2% Cu (as chalcopyrite) content in the ore. An exptl. model of the granulometer was tested in the Balkhash Cu-concgr. plant.

3349. Boals, R.E., Establish limits for pulverizer fineness tests; coal sampling, Power 105 214-15, June, 1961.

3350. Bodnya, M.D., et. al., Grinding of zinc oxide with solvent in a ball mill, Lakokrasochnye Materialy i ikh primenen (3) 62-3, 1961.

Grinding of ZnO can be speeded up and the quality of the product improved by grinding the oxide in the presence of white spirit and small amounts of lacquer. ZnO 80.5, white spirit 16.8, and lacquer 2.7% were charged into a 4-cu. m. ball mill containing steel balls of 10-40 mm. in diameter. A fineness of 20-25 μ was reached after grinding for 3-5 hours. Before discharging the mill, 3-15% of lacquer was added to the paste and ground for 5-10 minutes. The paste became thin and could be easily pumped into the mixing vessel containing the remaining lacquer. Enamels prepared according to this method have a better covering power, appearance, and resistance to H₂O.

3351. Bogert, J.R., Ore grinds ore, Metal Min. & Proc. 1 (7) 30-1, 1964.

Empire mine near Palmer, Mich. utilizes autogenous grinding in producing 1,200,000 tons of pellets, averaging 63% Fe, from low-grade magnetite ore; 6 Cascade mills accept and reduce coarse taconite ore as it comes from primary crusher at

rate of 70-80 tph each; Pebble mills follow Cascade mills and substitute for ball mills in final grinding stage; ore is ground to 95% minus 500 mesh; Cascade mills, with heavy wear-resistant, nickel-steel cast liners, are 24 ft in diam. 8 ft. long, rotate at 11 rpm. and are driven by 1500 hp motors.

3352. Bolin, D.C., Mining and crushing methods and costs at the Tiffin Limestone Quarry of the Thurber Earthen Products Co., Fort Worth, Tex., U.S. Bur. Mines Info. Circ. IC6531, 1931, 19 pp.

It describes equipment and operation at limestone quarry.

3353. Boller, Carl, Abrasion resistance measurements of coatings, Farbe Lack 69 505-14, 1963.

The German Wilborn (140 cm.-drop) and the ASTM (91.5 cm.-drop) abrasion tests are compared, and a refined app. and method are described.

3355. Boloni, I., Some functional regularities of comminution process in hammer mills, Acta Technica (Budapest) 41 (3-4) 381-98, 1962.

New methods of measurement that consist in weighing and recording change of weight of product fed in and of ground mass produced by using feed hopper and gathering receptacle, each being suspended on separate balance member; weight changes were measured by electro-tensometric method and registered by

by means of oscillograph having 8 circuits; development of stable operation of mill drum.

3356. Bombled, J.P., Grinding of clinker-slag mixtures, (Liants Hydrauliques, Paris). Rev. Mater. Construct. Trav. Publ. (593) 61-75, 1965. (French).

The grindability of a mixt. of clinker and slag, expressed as sp. surface increase per energy unit or per time unit, or as the time required to obtain a given surface area, is a linearly additive function of the same parameter for each material when ground sep. When ground together, the particles crushed first are largely clinker up to a sp. surface of $1600 \text{ cm.}^2/\text{g.}$, then the slag particle size decreases. The fineness of each constituent in a ground mixt. can be calcd. from the grindability of each constituent, the wt. fraction of clinker, and the overall sp. surface; the equations show that the sp. surface of the softer component (clinker) and of the harder (slag) both increase when the content of the former decreases. The strength of a clinker-slag mixt. contg. less than 50% slag increases with the slag content because the fineness increases in the same direction, but after the slag content exceeds 50%, the strength decreases because insufficient clinker is present. In clinker-gypsum mixts., where gypsum is the softer component, clinker sp. surface is always less than expected if the gypsum effect is neglected. Fly ash, although about the same grindability as clinker, is always finer in mixts. because it is

initially finer. These effects are also found in clinker ground alone; the chem. components, free CaO and tri-Ca silicate concentrate in the fine fractions because they are more grindable than di-Ca silicate. The mathematics is extended to the case of 3 constituents. No difference in strength, shrinkage, or rheology was observed between mixts. ground together and mixts. ground sep. before blending.

3357. Bond, F.C., Expert reviews design and evolution of early autogenous grinding systems, Eng. & Min. J. 165 (8) 105-11 1964.

Development of autogenous grinding, from secondary to primary stages is illustrated by operations at specific installations. 52 refs.

3358. Bond, F.C., Lab equipment and tests help predict metal consumption in crushing and grinding units, Eng. & Min. J. 165 (6) 169-75, 1964.

Method of testing different ores and other materials for their relative abrasive wear; equations relate laboratory tested abrasive wear index to actual metal wear in commercial machines; expression for commercial metal wear is pound of metal wear /kwh; it permits direct comparison between different machines, different feed and product sizes, and different materials; abrasion tester measures weight loss of steel paddle hitting falling ore particles for 1 hr; metal wear data for various

installations and materials.

3359. Bond, F.C., Calculation method of fine particle grinding, Aufbereitungs-Technik 5 (5) 211-18, 1964.

New exponential size distribution represents good method for screen analysis plots because upper part of distribution is expanded; this grid, structure and application of which are explained in detail, provides quantities which are helpful for mathematical computation of grinding processes, energy consumption, capacity, fineness, specific surface area, and crack length; natural or artificially induced grain sizes can be easily distinguished; calculations of ball milling characteristics are used as illustration.

3361. Bond, F.C., Particle size reduction-theory and practice, Can. Min. J. 84 (6) 43-8, 1963.

Three theories of mechanism of brittle rock breakage; application of Bond theory equation has revealed 3 principles which seem to govern operation of reducing size of brittle particles; types of equipment available for commercial crushing and grinding; processes of autogenous grinding; 2 most important trends in present day size reduction equipment are trends toward increasing machine size is particularly notable in ball mills, autogenous mills, and rod mills.

3362. Bond, F.C., Rosario-pioneer of autogenous grinding, Min. Eng. 15 (5) 55-8, 1963.

Mill treating silver lead zinc ore in Honduras employed autogenous grinding from 1918 to 1941; over 2,000,000 tons of ore was ground autogenously in cyanide solution; 3 5x22 ft. autogenous tube mills had 75-hp motors, and single spiral (scoop) feeders; hand-picked media consisted of larger ore fragments which survived mine fall; amount of ore media used was about 10 tpd. or 3.25% of weight of ore ground.

3363. Bond, F.C., Rock on rock grinding-growing technology, Eng. & Min. J. 163 (4) 80-3, 1962.

Rock-on-rock grinding causes less trans-grain breakage than steel media, and produces less extreme fines; this is advantage in grinding ores to unlocking size before concentration; other advantages and disadvantages, clarification of terms dealing with autogenous grinding mills; development of wet grinding, grain size of particles produced, application of automation, and results of laboratory and pilot plant tests.

3364. Bond, F.C., Wet versus dry grinding, Europaeisches Symposion "Zerkleinern", Frankfurt/M-1 97, 1962; Aufbereitungs-Technik 3 (3) 89-128, 1962.

3365. Bond, F.C., New ideas clarify grinding principles, Chem. Eng. 69 (3) 103-8, 1962.

Development of several new principles in crushing and grinding; comminution calculations should be based on difference in "energy register" of product and feed particles; energy input in comminution is directly proportional to new crack length produced; homogeneous materials have constant work index in reducing to different size ranges; report on improved methods for studying particle size distribution.

3368. Cierva, Piedad de la, and Arroyo, Luisa, Glass surface II: mechanical and polished strength, Bol. Soc. Espan. Ceram. 2 (2) 95-102, 1963.

The mechanical properties of glass and theories of glass polishing are reviewed. Surface crack patterns are mentioned for the study of mechanical weakness. For part I see J. Am. Ceram. Soc. 46 (6) 273-76, 1963.

3369. Bond, F.C., Three principles of comminution, Min. Congress J. 46 (8) 53-6, 1960.

First principle states that specific work input done in crushing and grinding equals energy register of product minus energy register of feed; second states that effective Kw-hr required to grind ton of rock to any product size varies as square root of diameter; third principle states that breaking strength of individual particles under compression depends on flaw structure of particles.

3370. Bond, F.C., Action in rod mill, Eng. & Min. J. 161 (3) 82-5, 1960.

New formula for proper rod size is derived. Broken rods appear to raise work index. Rods are observed to make 2 cycles per revolution. Power draft can lift them 3.2 times per revolution.

3371. Bond, F.C., Grinding ball size selection, Min. Eng. 11 (5) 536, 1959.

Discussion of paper from May 1958 issue.

3372. Bond, F.C., Tumbling mills and structural clay products, Am. Cer. Soc. Bull. 37 361-3, 1958.

3373. Boszhardt, A.K., and Hahn, M.P., Preventive maintenance for crushers and screens, Pit & Quarry 52 102-7, Feb. 1960; 122-4+, March 1960.

3374. Both, Hans Ulrich, Problems of vibration milling, Europaeischen Symp. Zerkleinern, I., Frankfurt am Main 466-73, 1962. Quartz at an av. particle size of 0.37 and 0.25 mm. and cement at 0.37 mm. is ground to an av. particle size of 0.02-0.12 mm. in a vibrating ball mill by varying the amt. and size of balls, throughput rate, and size and no. of mills.

3375. Bouchez, J.M., The sand-mill, Pitture e Vernici 36 677-83, 1960.

The function and construction and application limits of a sand-mill, built according to the American and French patents, are described. The grinding occurs by a violent agitation of pigments, resins, solvents, and pure siliceous sand of suitable dimension and the successive sand sepn. with a sieve. For some types of varnish-paste mixts., a study of contact time, energy consumption, and outputs was made.

3376. Bowden, F.P., and Tabor, D., The friction and lubrication of solids, Oxford University Press, 1964.

3377. Bowles, Oliver, The economics of crushed-stone production, U.S. Bur. Mines Econ. Papers EP12, 62 pp., 1931.

3378. Bowles, Oliver, Rock quarrying for cement manufacturers, U.S. Bur. Mines Bull. B160, 160pp, 1918.

This article describes chief types of cement, growth of industry and character of raw materials used. It also explains quarrying methods and equipment, with special attention to drilling and blasting, etc.

3379. Brach, I., Theories of brittle material crushing, Archiwum Budowy Maszyn 9 (1) 3-27, 1962.

Comparison of 4 existing crushing theories by Kick, Rittinger, Lewenson, and Bond. Combining Kick and Rittinger theories, a hypothesis of "multiple crushing" is advanced. New formula for

disintegration work of 1 kg of material is applied to a number of existing machines. Formula can be applied to rough crushing processes. Its applicability to fine crushing and milling requires experimental verification.

3380. Bradley, P.R., Milling practice at the Alaska Juneau Concentrator, U.S. Bur. Mines Info. Circ. IC6236, 16pp, 1930. This is the first of a new series of reports describing milling methods and costs in the various districts of the United States. It gives an account of methods used in coarse crushing and sorting, disposal of waste, fine grinding, concentrating, and re-treatment.

3381. Bramekamp, Karl J., Determining the dispersibility of titanium dioxide pigments in the ball mill, Schweiz. Arch. Angew. Wiss, U. Tech. 27 392-8, 1961.

A study was made of the factors affecting the efficiency of ball-mill dispersion, and a method is proposed for the comparison of dispersibility of various pigments by ball-mill grinding. The flow-point method of Daniel and Goldman (CA 40, 1067₄) is used to insure a fairly constant mix viscosity. At constant viscosity, the grinding efficiency increases with decreasing amounts of mix and with a combination of medium (20-mm.) and small (15-mm.) balls. The degree of dispersion per unit time is not greatly affected by viscosity variations within certain limits and these are determined. A table is given relating the

flow point to the amount of soybean alkyd resin and to the numbers and sizes of balls for optimum grinding effects.

3382. Brisse, A.H., and Kubhta, B.R., Better coal preparation through better crushing, Proc. AIME 18 17-21, 1959.

3383. Anon. National Malleable Steel Castings Co., Automatic casting of steel grinding balls, Elec. West. 109 103, Oct. 1952.

3384. Chujo, Kimbe, Okajima, Shoji, and Yamasaki, Masao, Measurement of specific surface by the nitrogen adsorption, Blaine, and other methods, and study on the formulas of grinding, Semento Gijutsu Nenpo, 14 101-6, 1960.

The specific surface and fineness of portland cements and silica sand ground in a laboratory ball mill were determined by the Blaine, Wagner, and nitrogen adsorption methods and by the Andreasen and air elutriation methods, respectively. From the results, the applicability of the formulas of Rittinger, Kick, Bond, and Tanaka on grinding is discussed.

3385. Broehl, W., Wear-resistant materials in crushing and grinding plant, Zement-Kalk-Gips 12 (1) 10-14, 1959.

Types of wear on crushing and grinding equipment. Use of five types of steel is discussed for various requirements of usage.

3386. Brotzen, F.R., and Wallace, J.F., Impact resistance of gray iron, Mach. Design. 29 85-7, Dec. 26, 1957.

3387. Brough, P.V., Milling methods and costs at the mill of the Tom Reed Gold Mines Co., Oatman, Ariz., U.S. Bur. Mines Info. Circ. IC6975, 25pp., 1937.

Describes practice of milling custom ore, in addition to that produced under company and lease operations. Chief gangue minerals in ore milled are quartz, calcite, silicified andesite from stringer loadings, quartz monzonite, and varying amounts of fluor spar, adularia, and oxides of iron. Paper includes milling costs.

3389. Brown, G.J., Principles and practice of crushing and screening, Quarry Managers' J. 47 (9) 335-44, 1963.

Methods of controlling shape and size of particles, conveying of rock being processed, warning devices, detection and removal of tramp metal, dust control, economical use of renewable crushing members, layout of crushing plant and equipment.

3390. Brown, J.H., Minerals beneficiation in 1961; crushing and grinding, Min. Eng. 14 70, Feb., 1962.

3391. Brown, R.L., Calculation of closed-circuit grinding, Brit. Chem. Eng. 4 463-6, 1959.

Matrix algebra is used in calculating the characteristics of a

product obtained from a recycle size-redn. process. This method is applicable when the characteristic of a material has a distribution which is altered in the process under consideration.

3392. Brown, J.H., Mitchell, S.R., and Weissman, M., Energy-size reduction relationship for the grinding of quartz. Trans. AIME 217 203-6, 1960.

Ball mill experiments were carried out to test a relation between energy input (time of grinding) and the size distribution modulus of Schumann. For quartz in 1-ft. steel mill the coefficient was 1.96. Used sieve and BET for fine particle analysis. At extremely long grinding times a limiting surface of $1.8 \times 10^2 \text{ cm}^6 / \text{gram}$ was approached.

3393. Brownlie, G., Performance of titanium dioxide pigments in a sand grinder, J. Oil & Colour Chemists' Assoc. 43 737-61, 1960.

With suitable precautions the sand grinder is very satisfactory for grinding mill bases contg. TiO_2 for paints, lacquers, and emulsion paints. In the lab. sand-grinding for 2 min. is equiv. to ball-milling for 2-8 hrs. or Kady-milling for 15 min.

3394. Broessor, G., Novel beam-shaped liner plates in coarse-grinding compartments, Zement-Kalk-Gips 17 (11) 529-30, 1964. New beam-type lining of high manganese steel for cement grinding mills that enables grinding to be performed with 20% lower

loading factor and reduced power consumption, without any change in throughput, is described.

3395. Bruthans, Zdenek, and Kral, Stefan, Porous concretes, Czech. Pat. 114 357, 2 pp., 4/15/1965.

Grinding concrete constituents and fillers to a particle size of 30-60 μ instead of the customary 90-200 μ improves the chem. binding of the reactants, owing to increased reaction surface, resulting in a more favorable macrostructural arrangement, increased homogeneity, and improved physicomach. properties of the concrete. Increased dispersion and amt. of the smaller particles affects the viscosity of the mixt., accelerates hydration, and improves the uniform structure of the porous concrete.

3396. Buckshee, W., Portable grinding is easy this way: large grinding jobs using unique grinding rig, Power Eng. 63 79, May 1959.

3397. Budnikov, P.P., and Nekrich, M., Work of disintegration in powder technology, Silikat Tech. 12 452-7, 1961.

Starting from the fundamental facts of solid-state physics, the conditions for the disruption of bonds in cryst. structures are discussed in general under the viewpoints of the practical importance of these facts for powder technology, e.g., in the production of refractories and oxide ceramics. In the range of brittleness and below the limit of elasticity the lattice

destruction is not combined with any considerable plasticity effects of deformation, and no losses of energy are observed. The energy economy of grinding is, therefore, particularly good in the brittleness range, less satisfactory in the plastic deformation and structural dislocations ranges. The application of the theory of rigidity and plasticity for the practice of ceramic raw material grinding is demonstrated in the function of modern vibration mills, and of steam-impact disintegrators. Particular consideration is given to the new electrohydraulic Yutkin method (Elektrogidravlich Effekty, Moscow, 1955), based on the effects of low-frequency (e.g., 2 to 100/sec.) discharges (25 kv., with a capacity of 0.1 to 0.2×10^{-6} f.) in a liquid medium by cavitation. The shorter the discharge impulse and the steeper its slope the higher the brissance of the impulse. The effect of the electrode material is remarkable for this effect: the voltage built up in the impulse discharge increases in the series steel-Dural alloy-Cu.

3398. Budnikov, P.P., and Nekrich, M.I., Problems of powder grinding, Poroshkovaya Met., Akad. Nauk UKr. SSR 1 (6) 17-26, 1961.

Review with 30 Refs.

3399. Budnikov, P.P., and Sokhatskaya, G.A., Properties of superfinely ground slag-portland cement, Trudy Gosudarst. Vsesoyuz. Nauch.-Izzledovatel, Inst. Tsement. Prom. (9) 3-50 1956.

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Superfine grinding (particles less than 3μ 65-85%; specific surface, detd. with the Deryagin surface-meter, $\sim 25,000$ sq. cm./g.) increases the hydraulic activity of slag-portland cements (I), prepd. with acidic, low-basicity, and basic slag. Relative increase in strength is considerably higher during the early periods of hardening (1.3 and 7 days). In tests of 1:3 mortars of high consistency, compression strength at the age of one day was as high as 415 kg./sq.cm., and 3 days up to 458 kg./sq.cm. Relative increase in activity with superfine grinding is greater in the case of I prepd. with lowactivity slag. than in the case of I prepd. with active basic slag. Superfinely ground I (II) shows shorter setting time. Optimal gypsum content of II is 5-7%. Strength of II is higher following a combined grinding of the components, than on grinding them separately and combining them thereafter. Heat of hardening of II is higher than that of conventionally ground I. Strength of concrete made with II is 50-155% greater than that of concrete made with conventionally ground I, at the same water/cement ratios. Water requirements of concrete made with II are higher.

3400. Bullet, A., Progress being made in beneficiating very refractory iron ores of France's Lorraine Basin, World Min.

18 (6) 27-9, 1965.

Commercial-scale plant for beneficiating new type of Lorraine iron ore has 3000 tpd capacity; ores are non-argillaceous

where Al_2O_3 to iron ratio is always 0.14 and argillaceous type where this ratio is 0.18 to 0.30; new plant at Longlaville will use Aerofall autogenous grinding, air sizing, and magnetic separation in three-stage units; this plant should raise iron grade from 30.0 to 42.0% with 94% weight recovery.

3401. Cantle, R., Symposium on milling, J. Can. Ceram. Soc. 29 28-30, 1960; Jones, Phil, ibid, 30-33; Proulx, J., ibid 34. They discuss the equipment and practice changes required by the conversion from milling with standard balls (sp gr=2.4) to high density balls (sp gr=3.3).

3402. Burson, H.H., Iinoya, K., and Orr, Clyde Jr., Particle size classifier for the subsieve range, Rev. Sci. Instr. 34 (9) 1023-23, 1963.

A classifier for dry powders in aerosol form, based on the combined mechanisms of impaction and adhesion and characteristic trajectories of particles was extensively tested with a variety of powders.

3403. Bursill, L.A., and McLaren, A.C., Transmission electron microscope observation of fracture in quartz and zircon, J. Appl. Phys. 36 2084-5, 1965.

Fracture marks show dislocations, but not plastic deformation in zircon and in quartz.

3404. Burstlein, E., Coke breeze for sintering iron ore, Steel Times 189 (5008) 72-6, 1964.

Ideal coke breeze should be perfectly graded product with median particle size of about 3 mm within relatively narrow range of about 1 to 5 mm; shortcomings of conventional methods of preparation, new technique for controlled progressive crushing of coke by means of crushers in conjunction with nonclogging screens is described; plant is self-regulating; particle size is held constant; capital costs are comparable with usual methods.

3405. Burch, Roy F. Jr., Apparatus for grinding spherical bodies, U.S. Pat 3 104 502, 9/24/63.

The apparatus comprises a rotatable disk having a shallow circular recess in one of its faces, means for moving it axially toward a member having a flat abrasive surface spaced from the disk and parallel to it, and a device for imparting linear unidirectional movement to the surface while the disk is in rotation.

3406. Bushuev, L.P., Configuration of region of detachment and effect of self-lining in planetary centrifugal mill, Izvestiya Vysshikh Uchebnykh Zavedenii, Mashinostroenie (10) 16-25, 1964. Disposition of material in horizontal and vertical-shaft centrifugal ball mills is investigated; structural parameters and volumetric charge are determined which would produce self-lining, i.e. formation of ground material layer protecting mill wall from wear.

3407. Cadwell, D.E., and Duwell, E.J., Evaluating resistance of abrasive grits to comminution, Am. Ceram. Soc. Bull. 39 (11) 663-7, 1960.

Abrasive grits are crushed reproducibly by excess of steel balls in mechanically shaken closed container; time is small fraction of that required for tumbling tests; comminution resistance index, based on screen analysis of crushed product, is given; commercial synthetic abrasive minerals are shown to have high comminution resistance.

3408. Calcott, T.G., Size distribution function, J. Appl. Phys. 35 250-1, 1966, 1964.

3409. Callahan, W.B., and Manz, W., (E.I. DuPont deNemours & Co., Bush Hse., London), The sand grinding process, J. Oil Colour Chemists' Assoc. 47 737-44, Discussion 744-9, 1964.

3410. Callcott, T.G., and Lynch, A.J., Matrix Analysis of breakage processes within rod mills, Australasian Inst. Min. & Met-Proc. 209 109-31, March 1964.

Comminution within rod mills has been investigated by use of matrix analysis of breakage processes; parameter, number of breakage stages, has been introduced and comminution within all rod mills has been expressed in terms of number of grinding stages and function which describes feed rate, mill diameter, and mill speed; effect of variation in feed rate, feed sizing

analysis and mill speed on number of breakage stages; no general relation is proposed because more study is needed.

3411. Carr, J.R., Effect of fragmentation on crusher performance, Min. Congress J. 48 (5) 20-4, 1962.

Measures taken for improvement of shovel and crusher performance through better fragmentation at New York titaniferous magnetite open pit operation; use of angle blast holes which reduced back-break, reduction of drill hole pattern, use of double line shots and use of ammonium nitrate reduced crusher cost/ton by 18%.

3412. Bryant, E.E., and Johnson, G.H., Rapid method of determining comparative subsieve fineness of milled porcelain enamels, Am. Ceram. Soc. Bull. 38 (11) 649-52, 1959.

The method involves a short term settling test. The average specific gravity of various portions in a settling column is measured with a hydrometer.

3413. Carvajal Melero, P., Concentration by flotation of pyrite-chalcopyrite ore at Riotinto (Spain), 6th Congress International de la Preparations des Minerals 49-91, 1963.

Flowsheet details on equipment, its performance, and automation.

3415. Charles, R.J., Energy-size reduction relationships in

comminution, Min. Eng. 10 (4) 481-4, 1958.

Discussion of Charles, R.J.; Energy-size reduction relationships in comminution; Min. Eng. 9 (1) 80-8, Jan., 1957.

3416. Charmbury, H.B., Kestner, D.W., Jr., and Confer, D.S., The effect of crusher type on the liberation of sulfur in bituminous coal, Europaeischen Symp. Zerkleinern, 1, Frankfurt am Main 1962, 284-309 (in English).

Seven types of industrial crushers (coalpactor, impactor, jaw, gyratory, single roll, granulator, and cuber) were compared in the sepn. of pyritic and marcasitic S from run-of-mine bituminous coal from the Upper Freeport seam in western Pennsylvania. The sink fractions in 2.96 sp. gr. liquid, of 6 size fractions less than 1.5 in. were analyzed for S. The S-bearing impurity had a sp. gr. of 4.40, while coal and assocd. impurities had sp. grs. of 1.50 and 2.65. Sink-float studies were made at sp. grs. of 1.40 and 1.60 to det. the characteristics of the clean coal and the S removal at these sp. grs. The jaw, coalpactor, gyratory, and cuber crushers performed well, while the roll crusher gave the poorest results.

3417. Charters, A.C., High-speed impact, Scientific Am. 203 128-31, Oct., 1960.

Photos of high-speed projectiles hitting targets. Photo of spalling of rock where struck by a nylon ball projectile.

3419. Chen, C.W., and Wiener, G.W., Brittleness of cobalt-iron alloys, J. Appl. Phys. 30 Supl. 199-201, April, 1959.

3420. Chernykh, S.I., and Azatyan, R.G., Experimental testing of a 2-stage pulverization method at the Akhtala concentration plant, Tsvetn. Metal. 38 (7) 12-16, 1965 (Russ).

To obtain a high degree of concn., it was necessary to grind sulfide ore contg. Pb, Zn, and Cu to 75-85% less than 0.074 mm. A 2-stage method was therefore recommended. The 1st stage resulted in 40-50% less than 0.074 mm. and the ore was used for stage flotation for Cu and Pb. In the 2nd stage of flotation the pulp had a particle size of 75-85% less than 0.074 mm. When the 2nd grinding was carried out without ball-milling, better results were obtained than with a ball mill. The extn. of Pb, Zn, and Cu increased by 3.75, 0.90, and 9.71% resp.

3421. Boyd, H., Particle size reduction III: Jet pulverization, Ceram. Age 78 (5) 41-44, 1962.

Particle size distributions for clay, frit, zirconium silicate, titanium dioxide, and aluminum oxide ground by jet pulverization against anvil are shown.

3423. Cieslinski, Walery, Grinding of raw materials in the modern cement industry, Cement-Wapno-Gips 15 (25) 34-7, 1960.
A review of modern grinding equipment used in the cement plants.

3424. Clary, J.O., and Matoney, J.P., Mineral concentration from clay fractions, Belg. Pat. 659 536; U.S. Appl. Feb. 20, 1964, 10 pp. May 28, 1965.

Enrichment of sandy, argillaceous, or other low-grade ores is obtained by differential crushing in slurry form and sepn. of the coarse and slime fractions. The apparatus consists of a smooth steel roll and a hard, resilient roll, e.g., of rubber. In operation, the ore is crushed to optimum size, suspended in 20-40 wt. % H_2O , and then pumped to the trough formed by the rolls. The roll spacing and speed is established by trial. The clay or slime is collected on the softer roll, and forms a solid cake upon pressure release (thixotropic); and rolls are sep. cleaned into troughs by knives. For example, Florida phosphate is crushed to not less than 1.41 mm. size, suspended in 20-40 wt. % H_2O , and roll crushed at 15 rpm. The concentrate is relatively free from clay.

3425. Anderson, G.E., Experiments on the rate of wear of sand grains, J. Geol. 34 144-58, 1926.

On the basis of experiments, Anderson concludes that the rounding of sand grains in nature by mechanical wear is an exceedingly slow process. In order to become rounded, sand grains must pass through more than one sedimentary cycle. Coarser materials fracture sand grains, hence sands must be isolated from coarser materials before rounding can take place. Rounding is believed to take place more rapidly in water than in

air. The relatively high degree of "rounding" in dune sands is attributed chiefly to selective transportation.

3426. Colback, P.S.B., and Wird, B.L., The influence of moisture content on the compressive strength of rock, Manuscript Nat'l. Mech. Eng. Res. Inst., Pretoria, South Africa, 1964.

The compressive strength was twice as high after drying as when wet. The 2 rocks tested were quartzite shale and quartzite sandstone of .28 and 15% porosity. Wetting by other fluids gave strengths which fit Griffith's theory as a result of different surface tension. Testing under hydrostatic pressure did not affect tensile strength. It took 5 to 200 days for moisture to become constant.

3427. Sullivan Concentrator Staff: The Consolidated Mining and Smelting Company of Canada Limited, The Sullivan Concentrator, in Milling in America, N. Arbiter, Ed., VII Int. Min. Proc. Cong. 177-204, 1964.

3428. Connor, P., et.al., Determination of particle size by beta-backscattering, J. Appl. Chem. 9 525-31, Oct., 1959.

3429. Conway, J.A., Mining and crushing methods and costs at the Quarry of the John T. Dyer Quarry Co., Monocacy, Pa., U.S. Bur. Mines Info. Circ. IC6405, 28pp, 1931.

It presents the history of the development of a trap-rock

quarry, explains methods used, and gives detailed explanation of costs.

3430. Cornet, I., and Grassi, R.C., Study of theories of fracture under combined stresses, ASME Trans. ser D 83 39-44, March, 1961.

3431. Cornu, P., Completely automatic plant for treatment of iron ore in aerofall mill, Zeit. Erzbergbau u. Metallhuettenwesen 17 (1) 25-8, 1964.

Characteristics of aerofall mill installed in ore treatment plant of Carol Lake in Canada; control system of 6 aerofall mills and automation of grinding several hundred tons of iron ore per hour.

3432. Cosson, J., Crushers and hammer-mills, characteristics of construction and use, Construction 14 (4) 97-102, April; (5) 138-45, May; (6) 174-80, June 1959.

Tables show types of equipment used in France, with size of jaw opening, number and size of rolls, weight, power needed, revolutions per min. hourly production, and make; criteria for choice of machines; construction of foundation for heavy machines.

3433. Bond, F.C., Crushing and grinding with pyro-processing, Pit and Quarry 54 (7) 62-63, 166, 1962.

B. discusses the three principles of comminution and presents formulas for the calculation of energy input. A table of average work indexes of common materials is included.

3434. Cowan, John G., and Haywood, Stuart A., Sintered alumina abrasives, Brit. Pat. 944 939, Dec. 18, 1963, 3pp.

Tough fine-grained abrasives are produced by wet grinding Al_2O_3 or its hydrate, with less than 20% of selected mineral sintering agents, to less than 5μ particle size, drying, compacting, granulating, screening, and sintering at 1400-1550°.

3435. Cox, A.W., Method and cost of quarrying crushing and grinding limestone at the Quarry of the North American Cement Corp., Security, Md., U.S. Bur. Mines Info. Circ. IC6554, 14pps. 1932.

3436. Coyle, D.S., Empire concentrator-iron ore's first two-stage autogenous grinding flowsheet, Minn. Univ. School Mineral & Met. Eng. Min. Symposium 9-13, January, 1965.

Two-stage autogenous grinding, six unit concentrator started up in fall of 1963 and had exceeded design capacity by Jan. 1964; autogenous grinding concept has commercially equalled pilot plant predictions with one main exception of pebble consumption; relatively small steel ball charge has been employed in some of primary mills since startup; grinding and concentrating flowsheet, mill capacity, grind, power requirements and metal wear are compared to pilot plant results.

3437. Coyle, D.S., Progress report on autogenous grinding, Min. Congress J. 49 (3) 35-40, 1963.

Two yr. of pilot plant testing were required to develop flow-sheet for new iron ore concentrator on Marquette range in Minnesota; pellet production will be over 1,000,000 tons/yr; concentrator facilities of plant will have first 2-stage, fully autogenous grinding flowsheet in iron ore industry; one of principal features is that required grind to achieve liberation of iron bearing mineral is in range of 95 to 98% minus 500 mesh.

3439. Crabtree, D.D., Kinasevich, R.S., Malar, A.L., Meloy, T.P., and Fuerstenau, D.W., Mechanisms of size reduction in comminution systems, I: Impact, abrasion and chipping grinding, Trans. AIME 229 201-6, 1964.

Each comminution mechanism produces particles of a characteristic size distribution.

3440. Crane, W.R., Iron-Ore (Hematite) mining practice in the Birmingham District, Alabama, U.S. Bur. Mines Bull. B239, 143pp., 1926.

This article discusses mining methods from early to recent practice and offers suggestions for improvements in mining methods.

3441. Crocker, B.S., Rock-pebble milling at Anaconda's new Butte concentrator, Min. Eng. 16 (5) 74-8, 1964.

Metallurgical and engineering factors considered in designing pebble mill grinding of copper ore from Butte mines in new concentrator; mills are 12 x 21 ft. rapid discharge pebble mills; ore rock is used for pebbles; mills are in closed circuit with cyclones; by varying pebble feed to mill, power is automatically controlled.

3442. Crocker, B.S., Review of autogenous grinding, Min. Congress J. 49 (11) 4851, 1963.

Equipment and current practices employed in autogenous grinding with sized media are illustrated by performance of plants in South Africa, Finland, Sweden, Canada, Germany and United States; autogenous grinding with unsized or run of mine media is illustrated by performance of installations in South Africa, Sweden, Canada and United States.

3445. Crocker, B.S., Developments in autogenous grinding, Min. Congress J. 47 (7) 52-5, 1961.

Development of autogenous grinding has gone along 3 main lines; dry primary grinding, wet primary grinding and secondary pebble grinding; wet pebble milling uses screened ore as grinding media; pebble milling practice in Canada, United States and South Africa; means of automatically controlling pebble load to give maximum power has been very successful; testing of ore suita-

bility; grinding of taconite in test mill.

3446. Crocker, B.S., Recent developments in pebble milling, Min. Eng. 11 (5) 527-30, 1959.

Autogenous grinding in fine grinding part of circuit, i.e., from 6 mesh to 92% -325 mesh; effect of ore hardness, pebble size, and flint pebbles; recent plants; capital cost of autogenous grinding plants; pebble grinding on sulphide ores; flexibility of pebble plants; pebble consumption; high speed mill operation.

3447. d'Argoeuves, N., and Javelle, P., Application of a vented ball mill to controlled grinding (in Fr.) Rev. Ind. Minerale 47 (3) 225-32, 1965.

A description of the grinding plant is given followed by a detailed description of some expts. using a calcareous ore contg. 25% Fe. The effects of variation of the quantity and diam. of the balls, air flow, and opening of the control sieve on the output are shown. The optimum conditions of operation and the results obtained from these are discussed and found comparable with those obtained by an autogenous mill.

3448. Dash, W.C., Distorted layers in silicon produced by grinding and polishing, J. Appl. Phys. 29 228-9, Feb. 1958.

3449. Datta, B.C., and Nandi, S.K., Ball-mill grinding of coal, I and II, Trans. Indian Inst. Chem. Engrs. 10 31-45, 46-52, 1957-58.

The efficiency of ball mill grinding was detd. by measuring the surface area of a high-ash coal. Differential screen analysis was selected for detg. the specific surface of the coal particles. Optimum conditions for batch ball-mill grinding are as follows: a feed size of 0.02 times mill diam., an initial charge equal to 20% of mill vol., mill speed at 63% of crit., and a grinding period not to exceed 15-30 min. Empirical equations are derived correlating operating variables with surface area. In open-circuit grinding with an air classifier, optimum conditions are as follows: a vacuum of 1.2 in. of H_2O in the classifier, mill speed at 44% of crit., feed charge equal to 10% of mill vol., very short grinding periods, ball size and load same as with batch grinding. In closed-circuit grinding, the optimum conditions are: feed charge equal to 2% of mill vol., and high vacuums as it results in greater circulating load and hence greater mill capacity. Time of grinding, ball size and load are the same as with open-circuit grinding.

3451. Davies, Gail F., and Dodds, Harry W., Powdering titanium without oxidation, U.S. Pat. 2 892 697, 6/30/59.

Ti and Ti-base alloys in the form of chips, sponge, etc., finer than 4 mesh or preferably 10 mesh, are pulverized to

sizes suitable for use in powder metallurgy, or about 80-90% between 30 and 100 mesh, by comminution in an attrition mill between Ti alloy plates in ice water, without a substantial increase in O and N.

3452. Bond, F.C., Recent advances in grinding theory and practice, Brit. Chem. Eng. 8 (9) 631-34, 1963.

Three principles of particle breakdown are defined and compared with the Rittinger and Kick theories. Equations are given for calculating product sizes from surface area measurement and for calculating the power required by, and the capacity of, grinding equipment.

3453. Dearden, J., and Swindale, J.D., Effect of alternate corrosion and abrasion on some ferrous metals, Iron & Steel Inst. J. 185 227-34, Feb. 1957.

3454. Bond, F.C., Crushing and grinding calculations: I, Brit. Chem. Eng. 6 (6) 378-85, 1961.

Comminution theories and principles are discussed, and work index equations for different particle size reduction methods are given. Sizes of grinding balls or rods and size distribution of grinding media are also discussed. II. Ibid., (8) 543-48. The effects of mill diameter, downward slippage of ball charge, and ratio of oversize to feed upon performance and power consumption are discussed. Mill and grinding media

wear is considered as is also mill speed. Factors are given for converting closed-circuit work values to open-circuit values. Correction factors are given for variations in work index which arise when laboratory grindability tests and impact crushing tests give differing values. 2 figs., 3 tables, 20 refs.

3455. de Kazinczy, F., Brittle and ductile fracture in metals, Jernkontorets Ann. 143 617-45, 1959.

Fracture in a perfect single crystal of a metal occurs at a stress 20-1000 times greater than in the com. metal, indicating that the fracture starts at some fault generally originating in the plastic deformation.

3456. Deney, S.J., Operation of a ball mill at supercritical rates, Tsvetn. Metal 35 (7) 3-8, 1962.

The effect of the percentage of crit. r.p.m. ψ and the filling coeff. of a ball mill with balls ϕ , on the sp. capacity q , detd. by the production of fresh -0.08 mm. particles, and the useful power N_n of the ball mill were examd. N_n was detd. by taking the difference in the power used by the ball mill when filled with balls and when filled with ore. With varying ψ and ϕ , the max. values of q corresponded to the max. N_n of a mill operating with ore under the same conditions. At ψ greater than crit., max. q and N_n were reached at $\phi = 10-20\%$, and were below the corresponding max. at ϕ greater than 20%. The curves

$N_n = f(\psi)$ for a mill operating with balls only were shifted to the right of the similar curves of operation with balls and ore. At ψ greater than crit., effective grinding can be expected only at ρ less than 20%. Increasing ψ increased N_n .

3457. Deney, Stoyan; Georgiev, Dimitor; Vasilev, Emanuil, and Tsal'ov, Effect of temperature on grinding and flotation of ore, Rudodobiv Met. (Sofia) 20 (2) 11-14, 1965 (Bulg).

Increase of the pulp temp. in the grinder and classifier from 10 to 55° increased the output of the aggregate by 16.5%.

3458. Denning, R.M., and Conrad, M.A., Directional grinding hardness of quartz by peripheral grinding, Am. Mineralogist 44 423-8, March, 1959.

3459. Denyakin, Z.A., Cyclone mill, Zh. Vses. Khim. Obshchestva im. D.I. Mendeleeva 7 577-8, 1962.

A detailed description is given of a rotary mill equipped with a spinning cone with openings of variable dimensions, for fine grinding of soft solids such as chalk and clay.

3460. Deshko, Yu. L., Kreimer, M.B., and Krykhtin, G.S., Crushing of materials in the cement industry, Moscow: Stroizdat, 275 pp., 1964.

3461. Boloni, I., Some regularities of grain distribution and

fineness variation as observed in hammer mill products, Acta Tech. Acad. Sci. Hung. 45 (102) 45-64, 1964. (In English)

The distribution of particle size can be approximated with reasonable accuracy as a log normal function, both for the end product and for a partially crushed load in hammer mills. The distribution curves of sieve fractions plotted in Gaussian co-ordinate systems are linear functions. The relation between average particle size and specific surface is hyperbolic. The selection of these otherwise equivalent parameters depends entirely on practical considerations. In continuous operation an increase in grinding capacity always results in a decrease in the fineness of the load, i.e., the mass being ground, and of the end product. Load quantity and grinding capacity, however, are not in a linear relation to each other. Increase in grinding capacity is not proportional to increase in load. The particle size of the load and the particle size of the end product show a relation apparently independent of the operating conditions of the mill. A finer load results in a finer product. A relation is shown between grinding time and particle size in the load and in the final product. For a given mill and a given particle size, grinding capacity is a bivariant function of load quantity and particle size. A standard expression for the particle size distribution is defined and found to be a logarithmic function of average size.

3462. Deters, Wolfgang, and Grohn, Hans, Mechano-chemistry of

cellulose and cellulose derivatives II: Mechanical-chemical degradation of cellulose and cellulose triacetate in a vibrating mill, (Tech. Univ. Chem., Leuna-Merseburg, Ger.). Faserforsch. Textiltech 14 58-62, 1963.

The equations described in Part I were used to calc. the av. degree of polymerization of material ground in the vibrating mill for any specific length of time. The values obtained showed good correlation with published results.

3463. Dettmer, P.B., Trends in design of large grinding mills, Min. Eng. 17 (4)57-63; (5) 68-71, 1965.

Reasons for trend toward larger mills include lower capital cost per unit of ground product, less building space required, better grinding efficiency with larger diameter mills, more efficient utilization of mill liners and grinding media, fewer and more economical units of ancillary materials handling equipment and more economical adaptation to automation and instrumentation; operating results for 4400 hp ball mills in cement industry; evaluation of application of larger mill installations to other minerals.

3466. Digre, M., Survey of developments and progress of grinding in tumbling mills for mineral dressing purposes during last 20 years, Bergvesen og Metallurgi 19 (7) 146-54, 1959.

Importance and possibilities of autogenous grinding, hydrocyclone classification and grinding control for present and future improvement are stressed.

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3467. Dimmick, R.L., et.al., Particle-sizing method for aerosols and fine powders, AMA Arc. Ind. Health 18 23-9, 1958.

3468. Bikerman, J.J., Work of fracture and surface energy, Glass Ind. 44 (7) 382-83, 409, 1963.

The opinion is often expressed that elastic deformations do not involve any release or absorption of heat. In reality, however, only reversible thermodynamic cycles on elastic bodies involve no heat transfer.

3469. Dixon, R.H.T., Some effects of heat-treatment upon the impact-fatigue life of Ni-hard grinding balls, J. Iron Steel Inst. (London) 197 40-8, 1961.

White cast-iron balls, 1½ in. diam., were heat-treated and repeatedly dropped 21 ft. The average life to fracture for four balls was 90-4350. The life as cast was 487 drops. The balls having the shortest life (90 drops) had been heat-treated 4 hrs. at 500° and air cooled; the DPN hardness was 625. The structure was 10% austenite tempered martensite pearlite aggregates in carbide matrix. The ball having the longest life (4350) had been held 48 hrs. at 275° and air cooled, and had a hardness of 770 DPN. The structure was tempered martensite bainite aggregates in carbide matrix. The impact-fatigue strength of Ni-hard is improved by the redn. of the austenite content of the as-cast material provided that the final structure is free of pearlite. The higher the proportion of tempered martensite,

as distinct from bainite, the greater is the strength of the iron. The alloy cast-iron has wear resistance much superior to that of forged medium C steel. No difficulties from ball breakage occurred in a 14-month test period.

3470. Dixon, R.H.T., Ni-hard grinding balls far outlive steel, Eng. 190 (4933) 598-9, Nov. 4, 1960; see also German Transl. in Aufbereitungs-Technik 2 (6) 250-2, June, 1961.

Double heat treatment further increases wear resistance of Ni-hard grinding balls so that under normal operating conditions, they can serve 14 times as long as steel balls in sinter mills; results of testing 2¼ in. diam. sand cast balls in refinery interested in development of improved types of Ni-hard. Cost twice as much, though.

3471. Djingheuzian, L.E., Forum on non-cataracting ball mill, Can Min. & Met. Bull. 51 (556) 495-504, 1958.

This article presents the following group of papers:

Study of Non-Cataracting ball mill, J.E. Myers;

Analysis of Non-Cataracting ball mill, H.E. Rose;

Grinding at Humboldt and Republic Mills, R.R. Smith;

Suggests following changes to a particular mill:

Reduce speed from 74 to 60% critical;

Reduce ball size from 1½ to 1 inch;

Reduce ball change from 40 to 25%. Get same production with lower cost. Reason: A classifying pool in mill.

Trunion overflow type mill. Need a good rod mill to prepare 8-10 mesh feed for ball mill.

3472. Djingheuzian, L.E., Forum on ball milling, Can. Inst. Min. & Met-Trans. 60 290-304, Discussion 378-9, 1957.

Study of operating data from ball mills operating in Quebec, Ontario, Manitoba and British Columbia; relationships between work index and liner shape, and work index and wear of balls; diameter and ball, of ball mill, reduction ratio, feed size, percent critical speed and percent mill volume occupied by ball charge; efficiency of ball mill.

3473. Dobson, P.S., and Wilman, H., Friction and wear, and their inter-relationship in abrasion of single crystal of brittle nature, Brit. J. Appl. Phys. 14 (3) 132-6, 1963.

Friction coefficient μ and mass wear rate M during abrasion of brittle material in single crystal form (rocksalt, cube face cleavage) studied quantitatively as functions of abrasive particle diameter D at load 0.5 kg; 3 types of (M, μ) relationship observed, in different ranges of depth of indentation of abrasive particles; modified theory of friction and wear in abrasion of brittle solids developed.

3474. Dobson, R.D., Disintegrating (crushing and grinding) Chem. Weekblad 55 (5) 45-6, 1959.

Attrition of materials in a closed circuit is described.

3475. Dolezil, Milan, Complex treatment and utilization of open-hearth slag (In Czech), Hutnicke Listy 20 (12) 850-4, 1965. The open-hearth slags contain Fe oxide 12.3-20.4, MnO 4.3-8.5, SiO₂ 12.0-22.0, Al₂O₃ 3.6-8.0, CaO 26.8-42.1, MgO 8.8-11.7, P₂O₅ 1.1-3.8, Cr₂O₃ 0.5-2.5, and S 0.1-0.3%. The most important economically is the content of metallic Fe, which in Czechoslovakian open-hearth slags is 5-15%. The slags consist mineralogically of wustite, complex Fe, Ca, Mg, Al, and Mn silicates, small amts. of magnetite, and graphite is present occasionally. The slag can be economically utilized by complex treatment which includes grinding, classification, and magnetic sepn. The products can be used in steelmaking, blast furnaces, and for production of sintered aggregates, lime fertilizers, and building materials.

3476. Dolezil, Milan, Bulandr, Jiri, and Jarkovsky, Vladimir, Pretreatment of the Barrandien lean iron ores, Celostatni Konf. Rudn. Hornictvi Upravnictvi, Prague 105-20, 1962.

Mineralogical and petrographic compn. of the Barrandien Fe ore is such that grinding to -1 or -2 mm. size is necessary.

3477. Domaas, F.B., World-wide mining operations now use advanced autogenous grinding systems, Eng. & Min. J. 165 (12) 90-9, 1964.

In new 42,000 tpd copper concentrator at Butte, Mont. twelve 12 x 21 ft pebble mills are driven by 1250-hp motors equipped

with grate discharge; in Sweden, wet primary autogenous system 22x7 ft mill treats Vassbo ore-very abrasive galena-bearing quartzitic sandstone; at Carol project, Newfoundland, 21 ft dry air-swept, combined crushing and grinding units take 6 to 8 in primary crushed specularite-magnetite ore and reduce it in one operation to its natural grain size; six 24x8 ft autogenous Cascade Mills at Upper Michigan plant treat cherty magnetite.

3478. Domaas, F.B., New ideas, equipment spur autogenous boom, Eng. & Min. J. 165 (10) 91-5, 1964.

Design, operation and applications of new autogenous grinding equipment including Aerofall mill which is lined with wear resistant liners to improve durability; Cascade mill eliminates possibility of size segregation longitudinally with mill; vertical impact pulverizer machine not only effectively grinds tough ore but does so with greatly reduced equipment wear and grinding costs; research by another company shows that intermediate autogenous grinding can efficiently replace rod mill and ball mill stage of conventional grinding circuit.

3479. Dorofeev, L.S., Electro-acoustic signals for control of ball mill loading, Teploenergetika 7 (9) 65-7, 1960.
Effect of interference signal on voltage and frequency of emf of acoustic signal; comparison of control methods where value of voltage and frequency is used as useful signal.

3480. Bhrany, U.N., and Brown, J.H., Particle-size measurement and control, Trans. AIME 223 (3) 248-54, 1962.

Several methods are compared.

3481. Doyen, J.E., Automatic crusher control means no human errors, Rock Prod. 67 (9) 64-6, 1964.

In addition to audible and visible alarms advising operator or rock crusher of problems, measurement and indicating or recording of variables are provided as valuable aids to operator; to achieve complete automation involves installation of controlling equipment; basic devices then send their signals to controllers rather than to operator through alarms, indicators, and recorders only; chart shows general variables, sending devices, and functions in both manual and automatic control systems.

3482. Drosihn, U., Wear problems of tube mills, Zement-Kalk-Gips 14 (8) 325-39, 1961.

Results of series of tests on lining plates made of various cast alloys; new high grade grinding balls cause fractures in conventional linings and require use of very hard linings made of rolled or forged steels.

3483. Druva, R.L., New equipment for today's flowsheet, Min. World 22 (10) 42-3, 1960.

New developments, techniques, automation and computer applications in milling industry; completely automatic 3-stage crushing and ore storage plant; trend continues to larger screen sizes and grinding mills and to autogenous grinding mills; new electrostatic separation at low capital and operating costs; developments in iron ore pelletizing processes and taconite ore beneficiation.

3484. Duke, James B., Grinding kaolin with sand, U.S. Pat. 3 097 801, 7/16/63, 5 pp.

Kaolin in aq. dispersions is rapidly ground by 10-35 mesh sand in a smooth rotating vessel to increase the proportions of finer particles such as the finer than $2\ \mu$ size desired for coating paper. The vessel should be charged to 40-75% of its capacity by vol. with the slurry contg. about 75% clay plus sand by wt. and 12-2-% clay/sand ratio, and rotated 1-6 hrs. at slower speed than required for the sand to travel as fast as the vessel or generally at 200-300 ft./min. peripheral speed. The sand is not abraded, and is readily screened from the clay after processing. The clay dispersion may be stabilized with 0.5% $\text{Na}_4\text{P}_2\text{O}_7$. In grinding 1200 g. kaolin of $6\ \mu$ av. particle size and 16% finer than $2\ \mu$, with 10 kg. sand of 10-35 mesh size for 4 hrs. at 80 r.p.m., the kaolin finer than $2\ \mu$ was increased to 43%, while when 25% of the sand was 120-325 mesh this product

amounted to 29% after the same processing. In another lab. test the 2 μ product was 44% with the vessel loaded to 45% capacity, and 33% with 75% capacity loading and other conditions the same. The 2- μ product was increased 40% with 12.5% clay/sand ratio, compared to 30% with 20% ratio, and 10% with 50% ratio, in a 6-hr. lab. test. In a larger drum 48 lb. kaolin rotated with 402 lb sand and 150 lb. H₂O had its 2- μ particle content increased from 16 to 58% in 1 hr.

3485. Dumoulin, G., Control of grinding by measurement of the permeability of the ground products, Ind. Ceram. (515) 18-22, 1960.

The sp. surfaces of finely ground materials are empirically detd. as a function of air movement through a known vol. and cross section of the material. The app. is illustrated and the development of the equations used is reviewed.

3486. Dunkin, H.H., Ore dressing developments in Australia, 1957, Chem.Eng. & Min. Rev. 50 (6) 43-50, 1958.
Equipment installed, tested.

3487, Dunning, John S., Quarrying and crushing methods and costs at the Avon Mountain Trap-Rock Quarry of the Atlas Sand, Gravel & Stone Co., West Hartford, Conn., U.S. Bur. Mines Info. Circ. IC6912, 7pp., 1936.

3488. Durczak, Stefan, and Tarczynski, Kazimierz, Influence of the mineralogical composition on the grinding properties of clinker, Cement-Wapno-Gips 19 (7-8) 206-13, 1964. (Pol.).

A review with 9 references.

3489. Ruhl, H., Stress distribution in the mill heads of large tube mills, Zement-Kalk-Gips 18 (5) 217-222, 1965.

3490. Dzhaparidze, P.N., and Tvaradze, L.R., Changes in the physicochemical and technological properties of coal after its pulverization in different gaseous media, Zh. Prikl. Khim. 38 (6) 1256-62, 1965 (Russ).

The effects of grinding coal in air, N, CO₂, and coke-oven gas on its properties were studied. The amt. of O-contg. compds. in the volatile portion in coking increased. The amount of CO₂ and H₂S was highest in the coking products of coal ground in air. The yield of tars was lowest after grinding in air. The highest crushing strength of briquets was exhibited by coal pulverized in N. The effect of the medium on Tkvarchel'sk coal was negligible. It was considerable for Tribul'sk coal.

3491. Eastman, E.A., and Rowland, F.P., Wet and dry primary autogenous grinding of iron ore, Int. Min. Proc. Congr. 7th, N. Arbiter, Ed., 537-45, 1964.

Experience with dry grinding. Aerofall mill used to prepare low-grade martite ore for gravity concentration and flotation

and wet grinding; Cascade mill for grinding hematitic ore for spiral concentration. In dry grinding mill, continuous comparison with conventional crushing and rod mill operation is possible and results are compared. Eng. Index, 168, Jan. 1966.

3492. Eckerd, I.W., Sanner, W.S., and Baker, A.F., Crushing chestnut-size anthracite to produce buckwheat No. 1 and rice sizes, U.S. Bur. Mines, Rept. Invest. No. 5578, 20 pp., 1960. The crushing of chestnut-size (1-5/8 X 13/16 in.) Pennsylvania anthracite in 4 com. crushers (impact, jaw, hammer-mill, and gyratory types) was studied to det. which could produce the largest portions of buckwheat Nos. 1 and 2 sizes (9/16 X 3/16 in.). Single pass dry and wet crushing techniques and the effect of stage crushing were evaluated. Calcns. were made to show the effect of closed-circuit redn. on production rates and yield of the various sizes. The data show that the gyratory crushers produced the greatest percentage of the desired sizes. A ring-type hammer mill produced the greatest tonnage of buckwheat No. 1 and rice (14.9 tons/hr.) during dry grinding tests, but the yield of these sizes was only about 55% as compared with 62-70% for the gyratory crushers. The impact and jaw crushers produced the smallest amt. of buckwheat and rice and the largest quantity of oversize material. The addn. of H_2O to the crusher feed reduced the capacity of both jaw and gyracone crushers but did not appreciably affect the sizes produced. When H_2O was used in a gyrasphere crusher at the rate of 135

gal./ton, the yield of buckwheat and rice declined 12% while a small increase occurred in crushing capacity. Stage crushing with the gyrasphere unit increased total output 26% and the yield of buckwheat and rice by 32.6%. Although closed-circuit operation of the same machine did not affect the output of buckwheat No. 1 and rice, it did eliminate oversize and increased the percentage of "on size" product and undersize produced.

3493. Banerjee, A., and Sen, Sudhir, Particle size determination of ceramic materials -- a review, Trans. Indian Ceram. Soc. 22 (1) 1-13, 1963.

The range and applicability of the methods used in determining particle size and size distribution in ceramic materials are reviewed.

3494. Ehrhardt, H., Considerations concerning function and design of impact crushers, Aufbereitungs-Technik 3 (10) 437-46; (11) 479-89, 1962.

Determination of regularities which would make possible calculation of impact processes; problem of throughput, size distribution, specific capacity, specific wear, impact velocity, properties of feed, form, dimensions and setting of impact elements.

3495. Eichholz, G.G., Radioactive marking of steel balls for

grinding tests, Canada Dept. Mines & Tech. Surveys, Mines Branch, Tech. Bull. TB 12, 6 pp. Nov., 1959.

Grinding balls were labeled with radioactive tracers in order to identify them and determine wear after various times and conditions of use; choice of radioactive isotope for tests was governed by availability, ease of handling, compatibility with molten metal, ease of detection, convenient half-life and cost; Co-60 and Fe-59 met these conditions.

3496. Ellman, R.C., and Belter, J.W., Grindability testing of lignites, U.S. Bur. Mines Rept. of Invest. RI5167, 38 pp., 1955. Presents results of a series of tests on grindability of lignites and factors that influence grindability determination.

3498. Escudero Sainz, E., Contribution to theory of size reduction of particles, Genie Chimique 88 (2) 49-53, Aug. 1962. Published data and laboratory tests are used to determine quantity of energy used in crushing; data provided by theories of Kick and Rittinger are employed. Before 32nd Int. Congres Indus. Chem., Barcelona.

3500. Esslinger, P., Problem of selecting materials for parts exposed to abrasive wear, VDI Z. 105 (26) 1209-18, 1963. Wear resistance is not a defined material property but constitutes a complex integral function dependent on wear conditions. This is attributed to interaction of variety of macro-and

micro-wear mechanisms, each of which shows different relationship with material properties. Relative contribution of these processes, depending on wear conditions, is analyzed. Example of cases where simple relationship can be derived between wear resistance and material properties.

3501. Everard, F., and Janes, R., Dry autogenous grinding and dry magnetic separation of iron ores. Trans. AIME 223 88-96, 1962.

A 6.5ft. Aerofall mill with separators was installed as a pilot plant for taconite, magnetite, other iron ores. Two kinds of dry separators were developed -- variants of unual magnetic design. Adding balls to Aerofall mill did not affect fine grained magnetite, but speeded production of specular ores. Optimim speed is uncertain. Dry separation is OK for coarse-grained ores.

3502. Eysiovich, S.G., Zhuravlev, S.I., and Sorokina, T.P., Production of rich concentrates from the Krivoi Rog magnetite quartzites, Obogashch. Rud 9 (1) 3-9, 1964 (Russ).

Technological flow sheets are offered for beneficiation of the Krivoi Rog magnetite ore finely disseminated in quartzites. The flow sheets provide for production of rich concentrates contg. 63.65, 67, and 69% Fe. The concentrates, contg. 63.65 and 67% Fe, can be produced by 3-stage wet magnetic sepn. The quality of the concentrate is detd. by the grain size of final

grinding: (1) 70% 0.053 mm. fraction (i.e. 90% 0.07 mm. fraction) yields 63% Fe concentrate, (2) 90% - 0.053 mm. fraction yields 65% Fe concentrate, and (3) 95% - 0.053 mm. fraction yields 67% Fe concentrate. The finishing of the 67% Fe concentrate by flotation (with subsequent addnl. grinding) yielded a concentrate contg. 69% Fe.

3503. Ewings, D.J., Automatic control of grinder and pulverizer installations, Indus. Electronics 1 (13) 691-3, 1963.

Unusual control problems in grinding and pulverizing machinery caused by greatly varying size of raw material are discussed; details of successful control system are given for vibratory feed system.

3504. Fabian, Robert J., Wear-resistant materials and coatings, Mater. Design Eng. 56 (6) 131-46, 1962.

A survey. 10 references.

3505. Fadeev, V.I., Modern equipment for the crushing and grinding of ores, Tr. Nauchn.-Issled i Proektn. Inst. Mekhan. Obrabotki Polezn. Iskop. (123) 241 pp., 1959.

3506. Fagerberg, B., New vibrating screen improves iron ore processing, Eng. & Min. J. 161 88-91, July, 1960.

3507. Fahlstroem, P.H., Autogenous grinding, Min. World 24 (10) 30-4, 1962; (11) 19-23, 1962.

Experience with grinding hard abrasive quartzitic ore to liberate galena at 70% minus 230 mesh at Vassbo in Sweden. Adjustment of feed composition, controlling feed from several bins, pulp density control, cyclone control, and mill speed control. Total wear including scrap losses is 1.02 lb/metric ton.

3508. Fahlstroem, P.H., Autogenous grinding during ore treatment at Vassbo mine, Zeit. fuer Erzbergbau u. Metallhuettenwesen 14 (11) 553-62, 1961.

Grinding properties of lead-zinc ore with pyrite and 85% quartz at Boliden, Sweden; annual throughput of plant is 150,000 tons; after preliminary crushing ore is ground in cascade type mill at rate of 15 to 28 tph; analysis of process of grinding. Uses Harding - Losche Cascade mill, speed 75% critical, power 23 KWH/ton..

3509. Fahlstrom, P.H. Son, Comminution by tumbling autogenous charges, Mine & Quarry Eng. 27 (6) 262-72, 1961.

Survey of rock grinding methods. Grinding is process of energy conversion in which density and hardness of grinding bodies is not significant, but size ration between grinding bodies are important. By use of rock grinding, costs are reduced, liberation is obtained at coarser mesh, and at the same time iron

contamination is avoided.

3510. Fahlstrom, Per H: son, Rock grinding in the Vassbo mine, Tek. Tidskr. 90 1237-45, 1960.

A commercial plant for wet rock grinding in one step is described.

3511. Fahlstroem, Per H:son, Rock grinding, Tek. Tidskr. 90 153-62, 1960.

A review of grinding by using the material to be ground as the grinding medium. The possibilities and advantages of the method are discussed.

3512. Fahlstrom, P.H., and Andren, T., Theory for wear in wet rod mills and Cascade mills, Int. Mineral Processing Congr. 7th-Tech. Papers, N. Arbiter, Ed., N.Y. 515-36, 1964.

Wear of rods, rod mill liners and Cascade mill liners is explained as constant linear wear rate of exposed surfaces.

Main factors affecting wear are ore hardness, mill diameter and mill speed and, in case of Cascade mills, ore density. Simple empirical formulas for steel consumption as function of these variables were deduced for two kinds of mills. Formulas are valid with great degree of certainty for rod wear, but are not proved for mill liners.

3513. Fahlstrom, P.H., and Andren, T., How rubber-lined grinding mills save money at Boliden, Metal Min. & Proc. 1 (6) 36-9, 1964; (7) 27-40, 1964.

Rubber is used to make nonplugging grinding mill discharge grates. Feed end and shell liners which reduce mill downtime for relining are decreasing comminution costs and raising grinding throughput at Boliden base metal concentration plants in Sweden. Preliminary test work done at Boliden in fitting ball and pebble mills with rubber liners, installation techniques, comparison of wear with steel liners and grindability characteristics of rubber liners.

3515. Fahrenwald, A.W., Gyratory ball mill, Min.Congress J. 45 (4) 94-7, 1959.

Design, principle of operation, and performance of mill; in gyratory mill each ball, under heavy pressure from all directions develops sphere or zone, of activity. Shell diameter, shell depth, static ball depth, radius of gyration, and gyrational frequency, are basic factors entering into design and operation of mill. Capacity of mill; steel consumption and grinding efficiency.

3518. Fahrenwald, A.W., and Thom, Clarence, Batch classification in the laboratory, U.S. Bur. Mines Rept. of Invest. RI2924, 5 pp., 1929.

Describes and illustrates a batch laboratory classifier and

elutriator and gives an application of the apparatus to grinding studies.

3519. Fairhurst, C. (Editor) Rock Mechanics, Proceedings of Fifth Symposium (May 1962) Macmillan, New York (1963).

3520. Fairs, G. Lowrie, Energy-new surface relationship in particle crushing, Ind. Eng. Chem., Process Design Develop. 1 (3) 236, 1962.

Correspondence on research by Zeleny and Piret. Energy usage for quartz (7.7×10^4 ergs/sq. cm.) is similar to that obtained by F. (CA 48, 4892d).

3521. Faust, J.W., Jr., and John, H.F., A comparison of etching and fracturing techniques for studying twin structures in Ge, Si, and III-V intermetallic compounds, J. Electrochem. Soc. 107 562-4, 1960.

Three methods of revealing twins by fracturing are discussed. The cleavage planes for Ge and Si are the (111) planes. On careful fracturing, these materials break on their cleavage planes. This technique is suitable for use on thin sections cut from grown crystals or on dendritic crystals which grow naturally in the (112) direction. In this technique a line is scribed across the (111) face parallel to the (110) direction to control where the fracturing is to occur; fracturing is accomplished by bending. Each twin plane changes the direction

of the (111) cleavage planes.

3522. Fawcett, H.H., and Gardner, G., Small particle detector, Ind. & Eng.Chem. 51 sup87A-8A, June 1959.

3523. Feld, I.L., McVay, T.N., Gilmore, H.L., and Clemmons, B.H., Paper-coating clay from coarse Georgia kaolins by a new attrition-grinding process. U.S. Bur. Mines, Rept. Invest. 5697, 20 pp., 1960.

Results of batch tests in 5- and 10-in.-diam. attrition grinders proved that a coarse kaolin contg. about 13% -2 μ , equiv. spherical diam. (e.s.d.) particles was readily ground to give a product with 88% -2 μ e.s.d. material. The process is basically the intense agitation of a slurry composed of the material to be ground, a granular grinding medium, and a suspending fluid. Attrition grinding may be done in many types of agitation devices, but max. grinding or particle-size redn. was obtained when the process was completed in units developing intense agitation. Some agitating devices, such as close-clearance shearing devices and high-speed blenders, are not satisfactory as attrition grinders because the grinding medium itself is crushed in these units. Ottawa sand (14 by 28 mesh) was the grinding medium used in most tests, but other granular materials, such as staurolite and zircon, proved satisfactory. As the size of the medium is decreased, the size of ground particles produced also is decreased. H₂O was the only liquid

used as a suspending fluid in this study, but there is no apparent reason why other liquids could not be used. Although effective attrition grinding was obtained with flocculated slurries, better performance was noted when the suspensions were deflocculated. Satisfactory dispersants included Na hexametaphosphate, $\text{Na}_4\text{P}_2\text{O}_7$, Na triphosphate, Na tripolyphosphate, Na silicate, and Na_2CO_3 . Best results generally were obtained when charges contained high percentages of solids and had a high ratio of grinding medium to material being ground. When this ratio is very large, the capacity of the grinder is very small. Satisfactory operation was obtained when the grinding medium comprised 48-95% by vol. of the total solids in the grinding charge. There are numerous other potential uses for this grinding process besides particle-size redn. per se. Some of these are: dispersion and (or) grinding of finely divided solid fuels in liquid fuels for use in boiler combustion chambers, diesel engines, gas turbines, or rocket reaction chambers, dispersions and (or) emulsification of solids or liquids in liquids, and promotion of known reactions and the possibility of finding new phenomena requiring the availability of large quantities of fresh surfaces and (or) extremely fine-sized particles.

3524. Fialkov, A.S., and Temkin, I.V., Perspectives of application of vibration milling in production of finely divided carbon-graphite materials, *Tsvetnye Metally* 32 (3) 53-60, 1959.

A method is described for the prepn. of graphite products by simultaneous pulverization and mixing of C materials, such as uncalcined petroleum cracking coke, microcryst. graphite, calcined pitch coke, birch charcoal, and high-temp. pitch with softening temp. greater than 120°, as binder, in an ultrasonic vibration mill. Four variations of production flowsheet are given.

3525. Fialkov, A.S., Toporov, G.N., and Chekanova, V.D., Possibility of controlling the content of functional groups on the surface of powdered carbons, Zh. Fiz. Khim. 37 566-9, 1963. The effect of grinding 45 min. in air in a vibratory mill and subsequent heating 2 hrs. at 450° on the content of COOH, phenolic, and carbonyl groups on the surface was studied with different grades of carbons and C black. Grinding increased the content of all groups.

3526. Finkin, E.F., Wear of copper, aluminum, mild steel, and zinc, and their wear particle shape factors, ASLE-Trans. 7 (4) 377-82, 1964.

Load is critical in determining wear mode, which is characteristic of a given material. Wear particle shape can be defined by ratios of dimensions; these have distributions different in form and mean values for various metals. Mean values of shape factors are independent of particle size and of each other. Surface roughness is not related to wear particle size for highly loaded sliding.

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3527. Abrecht, H., Lukacs, J., and Plötz, E., New method of the determination of the toughness of abrasive grains, Ber. deut. keram. Ges. 37 (8) 355-61, 1960.

The grains are thrown continually (by recirculation) against an impact surface by a centrifugal device, and the number of cycles required to halve the number of grains of the original size is taken as the impact resistance. The loss in weight of the impact surface is a measure of the abrasiveness of the grains. This method is more sensitive than previous ones.

3528. Anon., Abrasive materials in 1960, U.S. Bur. Mines Min. Market Survey, 1961, MMS 3246, 10 pp.; Asbestos industry in 1960. Ibid., MMS 3260, 2 pps.; Mica -- second half in 1960, Ibid., MMS 3242, 2 pp.

Each survey free from Pubs. Distrib. Sect., U.S. Bur. Mines Washington 25, D.C.

3529. Fitch, Elliott B., Hydrocyclones in closed-circuit grinding operations, U.S. Pat. 2 870 908, 1/27/59. Self-regulating features of a continuous, wet, closed-circuit grinding system are described.

3530. Fitton, A., and Jackson, R., Coal grinding plant tests on a ring-ball mill and a tube mill, J. Inst. Fuel 32 520-9, 1959.

Tests on a ring-ball mill and a tube mill are described, and a

comparison is made of the performance of the 2 mills. For a given output the power consumption of the tube mill is substantially const; that of the ring-ball mill is dependent on the Hardgrove index of the coal ground. However, the max. output of both mills depends on the Hardgrove index of the coal. When the power consumed by the sweeping air fans is taken into account, there is little difference in the power consumption of the 2 mills, esp. when the tube mill is operated at max. output. Reasons for this are discussed. The ring-ball mill has a greater drying capacity than the tube mill, and it is more economical when widely varying loads are to be met. However, the tube mill is simpler to operate and is suitable for use at high loads under steady conditions, provided that the moisture content of the feed is not too high.

3531. Foch, Pierre, and Busso, Raoul, Several coke fraction parameters, *Compt. rend. Congr. ind. gaz.* 73 445-62, 1956. An investigation is reported of the effects upon coke characteristics of charge density, grinding, and incorporation of coke dust into the charge. In general coke quality improves with increase of charge d., as it often does on addition of coke dust. Effects of grinding are complex; emphasis is placed on desirability of controlled grinding.

3532. Frangiskos, A.Z., and Smith, H.G., Effect of some surface-active reagents on the comminution of limestone and quartz, *Progr.*

in Mineral Dressing, Trans. Intern.Mineral Dressing Congr., Stockholm, 67-81, 1957 (Pub. 1958).

Expts. designed to show the effect of surface-active reagents on the comminution process are reported. The results indicate that the crushing of limestone and quartz may have a chem. aspect. When crystals are fractured, the residual elec. forces are satisfied by substances present in the ambient phase.

3533. Frechette, J.D. (Editor) Non-Crystalline Solids, John Wiley, New York, 1960.

3534. Schrader, Richard, Tetzner, Gottfried, and Grund, Heinrich Mechanical preparation of catalysts, Fr. Pat. 1 387 947, 2/5/65. 5 pp.

Active catalysts are mech. prepd. from inactive solid materials by a crushing process in air or another atm. or in an unreactive liquid. Thus, Co powder fritted at 850° was crushed for 90 min. in an Ar atm. by 13 mm. diam. steel balls in an oscillating crusher. Using this catalyst, 91% C₆H₆ was hydrogenated to cyclohexane. Similarly Ni and Fe catalysts were prepd. by crushing in air.

3535. Frenay, E., and Masson, A., Effect of fine particles on materials ground in dry-feed ball mills, Rev. matériaux constr. et trav. publ. C (520) 1-9, 1959.

To determine the effect of fines on grinding efficiency, a const. quantity of 10-65 mesh gravel was fed to lab. mills,

together with different quantities of 65-270-mesh gravel, both fractions previously obtained by pregrinding one original gravel sample. The more fines that were added before grinding, the larger the percentage of grains found after grinding that were either too coarse or too fine.

3536. Frenking, H., Investigations on interaction of forces in impact crusher, and comparative analysis of crushing operations in various rock, *Aufbereitungs-Technik* 1 (3) 107-20; (4) 170-83; (5) 216-25, 1960.

Measuring methods and electronic devices developed for study of crushing operations.

3537. Friedman, G.M., Determination of sieve-size distribution from thin-section data for sedimentary petrological studies, *J. Geol.* 66 394-416, July 1958; Correction 67 125, Jan., 1959.

3538. Fuerstenau, D.W., Retention time in continuous vibratory ball milling, *Mining Eng.* 11 1238-43; *Trans. AIME* 214, Tech. Publ. No. 60B10, 1959.

The exptl. data show that for a vibratory ball mill operating continuously in open circuit, at const. power input, the size moduli of the products are detd. by the total retention time within the mill, regardless of feed rate. Thus for a continuously operating low-level discharge mill, the retention time determines how long any given particle is subjected to the mill

action. In batch grinding the total grinding time is the retention time. In continuous grinding the factors which determine retention time are complex in that retention time depends on flow characteristics of the material passing through the mill. For dry grinding in a vibratory mill, the scale-up of batch lab. tests to continuous operation will be difficult without a knowledge of retention time, and this may entail experimental determination of retention time.

3539. Fuerstenau, D.W., and Cohen, A.P., Effect of feed size in comminution, Trans. AIME 223 (1) 62-3, 1962.

Various sieve fractions were prepared from crushed Brazilian quartz crystals and size distribution of products obtained by grinding each of size fractions was obtained. Experiments show that over very wide range in feed size, size modulus of product from rod mill is determined by energy expended per unit mass of material, independent of feed size.

3540. Fuerstenau, D.W., and Somasundaran, P., Kinetic analysis of size reduction, Aufbereitungstechnik 5 (5) 205-10, 1964.

Expression is derived for initial rate of formation of quartz and limestone particles when ground separately. In ball mill, deviations occur for sizes greater than 65 mesh. Initial rate of formation of particles in rod mills satisfies equation in region of 20 mesh. In case of grinding of mixtures, materials with least grindability remains coarser. During grinding,

certain size fraction of material is formed at constant rate which is characteristic of material.

3541. Fuerstenau, D.W., and Somasundaran, P., Comminution Kinetics, Int. Mineral Processing Conference Cannes, paper 3B, Pergamon Press, Oxford, 1963.

Initial rate of formation studies on a specific size fraction (4x8 mesh) of limestone, quartz, and a 50:50 mixture of the two. Results indicate a zero order reaction (rate proportional to time) for sizes finer than 65 mesh when ball milling and 20 mesh when rod milling. For the mixture, the rate of formation of fine quartz increases and fine limestone decreases as grinding proceeds, due to the difference in grindability.

3542. Fuerstenau, D.W., and Sullivan, Jr., D.A., Comminution of mixtures in ball mills, Trans. AIME 223 (2) 152-7, 1962. Investigation of comminution of quartz and limestone mixtures in ball mill, showing that distribution modulus of comminuted material is same whether it is ground separately or as part of mixture; analysis of ground products indicates that quartz and limestone consume energy during ball milling in proportion to their mass fraction in mixtures. (This is contradicted by their later paper #3540.)

3543. Fuerstenau, D.W., and Sullivan, Jr., D.A., Analysis of comminution of mixtures, Can. J. Chem. Eng. 40 (2) 46-50, 1962.

Investigation of comminution of quartz and limestone mixtures in rod mill has shown that distribution modulus of comminuted material is same whether it is ground separately or as part of mixture. Method for predicting rod milling characteristics of mixture of materials, provided grinding characteristics of individual materials are known.

3544. Fujino, Kiyoshi, and Taniguchi, Hiroyoshi, Performance of classifier and mill capacity in closed-circuit grinding, *Kagaku Kogaku* 24 93-8, 1960.

The partial collection efficiency of a classifier is assumed to obey the relation: $\eta = 1 - \exp (x/x_c)^{-1}$, where η is the efficiency, x is the particle size, 1 is the const. of performance of the classifier, and x_c is the cut-off size of the classifier. On this assumption, several charts are constructed for evaluating operating variables, such as circulating load, cut-off size of the classifier, residue of products, etc. A discussion of the performance and capacity of closed-circuit grinding is presented.

3545. Fulchiron, J., Lambert, D., and Pierre, Y., Autogenous ore milling in water, *Centre Doc. Siderurg., Circ. Inform. Tech.* (4) 931-53, 1964 (Fr).

A calcareous ore contg. 24% Fe, and 2 siliceous clay-cemented ores were test-milled in water suspensions. The app. consisted of a cascade mill fed from a Niagara screen; fines from the

mill were pumped back to the screen to pass through into a sampler, while the oversize product was segregated by a trommel in the mill outlet and returned to the mill. Good sepn. of the metallic constituents was attained, but with a high fines ratio. Power consumption was about the same as in dry autogenous grinding; the lower av. particle size of the products showed that wet grinding was more efficient. Pulp density was the only influential factor. The process is only applicable where fines represent discards or are both valuable and workable.

3546. Fullerton, W.J., and Cox, A.W., Crushing and grinding limestone at the Howes Cave, N.Y. plant of the North American Cement Corp., U.S. Bur.Mines Info. Circ. IC6553, 7pp., 1932.

3547. Fullerton, W.J., and Cox, Albert, W., Method and cost of quarrying, crushing, and grinding limestone at Catskill Plant of North American Cement Corporation, Catskill, N.Y., U.S. Bur. Mines Info. Circ. IC6522, 15pp., 1931.

Describes practice and equipment and gives cost at the cement-plant.

3548. Furness, E.M., and Henderson, A.S., Grinding magnetic taconite in rod mills, Mining Eng. 9 (12) 1359-60, 1957. Reduction of rate of rotation of rod mill at Reserve Mining Co's Babbitt plant resulted in reduction of rod breakage. Increase of mill length from 12 ft. to 14 ft. 7 in. improved grinding.

3549. Fushimi, H., Use of radioisotopes for measuring the grindability, Genshiryoku Kogyo 6 (1) 19-24, 1960.

Radioisotopes were used for studying the movement of balls in ball mills for the purpose of evaluating their efficiency.

About 2-3 mc. Co^{60} was placed in the 2-, 3-, and 4-in.-diameter balls used in conical com. ball mills, under the usual operational conditions. This permitted following the motion of the balls from outside the mills. The movement of the balls and, consequently, the grinding action, was greatly affected by the speed of rotation of the mill, the size distribution and the feed rate of the balls and of the raw material to be ground, presenting formerly unsuspected correlations between these factors. The method is very effective for evaluating the operation of ball mills.

3550. Gadomski, Michal, Mechanical grinder, Przegląd Geol. 9 544-5, 1961.

3551. Gahbauer, S.F., Bowl life is key to profit picture at Trap Rock Crushing plant, Eng. & Contract Rec. 77 (6) 71-3, June 1964.

Design and operation of Marmoraton Iron Mine trap rock crushing plant at Marmora, Ont. Problems associated with design and maintenance of crusher bowls with contradictory qualities being soft enough to withstand hard impact, yet hard enough to crush tough rock are outlined.

3552. Galanty, H.E., Size reduction paradox, Indus. & Eng. Chem. 55 (1) 46-52, Jan. 1963.

Review covering material characteristics, surface energy, laws of size reduction, limitations of laws, energy requirements, particle size distribution, temperature rise, method of force application, and factors affecting efficiency.

3553. Gammage, R.B., and Glasson, D.R., Crystal changes in vateritic calcium carbonate during ball milling, Chem. Ind. (London) (35) 1466, 1963.

X-ray diffractometer traces are presented which show the progressive conversion of vaterite CaCO_3 to calcite and aragonite during ball milling for periods up to 156 hours.

3554. Gardner, Robin Pierce, Phenomenological approach to the batch grinding of coals, Ph. D. thesis, Pennsylvania State Univ., Univ. Microfilms 61-2368, 147 pp.; Dissertation Abstr. 22, 194-5, 1961.

3555. Gardner, Robin P., and Austin, Leonard G., Chemical engineering treatment of batch grinding. I: A radioactive tracer technique for the determination of breakage functions, Europaeishen Symp. Zerkleinern, 1., Frankfurt am Main 217-31 1962. (In English).

A phenomenological treatment of the batch grinding process is possible by using a radioactive tracer technique and a digital

computer. The breakage process is characterized in terms of selection and breakage functions and then this information is used to compute size-wt. distribution. The selection function is defined as the fraction (by wt.) of particles of size x which are broken/revolution of grinding machine; the distribution function as y is less than x . A radioactive tracer technique is described which allows the measurement of these 2 functions over any range of grinding variables for ground coals. This technique uses a nuclear reactor to irradiate size fractions of coals. When the irradiated coal fraction is remixed with the complete grinding charge, its individual grinding properties can be evaluated independently of other sizes. Measurement of the selection and distribution function for chosen sizes of the grinding charge in the presence of all other sizes is possible without any assumptions. Exptl. data are given in terms of the selection and distribution functions for 1 bituminous and 2 anthracite coals as a function of particle size and grinding time.

3556. Garlick, O.H., Important advances in new ball-mill grinding techniques, Cer. Ind. 78 66-7, +, June 1962.

This article is an interview with author.

3557. Gartshore, J.L., Quebec asbestos industry; mining and milling, Can. Min. & Met. Bull. 55, 400-2, June 1962.

3558. Aiazzi, Giovanni, Grinding, Ceramica (Milan) 14 (6) 49-54, 1959.

The principles of grinding and its necessity in processing ceramic materials for bodies, vitreous coating, opacifiers, and colors are discussed. Equipment is described, and a formula is given for the determination of the specific surface of a ground material.

3559. Gaudin, A.M., and Meloy, T.P., Model and comminution distribution equation for single fracture, Trans. AIME 223 (1) 40-3, March 1962.

Theoretical statistical derivation of distribution equation for single fracture; equation is shown to accord with experiment.

3560. Gauldie, K., and Moelling, H.A., Principle of hydrokinetic crushing and its application in crushing hard materials, Aufbereitungs-Technik 2 (3) 99-103, 1961.

New method of crushing is characterized by unequal movements of crushing elements. It achieves maximum throughput, optimum form of grains and lowest possible weight of machinery. High speed machine used differs essentially from other crushers in its completely hydraulic drive.

3561. Geller, Z.I., Grinding of some materials in the cascade-shock crushing grinder, Trudy Groznensk. Neft. Inst. (19) 173-5, 1956.

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The cascade-shock grinder can be used for the fine grinding of hard materials such as magnetic iron ore and the low phosphorus quartzites.

3562. Gel'man, A.T., But, A.I., Berzon, Sh. A., Akunov, V.I., and Morgulis, M.L., Vibratory ball mill. U.S.S.R. Pat. 117 727 2/6/59.

The vibration of the mill's body is dampened by hollow rubber spheres.

3563. Gel'perin, N.I., and Polotskii, L.M., Fine grinding of solids in a vibrating ball mill, Khim. Mashinostroenie (1) 28-33, 1960.

Quartz, titanomagnetite ore, granite, and fluorite were ground in a lab. vibrating ball mill to det. the effect of the time of grinding, τ , the vol. of the material loaded, V_m , the vol. of the balls, V_b , the diam. of the balls, d_b , on the degree of dispersion of the grind, characterized by its sp. surface S and the total residue on a 100 mesh/cm sieve. The work, A , necessary to obtain a material of a given fineness was also detd.

The following relation was obtained: $S = e(\tau^M V_b^k) / V_m^n D_b^f$

where M , n , k , f , and e are consts. characteristic of each material. The shaft of the vibrator rotated at 3000 r.p.m. with an

amplitude of 3 mm. The power consumed can be expressed by the equation: $A = 6.92 \times 10^{-6} S^2$ kw.-hrs/ton. The grinding action of a vibratory ball mill consists of 2 elements, the impact force of the balls and the friction resistance of the balls and the ground material. Both elements were studied separately in special app.: The impact force by the falling-ball method; the frictional force by a recording frictional device.

3564. Gerry, C.N., Reduction mills in Idaho in 1925, U.S. Bur. Mines Info. Circ. IC6026, 29pp., 1927.

3565. Gerry, C.N., Reduction mills in Montana in 1925, U.S. Bur. Mines Info. Circ. IC6025, 18pp., 1927.

3566. Gerry, C.N., Reduction in mills in Washington in 1925, U.S. Bur. Mines Info. Circ. IC6024, 6pp., 1927.

Tabulates name, location, and when built; process, character of ore, when operated, and custom work; equipment and power used; and capacity in tons per day.

3567. Gerth, G., Vibration mills and their applications, Mine & Quarry Eng. 26 (1) 30-2, 1960.

Various types of intermittently and continuously operating German vibration mills; their grinding capabilities on different materials.

3568. Ghosh, S.K., Harris, C.C., and Jowett, A., Beneficial effects of reagents in solution on wet crushing of rock, Nature 188 1182, 1960.

The expts. of Frangiskos and Smith (see 3532) were repeated. Limestone was crushed in a drop-wt. mill after being treated with dil. NaOH and Na_2CO_3 at various concns. The samples treated with NaOH showed an increase in crushing over samples treated with 5.7-48.6% pure water. The samples treated with Na_2CO_3 showed an increase in crushing of 18.6-105%. Most of the new surface area produced is in the extremely fine sizes.

3569. Giardini, A.A., and Conrad, M.A., Directional hardness of strontium titanate by peripheral grinding, J. Am. Soc. 42 165-8, 1959.

Peripheral grinding of oriented, thin, single-crystal disks of

SrTiO_3 indicates a significant anisotropy of grinding hardness which is consistent with the $m3m$ symmetry of the crystal structure.

3570. Giesen, K., Investigation of toughness of abrasive grains, Radex Rundschau (5) 640-59, 1959.

Various crushing methods for measurement are described, and their advantages and disadvantages. Recommendations for further development of testing methods.

3571. Gilbert, I., and Wingham, D.W., Wear rate evaluation of mill lining and grinding media materials, Australasian Inst. Min. & Met-Proc. 207 95-105, 1963.

Used 8.5 x 12 ft. overflow ball mill with 2" balls, in secondary grinding of copper ore. Test balls were larger, for recovery -- $3\frac{1}{2}$ in. 50 balls used in each test.

3572. Gilbert, L.A., and Hughes, T.H., Some experiments in additive grinding, Europaeischen Symp. Zerkleinern, 1, Frankfurt am Main 170-93, 1962. (In English).

Tests on the grinding of quartz in a 3-in. diam. ring-ball mill with silicone showed that it produced no substantial improvement in grinding performance. The effect of varying concns. of silicone in a 5-in. diam. ball mill at 2 mill speeds showed that any improvements in grinding under these conditions were below those obtained by other investigators using similar

addns. in a stamp mill. Further tests on the wet grinding of quartz in the 5-in. ball mill with a cationic wetting agent at varying concns. over a range of pH values showed a slight decrease in grinding efficiency. The effect of electrolytes and dispersants on the grinding of limestone was investigated in a 6-in. diam. rod mill with Na_2CO_3 , Na_2SiO_3 , and $(\text{NaPO}_3)_6$ as additives. Only $(\text{NaPO}_3)_6$ had any effect on the fineness of grinding under certain operating conditions, producing a coarser product. The use of additives in conventional rod or ball mill practice results only in a decrease in grinding efficiency or has no effect at all.

3573. Gilvarry, J.J., Theory of the Distribution of fragment size in comminution, Trans.AIME 229 250, 1964.

3574. Gilvarry, J.J., Fragment size in single fracture-review of theory and experiment, Wear-Usure-Verschleiss 7 (3) 227-43, 1964.

Review covers content of papers by J.J. Gilvarry and B.H. Bergstrom published between 1961 and 1963.

3575. Gilvarry, J.J., Fracture of brittle solids; two-dimensional distribution function for fragment size in single fracture IV; theoretical , J. Appl. Phys. 33 3214-17, 1962.

3576. Gilvarry, J.J., Fracture of brittle solids; two-dimensional distribution function for fragment size in single fracture V: experimental , J. Appl. Phys. 33 3218-24, 1962.

3577. Gilvarry, J.J. and Bergstrom, B.H., Fracture and comminution of brittle solids-further experimental results, Trans. AIME 223 (4) 412-19, 1962.

It is shown that existence of 2 peaks in differential distribution for endoclastic particles, corresponding to effect of surface and volume flaws in interior of specimen, can be demonstrated from average of data for large number of specimens. It is shown by means of Coulter counter that data obtained from specimens fractured in gelatin display behavior at fragment sizes approaching 1μ which is demanded by limiting form of Gilvarry equation in this case.

3578. Giuliani, F., and Robledo, R.S., Influence of particle-size distribution on strength and workability of vibrated mortar (for bricks), Matls. Res. & Stand. 1 183-8, March 1961.

3579. Goddard, J., Harker, H.J., and Wilman, H., Theory of abrasion of solids such as metals, Nature (London) 184 (4683) 333-5, 1959.

Quantitative theory giving simple relation existing between friction and wear during abrasion of metals and similar solids where deformation is mainly plastic.

3580. Godfrey, K.A. Jr., Soapstone yields to pneumatic mill; Liberty stone Co., Rock Prod. 63 96-8, Dec. 1960.

3581. Godfrey, K.A. Jr., Big gyratories lick trap rock problems; Dulles International Airport, Rock Prod. 63 152-3+, May 1960.

3582. Godfrey, K.A. , New crushers increase yield, Rock Prod. 62 92-3, Sept. 1959.

3583. Godfrey, M.C., Influence of recent developments on specification of crushing plant, Quarry Managers' J. 48 (10) 405-16, 1964.

Several comparisons between conventional pressure crushing and impact breaking at varying capacity rates indicate that primary impact breaker development considerably reduces capital outlay and promotes higher efficiency. Impact breaking is best suited for reduction of relatively non-abrasive and low silica content materials such as limestone, dolomite, anhydrite, shale, and cement rock. Performance data, plant layout and costs.

3585. Anon., Ball mill wet grinding of porcelain enamels, Porcelain Enamel Institute, Process Development Committee. Porcelain Enamel Inst. Bull. P-305, 26 pp., 1960. \$2.

Section A is intended as a guide for the mill operator in the selection, installation, and operation of ball milling equipment. Section B contains a more detailed account of some of

the principles of efficient ball milling, compiled from data supplied by equipment manufacturers and ball mill operators. Section C describes modern methods for handling the materials to be milled and the products from the ball mills. Section D explains some of the theories of ball milling and relates them to the practical methods and procedures of mill room operations. The standard screen test for wet-milled porcelain enamel (ASTM C 285-54) is included.

3586. Gofman, M.S., and Shabalin, K.N., Crushing of bodies by free impact, Gornyi Zhurnal (3) 64-7, 1964.

Formula is deduced corresponding to experimental Kick's formula; it is applied to evaluation of crushing power of balls; data are presented which may be useful in selection of velocity of rotation of hammer mills for production of coarse fragments.

3587. Gol'din, M.L., et. al., Systems of automatic control of closed circuit of comminution of iron ores, Gornyi Zhurnal (4) 58-63, April 1964.

Results of studies conducted at YuGOK ore treatment plant in Krivoi Rog includes examination of automatic system for control of pulp density and control of charging grinding mill. Data on efficiency of grinding mill on content of +25 mm fragments. It is demonstrated that amount of fines depends directly on increase in amount of coarse ore fragments.

3589. Gray, S., Mill of Phoenix Copper Co., Ltd., Can. Min. & Met. Bull 55 186-9, March 1962.

3590. Anon., An interesting treatment for increasing wear resistance, Machinery, Lond., 104 627, 675, March, 1964.

Mentions American work in which a surface layer of fine hard particles has been electrodeposited in a matrix which may be of copper. The particles can be of one or more hard substances: silicon carbide, boron carbide, tungsten carbide, aluminum oxide and diamond are commonly used. Particle size normally ranges from 0.00004 in. to about 0.003 in. and the concentration may be varied from 0-50%. It is claimed that strongly adherent coatings can be obtained with thicknesses from 0.0005 up to many thousandths of an inch. Chemical resistance of the particles exceeds those of the matrix metals, and hardness, tensile strength, residual stress and ductility.

3591. Green, James L., A comparison of grinding mills in grinding phosphate rock, Trans. AIME 226 401-4, 1963.

There is very little difference in operating costs between ball mills and roller mills in the Florida operations.

3592. Gregoire, Pierre, Azou, Pierre, and Bastien, Paul, Effect of comminution on the polymorphism of Uranium, Compt. Rend. 257 (17) 2481-4, 1963.

Feeble expansion anomalies of the order $\sim 10^{-4}$

were noted in the formation of UC. U transformations are produced in powd. material at temps. different from those of the massive metal.

3593. Grigg, P.E., How to get more from your millroom, Ceram. Ind. 71 62-5, Dec., 1958.

3594. Grindrod, J., Giant portable primary crusher serves several separate plants, Pit & Quarry 56 50, Aug., 1963.

3595. Grindrod, J., Capacity doubled with new plant of French gypsum plaster producer, Pit & Quarry 55 126-9+, Nov., 1962.

3596. Grohn, H., Bischof, K., and Heusinger, H., Mechanochemistry of high polymers IV: Effect of vibration grinding on some properties of polyacrylonitrile, Plaste Kautschuk 9 180-3 1962.

Polyacrylonitrile (I) was partially degraded by vibration grinding under conditions described earlier. The degraded I in HCONMe_2 was studied viscometrically. The viscosity of I decreased during 180 hrs. vibration grinding from 2.57 to 0.44. The decrease was most rapid at the beginning of the process; in the latter stages, a limiting value was reached. Vibration grinding increased the soly. of I in HCONMe_2 by the scission of H bonds. The yellowish discoloration observed in degraded I could not be attributed to any chem. changes.

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3597. Grohn, Hans, and Deters, Wolfgang, Mechanochemistry of cellulose and cellulose triacetate. Mechanical-chemical degradation of cellulose and cellulose triacetate in the vibrating mill, Faserforsch. Textiltech. 13 544-9, 1962.

Samples of spruce and cotton cellulose (I) and of cellulose triacetate (II) were ground for various lengths of time and under various operating conditions in a vibrating mill. The samples were then examd. as to their av. degree of polymerization (P) and distribution. Moisture-free I degraded at a slower rate than I in the moist state, possibly owing to the recombination of intermediate macroradicals in the dry sample. This assumption was verified by the observation of OMe groups in samples where H_2O was replaced with MeOH. I dried by azeotropic distn. with C_6H_6 degraded at a somewhat slower rate than the air-dried I. All grinding duration /P curves tended to merge at higher grinding durations. Changes were also observed in the mol.-wt. distributions of II samples after grinding.

3598. Grohn, H., Bischof, K., Loesche, M., and Moeckel, K., Studies of the physical conditions of the degradation of vinyl polymers on vibratory grinding, Plaste Kautschuk 8 593-8, 1961. Tests were made with poly(Me methacrylate) (I), polystyrene (II) poly(vinyl chloride)(III), polyacrylonitrile (IV) and polyethylene (V), using lab. models of vibro-grinders with steel or porcelain balls as grinding media. Unless otherwise

indicated, the tests were made at room temp. in N. The degradation was measured viscometrically in dil. solns. in appropriate solvents under various conditions. The speed of degradation was found greatest within the first 10-20 hrs. of grinding. I showed the fastest degradation, followed by II greater than III greater than IV greater than V. The speed of degradation of I increased proportionally to the amplitude.

3599. Hiller, H.K., Impairment of strength of quartz glass rods through wetting by liquids, Nature 188 132-133, Oct. 8, 1960.

Results can be explained by penetration of foreign material into cracks, lowering surface tension.

3600. Anon., History of abrasive grains, Grinding Finishing 9 (2) 22-27, 1963.

Abrasive sharpening is traced back to 25,000 B.C. Natural abrasives and the development of synthetic materials are discussed, together with grain grading, grinding wheels, and grinding machines.

3601. Grzymek, Jerzy, Gustaw, Krystyna, and Ostap, Krystyna, Influence of some surface-active additions on the process of portland (cement) clinker grinding, Cement-Wapno-Gips 20 (1) 1-7, 1965 (Pol).

The process of clinker grinding was intensified by the addn. of

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naphtholsulfonic acids, oleic acid, sulfite wastes, and water. These addn., in amts. ranging from 0.1-0.5%, changes the surface tensions of different phases present in the clinker, accelerating the grinding process ~7-fold. Addition of gypsum is not as effective. The surface-active addns. have a protecting influence on the grinding media and the inside surface of the mills.

3602. Guenther, J. and Vock, Friedrich, Model studies with a planetary ball mill for the preparation of fine dispersions, (in Ger.) Aus. Forsch. 775-92, 1965.

The time required to reach a given degree of dispersion in a ball mill with a fixed axis t_H is related to the time in a planetary ball mill t_M by $t_H/t_M = m^2 - (\gamma_H/\gamma_M)^{1/2} (1 \pm C/n_H m^{1/2})$ where m is the ratio of diams. d_H/d_M , γ the d. of the balls, n is rpm. and C is the model const. given by $C = (30/\pi) (9.81/R_p)^{1/2}$ in which R_p is the radius of the planetary axis in m. The + sign is used when the frame and mill axis of the model rotate in opposite directions. The relation is valid when $n_M/n_H = (n_p/C) m^{1/2} - n_p/n_H$ where n_p is the rpm. of the planetary frame; and when the fraction filled with balls and the fraction filled with product are each equal in the model and in the example. The relation is verified exptl.

3902. Beke, Bela, Principles of comminution. Hungarian Academy of Sciences, Budapest, Hungary, 163 pp., 1964.

A review and discussion, emphasizing Russian and European research on size-energy laws. English edition of 1962 book.

3603. Guerrero, P.K., and Arbiter, N., Tumbling mill power at cataracting speeds, Min. Eng. 12 (5) 488-90, 1960.

Correlation of power consumed by tumbling mill with dimensions, speed, and load has been attempted by two principal methods; mathematical treatment of cylindrical shell charged with rods or balls and rotating. Fact that corrected Davis equation predicts power consumptions about 25% higher than actual is in accord with probable occurrence of slip in operating mills. Provides approximation of maximum power requirements for tumbling mills at 80% of critical speed level.

3604. Guner, M.I., Lovell, H.L., and Spicer, T.S., Factors affecting results of Hardgrove grindability test and proposed method of correction, (Paper 64-WA/FU-3, 15 pp.) ASME meeting Nov., 1964.

Four coals, from anthracite through high volatile bituminous, were used to study laboratory preparation of samples, effect of different types of laboratory grinding mills, and effect of inerts on results obtained from standard ASTM procedure; study indicates that inaccurate Hardgrove grindability indices may result from variation of size of sample, segregation of sample as indicated by ash content, and inaccuracy of 200 mesh screen aperture; proposed methods of compensating for these inaccuracies are included.

3605. Halbart, G., and Freymann, V., Ball mill linings, Zement-Kalk-Gips 13 (1) 17-23, 1960.

Behavior of grinding media charge in rotating mill; adherence of grinding media to lining; graphic method to determine minimum coefficient of friction which is necessary to eliminate sliding of charge on lining; proper shape of lining to increase coefficient of friction; results obtained with experimental mill. See Rock Products for English version.

3606. Halbart, G.J., and Freymann, V.F., Ball mills; their efficiency can be improved, Rock Prod. 60 (5) 6-7; (6) 157-8+; (7) 105-6+, 1957; 61 (1) 151-2+, 1958.

3607. Halton, P., Amylase activity, damaged starch, and water absorption, Milling, Feb. 10, 1961, 1 p. (reprint).

H₂O absorption and baking quality were studied on flour milled to different extents, to increase the content of damaged starch granules, with and without the addn. of fungal amylase. Whereas increase in damaged starch increases absorption at nil fermentation time, the increase is not so great after fermentation for 3 hrs. and the addn. of fungal amylase counteracts any increase. Heavy grinding adversely affects the baking quality of the flour.

3609. Hammond, M.L., and Ravitz, S.F., Influence of environment on brittle fracture of silica, Am. Cer. Soc. J. 46 329-32, July, 1963.

3610. International mineral processing congress proceedings
(6) Cannes, 1963; Pergamon Press, New York, 1965.

3611. Hardgrove, R.M., Grindability, a unit for coals or
equipment? Combustion 33 46, April, 1962.

3612. Hardinge, H., Autogenous grinding, Mining Congress J.
44 (10) 56-62, 1958.

Tumbling type of mill in which grinding media for material
being ground is material itself; methods of autogenous grinding
are complete or fully autogenous, partial autogenous, and
modified autogenous grinding; selection between dry or wet
grinding.

3613. Reese, A., Drive Motors for large tube mills, Zement-
Kalk-Gips 18 (10) 521-29, 1965.

3614. Harkort, D., The properties of refined kaolin and its
application in sanitary porcelain, Sprechsaal 96 (17) 381-6,
1963.

Discoloring impurities can be eliminated by fine grinding and
air sifting to eliminate the +40 μ m. fraction.

3615. Bernt, J.O., Automatic control of feed rates to grinding
mills, Minerals Processing 6 (10) 28-31, 1965.

3616. Zwicker, J.D., Sieve analysis to below two microns using micromesh sieves, American Ceramic Society Bull. 45 (8) 716-19, 1966.

3618. Harris, C.C., Monte Carlo Model of a Fracture Process, Nature, 1966.

3619. Harris, C.C., A method for measuring particle shape factors, Nature 187 401-3, 1960.

3620. Harris, C.C., Alternative forms of some exponential and power functions for graphical representation, J. Appl. Phys. 31 215, 1960.

3621. Harris, C.C., A generalized equation derived from alternative forms of the Gaudin and Rosin-Rammler size distribution equations, Second Symposium on Coal Preparation, Paper 8 191-210, Leeds University, 1957.

3622. Harris, C.C. and Jowett, A., Size analysis in the sub-sieve range by electronic counter, Nature, 1966.

3623. Harris, C.C., and Jowett, A., Sub-Sieve sizing by sedimentation balance, Nature 197 1192-3, 1963.

3624. Hayter, A.J., Modern trends in continuous centrifugal

separation and classification, J. Soc. Cosmetic Chemists 13
152-72, 1962. A review.

3625. Hedin, V.V., Neikov, O.D., and Erman, M.I., Combating
dust in an underground crushing installation, Gornyi Zhur.
(9) 69-72, 1959.

Drawing off of dust from a crushing unit located at a depth
of 392 m. is described.

3626. Heide, Kl., Influence of mechanical stress on hydrated
salts, Naturwissenschaften 50 (14) 496, 1963.

Mech. stress on hydrated sulfates during comminution of samples
produces significant changes. The dehydration of epsomite,
 $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, as a function of grinding time was studied by
thermogravimetric and thermoanal. means. Total loss of H_2O
may be only slightly affected, whereas the amts. of H_2O of
crystn. may be altered considerably at certain stages. The
intermediate $1\frac{1}{4}$ stage in the progression $\text{MgSO}_4 \cdot 2\text{H}_2\text{O} = \text{MgSO}_4 \cdot$
 $1\frac{1}{4}\text{H}_2\text{O} = \text{MgSO}_4 \cdot \text{H}_2\text{O}$ may actually be $1-1/8$ in but slightly
stressed samples and in powders ground for 20 min. may approach
the $1\frac{1}{4}$ value.

3627. Heikes, V.C., Reduction mills in Arizona in 1925, U.S.
Bur. Mines Info. Circ. IC6029, 28pp., 1927.

3628. Heikes, V.C., Reduction mills in Nevada in 1925, U.S.
Bur. Mines Info. Circ. IC6028, 29pp., 1927.

3629. Heikes, V.C., Reduction mills in Utah in 1925, U.S. Bur. Mines Info. Circ. IC6027, 12pp., 1927.

3630. Heikkinen, T., and Lehtonen, E., Two-stage autogenous grinding investigations at Outokumpu, Mine & Quarry Eng. 28 (11) 482-9, 1962.

Results of investigation at Finnish crushing plant and mill showed that it is possible to grind Outokumpu ore fully autogenously in 2 stages, and that it is possible to replace rod mills with autogenous mills of size equivalent to present secondary mills. Changeover to 2-stage autogenous grinding would also mean considerable reduction in crushing. Coarseness of ore coming from mine varies. (Same as 3631, which has better abstract.)

3631. Heikkinen, T., and Lehtonen, E., Experiments with 2-stage grinding at Outokumpu, Zeit. F. Erzbergbau u. Metallhuettenwesen 15 (8) 402-7, 1962.

Experiments were performed in mills 2.7 in diam. and 3.6 m long. Autogeneous grinding is efficient enough to eliminate preliminary grinding in rod mills. Fines are continuously removed. Primary grinding is performed using ore crushed to 15-25 cm in diam.

3632. Heinrich, H.E.A., Recent developments in dressing and preparation plants, Aufbereitungs-Technik 5 (4) 157-65, 1964. New equipment includes Rotex crusher, portable crushing plants

for quarry operation, autogenous mills for grinding cement raw materials, vibrating screen centrifuges which are experimentally used to dewater fine gravel and sands before shipment. Use of centralized lubrication for antifriction bearings, oil tempering for achieving optimum lubrication effects, employment of plastics bearings, and transition to permanent lubrication. Use of remote control of bin feeding stations and isotope measuring instruments.

3633. Henderson, B.R., Mining practice; better techniques from better equipment, Eng. & Min. J. 162 88-95, Jan. 1961.

3634. Henderson, S.M., Feed grinding studies, Agr. Eng. 42 (7) 350-2, 364, 1961.

Basic study of animal feed grinding procedures points out possible fallacy in size-classifying procedure. Emphasis is placed on need to design feed mill to produce more uniform product. Need to develop improved sizing procedure which would indicate shape of particles as well as dimensions.

3635. Herkenhoff, E.C., Mineral dressing 1959, Min.Cong. J. 46 45-9, Feb. 1960.

Lists recent developments, new equipment installed in North American iron mines, coal.

3636. Schultz, N.F., Energy -- new surface relationships in

the crushing of solids, Ph.D. Thesis, U. of Minnesota, Dissertation abstracts No. 3421, 257 pp., 1951.

3637. Herod, B.C., Alnore Mineral Company, Pit & Quarry 56 (12) 90-6, 1964.

Plant at Erie, Mich. specializes in custom grinding of alumina, ceramic materials, lithia mica, fluorspar, rare earth minerals, silica, zircon and other materials. Plans for further expansion of service include processing of exceptionally white, crystalline high calcium stone for paint, rubber and caulking manufacturers. Alumina and lithia mica form bulk of material processed. Mica is received in 12 in. lumps and is ground to 28 mesh for glass manufacture. Range of alumina product sizes is much greater.

3638. Herod, B.C., Stone formerly wasted becomes premium product, Pit & Quarry 55 110-12,+ June 1963.

3639. Hersam, Ernest A., The status of research in ore dressing, U.S. Bur. of Mines Rept. of Invest. RI2669R, 48pp., 1925. The article discusses ore-dressing processes in use in various centers of the United States, and describes the mechanism of ore dressing, and also considers separation, classification, concentration, flotation, elutriation of clays and coal, dewatering, etc.

3640. DeLonge, K.A., Alloy iron balls set new standard in cement grinding, Pit and Quarry, Feb. 1953.

Ni-hard balls with cement clinker show only 18-33% as much wear as forged steel balls.

3641. Goette, A., Results of a new investigation of dry fine size reduction, Freiburger Forschungshefte, A281, 1963.

3642. Debbas, S., and Rumpf, H., On the randomness of beds packed with spheres or irregular shaped particles, Chem. Eng. Science 21 (6-7) 583-608, 1966.

3643. Hill, J.M., Reduction mills in California in 1925, U.S. Bur. Mines Info. Circ. IC6023, 35pp., 1927.

3644. Hill, J.M., Reduction mills in Oregon in 1925, U.S. Bur. Mines Info. Circ. IC6022, 9pp., 1927.

Tabulates name and location; process, ore, and when operated; equipment and power; and the capacity in tons per day.

3645. Hiorns, F.J., Operational data on a ring-ball pulverizer, J. Inst. Fuel 32, 464-75, 1959.

Tests have been carried out on a ring-ball mill using a no. of different coals. Results of a statistical analysis of the tests with 2 of the coals are given. These show the signif-

ificance of air rate, classifier, and fuel:air ratio settings on fineness, rate of output, and power consumed; quant. expression is given to these effects. A simpler analysis is used to relate control settings to the same factors. This enables recommendations for operating the mill to be made. In addn., examples are given of nomograms, by means of which the fineness and rate of output may readily be obtained from control board readings, thus giving the mill operator information not ordinarily available.

3646. Hiorns, F.J., and Reed, L.E., The performance of an air-swept tube mill, J. Inst. Fuel 31 383-92, 1958.

Tests have been carried out on a full-scale air-swept tube mill, not fitted with a classifier, with 2 coals, Gedling and Midland coals having Hardgrove indexes of 51 and 64, resp. The tests covered the max. practical range of quantities of sweeping air, and in the case of Gedling coal they were carried out with 3 ball charges and at 2 levels of coal inside the mill. The tests with the Midland coal were carried out with one ball charge and at one coal level. Under normal conditions of operation the fineness of the product fell and the output rose linearly as the air rate through the mill was increased. The relation ceased to hold when the conditions were such that the

heat available was insufficient to dry the coal. Within the range covered during the expts. variation in either the ball charge or the level of coal in the mill had no appreciable effect on the output, but an increased ball charge caused the power consumed by the mill to increase.

3647. Urev, N.B., and Mikhailov, N.V., The dispersion of asbestos fiber under action of vibrations, Doklady Chem. Tech. U.S.S.R. (Consultants Bur. Translation) 162 75-8, 1966.

Lime solution speeds grinding.

3648. Hirst, W., Wear, Met. Revs. 10 (38) 145-72, 1965. Review covers mainly factors likely to influence wear of machinery or machine parts. Discussion of contact stresses, stresses and deformation in rolling, lubrication of nonconforming surfaces, scuffing, pitting. Conforming surfaces and dry wear. Range of wear rates, patterns of wear, mechanism of wear, dry wear of steels, severe wear in journal bearings, spark-hardening; and wear of carbon.

3649. Hobsbawn, P.B., El Salvador mill, Min.Congress J. 46 (11) 60-4, 92, 1960.

24,000 tpd mill features four identical concentrator sections. Treatment of sulphide ore consists of size reduction carried out in three crushing stages and two wet grinding stages, separation of bulk concentrate by flotation of sulphates and

further wet grinding of concentrates, followed by two cleaning stages and scavenger stage. Concentrates produced are processed for molybdenite before being sent to smelter.

3650. Hockings, W.A., Volin, M.E., and Mular, A.L., Effect of suspending fluid viscosity on batch mill grinding, Trans. AIME 232 (1) 59-62, 1965.

Batch grinding tests at short times were made in laboratory rod mill with 10x14 mesh quartzite in corn syrup-water mixtures of varying viscosity. Weight fraction broken and size modulus were independent of viscosity up to 20 centipoises, but at higher viscosities breakage of feed decreased while size modulus increased. Mechanisms of effect of viscosity are discussed on basis of particle dynamics.

3651. Hoff, Hubert, Wethebach, Paul, Labisch, Gerhard and Habig, Heinz, Steel for grinding bodies, Ger. Pat. 1 113 950, Appl. 8/6 / 1958.

Optimum conditions are given for the production of scale-free grinding bodies, e.g., balls for mills. The billets used have a compn. of C 0.9-1.1, Cr 1.6-1.9, Mn 1.0-1.2, Mo 0.45-0.55, Si 0.6-0.8, S and P each less than 0.025%. Rolling and forging of the bodies must be carried out with utmost care to prevent any flake formation.

3653. Holbrook, E.A., and Fraser, Thomas, Screen sizing of coal, ores, and other minerals, U.S. Bur. Mines Bull. B234,

140pp., 1925.

Outlines present practice in screening coal and gives a brief historical resume of the development of screening practice.

Also discusses coal-preparing machinery and gives data on screens for ore dressing.

3654. Holec, M., Transferable unit-assembly stone crushing plants, Czechoslovak Heavy Industry (10) 12-19, 1962.

Standard unit assembly system equipment developed which can be used for installation of medium capacity crushing plants. Main assembly units are described including primary stone crushing plant, secondary crushing and granulating plant, and grading equipment. Assembly units can be incorporated according to operating requirements into different types of installations.

3655. Holst, Karen, The influence of trituration time on the crushing strength of silver amalgam, Acta Odontol. Scand. 23 (3) 231-8, 1965. (Eng).

Prolonged trituration time was noted to increase the crushing time after 3 to 30 days of Ag amalgam for dental fillings but not Cu amalgam. A trituration time of 30 sec. seemed desirable.

3656. Ziegler, E., Influence of surfactants on grindability of solids, Schriftenreihe der Zementindustrie, 19 Bauverlag, Wiesbaden, 1956.

3657. Hosking, J.R., Measurement of factors affecting screening efficiency, Quarry Managers' J. 49 (4) 161-5, 1965.

Methods for measuring characteristics of commercial screening plant have been developed as part of program of research into problems arising in production of road-making aggregates to meet British Standard specifications. Methods include measurement of efficiencies of separation of each of screens of commercial plant from grading and output of screened chippings, of amplitude and frequency of vibration by means of stroboscope, of angle of slope by means of clinometer and of aperture size by means of specially designed taper gages.

3658. Houston, W.M., and LaVene, W.A., Current beneficiation practices for pebble phosphate in Florida, Min. Eng. 14 44-9, Nov., 1962.

3659. Huber Panu, I., and Popa, E., Establishing method for calculating capacity of crushers, Revue de Metallurgie (Bucharest) 3 (2) 59-83, 1958.

Method is based on design and principal dimensions of crusher, and on considerations of material to crush and resulting product. Theoretical basis of applied method and experimental studies is described.

3660. Huffman, S.A., Reserve cuts crusher down-time to 46 minutes for bowl and mantle change, Mining World 20 (10) 62-4,

1958.

At taconite mill, Silver Bay, Minn. bowl and mantle liner life averages about 130,000 tons of crude ore on 7-ft Symons crusher coarse bowls and 225,000 tons on fine bowls. Based on 42,000 tons per day, this means that approximately four steel changes are required each week.

3661. Hughes, William and Brown, Arthur D., Grinding solids in liquids, Brit. Pat. 971 756, 10/7/64, 6 pp.

A cylindrical shell contains several superimposed disks and agitators at the lower and upper end. The process material is agitated together with grinding pebbles; the fines are entrained by a liquid stream directed upward, and the residue is continuously rejected and recirculated.

3662. Hukki, R.T., Analysis of the potentialities of autogenous grinding mills, Europaeischen Symp. Zerkleinern, 1, Frankfurt am Main 393-411, 1962. (In English).

Industrial autogenous grinding practice as performed in grate mills of conventional shape in South Africa, in Cascade mills of Sweden, and in Aerofall mills of southern Rhodesia are analyzed and compared. The relative efficiencies of these mills are compared by the base mill power index. Because grinding is performed at subcrit. speeds, the base mill power index remains low. A large test mill of pilot plant size was operated at supercrit. speeds with the grinding medium, material to be ground, and the mill lining all consisting of the substance

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which is the object of the grinding operation. Base mill power indexes and mill capacities up to 2 or 3 times as high as those obtained above have been shown to be possible at supercrit. speeds.

3663. Hukki, R.T., Proposal for a solomonic settlement between the theories of Von Rittinger, Kick, and Bond, Trans. AIME 220 403-8, 1961.

3664. Hukki, Risto Tapani, Grinding of coarse material, Finn. Pat. 31 611, 1/10/61.

While the mill is driven in the supercrit. speed region, the relation of the maximal size or mass of the grinding particles to that of the material to be ground, and the relation of the max. mass of the grinding particle to the supercrit. speed of the mill, are chosen so as to maintain the striking effect during the whole of the grinding time as to correspond to the desired grinding result.

3665. Hukki, Risto Tapani, Grinding method using supercritical speeds, Finn. Pat. 31 481, 10/10/60.

The grinding is possible at a very large supercrit. speed margin, and an increase of the grinding capacity as well as a decrease of the power consumption is achieved. The method can be applied to grinding minerals, e.g. cement, but also in ground wood and knot pulp manuf.

3666. Hukki, Risto T., Grinding, Finn. Pat. 30 958, 1/7/1960. The capacity of grinding mills is increased by using as grinding medium a substance that has substantially higher sp. gr. than the av. sp. gr. of the material to be ground.

3667. Hukki, R.T., Grinding at supercritical speeds, Brit. Chem. Eng. 4 (8-9) 446-9, 1959.

Report on experiments carried out at Mineral Dressing Laboratory of State Inst. for Tech. Res., Helsinki, Finland; to obtain greater mill capacity in which material to be ground is also grinding medium, fundamental conditions for coarse and fine material grinding at sub and supercritical speeds in conventional rod, ball and autogenous mills are analyzed; methods for determining mill characteristics and for increasing mill speed are presented.

3668. Hukki, R.T., Self-grinding of ores at supercritical rotation speeds, Tsvetnye Metal 31 (11) 9-16, 1958.

The factors which affect the efficiency of self-grinding at supercrit. mill rotation speeds are discussed. Such factors are the ratio of velocity of falling bodies to mill diam., the momentum of a falling body, size reduction by impact and by grinding, feed size, grinding medium, mill construction, and operating conditions.

3669. Hukki, R.T., Fine grinding, Tsvetnye Metally 31 (10)

3-16, 1958.

A discussion of fine grinding in relation to ball mill productivity, grinding medium, speed, energy consumption, loading, self-grinding, lining wear, and wet grinding.

3670. Hukki, R.T., All-Autogenous grinding at supercritical speeds, Mine & Quarry Eng. 24 (7) 304-11, July 1958.

After analyzing various grinding techniques in current use and some of factors affecting mill performance, description is given of coarse grinding autogenous mill and particular reference made to its operation at supercritical speeds.

3671. Hukki, R.T., Grinding at supercritical speeds in rod and ball mills, Trans. Intern. Mineral Dressing Congr., Stockholm, 85-109, 1957. (Pub. 1958).

A preliminary report is given of grinding expts. in the supercrit. range up to the "de facto" contrifuging speeds in rod and ball mills of pilot-plant size. A theoretical analysis is given of the dynamics of tumbling mills and the advantages of milling at supercrit. speeds are discussed.

3672. Hutt1, J.B., Berkeley pit crushing-conveying plant designed to handle 1800 tons per hour, Eng. & Min. J. 158 102-4, Dec. 1957.

3675. Irani, R.R., and Kaelble, E.F., Particle size distribu-

tion measurements below five microns, Anal. Chem. 33 1168-70, 1961.

3676. Ironman, R., France is home to worldbeating mobile crusher, Rock Prod. 66 134, May 1963.

3677. Jackman, H.W., and Helfinstine, Coke crushing characteristics, Ill. State Geol Survey-Cir. (375) 11 pp., 1964.

Tests on coke from pilot and commercial ovens have indicated that amount of coke fines produced when crushing to 3/4 in. top size for chemical industry is dependent on coke strength as determined by ASTM tumbler test. Low tumbler stability index favors minimum production of fines and maximum yield of larger 1/2 by 3/4 in. pieces. Minimum production of fines is favored by high tumbler hardness index. Cokes made from Illinois bituminous B and C rank coals produce minimum of fines during crushing.

3678. Jackson, O.A.E., Autogenous-and composite-load milling practice at South African gold mines of Union Corp. Ltd., Int. Mineral Processing Congr. 7th-Tech. Papers 557-72, Sept. 1964.

Recent developments in South African autogenous milling practice include "run-of-mine milling" which treats ore direct from mine without crushing and without use of steel grinding media, in mills 12 ft. in. diam. and upward. Effects of variation in

major operating variables. Metallurgical data, mill linings and overall economics are analyzed.

3679. Jacobs, Wolfgang, and Feik, Hans Joachim, Large-scale milling of iron-quartz ore by rod and cascade grinders, Congr. Intern. Prepn. Minerais, 6^e, Cannes, France 62-89, 1963. (Pub. 1964) (Fr.).

The ore contains, on the dry basis, 8.8% hematite in the coarse grains mainly with silica, and 42.8% magnetite with 11% hornblende in fine grains: owing to the climate, the ore may contain less than 9% moisture. Following preliminary size redn. to 30 mm., the autogenous Cascade mill not using grinding balls is preferred to the classical rod mill for (1) single-step operation, (2) more selective grinding, and (3) better grindability and simplicity. Also appears in: Mineral Processing Proceedings, 6th.

3680. Jacobs, W., and Feik, J., Comparative experiments with grinding banded iron ore in rod mill and in cascade mill, Aufbereitungstechnik 4 (10) 409-23, 1963.

Ore treated was imported from Bong Range, Liberia. Cascade mill grinds pre-crushed ore in one operation to desired grain size, while feed to rod mill must be more thoroughly crushed. Cascade mill ensures real liberation of ground material and is more economical while action of rod mill is characterized by less selective grinding. See 3681.

3681. Jacobs, W., and Feik, J., Grinding experiment comparisons with a quartzband ore in a rod mill and a cascade mill, Eng. & Min. J. 164 88-9, August 1963.

3682. Jacobs, W., and Feik, J., Experiments with treatment of African iron ore, Zeit, f. Erzbergbau u. Metallhuettenwesen 15 (12) 623-31, 1962.

Treatment of magnetite-hematite ore from Bong Range in Liberia involves autogenous grinding, treatment in Humphrey separators, supplementary grinding, wet magnetic separation, and filtration, producing 66% Fe concentrate. See 3681.

3683. Jaeger, J.C., Elasticity, fracture and flow, 2 ed., Methuen, London, 1964.

3684. Jamieson, J.C., and Goldsmith, J.R., Some reactions produced in carbonates by grinding, Am. Mineralogist 45 818-27, July, 1960.

3685. Janelid, I., Mining huge ore bodies in Sweden, Min.Cong. J. 46 39-42+, Dec., 1960.

3686. Javelle, P., Fulchiron, J., and Guyot, R., Recent research studies by IRSID (Siderurgical Research Institute) in Field of autogenous grinding, Int. Mineral Processing Congr. 7th-Tech. Papers 595-611, Sept., 1964.

Details of pilot plant operations using 6 ft. Cascade Mill for wet grinding of oolitic Lorraine ore and magnetite ore from Anjou-Bretagne. With Lorraine ore 1 mm product was obtained from 250 mm feed while with magnetite ore 80 μ product was obtained from 15 mm feed with coarse ore added. Results are compared with those from conventional comminution circuit, Equivalent metallurgical results were obtained with energy consumption favoring autogenous grinding.

3687. Jebens, R.H., Ball mill for pigment dispersion and grinding, Chem. Eng.Prog. 55 (8) 59-63, 1959.

Consideration of grinding media, dispersion consistency, mill speed, and ball mill operation to achieve optimum results in wet grinding for size reduction, or for pigment dispersion into product. Correlation of ball size, density, velocity, paste density, pigment concentration and size, is given. To achieve maximum output from equipment the following conditions should be observed: vehicle viscosity should be as low as possible and mill speed should be 60 to 65% of critical speed.

3688. Jenike, A.W., Elsey, P.J., and Woolley, R.H., Principles of flow of crushed materials, Min. Congress J. 45 (8) 73-5, 1959.

In crushed material, stress conditions can be predicted with sufficient accuracy. Dynamic composition greatly modifies both flow pattern and strength of material. Strength is dependent on fine material present in mixture. Flow- factor tester is used

for testing direct shear.

3689. Jodra, L.G., and Josa, J.M., Processing of mineral ores (in Span.) Rev. Ser., Intern. At. Energy Agency (23-24) 79-133, 1962. Review with 158 Refs.

3690. Tovarov, V.V., Kinetics of grinding, Promstroizdat, Moscow 90-101, 1957.

3691. John, G., and Vock, F., Model tests with a planetary ball mill, Chem. Ingr. Tech. 37 (4) 411-17, 1965.

Geometric factors and math. relations are developed which permit extension of findings in the model setup to a large-scale gravity-type ball mill.

3692. Smekal, A., Compression breaking of cubical samples, Zeitschr. VDI, Beiheft Verfahrenstechnik, 159 et seq., 1938.

3693. Rumpf, H., The story of the development of the physics of fracture, Chemie Ing. Techn. 31 697-704, 1959.

3694. Joisel, A., The fracture of brittle materials in crushing, Zement-Kalk-Gips 16 13-22, 1963.

Brittle materials are defined as those in which the tensile strength does not exceed the shear strength. The investigation of the fracture of such materials must be based on a theory that

assumes their heterogeneity rather than on one that presupposes the material to be homogeneous and isotropic. Under compression the fractures are parallel to the strain because of the irregularities exhibited by the deformation modulus. Fractures occurring as result of size redn. are generally similar to those produced by nutcracker action, i.e., by shear and tension. Much of the energy expended in reducing the material is elastically recovered and transformed into heat energy after the break has occurred. A close relation exists between the amt. of energy used and the increase in surface area produced.

3695. Jovanovic, Dusan, Theoretical principles of the characterisation of powders. I: Distribution and mean characteristic properties, Tehnika (Belgrade) 18 2101-6, 1963.

Particle size distribution and mean diam. are math. discussed and reviewed. II: Incremental and cumulative methods of sedimentation analysis, Ibid. 2302-8. A crit. review.

3696. Joy, A.S., The surface energy of solids, in Powders in industry, Society of Chemical Industry Monograph (14) 53-78, 1961. (London).

3697. Rosin, P., Rammler, E., and Sperling, K., Particle size problems of coal dust, Bericht C 52 des Reichkohlenrates, Berlin, 1933.

3698. Kaminski, E., Change of biochemical and technological properties of flour by grinding, Biokhim. Zerna i Khlebopecheniya (7) 117-38, 1964.

Structural changes of starch grains caused by grinding resulted in a change of saccharifying and rising ability of flour. The amt. of sugar formed and the dynamics of CO₂ evolution in the fermentation of dough were shown to depend on the degree of damage to the starch grains. Saccharification was low with a small degree of damage, and CO₂ evolution ceased after 4 hrs. of fermentation. The diastase activity in flour was quite sufficient for the saccharification of the damaged starch grains and did not change with grinding.

3699. Kaminsky, W.A., Development of large spring-roll mills for cement works, Zement-Kalk-Gips 14 (11) 489-97, 1961.

Description of German Loesche, Berz, Pfeiffer and Peters mills of new design. All are suitable for combined grinding and drying of soft and medium-hard raw materials and also of coal. Some units are of 90 tph capacity. Exhaust air passes through cyclone dust collectors before going through fabric filter or electrostatic dust extractor.

3700. Kanavets, P.I., Experimental pilot plant for granulation of fine-ground materials by the chemical-catalytic method, Tr. Inst. Goryuch. Iskop., Akad. Nauk SSSR 22 57-69, 1963.

A granulating mill with a capacity of 300 kg./hr. of fluxed, noncalcined granules of ore-fuel mixts. (e.g., Fe ore 75,

CaO 15, and coke 10%), of coal, or of cement raw materials is described. Optimum conditions for the production of granules were investigated. The chem.-catalytic method consists of carbonizing the particles in a stream of hot gas (acidic gas from an ethanolamine factory + air + flue gas). A soln. of catalyst (unspecified) is poured over the granules before carbonization.

3701. Kanazawa, Takafumi, Hardness of fused phosphate granules quenched by various methods, Kogyo Kagaku Zasshi 60 1113-17 1957.

The grindability of fused phosphates produced from Florida phosphate, serpentine, and silica sand at 1350° was detd. by means of a ball-mill method for the samples quenched with H₂O and cooled with air. It was observed generally that the grinding is easier for H₂O-quenched phosphates than for air-cooled granules. An increase of concn. of SiO₂ increases the hardness, whereas Na₂O, by addn. of Na₂CO₃ to the original mixts., lowers the hardness.

3702. Kaplan, G.E., et. al., Effect of superfine grinding on the course of solid-phase reactions, Zh. Prikl. Khim. 36 95-101, 1963.

The solid-state reaction $\text{ZrSiO}_4 + 2\text{CaO} \rightarrow \text{CaZrO}_3 + \text{CaSiO}_3$ was investigated. Superfine grinding of reagents (av. grain size $\sim 1 \mu$) and thorough mixing markedly increased sintering even without addn. of mineralizers.

3703. Kapur, P.C., Mular, A.L., and Fuerstenau, D.W., Role of fluids in comminution, Can. J. Chem. Eng. 43 (3) 119-24, 1965. Size distributions of products obtained from grinding in water, air, and tetrabromethane are interpreted in terms of effect of fluids on relative proportions of abrasion, chipping and impact events occurring in mill. In ball milling of mixtures, asserts that components grind without significant interaction.

3704. Karachentzev, V.I., et. al., Wear-resistant cast iron, U.S.S.R. Pat. 169 553, 3/17/1965.

The wear-resistant cast iron described earlier (CA 58, 7667f) with improved working properties is obtained by changing the lower limit for C to 1.6% and for Ni to 0.8%. It contains C 1.6-2.8, Si 0.5-0.7, Mn 1.8-3.5, Cr 14-22, Ni 0.8-3.5, S less than 0.1, and P less than 0.1%.

3705. Karges, E.J., Is roller mill answer to your grinding problem, Rock Prod. 67 (9) 82-4, 1964.

Proper field of roller mill application is reduction of non-metallic minerals, rock products, and similar manufactured products. Roller mills are not suitable for fine grinding of abrasive materials. Materials must not contain excessive flint or quartz. System can dry, pulverize, classify, convey finished product to storage and, in many cases, beneficiate product as well. All of this is done in system operating entirely under suction. Installation can be made dust-free. Design, operation

and typical applications of Raymond roller mills.

3706. Karmazin, V.I., and Denisenko, A.I., Autogenous grinding of magnetite taconites from Krivoi Rog, Gornyi Zhurnal (10) 53-6, Oct. 1963.

Experiments performed under laboratory conditions indicate possibility of substituting fragments of material being ground for steel balls. This method of grinding contributes to production of better concentrates and reduces loss of iron in tailings.

3707. Karmazin, V.I., Denisenko, A.I., and Yurov, P.P., Industrial testing of method for comminution of low-grade magnetite quartzites without using balls, Gornyi Zhurnal (2) 67-70, Feb. 1964.

It is demonstrated that large lumps of ore may be substituted for steel balls. This results in 1.8-2 times less power required to drive mill. Ore containing magnetite grains of 20-40 μ size and 24.2-26.4% iron could be upgraded by magnetic separation to 58-62% iron content.

3708. Karmazin, V.I., Sergo, E.E., and Maletskii, N.A., Jet grinding of iron ore with simultaneous subsequent roasting, Obogashch. Rud 10 (2) 26-9, 1965. (Russ).

Three different jet mill constructions are described. Expts. were performed to det. the dependence of the speed of a flying

particle (v) on the yield of particles smaller than 0.0074 mm. The following exptl. equation was produced: $\gamma_{74} = av^2 - bv - c$, where a, b, and c are coeffs. detd. by the wt. of flying particles and materials of the plate on which these particles impinge. Comparison of the grinding performance in the jet mill and ball mill showed that with magnetite ore the jet mill gave higher extn. of Fe after magnetic sepn. (70-5%) and a smaller amt. of concretions (8-10%, as compared to 12-24% in a rod mill). Expts. with magnetizing roasting of the ore finely ground in a jet mill showed that the time of residence of 0.4-mm. particles in the jet mill was not adequate for adequate redn. of the Fe oxides to produce a magnetically separable product. An addnl. app. for the redn. of ore particles outside the jet mill is necessary. The design of such an app. is shown (using both dry and wet magnetic sepn.).

3709. Kashcheev, V.N., and Glazkov, V.M., Wear of metals in a stream of abrasive particles of varying hardness, Izvest. Vysshikh Ucheb. Zavedenii, Mashinostroenie (8) 132-8, 1960. The wear resistance was studied of annealed, Pb, Mg, Al, Sb, Ni, Bi, Zn, Sn, Cu, Cd, and steels of various hardnesses contg. 0.04% and 1.04% C when subjected to impact by mineral abrasive particles of varying hardness (coal, shale, calcite, magnesite, and a compd. of high hardness identified as OKC₁). The wear resistance of metals depended on the ratio of the hardness of the metal to the hardness of the abrasive particle. In general

when the hardness of the abrasive particle is less than that of the metal under test, the amt. of observed wear was small although greater than 0. When the hardness of the abrasive particle equaled or somewhat exceeded the hardness of the metal the amt. of wear increased sharply. A further increase in hardness of the abrasive particle relative to that of the metal under test produced a linear increase in the amt. of wear. For a given abrasive, the wear resistance of a metal is greater, the higher Young's modulus of the metal. The elastic modulus of a metal serves as an index of the characteristic interatomic forces existing in a metal lattice. An analogous characteristic is the modulus of rigidity (K) as expressed in the formula $F = -Ku$, where F is the quasielastic binding interatomic lattice force which resists displacement (u) of an atom from the equilibrium position. K is expressed as $4\pi^2 k^2 / h^2 m \theta^2$, where k is Boltzmann's const., h is Planck's const., m is mass of the atom, and θ is Debye's characteristic temp. For a given hardness of abrasive, wear resistance of a metal increased with increase in the modulus of rigidity. Factors affecting wear of metals by impact with particles include velocity of impact, sharpness of protuberances of the particle, angle of impact, and mechanical characteristics of the particle, which include hardness, weight, and magnitude. In the experiments, velocity and angle of impact and particle size were maintained constant, whereas sharpness of particles and mechanical characteristics of the impacting particle were varied.

3710. Kates, Leonard W., Grinding an aluminum-nickel alloy, U.S. Pat, 2 857 289, 10/21/1958.

At least 10% of an Al-Ni alloy is added to an aq. suspension contg. at least 1 alk. earth metal carbonate. The suspension is brought into contact with the grinding media in a ball mill. The inner surface of the mill is lined with Ni while the grinding media is composed of the alloy.

3711. Kawai, Seiichi, Determination of optimum particle size for separation in free crushing, (Univ. Kanazawa). Kanazawa Daigaku Kogakubu Kiyo 2 246-55, 1960.

Sand was crushed with a drop-wt. crusher under various conditions in order to det. the optimum particle size for removal of material from a mill. The optimum particle size was defined as the size of particle for which the increase in the sp. surface area of the particle per unit crushing energy begins to decrease markedly with decrease in size, and was expressed as function of the diam. of the ball mill and of the balls used.

3712. Kayatz, K., Theory concerning replenishment of tube mill media, Zement-Kalk-Gips 17 (11) 498-502, 1964.

Method of calculation for replenishing the tube mills with grinding media is derived and various functions of abrasive wear are discussed.

3713. Kaye, B.H., Powder size analysis, Paint, Oil Colour J. 147 (3463) 437-40; (3467) 735-8; (3479), 1373-5, 1965. (Eng). Three methods of detg. particle size distribution are reviewed: pipet, hydrometer, and diver (immersible hydrometer). The theory of each method and factors affecting their accuracy are discussed.
3714. Kayser, Walther, New developments in cyclone separators, Europaeischen Symp. Zerkleinern 563-86, 1962. Review and comparison of commercial units. 12 refs.
3715. Kebble, H.R., Notes on milling experiments at South African Land and Exploration Company, Ltd., So. African Inst. Min. & Met. J. 62 (6) 375-90, 1962; (8) 488-90, 1962. Test work was conducted with grinding mills running at various speeds ranging from 81% to 136% of critical. Object of tests was to determine whether there was any advantage in changing from speeds generally accepted as standard. Investigations were made in both primary and secondary milling circuits. There is no practical or economical advantage in operating 6-ft 6-in. diam by 20-ft pebble mills at supercritical speeds.
3717. Renyi, A., On the mathematical theory of comminution, Epitoanyag 2 177-183, 1950.

3718. Kelsall, D.F., Study of breakage in small continuous open circuit wet ball mill, Int. Mineral Processing Congr. 7th-Tech. Papers 33-42, Sept. 1964.

Results of controlled grinding experiments made with homogeneous solid samples in small wet ball mill. Results are used in attempts to correlate data by both digital and analog computer techniques and to develop both realistic mathematical model and electrical analog which will accurately simulate dynamic behavior of open circuit wet ball mill.

3719. Kenny, W.J., and Piret, E.L., Slow compression crushing of single particles of glass, AIChE J. 7 199-202, 1961.

3720. Rosin, P., and Rammler, E., Laws of commulative particle size in cement, Zement 22 427-433, 1933.

3721. Keys, J.D., and Eichholz, G.G., Measurement of wear rate of cast grinding balls using radioactive tracers, Can. Dept. Mines & Tech. Surveys-Mines Branch, Tech. Bull (18) 14 pp., June 1960.

Co-60 tracer was added to molten metal prior to casing. Cast balls were used in mill at iron mine. Radioactive batch was added to ball mill which had normal charge of about 77.3 tons (metric). Charge was sampled at weekly intervals to pick out some of radioactive balls. These balls were inspected and weighed, and wear rate has been calculated.

3722. Kharkovskii, S.E., Rational feeding of hammer crushers, Coke & Chem. USSR (English Trans. of Koks i Khimiya) 8 8-10, 1964. Hammers will only strike lumps of coal squarely and effectively provided coal is falling into crusher at exact velocity required in accordance with machine design. Crusher should be equipped with feeders capable of delivering coal at regulated velocities within range determined by optimum size analysis of crushed product. Aim of experimental program is to find correct range of feed velocities, and to determine corresponding size analyses of crushed product. $V = mql/120$, Q = no. of hammers, l = hammer depth, m = speed, rev/min. Example: $v = 5$ m/sec.

3723. Kheifets, S.B., New laboratory equipment for the grinding of material, Zavodskaya Lab. 27 610-12, 1961. Described and illustrated are the construction and operation of 2 new types of lab. mills, (planetary and vibratory) for the grinding of dry and wet materials. Throughputs depend on the desired particle size; rates of up to 500 g/hr. were attained for particle size of the initial material of 100-50 μ . Particle sizes as small as 5 μ were produced with a mill by using gas jets at pressures of 7-8 atm. Operating temp. is 15-20°, making the mill suitable for reducing materials of low m.p.

3724. Khodakov, G.S., and Kudryavtseva, N.L., Peculiarities of the adsorption of gases and vapors on materials aggregated in grinding, Zh. Fiz. Khim. 37 (10) 2241-8, 1963.

The sp. surface, S_a of aerosol, initially ~ 200 sq.m./g., decreased after 2 min. of grinding dry and in H_2O to 60 and 172 sq. m./g., whereas grinding in Me_2CO and alc. increased it to 230 and 252 sq. m./g., resp. The decrease in S_a of aerosol, unlike that of quartz, corundum, and calcite, was irreversible. The av. particle size of quartz observed microscopically and detd. by N absorption was the same. Surfaces of powders, the aggregates of which had been broken up by addnl. grinding in H_2O , were equally accessible to H_2O and N vapors at 20 and -195° . resp. The surfaces were more accessible to CO_2 and H than to N and less than to H_2O vapors. The results indicated that the surface was only partially accessible to H_2O and other vapors, so that the true degree of dispersion of finely ground hard powders cannot be detd. by the adsorption method. The closest approxn. to the true value can be obtained by addnl. grinding in H_2O .

3725. Khodakov, G.S., and Rebinder, P.A., Mechanism of quartz comminution in surfactive media. Kolloid. Zhur. 23 482-90, 1961. Irreversible deformations of comminuted solids under the effect of surfactive agents are studied on quartz in the presence of water. Grinding of α -quartz in a vibration mill causes amorphization of the surface to a const. depth of 20 A. In dry air, coarse quartz-particles show a shallow, and small particles a deep amorphization amounting to several hundred A. (due to the decrease of active impurity concn. at the surface of small

grains). The energy necessary for the amorphization is approx. 10 times that for elastic deformation limit with grains 1-2 μ in diam. Exptl. data can be described by an equation leading to the known relations of Kick (coarse), of Rittinger (middle-fine) disintegration laws. A smaller depth of amorphization means an increase of brittleness and effectiveness of comminution.

3726. Khodakov, G.S., and Rebinder, P.A., Influence of the medium on the formation of an amorphous phase in quartz during mechanical dispersion, Dokl. Akad. Nauk SSSR 131 1316-18, 1960. The thickness of the amorphous phase on the quartz particles increased rapidly with surface area when the medium was air. It remained const. at 20 A. over a wide range of surface area when the medium was 80% H_2O . In 1.2% H_2O mixt. a sharp increase occurred at a surface area corresponding to a unimol. H_2O layer; the amorphous phase formed most rapidly for this H_2O concn. X-ray study showed that the crystal-grain size did not decrease during pulverization, and the amorphous phase is attributed to plastic deformation.

3727. Khodakov, G.S., and Rebinder, P.A., Effect of medium on the fine-grinding of solids, Kolloid. Zhur. 22 365-75, 1960.

The influence of the surrounding medium on the effectiveness of quartz fine-grinding was examd. in dry air, and in H_2O ,

acetone, alc., benzene, triethanolamine, paraffin, and paraffin oil, by the use of a vibration mill with a 3, 4, or 5.0 mm. amplitude. At 0.04% humidity, the dispersion rate is markedly higher than in dry air; the rate increases up to 2% humidity. Max. rate was observed at an av. monolayer H_2O -coating of quartz particles. At a higher humidity, the dispersion rate decreases again, reaching a min. at 30% moisture. In liquid medium, 50-80% H_2O , it attains its max. value. Decrease of hardness under the effect of above additives was observed with calcite, corundum, talcum, and other solids; whereas by the dry-air grinding of corundum it is impossible to reach more than 6-7 sq. m./g., in H_2O 50 sq. m./g. are easily obtainable. Sometimes, an apparent aggregation of dispersed particles occurs, due to the clogging of small surface cracks by the finest particles. The agglomerates can be broken down by a short grinding in H_2O .

3728. Khotuntsev, L.L., and Pushkin, V.S., Emulsification and comminution of various materials, U.S.S.R. Pat. 152 652, 3/22/63.

To increase the efficiency of dispersers, used for the emulsification and comminution of materials, superheated steam is introduced in the material to be treated.

3729. Khvatov, Yu.A., Vilenkin, D.M., and Knyazhitskii, Yv. A., New wear-resistant profiles of lining plates in ore grinding

mills, Gornyi Zhurnal (12) 31-5, 1963.

Most efficient lining in rod mills has wave-shaped profile.

Ribbed plate is very promising in treating Krivoi Rog type low-grade iron ore. Use of these plates will result in annual saving of 3000 tons manganiferous steel.

3730. Reh binder, P.A., Sareiner, L.A., and Zsigacs, K.F., Izvestia Akad. Sci. U.S.S.R., 1944.

3731. Kiesskalt, Siegfried, Wet milling of bronze, Ger. Pat. 933 883, 10/6/55.

Approx. 2-3% Hg or HgCl_2 is added during pulverization of bronze in ball mills to activate the metal surfaces. The effect can be increased by addn. of polar liquids, e.g., C_{10} - C_{12} alcs. The process is especially applicable to Al bronzes.

3732. Kiesskalt, S., and Bachmann, D., Vibration mills and vibration milling, Aufbereitungs-Technik 2 (10) 419-21, 1961. Operation of vibratory mill of 0.64 liter, type H.E. Rose, is compared with machine of 300 liters useful volum. Efficiency of vibratory mills is not proportional to velocity and is much greater than in vibrating sieves.

3733. Kihlstedt, P.G., The relationship between particle size distribution and specific surface in comminution, Symposium Zerkleinern, 205-16, Rumpf, H., and Behrens, D., Eds., Verlag

Chemie Weinheim/Bergstr, 1962. SA 3734, 3735 for abstract.

3734. Kihlstedt, P.G., Assessment of comminution by means of particle size and specific surface, Int. Mineral Processing Congr. 7th-Tech. Papers 11-17, Sept, 1964.

See 3735 for abstract.

3735. Kihlstedt, P.G., The relation between particle-size distribution and specific surface in comminution, Zement-Kalk-Gips 16 (2) 41-4, 1963.

Sp. surface and particle size distribution in studies of various kinds involving continuous grinding are plotted. The statistical relation between the sp. surface, S (sq. cm./sq.cm.), and screen size for 80% passage, K_{80} (cm.), agrees fairly well with the formula $S (k_{80})^{\frac{1}{2}} = C$, where C is 500-1000, depending on the nature of the material and the method of grinding.

This relation seems to be closely assocd. with the finite surface of matter and indicates that the Bond and Rittinger laws of comminution are different expressions of the same fundamental law.

3736. Lazar, J., Investigation of the size distributions of finely comminuted materials, Acta Technica, 32 325-41, 1961.

3737. Kihlstedt, P.G., Mineral Dressing, in Powders in industry, Society of Chemical Industry, Monograph No. 14, 373-84, London 1961.

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3738. Kirpichev, V.L., Early Russian proposal of grinding law, Zhurnal Physio-Chimiecheskova Obstzmva 6 (1) 152-5, 1874.

3739. Kinasevich, R.S., et.al., Mechanisms of size reduction in comminution systems. II: Interpreting size distribution curves and the comminution event hypothesis, Trans. AIME 229 207-10, 1964.

Quartz, limestone, barite, corundum, galena, pyrite, glass beads, and crushed glass were ground, either sep. or as mixts., in an 8-in. diam. X 9-in. long lab. mill with rods or balls. The concept of an av. event, which is a combination of the impact, abrasion, and chipping events, is introduced. The av. event det. the size distribution and energy-size redn. relation for the comminution process. Particle size and shape, cleavage, and hardness detd. the amts. of impact, abrasion and chipping events in a tumbling mill. Changing feed size changed the proportion of the 3 types of events, which changed the size distribution of the product. Glass balls were readily nipped in the mill and the product had a distribution modulus of unity, indicating that the grinding occurs by impact with this feed; angular feed particles gave a product with a distribution modulus of 0.8. In most cases the kinds of events were not altered when the materials were ground as mixts. In some tests a softer material increased the distribution modulus of the harder mineral by preventing it from abrading itself.

3740. Kinasevich, R.S., and Fuerstenau, D.W., Research on the mechanism of comminution in tumbling mills, Can. Met. Quart.

3 (1) 1-25, 1964.

Fracture by impact produces fragments with size distributions that are characterized by a distribution modulus, α , equal to 1.0. Size redn. in a tumbling mill generally gives values of α less than 1.0 because comminution results not only from impact, but also from attrition and chipping of particles. Soft particles are more susceptible to attrition than harder particles. If the particles are too tough to break in the ball mill, or if they are quite friable, an important mechanism of comminution appears to be chipping. Because these 3 phenomena may occur differently within a rod mill than in a ball mill, the distribution modulus of a rod-mill product may differ from that of a ball-mill product. However, these 3 effects can be considered to give rise to av. comminution events occurring in the mill, and these av. events can generally be summed to give the size distribution of the total product and the relation of that size distribution to the expended energy. In the ball milling of mixts., energy consumption by a given mineral is detd. by its vol. fraction in the mill. In the case of rod milling, energy is consumed preferentially by the material with the lower grindability because, being the harder mineral, it would wedge the grinding rods apart. Consequently the softer mineral is protected, while the harder mineral bears the brunt of the crushing and impact forces due to the weight

of the rods.

3741. Kisel'gof, M.L., and Polferov, K.Ya., Centrifugal dust separators for large ball drum grinding mills, Teploenergetika (11) 22-8, 1963.

Performance characteristics of existing separators are compared for their use in mills grinding anthracite fines and coal. Ball mill test results on special models of WTI-TKZ type separator.

3742. Klimpel, R.R., and Austin, L.G., Statistical theory of primary breakage distributions for brittle materials, Trans. AIME 232 (1) 88-94, 1965.

Equation is derived describing fragment size for single fracture of brittle solids. It contains equations of earlier workers as special or approximate cases and, in addition, is capable of describing coarse distributions in which few large particles are produced on fracture. Equations can be fitted well to single fracture experiments where overbreakage is avoided.

3743. Levenson, L.B., and Cigel'nuj, P.M., Drobil'no - sormirovochine machine u ismanovki, Moscow, 1952.

3744. Klovers, E.J., and Seidl, A.C., Grinding mills get new drive system, Allis-Chalmers Elec. Rev. 26 (3) 10-11, 1961.
How savings in initial cost, erection, operation and mainten-

ance are gained with new grinding mill drive, using 2 synchronous motors. Factors to be considered in design of motors.

3745. Knauth, Berthold, Investigation of the crushing of dry brown coal in sieve-hammer mills, Freiburger Forschungsh. Allo 10-104, 1958.

A general review of the subject with some original observations. Various mills in use are described and discussed. Theoretical considerations of crushing are presented, along with some expts., from which it is concluded that the mill giving best results is between 0.4 and 0.6 m. wide with a hammer speed of 60 m./sec. or more.

3746. Kneschke, A., Method of calculating fineness and uniformity of any ground material, VDI Zeit. 101 (11) 413-18, 1959. Definition of "fineness" and "uniformity". Derived equations are valid for any ground material and are applied in particular to ROSIN-RAMMLER ground material.

3747. Knoll, H., Change of anatase into brookite, Naturwissenschaften 50 (16) 546, 1963.

After long grinding of tempered samples of anatase in an agate ball-mill, the x-ray lines for brookite appeared. Complete transition of anatase to brookite was achieved by grinding for

30 hrs. samples previously heated for several hrs. to 600°, and contg. some brookite and 0.5-2.0% H₂O.

3748. Kochanovska, Adela, The x-ray study of the fine structure of ground powdered nickel, Czechoslov. J. Phys. 7 455-67, 1957.

The changes were studied in the fine structure caused by grinding powd. Ni of great purity obtained from Ni oxide by reduction in a H atm. and annealing. The curves depicting the course of the widths, intensities, and positions of diffraction lines as a function of the grinding time mutually correspond. The increase in the width of the diffraction lines corresponds to the decrease in their integral intensities and lessening of the interplanar distances, where the limiting values, i.e. the max: of the width, the min. of the intensity, and min. values of the interplanar distances, together with the max. of plastic anisotropy, are obtained for the same duration of the grinding process (16 hrs.). It is shown that during the long-period grinding process partial self-recovery of this material takes place. The cause of the decrease in interplanar distances, which was found in the 1st phase of the grinding process (instead of the increase expected according to theory),

should probably be sought in the residual H that is located interstitially in the lattice and that in the course of the plastic deformation, accompanied during the grinding process by an increase in temp., is eliminated from the lattice.

3749. Kochanowsky, B.J., Portable crusher for open pit and quarry operations, Min.Eng. 12 (12) 1271-4, 1960.

Gyratory, jaw, roll, hammer, and impact crushers can be used in portable arrangement. Highest crushing capacity can be obtained with gyratory crusher, but its height and necessary heavy foundation are disadvantages for its use as mobile crusher.

3750. Koegl, Franz, and Rewig, Horst, Comparative investigations for the determination of grain size of grinding materials of small size, using a particle-counter system, Silikat Tech. 16 (9) 295-8, 1965. (Ger).

Commercial grain sizes of fine-grinding wheels are in the range from 3.5 to 40 μ in diam., and are standardized on the basis of the Stokes sedimentation theory, with a Reynold flow coefficient of less than 0.2. Particularly strict requirements must be fulfilled for the monodispersity of lapping powders of the optical industry. For the continuous control of

monodispersity, the common Andreasen pipet method is not sufficiently accurate and is too time-consuming. Microscopic counting is too tiresome. The com. Coulter counter device, however, proved to be a nearly ideal instrument for the continuous control of grinding powders. Its discriminator data can be directly recalcd. to find equiv. spherical particle diams., and the discriminator sum data give percentages of the grain size fractions in different size classes as necessary in practice. Comparison of the Coulter counter serial results with those of the Andreasen pipet method indicates that the latter data are systematically shifted to finer grain sizes. Anomalies may even occur, when viscosity-modifying additions to the suspension liquid are made, whereas the Coulter counter data are not influenced in this case. The latter data are also more conclusive in explaining incidental anomalies observed in grinding opt. glass. Microscopic countings, however, are in good agreement with the results obtained by the Coulter counter. Recently, an improvement and simplification of the Coulter counter is presented by the new counter system TuR ZG 1 (developed by Wiss.- Techn. Zentr. f. Radiolog. Techn. u. Medizin. Elektronik, Dresden). For particles in the range from 2 to 50 μ the max. error of measurement is 5%, the reproducibility $\pm 1\%$ for 5,000 recorded particles.

3751. Kon, I.I., Multichamber vibratory ball mill, U.S.S.R. Pat. 131 608, 9/10/60.

3752. Kon, I.I., Vibrating ball mill, U.S.S.R. Pat. 114 028, 7/30/58.

An improvement is described of the ball mill of U.S.S.R. 103 835.

3753. Kondo, Y., and Gaudin, A.M., Sizing comminution products in the extremely fine range, Trans. AIME 229 292-9, 1964.

A combined method for sizing in the sub micron range was developed by using centrifugation and gamma-emission. Centrifugation of suspended albite, the Na feldspar, was carried out at 4°. Gamma-activation of the sample suspension was induced prior to centrifugation by irradiating it in a nuclear reactor. A scintillation counter with a discriminator was used to measure the activity of a beam of suspension as it was sedimenting in the centrifuge. Dissolved Na ion caused a nonsettling activity in the measurement.

3754. Konno, S., and Nogi, S., Degradation of coal size, (In Japanese) Resources res. Inst.-Coal preparation 14 (73) 262-73, Sept. 1964.

Study of processes of degradation of coal size, from mine face to preparation plant was made at Isohara mine, Japan. Greatest breakage occurred between coal face and coal bin and between coal bin and coal preparation plant. Corrective measures included improvement of chutes.

3755. Kopeliovich, L.V., Zakhareva, M.A., and Ivanov, N.K., Influence of wear on working faces of crusher hammers on size analysis of charge, Coke & Chem. USSR (English Trans. of Koks i Khimiya) (5) 12-13, 1964.

It has been established that as hammers wear, proportions below 3 mm and below 0.5 mm in size in crushed charge fall off.

Judging by correlation coefficient, influence of hammer wear is minor, even if working faces are only replaced every 10 to 15 days, at normal intensity of crushing. It is useful to extend service life of hammers to 40 to 50 shifts, since consumption of valuable metal is reduced and less work is expended in servicing crushers.

3756. Korach, Mor, Grain size distribution of crushed products, Proc. Conf. Silicat Ind., 6th, Budapest 221-30, 1961. (Pub. 1963).

Theoretical aspects of distribution curves of crushed products are discussed.

3757. Korda, E. Pierre, Jet crushing and drying, Aufbereitungs-Technik 2 (6) 230-9, 1961.

Efficiency of machines ranges from 50 g to 5 or 10 tons/hr.

Energy consumption and wear of machines are rather low. Expenditure of energy for drying purposes is insignificant.

Products are not warmed in crushing. Size curve is very

narrow and fineness of grain is in micron and submicron range.

3758. Kovalev, G.A., The influence of dry grinding of a substance on the character of its x-ray powder photograph, Zapiski Vsesoyuz. Mineral. Obschestva 86 401-3, 1957.

Dry grinding of various minerals leads to partial or complete disappearance of lines on the x-ray powder photographs.

3761. Krause, Witold, Kaziszyn, Irena, and Gryzbowski, Stefan, Koks, Smola, Gaz 10 (2) 43-8, 1965. (Pol).

Expts. with different types of coal from Poland were carried out. Coking expts. by progressive crushing confirmed a distinctive improvement in M-40 and M-10 parameters in comparison with the coke obtained by the normal method. The best results were achieved by using a sieve with 2-mm. openings to obtain a mixt. of grains 95-7% less than 2 mm. and 42% less than 0.5 mm. The petrographic crushing expts. did not result in significant improvements. The method is more complex and expensive. The results demonstrated the desirability of introducing progressive crushing on a com. scale and the possibility of reducing the cost by mixing larger proportions of cheaper coal with the charge. The method also produces greater uniformity in the quality of the coke and improves its structure.

3762. Kravchenko, V.S., et. al., Dustless breaking of rocks electrically, Min.Cong. J. 47 53-5, May 1961.

3763. Krebs, M., Synchronous drives for grinding mills, Rock Products 66 (11) 105-6, 1963.

Two vital points to consider in direct-connected motor starting are torque during acceleration and torque during pull-in. To arrive at nominal starting torque rating of motor, it is necessary to consider actual expected mill loading, system voltage drop due to starting inrush, and pull-in torque requirements. Synchronization or pull-in troubles on mills usually originate because slip-cycle duration at maximum subsynchronous speed is insufficient to permit field strength to build up to value required for pull-in.

3764. Kredba, Jaroslav, Batuska, Miloslaw, Hlavac, Jan, and Prochiazka, Swante, Influence of alkali content on the properties of artificial white corundum for grinding purposes, Silikaty 2 162-8, 1958.

Alkali and CaO are concd. in the block upper parts of the molten corundum substance which gives rise to scaly crystals of B-corundum. An abrasive material contg. a substantial percentage of B-corundum has greater tendency to be splintered and abraded.

3765. Kremheller, A., Faria, S., and Levin, A.K., Ball milling and the determination of lattice chloride in zinc sulphate, J. Electrochem. Soc. 107 753-8, 1960.

Ball milling, followed by displacement washing, permits a distinction to be made between lattice Cl^- and internal-surface Cl^- as parts of volume Cl^- . The surface area, which is detd. by gas adsorption methods, increases rapidly in the beginning and then in a linear manner as a function of milling time. The extent of linearity between surface area and milling time is considered a measure of crystallinity. The max. amt. of lattice Cl^- becomes incorporated at a processing temp. near 700° after a processing time of 2 hrs. ZnS gradually loses its ability to luminesce under ultraviolet irradiation during milling; the log of the luminescence emission is about proportional to the newly formed surface. It appears that the luminescence centers consist of lattice regions of about 0.2μ in diam., as is indicated by the observed min. size of luminescent particles. The luminescence emission of milled samples can be restored by reprocessing, altho the degree of restoration is highly sensitive to impurities introduced during milling.

3766. Kryzhov, L.V., et.al., Recommendation to increase economic efficiency of underground crushing of iron ore, Gornyi Zhurnal (9) 17-19, 1962.

Statistics on underground crushing of ore in mines of Krivoi Rog and Urals using crushers with aperture 900×1200 mm. Economic

analysis of underground crushing. Advantages of 3-shift work.

3767. Kubo, T., et.al., Structural change of TiO_2 and ZnO by means of mechanical grinding, Kogyo Kagaku Zasshi 66 (3) 318-21, 1963.

Structural change in TiO_2 and ZnO by mech. grinding was studied mainly by x-ray diffraction. By grinding for 96 hours, anatase-type TiO_2 obtained by H_2SO_4 -method is changed almost completely to amorphous state and anatase-type TiO_2 obtained from $TiCl_4$ is changed mostly to rutile-type. Relative amts. of anatase, rutile, and amorphous TiO_2 was detd. after grinding for 24, 48, and 96 hrs. By grinding for 96 hrs., the particle size of rutile-type TiO_2 and ZnO is decreased and the lattice distortion of the particle increases. When the ground TiO_2 is heated, the inner strain recovers gradually even at lower temps., but the growth of crystals is remarkable above 900° .

3768. Kuebrich, Gerhard, Determination of the degree of grind-
int of materials, Ger. (East) Pat. 37 749, 5/5/1965. 5 pp.
The degree of grinding of materials, e.g., cement, is measured by passing a known sample through a screen and weighing the residue. The wt. is then translated into a d.c. signal.

3769. Kuong, J.F., Nomogram for critical speed of grinding mills, Brit. Chem. Eng. 7 218, 1962.

3770. Kupchinov, V.N., Effect of grinding on the inner fields of ferrites, Belorus. Politekh. Inst. im. Stalina, Sbornik Nauch. Rabot (61) 81-92, 1957.

The effect of inner fields is esp. great for ferrimagnetic substances, i.e. materials with 2 magnetic sublattices, such as ferrites. The anisotropy field enters into the complete effective field with the factor $(M_1 - M_2)/(M_1 + M_2)$, which can be large, since the magnetizations of the sublattices M_1 and M_2 have opposite signs. Inner fields of the ground material are greater than those of the same material when intact. This is confirmed by the facts that grinding causes the frequency of the natural resonance to shift to the zone of higher frequencies, and that in a ground state some ferrites produce, in a 10-cm. wave zone, a rotation of the polarization plane of the electromagnetic wave passing through the ferrites in the direction opposite to that exhibited by the same materials when intact. These facts confirm the published assumptions that the properties of the ground material are not simply weakened proportionally to its vol. concn., but undergo deeper changes.

3771. Kurenkov, I.I., Preparation of heavy medium suspensions by comminution of ferrosilicon, Nauchn. Soobshch., Inst. Gorn. Dela, Akad. Nauk SSSR 19 35-46, 1963.

A review with 9 references.

3772. Kutman, B.L., Effect of rotation speed and liner construction upon performance of drum type ball mill, Teploenergetika 6 (11) 24-8, 1959.

Recommendations for liner design.

3773. Kuznichenko, A.N., Kukolev, G.V., and Kuznichenko, A.P., Grinding ceramic materials in ball mills, U.S.S.R. Pat. 133 391, 10/10/1960.

The grinding of leaning materials for use in the refractory and porcelain industry is facilitated by adding 1.0-1.5% of soap lye to the mill. This addn. reduces the grinding time by 20-30% and increases the fineness of the product.

3774. Rammner, E., On the size distribution laws of comminuted materials, Forschungen und Fortschritte 30 1-9, 1956.

Coal grinding in ball mills, ring-roll, impact mills.

Literature review.

3775. Lakunov, V., and Dubinskii, M.G., High temperature jet mill, Akademiya Nauk SSSR, Izvestiya, Otdelenie Tekhnicheskikh Nauk, Energetika i Avtomatika (4) 55-9, July-Aug, 1961.

Problems associated with design of mill for grinding various materials, operating with preheated compressed air, or gas obtained from special h-p combustion chamber. Selection of dynamic parameters of gas.

3776. Yamaguchi, G., Kubo, Y.I., and Ogawa, H., Fractures in thin sectioned corundum crystals, Bull. Chem. Soc. Japan 39 (2) 287-94, 1966.

3777. Lampman, J., Selection and performance of abrasion-resistant materials in the mining and quarrying industries, Pit & Quarry 55 114-17+, March 1963.

3778. Langemann, H., Kinetics of grinding hard solids, Chemie-Ingenieur-Technik 34 (9) 615-27, 1962.

Kinetics of grinding processes in ball mill. Graphic method for determining mill efficiency. Number of grinding bodies, impact value, kinetic impact energy, distribution of energy, efficiency of mill and its output capacity, and grinding potential of ball mill under premise of nonhomogeneous charge, were calculated.

3779. Lauer, O., The use of precision microsieves in particle size determination, Staub 20 69-71, 1960.

The newly-developed precision micromesh sieves, which are produced by the electroforming process, are being incorporated in the Alpine "air jet sieve". Much greater screening precision is achieved with these sieves than with the conventional wire mesh sieves. A large no. of fine powders such as talcum, zircon dust, and D.D.T. carrier mixture have been screened successfully with the new sieves.

3780. Lavergne, P.J., Reinforcement of ceramic grinding disks with steel annular ring, Can.Geol. Survey-Paper (64-58) 3 pp., 1965.

Extensive experience using ceramic grinding disks has shown that lifetime of these disks is relatively short when pulverizing hard, fine-grained rocks. To prevent chipping, cracking, and splitting of expensive ceramic disks, steel annular ring has been designed, which when properly fitted, increases resistance of disks substantially and greatly prolongs their life.

3781. Lawford, W.H., and Major, F.W., Further studies of pulp evaluation with the P.F.I. mill, Pulp Paper Mag. Can. 66 (11) T571-T577, 1966.

Comparative studies on bleached softwood pulps with P.F.I. mills showed that even though large beating-rate variations could exist between mills, relative strength levels of the refined pulps were not affected. The P.F.I. mill has excellent performance stability and is not affected by consistency changes as is the Mead refiner. Both the Mead refiner and Valley beater produced slightly more fines than the P.F.I. mill, and the resulting strength properties suggest that the Mead refiner is less effective in developing bonding areas on the fibers.

3782. Lazar, E., Laws of size distribution of mechanically crushed materials, Acta Technica (Budapest) 17 (3-4) 175-217, 1957.

Derivation of comprehensive law, according to which shape of weight distribution curve of grain size depends on number of effects of disintegration suffered. Large number of disintegrating actions result in logarithmic normal curves, medium number in normal curves, and small number in curves distorted to right.

3783, Lazar, J., Investigation of variations in granulometric composition of particle during crushing process, Acta Technica (Budapest) 46 (1-2) 127-49, 1964.

Experiments showed that in progress of crushing, peak of density curve is shifted more and more to left, and this process is faster when gap is narrowed. Its limit is complete closure of gap, i.e., gapless crushing device.

3784. Lazovskii, I.M., Korenskii, V.I., and Mochalova, R.V., Bulk density of coal charges as function of size analysis and moisture content, Coke & Chem. U.S.S.R. (Engl. Trans. of Koks i Khimiya) (11) 5-8, 1964.

Characteristics of variation in bulk density of binary, ternary and four-component mixtures of size fractions of coal, have been established under laboratory conditions; optimum size analyses for providing maximum bulk densities depend on moisture content of coal; increasing above-3-mm content of crushed coal leads in every case to increase in bulk density.

3785. Lean, J.B., and Worner, H.K., Comminution of hematite-quartzites by combined reduction and autogenous grinding, Cong. Inter. Prepn. Minerals, 6th Cannes, France 540-55, 1963, (Pub. 1964) (Fr).

Lab. and pilot-plant expts. are described whereby hematite-quartzites are crushed in an autogenous manner at 600° in gas reducers. From a jaspilite with 32% Fe, broken down to 5 in. in a jaw crusher, a final product was obtained with 55% less than 300 mesh at 400 lb./hr. with a grinder 4 ft. in diam. by 1.5 ft. long, the occupied vol. in the interior being 20%. Also appears in Mineral Processing Proceedings, Ed. by A. Roberts, 441-452.

3786. Leblanc, Raymond, Grinding of micaceous materials, Brit. Pat. 872 231, 7/5/1961.

The ease of grinding mica or micaceous minerals to finer than 325 mesh is improved by preheating the material for 5-15 min. at 1000-1600°F., preferably 1400°.

3787. Lee, C.A., Are you getting the most out of closed-circuit grinding? Chem. Eng. 68 112+, May 29, 1961.

3788. Legrand, C., and Bertrand, A., Remarks on the influence of crushing on quantitative x-ray analysis, Bull. Soc. franc. ceram. (50) 69-74, 1961.

Calibration curves are presented which were prepd. from synthe-

tic mixes of cristobalite and (or) tridymite with quartz and with $\alpha\text{-Al}_2\text{O}_3$ as the internal standard. Grinding increased the amorphous phase. A vibro-grinder was found more likely to change the structure than a Danguoneau grinder. However, grinding did not affect the cristobalite and tridymite content of silica bricks as much as it did the pure compds.

3789. Bhattacharya, T.K., and Zwicker, E.F., Ionizing irradiation effects on the fracture surface energy of potassium chloride, J. Applied Phys. 37 (2) 771-790, 1966.

3790. Lehmann, H., Practical study designed to determine course of grinding bodies movements in drum mill of 1 m diam, Bergbauwissenschaften 11 (19-20) 434-9, 1964.

Behavior of grinding bodies in cylindrical mill model is compared with movement patterns in working mills. Using appropriate charge it is possible to create conditions when there is no movement of bodies in mill during supercritical grinding. Movement of grinding bodies starts when mill is filled with large charges.

3791. Lehmann, Hans, Practical investigations of the motions of milling media in a model drum of one meter diameter, Tonind. Ztg. Keram. Rundschau 88 (7-8) 167-72, 1964.

In a ball-mill drum, tests were made with balls and cylinders by varying r.p.m, per cent loading, ratio of drum/load diam.,

and sizing of load.

3792. Lelkes, Gabor Janos, Vibrating ball mill, Ger. Pat. 1 054 311, 4/2/1959.

The vibrating mill described, with ball filler and a continuously variable speed drive, is useful for microfine pulverizing (from 1μ to less than 0.1μ of coarse ceramic and metal-ceramic powders. These are ground at a const. vibration amplitude, but the vibration frequency has the control range 20-250 cycles/sec. The frequency is increased with decreasing particle size. The interior of the grinding chamber is coated with an elastic plastic, e.g. weldable poly (vinyl chloride).

3793. Lenaway, W.E., Intermediate fine grinding, Chem. Eng. Progr. 60 (3) 100-3, 1964.

The development and operation are described of an air-swept comminutor producing a product size distribution of zero % + 100 mesh and 90% -325 mesh or better in a single pass. It is intended for use in applications between those of the screen-type hammer mills and recycle fine grinders.

3794. Lendrum, F.C., Stress corrosion cracking in rod mill heads, Can. Min. J. 86 (1) 61-5, 1965.

Grinding circuits at Denison Mines, Elliot Lake, Ont. Comprise two identical lines, each consisting of one 10-1/2x14 ft rod mill and two 12x32 ft rake type classifiers that are in closed

circuit with two 10- $\frac{1}{2}$ x24 ft pebble mills. After grinding 5 million tons of ore, both mills developed cracks around inner bolt circle; repair was made by stress-relieving all bolt holes by grinding off edges, drying head and forcing rubber cement into all cracks; tests indicate that cracking was caused by stress corrosion.

3795. Leonard, J., Symposium on problems of wear -- metallurgist's point of view, Rev. Universelle Mines 18 (9) 649-50, 1962.

A review of wear theories and solutions.

3796. Leonov, Yu. S., Effect of grinding on the luminescent properties of tungstate luminophors, Optika i Spektroskopiya 12 265-70, 1962.

The effect of grinding on the luminescent intensity and absorption and emission spectra of CdO-WO₃ and ZnO-WO₃ luminophors was studied. One reason for the decrease in luminescent intensity after grinding is the absorption of the luminescent radiation by oxide particles which after grinding are not covered by layers of the luminophor. See 3800.

3797. Leopold, B., and Fujii, J.S., Degradation by mechanical action as a means of studying cellulose-water interaction, J. Polymer Sci., Pt. C 11 149-60, 1965.

Plasticity is the main factor detg. the extent of cellulose

degradation in a vibratory ball mill. Milling in an inert solvent (C_6H_6) caused rapid degradation. Solvents that plasticize cellulose, such as H_2O or MeOH, decrease the degradation rate. Lignin decreases the ability of cellulose to absorb mech. energy, thus increasing the extent of degradation. Glucomannan facilitates the H_2O -cellulose interaction, reducing the degradation, while xylan has no effect. The effect of glucomannan is attributed to its close assocn. with cellulose in the cryst. core of the microfibrils, while xylan is located near the surface.

3798. Lester, R.H., Subsieve particle size measurements on porcelain materials, Am. Ceram. Soc. Bull. 37 129-34, March 15, 1958.

3799. Leulling, H., Abrasion-resistant material for crushing and grinding, Zement-Kalk-Gips 15 535-8, 1962.

The detg. factors for assessing the abrasion resistance of a material, i.e., the design of the crusher and the petrographic structure and abrasive sharpness of the feed material, are discussed.

3800. Levshin, V.L., and Ryzhikov, B.D., Causes of the drop in luminescence intensity during the mechanical crushing of zinc sulfide phosphors, II. Optika i Spektroskopiya 12 400-6, 1962.

Measurements were made of the luminescence intensity as a function of the particle size for the ZnS-Cu (3×10^{-5} g./g.), ZnS-Sm, and ZnS-Pb phosphors. Hg 436, 405, 366 and 312 m μ lines and a cathode lamp served as the excitation source. The decrease in intensity in the case of excitation in the region of the fundamental absorption was much smaller than in the case of long-wave excitation only for particles less than 10 μ , i.e., when the scattering played a predominant role. For particles with dimensions greater than 10 μ the reverse was true. In deformed crystallophosphors there appears in general an internal as well as an external extinction of the luminescence. The external extinction was especially noticeable at higher annealing temps. (1100°). The results indicate that explanations previously advanced of the drop in intensity of crushed phosphors (Frey, CA 44 3358a; Gisolf, CA 33 2415) are not adequate.

3801. Lewis, F.M., and Goodman, J.E., Grinding practice at Tennessee Copper Co's Isabella Mill, Mining Eng. 9 (11) 1253-5, 1957.

Larger, slow speed, under-loaded ball mill and hydraulic classifier are 40% more efficient than small high speed, normally loaded ball mill and rake classifier.

3802. Rehacek, K., Effect of certain factors on dispersion in ball mills, Fabre Lack 72 (3) 201-5, 1966.

3803. Lhoest, A., and Lesgardeur, A., Ore treatment and sintering of fines in eastern plant of Cockerill-Ougree S.A. at Seraing, Aufbereitungs-Technik 4 (5) 207-13, 1963.

Treatment involves crushing 50-200 mm ore to 0.50 mm size, screening through heated screens, and sintering.

3804. Liberti, Arnaldo and De Vitofrancesco, Giuseppe, Structural changes in silica particles following mechanical and thermal treatments, Staub 25 (4) 161-4, 1965. (Ger).
Infra-red spectroscopy was used to investigate the changes in the surface layers of quartz particles. These changes depend on the comminution process that has been used. In the present case a steel ball mill and wet and dry grinding in an agate mortar were employed. The wet grinding leads to a nonhydrolyzed readily sol. surface layer, while dry grinding destroys the cryst. structure and can, in time, change the whole of the particles to amorphous silicic acid. Subsequent heat treatment at 300° can, however, reconvert the amorphous material to the cryst. state.

3805. Liberti, A., and Devitofrancesco, G., The nature of ground quartz particles, Chem. Ind. (London) (51) 1983-4, 1963.
The nature of ground quartz particles was investigated by

infrared absorption studies. Pure quartz was ground under H_2O in an agate mortar for 50 hrs. and for the same time in a dry state. In both cases the particle size was less than 2μ , at which size absorption peaks are unaffected by smaller particles. Wet-ground quartz gave absorption peaks at 694 and 780-800 $cm.^{-1}$; the optical d. vs. concn. was a straight line; optical d.: 0.16 for a peak at 694 $cm.^{-1}$ and 0.9 for a peak at 800 $cm.^{-1}$ (0.5% quartz, 0.53 mm. thick). By leaching with 10% NaOH wet-ground quartz showed the same peaks; optical d. vs. concn. was a straight line; optical d. 0.3 and 1.8, resp., under the same exptl. conditions. Dry ground quartz showed, in addn. to the above peaks, at 950 and 3400 $cm.^{-1}$ owing to OH vibration of the silanol group and indicated amorphous silica. Extending the dry grinding time led to a change of the doublet at 800 $cm.^{-1}$ to a singlet; later they disappeared, leading to 950- and 3400- $cm.^{-1}$ peaks, which increased in proportion. From these results it was concluded that quartz particles have an easily sol. layer at the surface which should be considered as a disturbed or semicryst. state. The thickness of this layer depended on the grinding time, and under these exptl. conditions, about 50% of the particles was affected.

3806. Liessmann, G., Use of microwaves in crushing of rocks-statement of problem and literature review, *Bergbautechnik* 14 (1) 46-7, 1964.

Continuous-wave magnetron with power as high as possible should

be used as generator. Frequencies prescribed by law are indicated and attention is drawn to dangers resulting from free emission of high-energy microwaves. Protection of magnetron from reflected waves, parallel operation of several magnetrons, and choice of favorable shape of antenna.

3807. Lintner, E.J., Methods and costs of mining and crushing gypsum at the Mine of the Ebsary Gypsum Co., Inc., Wheatland, N.Y., U.S. Bur. Mines Info. Circ. IC6971, 19pp., 1937.

Methods and practices employed by Ebsary Gypsum Co., one of the largest operators of the State, typify standard methods followed by gypsum producers in western New York.

3808. Lintner, E.J., Methods and costs of mining and crushing gypsum at the Mine of the Victor Plaster, Inc., Victor, N.Y., U.S. Bur. Mines Info. Circ. IC6967, 18pp., 1937.

Describes operations at mine typical of conditions in western New York. Cost tabulations represent local operating expenditures only and not total production costs.

3809. Lintner, E.J., Mining and grinding methods and cost at the Malvern Clay Co., Malvern, Ohio, U.S. Bur. Mines Info. Circ. IC6962, 22pp., 1937.

This is one of a series describing clay mining, crushing, and grinding methods at various operations throughout the United States. Cost tabulations represent local operating expendi-

tures only and not total production costs.

3810. Lintner, E.J., Mining and grinding methods and costs at the Evans Pipe Co., Clay Mine, Uhrichsville, Ohio, U.S. Bur. Mines Info. Circ. IC6929, 18pp., 1936.

This is one of a series being issued by the Bureau describing clay mining, crushing and grinding methods at typical operations in Tuscarawas County (Ohio) clay center.

3811. Lintner, E.J., Mining and grinding methods and costs at the Dennison Sewer Pipe Co., Clay Mine, Dennison, Ohio, U.S. Bur.Mines Info. Circ. IC6921, 16pp., 1936.

3812. Lippert, Ayel, and Muschelknautz, Edgar, Process for the automatic breaking of a column-feed of granular or pulverized material, Belg. Pat. 645 008, 6/30/1964; Ger. Appl. 3/19/1963, 15pp.

A granular or pulverized material can be transported in a column-form pneumatically or hydraulically without packing by moving it a short length along a tube then breaking it with expansion, either by use of a gas or a gravity pressure drop, similar to piston flow. Relief points are provided at short intervals in the conveying conduit where pressure is relieved and the released pressure is passed back to balance pressure losses in the conduit, with consequent expansion and mobility of the material being transported.

3813. Lipson, C., Wear consideration in design, Machine Design 35 (25) 156-64; (26) 177-85; (27) 182-91; (28) 142-7; (30) 140-4, 1963; 36 (1) 121-4, (2) 167-73, 1964.

Basic theories of wear. External wear mechanisms of scoring and seizure; effects of metallic inclusions, surface films and lubricants on wear rate; methods of resisting abrasive wear; effect of residual stresses on physical wear properties; contact stresses; corrosion and cavitation; fretting, fretting corrosion, pitting and spalling; high-temperature oxidation and stress-corrosion cracking; surface treatment for wear resistance; polishing, electroplating, anodizing, metal spraying, hard facing, case hardening.

3814. Lissenden, A., Vibratory grinding mill, Chem. & Process Eng. 46 (4) 203-4, 1965.

New type of vibratory grinding mill has been developed for production of superfine particles below 10 μ . Mill has no rotating parts and is electromagnetically activated. It has been combined with classifier and Japanese sedimentograph, so that particles down to several microns can be estimated. No production data are given.

3815. Lodding, W., Continuous control of particle size, Eng. & Min. J. 165 (7) 82-4, 1964.

In new method proposed for on-line screen analysis of ore and pulp streams, sample stream is withdrawn from main stream in

continuous splitter; sample stream is then separated into 3 fractions on 2-deck screen; weight ratios of all 3 screen products are measured and recorded continuously. 2 screens should be so chosen that one is coarser than mode of size distribution, and second screen smaller than mode. Precision and sensitivity of method.

3816. Lueling, H., Recent developments of wearing plates for crushing hard materials, *Aufbereitungs-Technik* 5 (5) 271-3, May 1964.

Factors which must be considered in production of wearing plates, including criticism of use of austenitic manganese steels as lining material in construction of mills. Instead of these alloys, martensitic and in certain borderline cases even martensitic carbide alloys seem to gain ground to great extent, primary importance being attached to further development of toughness measurement and to choice of adequate shapes for grinding liners.

3817. Lueling, Heinrich, Wear-resistant materials used for crushing hard substances, *Europaeischen Symp. Zerkleinern*, 1., Frankfurt am Main 631-45, 1962.

Many factors must be considered on selecting wear-resistant materials for crushing hard materials. The wear on crushing hard materials consists of macro wear, grinding wear, and abrasion wear. The petrographic structure is important in

coarse crushing, the individual minerals on fine grinding. The mineralogical hardness, the crushing strength, and the kind of resulting splinters must be considered for the classification of materials to be crushed. The wear-resistant materials are divided into 3 groups: austenitic Mn steels, martensitic Cr, Mn, Ni, Mo, and V alloy steels, and martensitic-carbide cast iron. This division simplifies the selection of suitable alloys. The wear resistance of an alloy depends on the microstructure. The microstructure of the 3 groups is discussed.

3818. Luelling, H., Abrasion resistant materials for crushing and grinding, Zement-Kalk-Gips 15 (12) 535-8, 1962.

Same as 3817.

3819. Luzanov, V.K., Laboratory centrifugal mill, Tsvetn. Metal. 36 (5) 76-7, 1963.

The construction of a 1.3 l. capacity, wet, centrifugal conical mill is described. The 6-blade impeller is of the radial type. The grinding medium is 3-5 mm. hollow shot. The mill is capable of grinding 1000 g. of $-0.43 + 0.3$ mm. scheelite ore to 96% - 0.074 mm. in 160 sec. The mill has a larger capacity than a similar ball mill and yields a product more uniform in size.

3820. Luzanoy, V.K., Centriclone mill for fine grinding, Tsvetnye Metally 32 (4) 78-9, 1959.

A centrifugal centriclone mill is described, consisting of a cylindrical or somewhat conical tank fitted with a Fahrenwald flotation machine-type impeller. The impeller has holes to decrease the pressure and to assist circulation within the tank. The grinding medium is shot, balls, or ore. The mill operates in circuit with a hydrocyclone which returns coarse material to the mill. The mill is useful for addnl. grinding of concentrates. In a test with Mo sulfide concentrate, the feed contained 89.8 and the hydrocyclone 98.35% material -0.074 mm. in size; Mo extn. in the clean-up cycle was increased by 8-9% abs., and Mo content of the concentrate was also increased.

3821. Luzin, P.M., Grinding in hammer mill, Teploenergetika (6) 10-14, 1965.

Results of investigation using system of tracers for studying distribution and movement of coal and lignite particles in two-row axial mill during normal operation and during period of overloading. Tracers featured two 5x5x75 mm rectangular membranes installed on inner lining of mill body. Uniform coal feed and extreme air flow are required for efficient operation.

3822. Luzin, P.M., Effect of moisture on pulverization of coal of Nazarovskoe deposit in hammer mill, Teploenergetika (2) 66-8, 1965.

Influence of moisture of raw fuel on grinding characteristics, and conditions of drying of coal during grinding process in hammer mill testing unit were studied.

3823. Mabson, L.R., Primary crusher selection, Mine & Quarry Eng. 27 (3) 114-21, 1961.

Factors to be considered in selecting primary crusher include characteristics of material to be broken, plant capacity, product size and shape and factors dependent on method of mining rock or ore.

3824. Maier, Georg, Device for mechanical disintegration and crushing of mineral matter, Ger. Pat. 966 771-2-3, 9/5/1957. Addns. to Ger. 965 961 (below.)

3825. Maier, Georg, Centrifugal mill for selective disintegration of minerals, Ger. Pat. 965 961, 7/4/1957.

3826. Maier, H., Kinetics of comminution of hard materials; experiments on wet grinding and grindability limit, Aufbereitungs-Technik 6 (1) 1-6, 1965. (In German).

Problems of wet grinding in ball mills and quartz grinding tests. Grinding rate is a function of liquid filling ratio

and charge of material to be ground. Grindability limit and thus limit of inhomogeneities in case of quartz is investigated by means of surface measurements.

3827. Makky, S.M., Fracture theory of surfaces of maximum shear, Matl. Res. & Stand 2 655, August 1962.

3828. Mamen, C., From taconite to pellets at Adams Mine, Can. Min. J. 86 (5) 65-71, 1965.

Operation near Kirkland Lake, Ontario upgrades ore containing 23% Fe and produces 1,000,000 tons/yr of pellets containing 66% Fe. Eight different ore bodies, containing estimated 100,000,000 tons of ore, will be mined by open pit. Mined ore is reduced in three stages to minus 5/8 in. Concentrator has three similar parallel milling circuits, consisting of rod mill, ball mill, bank of cyclone classifiers, and rougher and finisher magnetic separators. Traveling grate kiln heats pellets to final temperature of 2400 F.

3829. Mann, Robert T., Methods and costs of quarrying, crushing, and grinding limestone at the plant of Southwestern Portland Cement Co., El Paso, Tex., U.S. Bur. Mines Info. Circ. IC6608, 13pp., 1933.

3830. Marchand, Andre, Pacault, Adolphe and Forchioni, Alain, Increase in the diamagnetism of graphite by grinding, Compt. Rend. 255 (8) 1257-9, 1962.

The effect of grinding by means of a rotary B carbide grinder on the diamagnetism of Madagascar (G_M) and Ceylon (G_C) natural graphites and 2 synthetic graphites (G_1) and (G_2) was studied. All samples were purified in Cl_2 at 3000° . The diamagnetic susceptibility of G_M and G_C was increased after grinding, while that of G_1 and G_2 was decreased. The susceptibility of ground G_M was decreased to its initial value by heating in Ar to 2650° . The effect of grinding on G_M was ascribed to the creation of defects.

3832. Margulis, V.S., Shupov, L.P., and Ostapenko, P.E., Prospects of using in mining industry jet mills of counter-current type, Gornyi Zhurnal (9) 66-8, 1962.

Principle of comminution is based on use of 2 nozzles facing each other and ejecting ore carried by air, superheated steam, products of combustion of liquid and gaseous fuels, or water. Impact of particles in opposed jets results in comminution. Data on comminution of magnetite ore and cost of comminution.

3833. Marot, Paul, Separation of mixtures of particles with different sizes and weights, Ger. Pat. 1 015 391, 9/12/1957. A multistep sepn. process for coal dust, powd. ore, etc., is described which avoids the excess diln. of the sludge dispersions.

3834. Marshall, J.E.F., Laboratory techniques, comminution, classification and hydro-metallurgy, Mine & Quarry Eng. 29 (10) 443-51; (11) 493-500; (12) 537-44, 1963.

Reviews of papers presented at 6th International Mineral Processing Congress held at Cannes, France in 1963, include 50 papers on laboratory techniques, comminution, classification, hydrometallurgy, gravity concentration, flotation of iron ores, magnetizing, roasting and magnetic separation, flotation theory, flotation practice, and control and automation.

3835. Marton, F.D., Grinding-mill control system increases mill output by 75 barrels per day, Instr. & Control Systems 32 1034, July 1959.

3836. Masson, A., Study of optimum operating conditions in crushing carried out in ball mills with smooth liners, operating on wet fines, Rev. Universelle des Mines 18 (4)333-42, 1962.

Optimum values were determined for rotating speed, quantity of crushing charge and of material to be crushed. Wet and dry crushing compared.

3837. Masson, A., Contribution to the study of the optimum loading charge in dry-ball mills, (Univ. Liege). Rev. materiaux construct. et trav. publ. C (531) 303-12, 1959; (532) 12-16, 1960.

Lab. tests under different conditions indicate that at the optimum rotation speed (75% of the crit. speed) the optimum charge for max. redn. is that which fills the spaces between the balls (vol. ratio charge/spaces $V = 1$). The crit. speed N_c is that at which particles are held against the interior surface of the mill. Near N_c , the greatest redn. occurs at 0.21 V; at 83.5% N_c , 0.63 V; 72% N_c , 1.26 V. The later speed is most common in industry and gives the least overgrinding. To limit the production of fines, V should be lower than optimum. The greatest energy consumption occurs at 83.5% N_c . Various parameters used for characterizing particle size and size distribution are compared. For sym. distributions, 2 parameters are adequate, a measure of av. size and one of spread. Non-sym. or anomalous distributions require addnl. parameters. The parameters which best described the materials tested (Meuse gravels) were the geometric mean dimension k_m , where $\log k_m = \sum [(N_x / 100) (\log d_x + \log d_{x+1}) / 2]$ and W_x is the wt. between dimensions d_x and d_{x+1} in geometric progression, and the geometric standard deviation σ , where $\log \sigma = [\sum (W_x / 100) \{(\log d_x + \log d_{x+1}) / 2 - \log k_m\}^2]^{1/2}$. k_m correlates well with the proportion of ground material (in this work -65 mesh) and σ with the ratio of fines (-200 mesh) to total ground material.

3838. Matrozov, V.I., and Golovachevskii, Yu. A., Pneumatic crushing of granulated superphosphate, Khim. Prom. 598-600, 1960.

The construction of an exptl. pneumatic crusher is described. Diagrams showing the yield of different-size fractions as a function of the air velocity are presented. The total resistance to flow (ΔP_m) of the equipment is detd. from the empirical equation: $\Delta P_m = 0.16w^{2.12} (1 + 0.52 g)$, where w is the air velocity in m/sec., g is the solids concn. in the air stream in kg./kg. air, and ΔP_m is in mm. H_2O . The min. energy consumption per unit wt. product occurs at $w = 35-7$ m/sec.

3839. Mart'yanov, Yu. A., Revazashvili, B.I., and Shtern, M.D., Wet grinding of cast iron turnings at Karsakpai Beneficiation Plant of Dzhezkazgan Mining-Metallurgical Combine, Tsvetnye Metally 33 (11) 11-17, 1960.

A flow sheet for the wet grinding of cast iron shavings, for use in Cu cementation by the Mostovich process, is described. The appl. includes a ball mill, a classifying ejector box, and hydrocyclones. Wet grinding is claimed to be 40% more effective than dry grinding in the production of 38-40% -0.1 mm. fraction.

3840. Martyny, Wm.C., Treatment of fine-grained, luminescent phosphors, Ger. Pat. 1 012 175, 7/11/1957.

A method is described for pre-airing and applying phosphors to

tubes for fluorescent light. In a ball mill of 94 liter capacity, 30 kg. of annealed inorganic phosphor (I) is powdered to the desired grain size ($2-3\mu$) with reagents. See CA 54 11721b.

3841. Mular, A.L., Comminution in tumbling mills: a review, Canad. Metallurg. Quart. 4 (1) 31-74, 1965.

Reviews 30 articles dealing with ball mill kinetics, especially relating energy to size modulus.

3842. Fahnrenwald, A.W., New type ball mill 25% more efficient, Metal Min. and Proc. 2 (3) 30-31, 1966.

Space mill. Balls in a chamber which oscillates about a vertical axis. Capacity is 6 times ball mill per wt of ball load. 12-in mill runs at 700-1000+ orbits/min.

3843. May, J.R., and Warner, R.K., Find grinding of artificial graphite, Proc. Conf. Carbon, Buffalo, 4th 741-50, 1959.

Homogeneous dispersions of fissile and fertile material in graphite are being considered as fuel for high-temp., gas-cooled nuclear reactors. A possible method of fuel prepn. involves compaction of finely ground artificial graphite with U and Th metal powders. Size redn. of artificial graphite is, therefore, of interest in the prepn. of graphite-fuel compacts. Reactor graphite has been successfully size-reduced in a jaw crusher, pin disk mill, and ball mill to give a material 50% finer than 9μ , and with B.E.T.N. absorption surface area

ranging up to 18 sq. m./g. The variables in ball milling have been studied; Ni-Hard balls give a faster grinding rate but a higher contamination than is obtained with steel balls. Leaching with boiling HCl removes contamination introduced by such grinding. The Rosin-Rammler function $R = 100 e^{-(x/x_n)^n}$ is applied to size distributions of the ground graphite. In the size range 70-1000 μ the distribution const. n equals 1, which is consistent with published data for other materials. However, above and below this size range, the distribution const. approximates 2. This high value for n for the subsieve range has not been previously reported, but is not peculiar to artificial graphite, because other materials have a similar value.

3844. Mayer, W., International congress on ore treatment in 1964, Glueckauf 101 (4) 264-9, 1964.

3845. Mayer, F.W., Problems encountered in the elucidation of separation processes in granular masses, Chem. Ing. Tech. 32 155-63, 1960.

A review covering: sepn., subdivision, and partition; factors influencing sepn. processes; sepn. nos. and distribution curves, as well as properties, characteristics, and use of curves.

3846. Cohen, E., et.al., The residence time of mineral particles in cyclones, Inst. Min. and Met. Trans. 75 (6) C129-38, 1966.

3847. McAnally, S.G., Mining, crushing, and grinding methods and cost at the Reliance Cement-Rock Quarry of the Giant Portland Cement Co., Egypt, Pa., U.S. Bur. Mines Info. Circ. IC6448, 16pp., 1931.

Describes practices in use more or less throughout the Lehigh Valley cement district.

3848. McDonald, D.F., and Enzian, Charles, Prospecting and mining of copper ore at Santa Rita, N. Mex., U.S. Bur. Mines Bull. B107, 122 pp., 1916.

This article presents a detailed study of mining operations and costs. Also discusses timekeeping, accounting, and warehouse methods.

3849. Wieland, W., Experiments with a model ball mill, Silicates Industriels 30 (1) 41-6, 1965.

3850. Maeder, H.J., Vibration Mill Palla-U, Operating experience and observations on the milling process, Aufbereitungstechnik 6 (3) 175-80, 1965.

3851. Weiss, H., Method of operation and experimental results with the Rotex breaker, Aufbereitungstechnik 6 (3) 166-174, 1965.

3852. Matouschek, F., The significance of the fineness of the raw material on cement kiln output, Zement-Kalk-Gips 18 (6) 296-8, 1965.

3853. McQuitty, S., and Rivet, L.S., Ore pebble regrind of sulfide concentrates in the Hardy concentrator, Falconbridge, Can. Mining Met. Bull 624 (4) 397-400; Trans. Can. Inst. Mining Met. 67 67-70, 1964.

In the Sudbury area the ore consists of the sulfide minerals pentlandite, chalcopyrite, and pyrrhotite, with lesser amts. of pyrite and magnetite. Ni occurs chiefly as pentlandite, part of which is disseminated throughout the pyrrhotite. A grate discharge pebble mill in closed circuit with cyclones regrinds 25-30 tons/hr. of sulfides to approx. 90% - 25 mesh. The consumption of the screened ore grinding medium is 2.5 lb. /kw-hr., or less than 1% of the tonnage of reground sulfides.

3854. Meaders, R.C., and MacPherson, A.R., Technical design of autogenous mills, Min. Eng. 16 (9) 81-3, 1964.

Study of technical design of autogenous mills made to determine effect of both design and operating variables on results. It was shown that variables of major importance are height and spacing of shell lifter bars, method of product discharge, length of mill, and speed of mill. Tests were conducted in wet mill and dry mill to evaluate effects of these variables using limestone, iron ore and uranium ores. Less kilowatt-hour

per ton were required in dry grind; however, on basis of power per unit of surface, wet grind was more favorable.

3855. Medvedeva, A.P., Increase in the grinding rate of caked magnesite under the action of surface-active substances, Byull. Nauch.-Tekh. Inform. Vsesoyuz. Nauch.-Issledovatel. Inst. Ogneuporov (1) 37-45, 1956.

Adsorbing surface-active substances (SSB, C_7 - C_9 fatty acids, and colophony) show a marked accelerating effect on the grinding of caked magnesite in a vibratory mill. Results of lab. expts. were confirmed in a ball mill of 100-kg. capacity. The secondary caking of finely dispersed powder of magnesite is not made worse by the addn. of the mentioned substances. The adsorption of lignosulfonates of sulfite liquors on finely ground magnesite powder of detd. chem. compn. and various sp. surface values was studied.

3856. Meisner, H.P., Michaels, A.S., and Kaiser, Robert, Crushing strength of zinc oxide agglomerates, Ind. Eng. Chem. Process Design Develop. 3 (3) 202-5, 1964.

By action of cohesive forces of the van der Waals type, fine particles of Zn oxide spontaneously form agglomerates. By assuming the constituent particles all to be spherical and of the same diam. d , as a 1st approxn. the av. coordination no. of these particles can be calcd. from ϕ , the vol. fraction of solids in the agglomerate. The force which an agglomerate of

diam. D can support is a unique function of D , d , and ϕ . This relation agrees with exptl. data for 2 different Zn oxide powders.

3857. Meloy, T.P., Cumulative and weight retained tables for Gaudin-Meloy size distribution, Trans. AIME 226 (4) 357-61, 1963.

3858. Meloy, T.P., and Bergstrom, B.H., Computer simulation of comminution circuits, Quart. Colo. School Mines 59 (4) 443-63, 1964.

The use of a computer to simulate comminution circuits is described. A linear math. model is formulated which describes single and repeated fractures in grinding operations and the simulation of comminution circuits. Basically the model consists of describing the probability of a particle being broken in a given unit length of time, the size distribution of the daughter fragments once it is broken, and the residence time for the particle in the mill. The computer test indicates that the probability of a particle being broken is a function of the amt. of material fed to the mill. The results show that the mill will behave in a manner dependent almost exclusively on the type and amt. of material fed into it.

3859. Meloy, T.P., and Bergstrom, B.H., Matrix simulation of ball mill circuits considering impact and attrition grinding, Int. Mineral Proc. Congr. 7th-Tech. Papers 19-31, Sept., 1964.

Open and closed circuit grinding have been simulated by a model derived probabilistically and expressed in matrix algebra. Sharpness of separation of classifying operation is most important factor in performance of circuit. Next in importance are probability of particle being broken in given length of time and residence time of particle in mill. Shape and size distribution of daughter fragments from fracture are relatively unimportant.

3860. Mark, T., Klemm, W., and Smekal, A., Ultramicroscopic structures and scratches, *Naturwissenschaften* 31 143-4, 1943.

3861. Berry, J.F., and Bruce, R.W., A simple method of determining the grindability of ores, *Can. Min. J.* 87 (7) 63-5, 1966. Method compares the size distribution parameters of an unknown and a reference ore ground to the desired fineness under the same conditions in a 12-inch laboratory mill. Results are expressed in terms of Bond's work index.

3862. Mergel, S., Grinding media classification in tube mills with graded grinding plates, *Zement-Kalk-Gips* 13 (8) 351-4, 1960.

Clasification effect obtained by reverse installation of graded plates and ridged plates in tube mill is explained. Difference in slope of surfaces of plates causes small grinding media to display "preferential" rebound into free space towards outlet of mill.

3863. Meyer, Guenter, Concentration of reduced iron ores, Ger. Pat. 1 191 762, 4/29/1965. 2 pp.

To prevent Fe particles from enclosing gangue during crushing of reduced ores or ore concentrates, they are subjected to a selective electrohydraulic size redn. and the metallic Fe is then sepd. from the gangue magnetically or gravimetrically. In the electrohydraulic process, an elec. discharge is passed through an aq. suspension of the ore. This produces a shock wave, the energy of which is transferred to the ore particles, causing them to break up.

3864. Gillis, A.E., Circuitry and equipment installed for control of the grinding circuit at East Malarlic Mines Ltd., Can. Min. J. 87 (3) 48-9, 1966.

Found that different sonic frequencies needed for rod mills than ball mills.

3865. Mikhailov, M.; Khristov, Khr.; and Pavlov, Vl., Grinding of lignite coal from Maritsa-Iztok Basin and its combination in a chamber furnace, Izv. Tsentr. Lab. Energ., Bulgar. Akad. Nauk 7 45-55, 1964. (Bulg.)

The results of grinding in a tangential pit mill with gravitational separator were reported. The adverse characteristics of the dust and the disadvantages of the use of a gravitational separator in the grinding of lignites were described.

3866. Marcotte, E.J., Automatic control of a grinding circuit as experienced at East Malartic Mines, Can. Min. J. 87 (3) 50-54, 1966.

Automatic feed control has eliminated workers, improved performance.

3867. Millard, D.J., Newman, P.C., and Phillips, J.W., The apparent strength of extensively cracked materials, Proc. Phys. Soc. 688 723-8, Oct. 1955.

3868. Hardinge, H., Autogenous Milling, Aufbereitungstechnik 1 (1) 46-52, 1960.

3869. Miller, D.R., Friction and abrasion of hard solids at high sliding speeds, Proc. Roy. Soc. (London) A269 368-84, 1962. An investigation was made of the friction and wear of hard solids, such as sapphire, rutile, TiC, SiC, diamond, and fused silica sliding on metal surfaces at very high speed (700 m/s.). Hard solids can undergo extensive wear when rubbed against metals of much lower hardness. There is evidence that this apparently anomalous effect is due partly to the abrading effect of small particles of the harder material which becomes dislodged and dragged across the surfaces. This disintegration may be caused by thermal shock due to the high temp. gradients produced, while in some cases chem. reactions or solid solns. may lead to strong adhesion between the metal and the nonmetal.

With diamond there is supporting evidence that the abrasion process is accompanied by a thermal transformation into amorphous C.

3870. Minkhorst, J.H.K., and Muysken, P.J., Development of impact roll crusher, *Geologie en Mijnbouw* 44 (9) 313-15, 1965. Impact roll consists of heavy roll with one breaking ridge, which is eccentrically suspended by compound leaf springs between two circular disks carried on horizontal shaft driven at speed of 240 rph. Mass and speed give roll sufficient kinetic energy to break hard material without slowing down. Fitted with this impact roll, crusher has satisfactorily handled large lumps of hard stone which used to pass unbroken.

3872. Mitchell, R.J., Portability equals profits at Miami crushed rock, *Rock Prod.* 67 (11) 64-5, 1964. Portable crushing plant at Miami, Fla. operation follows excavation and continuously stockpiles coral limestone as it moves, reducing problems of truck haulage and stockpiling. 300-tph portable crusher follows stockpile of pit-run rock around rim of pond, converts it to -2 in. roadbase, and stacks it in windrow. Limestone, which is from 30 to 35-ft thick, is drilled out in 36-hole pattern by rotary drill.

3873. Mitchell, R.J., Crushing roundup, Rock Prod. 67 (3) 59-92, 1964.

Factors in selection of crusher equipment. Design features, construction, advantages and limitations of various types of crushers. Method of calculating crusher power requirements. Operation and applications of closed-circuit crushing and portable crushing units. Use of hardfacing for protecting crusher parts against abrasion.

3874. Mitchell, R.J., Soderberg, H.E., and Doyen, J.E., What you should know about crushing, Metal Min. & Proc. 1 (9) 21-39, 1964.

Factors to be considered in selecting kind and capacity of crushers. Principles of operation and utilization of roll, gyratory, cone, hammermill and impact crushers. Horsepower required in crushing operation can be determined from equation relating horsepower and work index of material being reduced. Calculation of total load for crusher operating on closed circuit. Use of hard-facing with abrasion-resistant alloys to rebuild crusher parts. Causes and factors influencing generation of dust from crushers. Dust collectors and dust control systems. Devices and functions for automatic control of crushers. Practical examples of automation systems.

3875. Miyawaki, I., Soeda, N., and Shiota, K., Relation between size of material and grinding time in ball milling, Min. & Met. Inst. Japan-J. 77 (876) 389-93, 1961.

Samples of limestone were ground in laboratory ball mill to evaluate energy-size reduction relationships. Both Gaudin-Schuhmann and Rosin-Rammler functions are applicable to size distribution of grinding products in fine sizes. Equation for calculation of grinding time.

3876. Moelling, H.A., Mechanical feeding devices for crushers, Europaeisches Symposion "Zerkleinern", 119-26, 1962.

3877. Moelling, H.A., Types and function of modern machines for coarse crushing, Aufbereitungs Technik 2 (2) 45-63, 1961. Illustrated systematic survey on types of crushers, their function and essential differences. Fields of action of crushers are plotted in graph and related to grain sizes, throughput behavior and corresponding conveying equipment. Scheme of quality index which would permit classification of different types of crushers.

3878. Moelling, H.A., Selection of primary crushers, Aufbereitungs-Technik 1 (10) 422-8, 1960.

Properties of coarse crushing machines as far as technical engineering, efficiency and maintenance are concerned, are compiled in valuation table which permits selection of optimum

system for every individual purpose. Advantages and disadvantages of principal groups of crushers. Comparison is drawn between precrushing by blasting and by machines.

3879. Moelling, H.A., Definition of terms used in crushing technology, *Aufbereitungs-Technik* 1 (8) 340-8, 1960.

Conditions concerning raw materials, e.g., shape of particles, reduction ratio in various machine systems, and throughput; facts and values directly related to crushers, as for instance width of crusher setting, angle of nip, specific energy consumption.

3880. Moelling, H.A., Fundamental problems of coarse crushing, *Aufbereitungs-Technik* 1 (7) 287-98, 1960.

From a critical survey of existing knowledge it is concluded that one of the major difficulties encountered is the variation of strength of large lumps. This illustrated by cited Russian experiments. The use of a size reduction factor is advised against, and energy input calculations according to Bond or Svensson and Murkes are said to be often erroneous. Theories of hardness and toughness are analyzed, and results are stated in table. Product size distribution is represented as curve, and dealt with as function of setting of crusher, of material to be crushed and of permissible proportion of over-sizes.

3882. Mordovin, P.I., and Shilov, S.V., Mill balls of "Uralite",
Steklo i Keram. 15 (9) 40-1, 1958.

Use of balls for ceramic grinding with a body mix of 61.6% tech.
grade Al_2O_3 , 30.9% clay and 7.4% dolomite, vacuum-filtered,
pressed into cylinders 40-5 mm. in diam. and 40-2 mm. long, and
fired at 1450° for 13.6 hrs. raises the capacity of the mill
by 1.4-2.6 times that with silica balls. In compn. they are
not less than 75.9% Al_2O_3 nor more than 18% SiO_2 . Their sp.
gr. is 3.0-3.2 in comparison with 2.5-2.6 for silica.

3883. Morgan, B.B., The adhesion and cohesion of fine particles,
British Coal Utilization Monthly Bull. 25 (4) 125-37, 1961.

3884. Morgulis, M.L., Modern technology of fine grinding
and sharp classification, Zh. Vses. Khim. Obshchestva im. D.I.
Mendeleeva 10 (1) 67-72, 1965 (Russ).

A description is provided for a variety of mech. mills and
separators suitable for size sepn. of solids.

3885. Mori, Yoshiro (Univ. Tokyo), Jet pulverizing, Europaei-
schen Symp. Zerkleinern, 1., Frankfurt am Main 515-30, 1962
(in English).

Grinding occurs primarily in the vicinity of the nozzle; body
crushing and surface grinding occur simultaneously, with the
former controlling at high power; the grinding rate is propor-
tional to nozzle cross-sectional area and pressure; and recycle

frequency is inversely proportional to the particle feed rate.

3886. Mori, Yoshiro and Jimbo, Genji (Univ. Tokyo), Mechanism of all-mill grinding, Kagaku Kogaku 23 138-45, 1959.

The mechanism of the grinding of particles was investigated by means of ball-mill grinding, by using silica balls with 4 different diams. and sintered corundum balls of one diam.

In Japanese, with English titles on figures. Data on particle size distributions vs. time for grinding sand, glass, cement clinker. Mill was about 1/3 full.

3887. Mosyagin, D.S., Drying and grinding apparatus for clay, U.S.S.R. Pat. 128 740, 5/15/1960.

3888. Muehlberg, Heinz, Optimal granulation of crude salt for the hot dissolving process, Frieberger Forschungsh. A316 35-42, 1964 (Ger.).

The grinding plants for pulverization of crude salt in the various German potash works are discussed. Plots are given for K_2O distribution as dissolved salt and residue against grain size for the various mills. Pulverizing schemes for the various mills are presented. Optimum granulation conditions are discussed for the various mills.

3889. Muehlhaus, L., Statistical treatment of problems in particle size analysis, exemplified by the particle size analyzer, Chem. Ingr. Tech. 37 (10) 1028-38, 1965.

A math. analysis is presented of the dispersion in particle size distribution. The detn. of the distribution parameters from a math.-statistical model and geometric-optical exptl. data resulted in a proposed test procedure which permits appropriate corrections. The use of the analyzer is described and inherent specific faults of this app. are discussed. Figures, photomicrographs, and diagrams are presented.

3890. Bernutat, P., Selection of Optimum drives for tube mills, Zement-Kalk-Gips 19 (5) 223-30, 1966.

From power formula, gear size is calculated. Also deduces optimum L/D for mill to maximize production per weight of shell. For single compartment, $L/D = 1.5$.

3891. Charles, R.J., Energy-size reduction relationships in comminution, Trans. AIME 208; Min. Engrg. 9 80-8, 1957.

3893. Mular, A.L., Relationship among size modulus, size ratio and integral rate at which fines are produced, Trans. AIME 223 (4) 422-7, 1962.

It is demonstated that the Gaudin-Meloy distribution for single fracture is equally applicable to multiple fracture and is related to Gaudin-Schuhmann distribution, at least when the

distribution modulus is close to unity. Equations are related to input energy to mill.

3895. Mular, A.L., Relationship among mass, energy and size modulus at low reduction ratios, Trans. AIME 223 (4) 437-41, 1962.

Experimental results in conjunction with equation demonstrate fact that energy input which produced fracture is not expended on broken starting material inside mill at any time.

3896. Mular, A.L., Volin, M.E., and Fuerstenau, D.W., Effect of feed size on the integral rate of grinding, Trans. AIME 229 331-4, 1964.

3897. Carbonnear, C., Faucher, J.R., Opening a new source of Columbian raw material, in Milling in America, N. Arbiter, Ed., VII Int. Min. Proc. Cong. 479, 1964.

3898. Mulhearn, T.O., and Samuels, L.E., Abrasion of metals-model of process, Wear-Usure-Verschleiss 5 (6) 478-98, 1962. Structure of silicon carbide abrasive papers is studied by microscopic examination of sections, and results are used as basis for theoretical model of abrasion of nonwork-hardening metals. Model takes into account shape of contacting abrasive particles, their attitude in abrasive paper, and their deterioration with use. Equations are developed for mean depth

of scratches produced and for rate of metal removal, both of which agree well with experiment. Experiments and theory allow assessment of relative importance of various factors and determination of optimum characteristics of practical abrasive papers.

3899. Mulisch, E., Vibrating ball mills and their introduction into processing, *Aufbereitungs-Technik* 4 (4) 151-6, 1963.

Development of vibrating mills, designs, fields of application and results obtained in mills. Methods of installing mills in series.

3900. Mulisch, Erich, Vibration mills and vibrating grinding of refractory raw materials, *Interceram* (2) 101-3, 1963 (in English).

Detailed report with diagrams of development of vibration mills for dry and wet grinding with examples of use in ceramic industry. Superiority of vibration mills over tube mills is emphasized. Size distributions of products vs. time are given.

3901. Hukki, Risto. T., Autogenous mills operated at supercritical speeds, *Mining Cong. J.* 51 (9) 120-127, 1965.

Supercritical grinding is limited by rate of wear of liner. Cannot operate a mill at supercritical speeds if $D/4$ greater than 4 as in Aerofall and Cascade mills. Favors grates to reduce pulp liquid buoyancy on media. Use Osborne or bar liners to act autogenously. No data.

3903. Myagkov, M.I., Some features of flowsheets for treatment of magnetite iron ores, Gornyi Zhurnal (11) 52-7, 1963.

Data on performance of 14 plants for wet magnetic treatment of iron ores. Economic efficiency of magnetic and nonmagnetic treatment of rod mills effluent. 6 flowsheets are examined and possibility to increase capacity of ore treatment plants of Krivoi Rog.

3904. Myers, A.T., and Wood, W.H., Ceramic mills in a paint mixer for preparation of multiple rock samples, Appl. Spectroscopy 14 136-8, 1960.

Multiple ceramic grinding mills are suitable for prepn. of rock and mineral samples for emission and x-ray spectrochem. analysis. Effect of amt. of charge and grinding time on size analysis is given for granite, basalt, quartz sand, and anorthite with pyroxene.

3905. Myers, John F., Study of the noncatacting (N-C) ball mill, Can. Mining Met. Bull. 51 495-7; Trans. Can. Inst. Mining Met. 61 269-78, 1958.

3906. Naeser, G., Scholz, W., and Fiedler, A., The dependence of the energy content of NaCl, ZnO, and Cu powders on grinding time, Kolloid-Z. 188 147-52, 1963.

The relation between the grinding time as a measure of mech. treatment, and the energy content of solids was measured

calorimetrically by (1) dissolving in water (for NaCl), (2) conversion with HCl (for ZnO), or (3) with the aid of a AgNO_3 soln. (for Cu powder). For NaCl and ZnO, the relation between the grinding time and the energy content is characterized by numerous max. and min. Probably Cu powder behaves similarly, although only the 1st strong max. was measured. The bulk vol. of NaCl as a function of grinding time is analogous to the variation of energy content. Also, the Brunauer-Emmett-Teller surface area is a wavelike function of grinding time. These results support the hypothesis that consecutive disturbances and realignments occur in solids during continued mech. treatment. The wavelike variation of phys. properties with time is then a result of the interaction of these phenomena.

3907. Naeser, G., Scholz, W., and Fiedler, A., Mechanical activation and passivation: the effect of the grinding material and grinding media on the sintering of ceramic oxide, Ber. Deut. Keram. Ges, 39 (5) 280-5, 1962.

If grinding is continued for sufficiently long periods, the curves for the relation between grinding time and the strength, both before and after sintering, of AlSiO_2 and calcined dolomite have pronounced max. and min. This is greatly influenced by the type of mill and considerably affected by the grinding media. With certain grinding durations the increase in strength reaches up to 100% of the initial value only to greatly decrease again on further grinding in an extra ordinary

manner. Poured vol. also changes with grinding time along a curve with great irregularities. Such mech. activation and passivation is due to an alteration of the disturbance and heating of the cryst. lattice during grinding.

3908. Naeser, G., and Scholz, W., Activation and inhibition of chemical reactions and sintering phenomena by mechanical treatment, Ber. Deut. Keram. Ges, 39 (2) 106-14, 1962.

The reactivity of solids was shown to exhibit both max. and min. as functions of the degree of comminution, deformation, or applied stress. Portland cement ground for 15 min. in a vibratory mill had a 28-day bending strength of 98, and compressive strength of 586, compared to 70 and 340 kg./sq. cm., resp., for the unground material as received. The same values for cement powder heated to 500° for 2 hrs. in air were 46 and 219, and were increased to 80 and 503 kg./sq. cm., resp., by 15-min. vibratory milling after heating. The wt loss of sugar C heated to 1100° in wet H was increased 3 times, and that of graphite 25 times, after a 10-pass cold rolling, compared to wt loss rates of untreated standards. Similarly, the redn. of Fe silicates by H at 850° showed a 4-fold increase after rolling of the 40% SiO₂-60% FeO powder. Cold rolling of Si steel sheet to 40% redn. increased N absorption by 180%, scaling at 500° by 200%, carburization by 400%, decarburization by 175%, and sulfuration by 130%. The rate of diffusion of N in steel is impaired during elastic deformation, enhanced during plastic

deformation, and re-impaired shortly before yielding; an example of activation-passivation effects. Below 680° the thermal decompn. of CaCO_3 was intensified by 22 passes between rolls, while the same treatment retarded decompn. above this temp. The redn. of Fe_2O_3 by H at 400° was activated by rolling pre-treatment of less than 50 passes, but the reducibility as recorded by wt. loss was decreased with the rolling extended to 50-100 passes. The rate of dissoln. of mild steel sheet in 10% H_2SO_4 at 50° had a marked min. at 85% deformation by cold rolling, followed by a max. at 90% deformation.

3909. Nagaev, R.F., Dynamics of vibroshock crusher with pair of self-synchronizing vibrators, Akademiya Nauk SSSR, Izvestiya Otdelenie Tekn. Nauk, Mekhanika i Mashinostroenie (5) 46-53, Sept.-Oct. 1963.

2 sided ore crusher consists of spring-mounted frame and heavy jaw oscillating on shaft supported in frame-mounted bushings. 2 self-synchronizing imbalance vibrators mounted on jaw top are driven by V-belts from asynchronous motors fixed to frame. Nonlinear equations of system's motion are solved using small parameter method.

3910. Nagel, T., New method of impact shattering, Eng. & Min. J. 159 110-111, April, 1958.

Breaking down solids into extremely fine sizes without the aid of mechanical moving parts.

3911. Naique, R.A., Tentative establishment of general law of granulometric distribution of particles produced by crushing, *Tecnica* 34 (300) 335-59, Mar., 1960.

Preliminary study of size distribution of particles resulting from various comminution operations is made in order to advance experimental confirmation of new method of study of energy and size distribution relationship.

3912. Nakagawa, Yuzo, New theory of crushing and grinding, *Kagaku Kogaku* 22 776-9, 1958.

For impact crushing by a falling hammer, an expression which correlates the net work spent during the crushing and the work necessary for size redn. was derived. Also a relation between the net work required for crushing for a specific impact and the no. of impacts used is proposed. This equation is extended to include the calcn. of the total net work consumed during the whole crushing process. Further, equations for the increase of surface area of the material during the crushing process and for the particle size distribution are derived.

3913. Nakagawa, Yuzo, and Matsui, Kunio, Relation between number of blows, mill revolutions, net work input to crushing, surface increment, and size distribution of crushed products, *Kagaku Kogaku* 24 500-7, 1960.

Crushing was performed by dropping a steel ball or steel hammer on a plunger placed on cubic or powdery samples in a steel

mortar, or by driving a ball mill at normal speed. The exptl. results were correlated as relations between no. of blows, net work input to crushing, surface increment, and size distribution of crushed products.

3914. Nakagawa, Yuzo and Matsui, Kunio, Fundamental studies on ball mill grinding, Kagaku Kogaku 22 616-23, 1958.

The capacity, power, and efficiency of a ball mill were detd. experimentally, and the effects of mill speed, total no. of revolutions, ball load, and mill diam. were investigated and discussed.

3915. Nakagawa, Yuzo, Okuda, Satoshi, Inamura, Seiich, and Yashima, Akira, Measurement of actual work done by the impact compression of powdery materials and its relation to crushing, Kagaku Kogaku 22 624-34, 1958.

Crushing of powdery materials (stoneware and hard chalk) was accomplished with a drop hammer. The impact resistance force was measured with a wirestrain-gage dynamometer and a Brown-tube oscilloscope, and the total deformation of the packed sample was detd. with a photo-elec. tube or a depth gage. The relations between impact resistance force and impact displacement were obtained for various samples relative to loading conditions.

3916. Narjes, A., The prevention of coal dust explosions by use of inert gas, Zement-Kalk-Gips 16 (9) 357-63, 1963.

To reduce the hazard of dust explosions in coal-grinding equipment, particularly if high-volatile coal is being processed, individual units of the combined drying and grinding plant should be so adjusted that an atm. with an O concn. of 8.5% from an oil-fired producer may be maintained within it. For this purpose, it is necessary to operate with circulating air and to pass to the dust precipitator only a portion of the gas flowing through the plant. With a low excess air factor ($n = 2.4$) and a high temp. (about 1000°) in the hot-gas producer, a relatively low mill inlet temp. (340°) and a low O content in the system are obtained. Flow sheets are shown and illustrative heat and material balances are presented.

3917. Nastase, Maria, Oprescu, Angela, and Museteanu, Cr., Possibilities of concentrating the iron ore from Palazul Mare, Rep. Populara Romina, Com. Geol. Dari Seama Sedintelor 50 (1) 245-55, 1962-63, (Pub. 1964) (Rom).

The ore contained mainly magnetite and very little pyrite, hematite, limonite, and chalco-pyrite, to a total of 25-8%, and gangue minerals (mainly quartz, with some hornblende, actonite, tremolite, chlorite, and calcite). The total Fe content was 22.8-22.9% and the HCl-sol. Fe content was 19.26%, while the SiO_2 and Al_2O_3 contents were 53.3 and 10.37%, resp. A mineralogical study and technological expts. indicated the necessity

for grinding of the ore to less than 0.10 mm., since the magnetite and gangue minerals are intimately assocd. At greater than 0.10 mm. the concentrates contained 25-7% Fe, while at less than 0.10 they contained 48-50% Fe and 20% SiO₂, corresponding to 70% extn. and tailings contg. 8-9% Fe. This could be further improved by grinding to -0.075 mm., the concn. being followed by a reconcn., resulting in concentrates with 59.12% Fe and 12% SiO₂, the recovery being 70%. Since the tailings of the fractions 0.1-0.5 mm. contained the same amts. of Fe as those of the -0.10-mm. fraction, it was possible to reduce the amt. of ore to be ground by introducing a magnetic separator in the mill-classifier circuit.

3918. Obert, Leonard, Windes, S.L., & Duvall, W.I., Standard test methods for physical properties of rocks, U.S. Bur. Mines Rept. Invest. 3891, August 1946.

Shows that compression strength of a cylinder depends on its length due to frictional restraint caused by platens.

3919. Matveev, M.A., Steklo i. Keram, 16 17, 1960.

Experiments on wear of ceramic grinding bodies in a 10-liter laboratory vibrating mill.

3920. Nemetschek, Th., and Pollmann, S., Influence of grinding, ion exchange, quartz isolation in slate clay, Ber. Deut. Keram. Ges. 39 447-53, 1962.

Certain slate clays were investigated to det. the sepn. of quartz by a new kind of flotation, namely, to substitute the K ions of certain clay minerals (micas and micaceous rock minerals) which were not exchangeable with inorg. ions, by long chain primary n-alkylammonium ions. The thereby formed alkylammonium mica is capable of swelling in water and in nonaq. liquids and has organophile character. These clay platelets can be shaken from an aq. suspension to a nonaq. liquid and can be sepd. in a sepg. funnel from the original suspension medium. The examn. was by x-ray and electron microscope. Samples were refined by wet grinding in an agate mill. (The coarsest quartz grains were less than 10 μm . in diam.). Wet grinding was more suitable, because it does not damage the lattice as much as dry grinding; boiling water can cause morphological changes in clay minerals. See CA 58 4276f, 1963.

3921. Nesvizhskii, O.A., Increase of period of service of grinding balls for ball mills, Gornyi Zhurnal (4) 62-5, 1962. Manufacture of steel and cast iron grinding balls. Results of testing wear and hardness of balls manufactured by centrifugal casting. Metallurgical aspects of manufacturing most efficient grinding balls.

3922. Nesvizhskii, O.A., and Khorin, Ya.D., Selection of material for manufacture of lining plates in ball mills, Gornyi Zhurnal (8) 62-7, 1963.

Analysis of conditions of liner plates, performance, effect of their shape, and kind of steel used. Recommendations are made concerning selection of steel characterized by good resistivity to abrasion.

3923. Nickel, O., Results and recent developments in field of wear-resistant Ni-Hard materials, *Aufbereitungs-Technik* 5 (9) 371-384, 1964.

Effect of composition, heat treatment and structure on properties of Ni-Hard materials. New term, impact fatigue life, has been introduced which is important for wear-resistant materials. Method of testing impact fatigue life and results obtained on Ni-Hard materials. Ni-Hard 4 has particularly high impact fatigue life and is more wear-resistant than Ni-Hard 2. Results of tests and wear figures obtained in such fields as cement and coal grinding, ore mining, iron and steel production and finishing.

3924. Nijman, J., Particle size reduction, *Brit. Chem. Eng.* 8 (6) 408-11, 1963.

Review covers developments in theory and practice of size reduction as reported in literature and provides commentary on trends. Subjects include specific machinery, use of correlation techniques, comparison of behavior, influence of surface properties of solids, cement mills, ceramic industry problems, theory of various mill types, and fundamental theory.

3925. Nijman, J., Relation between breakage mechanism and scale-up in ball mills used for coarse grinding, Europaeischen Symp. Zerkleinern, 1, Frankfurt am Main 249-57, 1962 (in English). In coarse grinding, size redn. of particles is caused by breakage rather than by abrasion. The breakage mechanism can be studied from the disappearance of particles present in the original mill feed. With a const. breakage velocity, the calcn. is then analogous to that of chem. reaction vessels. The relation between size of mill, ball, and particle diam. and breakage velocity can thus be shown. Theoretically, the energy available for breakage causes the movement of the balls in part of the toe. Breakage occurs between these moving balls and the mill lining. As the theoretical equation, $K = f \cdot \rho \cdot R^{0.5} d \cdot r^{-1}$ (where K is breakage velocity, f is a proportionality factor; ρ is d. of balls; R is radius of mill; d is size of particle; and r is ball radius) and the exptl. data showed reasonable agreement, the equation can be used for scale-up operations. However, in scale-down, a change of mechanisms occurs and makes it inadvisable to use exptl. mills of small size.

3926. Nijman, J., Design of ball mills, Chem. Weekblad 57 261-4, 1961.

The probability of breaking a given particle and the partition of the particles after breaking are examd. For the probability of breaking, a const. k is found which has the same significance as the velocity const. in a chem. 1st-order reaction: $-dH/dt =$

kH , or $\ln H_0 - \ln H = k t$, in which H is the amt. of material A to be ground, and t is the time. From the expts. of Coghill and DeVaney (CA 32, 4832⁹) the value of k is calcd. and plotted as a function of the reciprocal value of H . Within wide limits a straight line is obtained, so the probability of breaking a particle of substance A is inversely proportional to the load of the ball mill. Departures from the straight line are found for H less than 50 cc./l. and for H greater than 300 cc./l., meaning that the mill has been under or over-filled, resp. The same amt. of particles is broken in a given time, when the ball mill has been properly loaded. Thus, it is impossible to effect the compn. of the final product by changes in load (as long as the rubbing action of the balls can be ignored as compared to their breaking effect), and the use of a 2nd ball mill operated at a lower revolution rate is recommended. Some remarks are made on the larger ball mill from the results for a smaller one, since both vol. and surface are of high significance for the movement of the balls and the latter, in its turn, is of vital importance for the grinding procedure.

3927. Nijman, J., Crushing and grinding literature in 1960, Brit. Chem. Eng. 6 324-6, 1961. 45 references.

3928. Nijman, J., Ball-mill grinding, Brit. Chem. Eng. 3 76-80; 414-17, 1958.

Reviews previous work on single-particle crushing to see if it can give the breakage function needed for analysis of mills such as ball mills. The influence of K_{casc} (breakage const. due to cascading) is difficult to evaluate, even when independent of the wt. of particles in the mill, as is that due to cataracting, because of wall effect, cushioning, and surface properties of balls and particles. The author concludes that Andreassen's theory (Trans. Inst. Chem. Eng. 35 104, 1957) is in accord with existing facts regarding particle behavior, but that of Matz (Verfahrenstechnik in Einzeldarstellung. Bd. III Anwendung des Aehnlichkeitsgrundsatzes in der Verfahrenstechnik, 1954 (C.A.49, 2853 e) is too simple for large scale-up ratios.

3929. Nijman, J., and de Nie, L.H., Grinding in ball mills, Aufbereitungs-Technik 3 (3) 109-15, 1962; 3 (6) 257-61, 1962. Grinding process and effect of some variables upon grinding rate in ball mills. Results of Coghill tests concerning dry grinding of chert and of dolomite as well as wet grinding of dolomite.

3930. Nikitin, V.M., Selection of rational aerodynamic scheme and constructive design of high speed hammer mill, Teploenergetika (10) 13-17, 1962.

Study of grinding process in high speed mills. Model tests of 3 types of mills including closed nonventilated mills,

ventilated mills and mills with helical system of motion of ground product.

3931. Norman, T.E., Climax finds new austenitic alloy ideal for ultra-abrasive mine-mill applications, Eng. & Min. J. 166 (4) 86-90, 1965.

Climax 6-1, intermediate range alloy (6% Mn, 1% Mo), Pat. 3 113 861. For ball mill liners it is not so wear-resistant as other alloys, but much tougher.

3932. Norman, T.E., Factors influencing resistance of steel castings to high stress abrasion, Modern Castings 33 (5) 89-98, 1958.

Evaluation of abrasion resistance of various types of cast steels used in grinding mill liners. Abrasive wear in ball and rod mills; elements in wear testing materials. Procedure for short time wear test. Correlation between relative wear rates, variables influencing wear rates of martensitic, pearlitic and austenitic steels.

3933. Norman, T.E., and Ott, G.E., Recent developments in wear-resisting cast materials used in construction of machines for crushing hard materials, Giesserei 46 (16) 441-7; (17) 471-8 1959.

Economic significance of wear caused by crushing hard minerals. Description of wear-resisting cast irons according to their

properties and production, which have been used successfully in large ore mining and treatment installation in United States. Examples of three types of wear and application of materials considered.

3934. Rey, Bull. Soc. France Ceram. 44 35, 1959.

States that shape of particle depends on mill used.

3935. Occella, Enea, Alterations in crystalline structure of some soft minerals subjected to comminution, Ric. Sci., Rend. Sez. A 3 (6) 897-906, 1963.

Eight soft-mineral types (chrysotile, crocidolite, tremolite, talc, phlogopite, muscovite, chalk, and galena) were ground for various periods of time to obtain samples with particle sizes less than 100, 30, or 10 μ . X-ray diffraction analysis showed that these relatively inelastic compds. (esp. phlogopite and chrysotile) suffer significant losses in structural ordering even when the crystals are reduced to a few μ , and are thus different from quartz where the thickness of the "amorphous" layer is less than 0.1 μ . This phenomenon requires attention when instrumental analysis is performed on ground, soft minerals, esp. when they are ground together with hard minerals.

3936. Occella, E., and Henking, E., Differential grinding of rocks and synthetic materials in connection with their silica content, Med. lavoro 52 81-91, 1961.

Treatment of 23 minerals and brick compns. by a standard grinding and sieving procedure showed a higher tendency toward formation of dust of small particle size in bricks than in minerals of similar compn. There is no relation between particle size and free silica content, which is generally lower in the smaller particles. The dust of industrial atm. may in some cases be considered essentially silica-free, when siliceous materials are being processed.

3937. Ohe, W., Raasch, J., and Rumpf, H., Bearing capacity of discharge walls in ball and tube mills, Europaeisches Symposium Zerkleinern , Frankfurt/M-1 89, 1962; Aufbereitungs-Technik 3 (3) 89-128, 1962.

3938. Olds, A.R. Jr., and Ho. T., Primer on large ball mill drives, Minerals Processing 5 (3) 36-9; (4) 38-41, 1964.

Pt. I: Ball mill load and drive requirements, factors in selecting drives, drives available, important characteristics of synchronous motor, wound-rotor motor, salient-pole synchronous induction motor, nonsalient-pole synchronous induction motor and super synchronous motor. Pt. II: Comparison, limitations, advantages and uses of wound-rotor induction motors and synchronous motors; applications of phase advances,

motors with enclosed reduction gears, motors and friction clutches; example on possible savings, before taxes, due to power factor (pf) improvement, if wound-rotor motors are selected as mill drives, if synchronous motors of 1.0 pf are selected as mill drives, if synchronous motors of 0.8 pf are selected for mill drives; example of possible savings, before taxes, due to higher efficiency of mill drive motors.

3939. Olds, A.R. Jr., Olsen, K.E., and Watson, I., More on large grinding mill drives-background and tests, IEEE-Cement Ind. Tech. Conf. 15 pp., April 1964.

Background leading to application of larger mills and drives in cement industry is reviewed and tests conducted on large new drives described. Results of mechanical speed-torque and and electrical measurements obtained in tests are presented.

3940. Olevskaya, I.V., Application of electronic logic recording device in control system of ore treatment plant, Gornyi Zhurnal (10) 12-17, 1963.

Use of ELRU-2M electronic control device supervising conveyors, amount of ore crushed, density of classifier effluent, temperature of slurry, density of slurry, residual concentration of sulfur, tons in slurry of molybdenum recycle, steam pressure, and water pressure.

3941. Reiners, E., Chem. Ing. Tech. 32 335, 1960.

Contributes interesting information from high speed camera pictures on breakage phenomenon.

3942. Ott, Ronald L., Mechanism of the mechanical degradation of cellulose, J. Polymer Sc. Pt. A2 (2) 973-82, 1964.

High-viscosity, acetate-grade cotton linters with a no. av. degree of polymerization (D.P.) of 1710 were ground in a vibratory ball mill under N for periods of time ranging from 17 to 36 hrs. The grinding was carried out on air- and oven-dried cellulose samples alone and in the presence of cyclohexane and CCl_4 contg. I. The rate of degradation increased as the I concn. in CCl_4 and cyclohexane increased from 0 to 2.0 g./l. The I accelerated the degradation by preventing the recombination of at least some of the macroradicals formed during the milling of cellulose. See CA 60 8219b, 1964.

3943. Ottley, D.J., Size reduction symposium, Min. Mag. 106 (6) 329-33, 1962.

Topics under discussion and principal features of some of 43 papers presented at Symposium on size reduction held in Frankfurt, Germany, April 1962.

3945. Ozhigov, E.P., Qualitative analysis of local ores by grinding, Tr. Dal'nevost. Filiala, Akad. Nauk SSSR, Ser. Khim. (5) 116-24, 1961.

Zn, Pb, Sn, and Bi were detd. in a mineralogically complex ore contg. 22 elements. The change of color after grinding the sample with several reagents proved the presence of the element sought. See CA 57 9197c, 1962.

3946. Pacault, Adolphe, Marchand, Andre, Boy, Francis, and Poquet, Elizabeth, Increase in diamagnetism of natural graphite by grinding, Compt. Rend. 254 1275-7, 1962.

Grinding natural graphite by different methods increases the diamagnetism to approach that of pyrolytic graphite. Most effective is a rotary grinding in a B carbide mortar. Susceptibilities over a temp. range are given.

3947. Lin, Hsien-chih, Scientia Sinica 8 1295, 1959.

Details of movement of charge in a ball mill. Relates optimum ball charge to rotational speed.

3948. Panu, Huber and Popa, Emil, Method of calculating the capacity of ball mills, I. Rev. met. Acad. rep. populaire Roumaine 3 59-83, 1958.

Math. treatment, verified by expts. with materials such as quartz, on capacity of ball and rod mills for reducing particle size of feed product to specified limits.

3949. Panu, Huber, and Popa, Emil, Method of calculation of the capacity of crushers. I. Acad. rep. populare Romine, Studii cercetari met. 2 499-522, 1957.

A method is presented for the calcn. of the capacity of ball mills and roll crushers. Using Rittinger's Law for the crushing energy needed, a formula is derived for the capacity of such crushers as a function of their dimensions, of the increase of the specific surface of the crushed material, and of the resistance of the material to crushing as characterized by a parameter termed the "relative crushing index". This formula is rearranged to allow th calcn. of the specific surface and of the relative crushing index. In order to find the specific-surface independently, formulas are derived in terms of parameters which can be detd. by simple experimentation, such as a sieve analysis, so that the practical application of the method is not hampered by requirements for special app. The specific surface can be detd., once the screen analysis of the material is known. For the material passing through the finest sieve, a new formula for specific surface is used based on Gaudin's equation (Principles of Mineral Dressing, 1939(C.A. 34, 1605³)). The method was checked experimentally with quartz and a complex mineral from the Ruschita deposits and was found to give accurate results.

Rittingers law is shown to hold if the agglomeration during milling is subtracted. The capacity of a continuous ball mill with length L and internal diam. D is $0.16 LD^2/t_s \text{ cm.}^3/\text{sec.}$, where t_s is the time required to mill to the same sp. surface area in a batch ball mill of the same diam. A formula is given to calc. the distribution of ball diams. along the length of the mill. This distribution gives a max. throughput together with a well defined surface area.

3952. Papadakis, M., Application of grindability values in investigation of mode of operation of ball mills, Zement-Kalk-Gips 16 (4) 131-4, 1963.

Behavior of materials being ground in tube mill depends on fracturing behavior and agglomeration tendency. With knowledge of these variables it is possible to establish relationship governing longitudinal distribution of grinding media for maximum throughput associated with certain mill dimensions and fineness of material.

3953. Papadkis, M., Contribution to investigation of industrial ball mills, Aufbereitungs-Technik 2 (9) 353-64, 1961.

Grindability of material depends on capacity to break down and on capacity to agglomerate due to effect of impact causing breakdown. Optimum distribution of crushing bodies in open circuit ball mill.

3954. Papadakis, M., Crushing of materials, Annales des Mines 707-22, Nov. 1959.

Crushers are divided into three categories: slow, percussion, and rapid types. Ball mills of rapid type work at maximum efficiency when rate of loading by volume is in neighborhood of 0.40, and its speed is three quarters of critical speed. Theory explaining behavior of materials in ball mills. Crushability depends on breakability and agglomerability. English summary.

3955. Papadakis, Michel, Linings for ball mills, effectiveness of linings provided with projections, Rev. matériaux construct. et trav. publ. C, (518) 292-9, 1958.

These linings are more effective than smooth linings (both in power consumption and time required/ unit cement of a given fineness) only when the rotation rate and the vol. of the charge are low, $18/\sqrt{D} - 25/\sqrt{D}$ turns/ min. (D in m.) and clinker-ball ratio 20% by vol. The most efficient operation is obtained, however, at faster rates (about $30/\sqrt{D}$) and clinker-ball ratios (about 40%). Smooth linings are then more effective, but these conditions are not always realized in practice. Linings with projections are more wear resistant.

3956. Jax, Karl M., Ceramic balls for grinding mills, Ger. Pat. 1 072 179, 12/24/1959.

Wear-resistant grinding balls (sp. gr. greater than 4) consist

3959. Pascu, N., Ripan, R., and Buturca, F., Determination of crushing and flotation time of gold minerals at Rosa Mountain, Studii Cercetari Met. 10 (1) 155-65, 1965 (Rom).

The flow of materials in the Au extn. plant was followed by the addn. of 3 g. radioactive ¹⁹⁸Au powder, activity 0.3 c. This procedure revealed that: mineral crushing time was 10-15 min., speed of mineral passage through the mill, 1 min., and through the classifier, 1½ min. Flotation time was 10 min. Loss of Au in the discharge fluid was 0.09 g. Au/ton.

3960. Koulen, K., Zement-Kalk-Gips 13 (4) 158-162, 1960.

Literature survey with many references on closed circuit grinding and sieving in Germany. Results are inconclusive because experiments are poorly controlled. They need statistical basis.

3961. Pasquet, Maurice and Joco, Gerard, Autogenous grinding of Lorraine iron ores for magnetic enrichment, Congr. Intern. Prepn. Minerais, 6^e Cannes, France 90-111, 1963 (Pub.1964) (Fr). Soft oolitic grains contg. approx. 50% Fe are cemented by calcite or silicates. Following grinding to 800 μ, autogenous milling gives better sepn. of the oolite grains, while hot air transport provides simultaneous drying. The Aerofall mill is preferred to the Cascade mill, since air flow speed vs. sizing is more flexible than by internal sieving. Optimum grinding time must be ensured by balancing air flow, addn. of grinding balls to assist the lateral deflectors, and venting in the

discharge chamber. An overall 80% recovery is obtained by final magnetic sepn.

3962. Pasquet M., and Pevergne, L., General considerations on the crushing of Lorraine iron ores to a suitable size for agglomeration, Europaeischen Symp. Zerkleinern, I., Frankfurt am Main 323-40, 1962 (in French).

For the agglomeration of Lorraine iron ore, particles less than 10 mm. are required with max. distribution at 0.1-6 mm. Existing secondary grinders give less than 40% on size. Tests with 7 types of rotary grinders of capacities of 50-200 tons/hr. showed that 100% on size is obtained with 22-6% less than 0.1 mm. and 5-8% between 6 and 10 mm., starting from a material between 0 and 200 mm. These results are obtained when the mill has an internal screen of 20 or 30 mm. The optimum peripheral velocity depends on the no. of hammers: a min. of 50 hits per sec. is required.

3963. Patat, F., and Langemann, H., Kinetics of grinding hard substances II: Temperature dependence of the comminution velocity, Chem. Ing. Tech. 34 15-20, 1962.

Determinations of the activation energy of comminution were made. The magnitude of the energy values would exclude the participation of lattice defects and indicates that superdislocations act as centers of fracture. Literature data are analyzed. 48 refs.

3964. Patat, F., and Langemann, H., Kinetics of grinding hard substances I, Chem. Ing. Tech. 31 561-8, 1959.

In order to relate the rate of grinding or comminution and the properties of the ground material, a method of differential grinding is proposed. Interpretation of model expts. with quartz fractions in ball mills were successful. Many diagrams and 24 references are given.

3965. Patat, F., and Mempel, G., Kinetics of grinding hard substances, IV: Ball mill grinding (In Ger.), Chem. Ingr. Tech. 37 (9) 933-9, 1965.

Expts. in a lab. ball mill of 900 cc. vol. and of 110 mm. are reported. The steel balls occupied 34% of the vol. Exptl. data were evaluated by means of the equation $\Delta G/\Delta t = -kG^n$ g./min. , where G is remaining fraction of the charge in g., n the exponential order, k the velocity const., and t the time. The conditions leading to various orders of n are discussed as a function of charge concn., mill rotation, resistance of material to comminution, and choking of the mill.

3966. Patterson, W.R., and King, D.E., Magnetic logic maximizes crusher output, Control Eng. 10 (1) 97-9, 1963.

Automatic control system of Massachusetts Broken Stone Co. Static switches based on magnetic amplifier provide high reliability and require no special power supply. Simple logic network continuously controls 2 primary variables to optimize

rock crusher's output.

3967. Patterson, W.R., and King, D.E., Set it and forget it, Rock Prod. 65 (2) 100-7, 1962.

Static control of automatic crushing system at Massachusetts Broken Stone Co. has no moving parts thus giving freedom from maintenance and environmental hazards. Static device is magnetic amplifier type using conventional 110 v a-c power source. In automated system static devices control feed rate and crushing setting. Variables in crusher performance. Design of system and flow sheet with regard for variables.

3968. Paulsen, H., Grinding media distribution in tube mills, Zement-Kalk-Gips 17 (9) 392-6, 1964.

Investigation of size distribution of mixed charge to be located at larger diameters than that of sorted charge. Formulas of F.C.Bond and M. Papakadis, by means of which size of balls for replenishing charge can be calculated, are explained.

SLA Trans. TT65-11963,

3969. Pavlov, V.A., Laws of plastic deformation and breakdown, U.S. At. Energy Comm. AEC Trans. 4513, 272-93, 1958.

A review with 57 references.

3970. Pawluschkin, N.M., Effect of dispersity and the form of starting material on the properties of sintered corundum, Freiburger Forschungsh. B 78 23-42, 1963..

Sintering temp. of corundum decreases with decreasing particle diam. down to 0.5μ av. diam., then increases again. Sintering of 0.5μ particles occurs around 1700° . Microhardness keeps increasing with decreasing particle size. Aluminas calcined at $1000-1500^\circ$ grind easily, and those over 1600° only with difficulty. Grinding time can be decreased by using a high ball-to- Al_2O_3 ratio and using heavy balls.

3971. Matouschek, F., Zement-Kalk-Gips 13 (9) 394-409, 1960.

For liner wear with raw cement and clinker, Matoushek published a mathematical approach by way of statistical analysis, with many references on the subject. The ideal solution is said to be in combined effects of proper choice of alloy and surface and shape of the liners. Chrome and manganese steels are compared. Shape is less important in first raw mill chamber than in the second.

3972. Peck, W.C., Vibration mills and vibration milling, Indus. Chemist 38 (447) 223-5, 1962..

Vibration ball milling is used to prepare tungsten carbide, for grinding graphite or sugar carbon used to produce tungsten carbide, and for mixing and coating tungsten carbide with cobalt prior to sintering. Application of dimensionless analysis.

Importance of rate of milling. Reviews Rose & Sullivan.
Problem to make full-sized mills continuous and provide cooling to dissipate the heat of milling.

3973. Halbart, J., and Freymann, V.F., Zement-Kalk-Gips 13
(1) 17-23, 1960.

Halbart and Freymann discussing Davies and Ugglia's theory on the movement of the charge within a mill, conclude that the space in between liner bars is essentially connected with ball diameter. Ball packing geometry is considered, a thing that is overlooked by many authors. A liner construction is proposed in which the distance between bars is smaller toward the discharge of the mill. This causes worn (smaller) balls to move towards the finer milling zone. Proper attention is also given to the coefficient of friction between different rows of balls. See 3606 for translation.

3974. Pendleton, A.G., Fluid energy milling, Chem. & Proc. Eng. 44 (12) 733-9, 1963.

Evolution of various types of fluid energy mills and their characteristics. Advantage of this system is that fluid energy milling can also perform other operations such as dehydration, de-agglomeration and simple chemical reactions. Joule-Thomson effect enables fluid energy mill to be used for reduction of heat-sensitive materials. Narrower size-distribution range is obtained with fluid energy milling.

Analysis of conditions of liner plates, performance, effect of their shape, and kind of steel used. Recommendations are made concerning selection of steel characterized by good resistivity to abrasion.

3923. Nickel, O., Results and recent developments in field of wear-resistant Ni-Hard materials, *Aufbereitungs-Technik* 5 (9) 371-384, 1964.

Effect of composition, heat treatment and structure on properties of Ni-Hard materials. New term, impact fatigue life, has been introduced which is important for wear-resistant materials. Method of testing impact fatigue life and results obtained on Ni-Hard materials. Ni-Hard 4 has particularly high impact fatigue life and is more wear-resistant than Ni-Hard 2. Results of tests and wear figures obtained in such fields as cement and coal grinding, ore mining, iron and steel production and finishing.

3924. Nijman, J., Particle size reduction, *Brit. Chem. Eng.* 8 (6) 408-11, 1963.

Review covers developments in theory and practice of size reduction as reported in literature and provides commentary on trends. Subjects include specific machinery, use of correlation techniques, comparison of behavior, influence of surface properties of solids, cement mills, ceramic industry problems, theory of various mill types, and fundamental theory.

3925. Nijman, J., Relation between breakage mechanism and scale-up in ball mills used for coarse grinding, Europaeischen Symp. Zerkleinern, 1, Frankfurt am Main 249-57, 1962 (in English). In coarse grinding, size redn. of particles is caused by breakage rather than by abrasion. The breakage mechanism can be studied from the disappearance of particles present in the original mill feed. With a const. breakage velocity, the calcn. is then analogous to that of chem. reaction vessels. The relation between size of mill, ball, and particle diam. and breakage velocity can thus be shown. Theoretically, the energy available for breakage causes the movement of the balls in part of the toe. Breakage occurs between these moving balls and the mill lining. As the theoretical equation, $K = f \cdot \rho \cdot R^{0.5} d \cdot r^{-1}$ (where K is breakage velocity, f is a proportionality factor; ρ is d. of balls; R is radius of mill; d is size of particle; and r is ball radius) and the exptl. data showed reasonable agreement, the equation can be used for scale-up operations. However, in scale-down, a change of mechanisms occurs and makes it inadvisable to use exptl. mills of small size.

3926. Nijman, J., Design of ball mills, Chem. Weekblad 57 261-4, 1961.

The probability of breaking a given particle and the partition of the particles after breaking are examd. For the probability of breaking, a const. k is found which has the same significance as the velocity const. in a chem. 1st-order reaction: $-dH/dt =$

kH , or $\ln H_0 - \ln H = k t$, in which H is the amt. of material A to be ground, and t is the time. From the expts. of Coghill and DeVaney (CA 32, 4832⁹) the value of k is calcd. and plotted as a function of the reciprocal value of H . Within wide limits a straight line is obtained, so the probability of breaking a particle of substance A is inversely proportional to the load of the ball mill. Departures from the straight line are found for H less than 50 cc./l. and for H greater than 300 cc./l., meaning that the mill has been under or over-filled, resp. The same amt. of particles is broken in a given time, when the ball mill has been properly loaded. Thus, it is impossible to effect the compn. of the final product by changes in load (as long as the rubbing action of the balls can be ignored as compared to their breaking effect), and the use of a 2nd ball mill operated at a lower revolution rate is recommended. Some remarks are made on the larger ball mill from the results for a smaller one, since both vol. and surface are of high significance for the movement of the balls and the latter, in its turn, is of vital importance for the grinding procedure.

3927. Nijman, J., Crushing and grinding literature in 1960, Brit. Chem. Eng. 6 324-6, 1961. 45 references.

3928. Nijman, J., Ball-mill grinding, Brit. Chem. Eng. 3 76-80; 414-17, 1958.

Reviews previous work on single-particle crushing to see if it can give the breakage function needed for analysis of mills such as ball mills. The influence of K_{casc} (breakage const. due to cascading) is difficult to evaluate, even when independent of the wt. of particles in the mill, as is that due to cataracting, because of wall effect, cushioning, and surface properties of balls and particles. The author concludes that Andreassen's theory (Trans. Inst. Chem. Eng. 35 104, 1957) is in accord with existing facts regarding particle behavior, but that of Matz (Verfahrenstechnik in Einzeldarstellung. Bd. III Anwendung des Aehnlichkeitsgrundsatzes in der Verfahrenstechnik, 1954 (C.A.49, 2853 e) is too simple for large scale-up ratios.

3929. Nijman, J., and de Nie, L.H., Grinding in ball mills, Aufbereitungs-Technik 3 (3) 109-15, 1962; 3 (6) 257-61, 1962. Grinding process and effect of some variables upon grinding rate in ball mills. Results of Coghill tests concerning dry grinding of chert and of dolomite as well as wet grinding of dolomite.

3930. Nikitin, V.M., Selection of rational aerodynamic scheme and constructive design of high speed hammer mill, Teploenergetika (10) 13-17, 1962.

Study of grinding process in high speed mills. Model tests of 3 types of mills including closed nonventilated mills,

ventilated mills and mills with helical system of motion of ground product.

3931. Norman, T.E., Climax finds new austenitic alloy ideal for ultra-abrasive mine-mill applications, Eng. & Min. J. 166 (4) 86-90, 1965.

Climax 6-1, intermediate range alloy (6% Mn, 1% Mo), Pat. 3 113 861. For ball mill liners it is not so wear-resistant as other alloys, but much tougher.

3932. Norman, T.E., Factors influencing resistance of steel castings to high stress abrasion, Modern Castings 33 (5) 89-98, 1958.

Evaluation of abrasion resistance of various types of cast steels used in grinding mill liners. Abrasive wear in ball and rod mills; elements in wear testing materials. Procedure for short time wear test. Correlation between relative wear rates, variables influencing wear rates of martensitic, pearlitic and austenitic steels.

3933. Norman, T.E., and Ott, G.E., Recent developments in wear-resisting cast materials used in construction of machines for crushing hard materials, Giesserei 46 (16) 441-7; (17) 471-8 1959.

Economic significance of wear caused by crushing hard minerals. Description of wear-resisting cast irons according to their

properties and production, which have been used successfully in large ore mining and treatment installation in United States. Examples of three types of wear and application of materials considered.

3934. Rey, Bull. Soc. France Ceram. 44 35, 1959.

States that shape of particle depends on mill used.

3935. Occella, Enea, Alterations in crystalline structure of some soft minerals subjected to comminution, Ric. Sci., Rend. Sez. A 3 (6) 897-906, 1963.

Eight soft-mineral types (chrysotile, crocidolite, tremolite, talc, phlogopite, muscovite, chalk, and galena) were ground for various periods of time to obtain samples with particle sizes less than 100, 30, or 10 μ . X-ray diffraction analysis showed that these relatively inelastic compds. (esp. phlogopite and chrysotile) suffer significant losses in structural ordering even when the crystals are reduced to a few μ , and are thus different from quartz where the thickness of the "amorphous" layer is less than 0.1 μ . This phenomenon requires attention when instrumental analysis is performed on ground, soft minerals, esp. when they are ground together with hard minerals.

3936. Occella, E., and Henking, E., Differential grinding of rocks and synthetic materials in connection with their silica content, Med. lavoro 52 81-91, 1961.

Treatment of 23 minerals and brick compns. by a standard grinding and sieving procedure showed a higher tendency toward formation of dust of small particle size in bricks than in minerals of similar compn. There is no relation between particle size and free silica content, which is generally lower in the smaller particles. The dust of industrial atm. may in some cases be considered essentially silica-free, when siliceous materials are being processed.

3937. Ohe, W., Raasch, J., and Rumpf, H., Bearing capacity of discharge walls in ball and tube mills, Europaeisches Symposion Zerkleinern , Frankfurt/M-1 89, 1962; Aufbereitungs-Technik 3 (3) 89-128, 1962.

3938. Olds, A.R. Jr., and Ho. T., Primer on large ball mill drives, Minerals Processing 5 (3) 36-9; (4) 38-41, 1964.

Pt. I: Ball mill load and drive requirements, factors in selecting drives, drives available, important characteristics of synchronous motor, wound-rotor motor, salient-pole synchronous induction motor, nonsalient-pole synchronous induction motor and super synchronous motor. Pt. II: Comparison, limitations, advantages and uses of wound-rotor induction motors and synchronous motors; applications of phase advances,

motors with enclosed reduction gears, motors and friction clutches; example on possible savings, before taxes, due to power factor (pf) improvement, if wound-rotor motors are selected as mill drives, if synchronous motors of 1.0 pf are selected as mill drives, if synchronous motors of 0.8 pf are selected for mill drives; example of possible savings, before taxes, due to higher efficiency of mill drive motors.

3939. Olds, A.R. Jr., Olsen, K.E., and Watson, I., More on large grinding mill drives-background and tests, IEEE-Cement Ind. Tech. Conf. 15 pp., April 1964.

Background leading to application of larger mills and drives in cement industry is reviewed and tests conducted on large new drives described. Results of mechanical speed-torque and and electrical measurements obtained in tests are presented.

3940. Olevskaya, I.V., Application of electronic logic recording device in control system of ore treatment plant, Gornyi Zhurnal (10) 12-17, 1963.

Use of ELRU-2M electronic control device supervising conveyors, amount of ore crushed, density of classifier effluent, temperature of slurry, density of slurry, residual concentration of sulfur, tons in slurry of molybdenum recycle, steam pressure, and water pressure.

3941. Reiners, E., Chem. Ing. Tech. 32 335, 1960.

Contributes interesting information from high speed camera pictures on breakage phenomenon.

3942. Ott, Ronald L., Mechanism of the mechanical degradation of cellulose, J. Polymer Sc. Pt. A2 (2) 973-82, 1964.

High-viscosity, acetate-grade cotton linters with a no. av. degree of polymerization (D.P.) of 1710 were ground in a vibratory ball mill under N for periods of time ranging from 17 to 36 hrs. The grinding was carried out on air- and oven-dried cellulose samples alone and in the presence of cyclohexane and CCl_4 contg. I. The rate of degradation increased as the I concn. in CCl_4 and cyclohexane increased from 0 to 2.0 g./l. The I accelerated the degradation by preventing the recombination of at least some of the macroradicals formed during the milling of cellulose. See CA 60 8219b, 1964.

3943. Ottley, D.J., Size reduction symposium, Min. Mag. 106 (6) 329-33, 1962.

Topics under discussion and principal features of some of 43 papers presented at Symposium on size reduction held in Frankfurt, Germany, April 1962.

3945. Ozhigov, E.P., Qualitative analysis of local ores by grinding, Tr. Dal'nevost. Filiala, Akad. Nauk SSSR, Ser. Khim. (5) 116-24, 1961.

3949. Panu, Huber, and Popa, Emil, Method of calculation of the capacity of crushers. I. Acad. rep. populare Romine, Studii cercetari met. 2 499-522, 1957.

A method is presented for the calcn. of the capacity of ball mills and roll crushers. Using Rittinger's Law for the crushing energy needed, a formula is derived for the capacity of such crushers as a function of their dimensions, of the increase of the specific surface of the crushed material, and of the resistance of the material to crushing as characterized by a parameter termed the "relative crushing index". This formula is rearranged to allow th calcn. of the specific surface and of the relative crushing index. In order to find the specific-surface independently, formulas are derived in terms of parameters which can be detd. by simple experimentation, such as a sieve analysis, so that the practical application of the method is not hampered by requirements for special app. The specific surface can be detd., once the screen analysis of the material is known. For the material passing through the finest sieve, a new formula for specific surface is used based on Gaudin's equation (Principles of Mineral Dressing, 1939(C.A. 34, 1605³)). The method was checked experimentally with quartz and a complex mineral from the Ruschita deposits and was found to give accurate results.

3950. Papadakis, Michel, Problems in simulation of ball mills, Rev. Mater. Construct. Trav. Publ, (572) 157-62, 1963.

Relations developed predict the sp. surface obtainable in a closed-circuit ball mill after a given grinding time with given ball and mill diams. and a homogeneous material. The equations were checked exptl. with 64- and 36-cm. mill diams. and 2, 4, and 6-cm. ball diams. Grinding efficiency and sp. surface limitations depend on the coeff. of agglomeration, which is a function of the grinding body and of the type of material ground. Specific surface vs. time is linear if the ball diam. is decreased with time. In open-circuit grinding, the mill diam. or the ball diam. may be decreased with the distance from the mill feed end. The effect of material circulation is uncertain; experimentation on this factor continues. The method may be used to find the sp. surface of a material ground in an existing ball mill, or to design a ball mill for a particular material and grinding regime. .

3951. Papadakis, Michel, Grindability characteristics as applied to the analysis of ball milling, Europaeischen Symp. Zerkleiern, I, Frankfurt am Main 341-59, 1962. (In French). The coeff. B, which indicates the tendency for a material to break up, can be detd. by a compression test. The coeff. A for the agglomerating tendency must be detd. in a milling expt. Values of A are 0.02-0.03 for sand and 0.04-0.04 for clinker. Values of B are 80×10^{-7} and 78×10^{-7} cm.²/erg, resp.

Rittingers law is shown to hold if the agglomeration during milling is subtracted. The capacity of a continuous ball mill with length L and internal diam. D is $0.16 LD^2/t_s \text{ cm.}^3/\text{sec.}$, where t_s is the time required to mill to the same sp. surface area in a batch ball mill of the same diam. A formula is given to calc. the distribution of ball diams. along the length of the mill. This distribution gives a max. throughput together with a well defined surface area.

3952. Papadakis, M., Application of grindability values in investigation of mode of operation of ball mills, Zement-Kalk-Gips 16 (4) 131-4, 1963.

Behavior of materials being ground in tube mill depends on fracturing behavior and agglomeration tendency. With knowledge of these variables it is possible to establish relationship governing longitudinal distribution of grinding media for maximum throughput associated with certain mill dimensions and fineness of material.

3953. Papadkis, M., Contribution to investigation of industrial ball mills, Aufbereitungs-Technik 2 (9) 353-64, 1961.

Grindability of material depends on capacity to break down and on capacity to agglomerate due to effect of impact causing breakdown. Optimum distribution of crushing bodies in open circuit ball mill.

3954. Papadakis, M., Crushing of materials, Annales des Mines 707-22, Nov. 1959.

Crushers are divided into three categories: slow, percussion, and rapid types. Ball mills of rapid type work at maximum efficiency when rate of loading by volume is in neighborhood of 0.40, and its speed is three quarters of critical speed. Theory explaining behavior of materials in ball mills. Crushability depends on breakability and agglomerability. English summary.

3955. Papadakis, Michel, Linings for ball mills, effectiveness of linings provided with projections, Rev. matériaux construct. et trav. publ. C, (518) 292-9, 1958.

These linings are more effective than smooth linings (both in power consumption and time required/ unit cement of a given fineness) only when the rotation rate and the vol. of the charge are low, $18/\sqrt{D} - 25/\sqrt{D}$ turns/ min. (D in m.) and clinker-ball ratio 20% by vol. The most efficient operation is obtained, however, at faster rates (about $30/\sqrt{D}$) and clinker-ball ratios (about 40%). Smooth linings are then more effective, but these conditions are not always realized in practice. Linings with projections are more wear resistant.

3956. Jax, Karl M., Ceramic balls for grinding mills, Ger. Pat. 1 072 179, 12/24/1959.

Wear-resistant grinding balls (sp. gr. greater than 4) consist

discharge chamber. An overall 80% recovery is obtained by final magnetic sepn.

3962. Pasquet M., and Pevergne, L., General considerations on the crushing of Lorraine iron ores to a suitable size for agglomeration, Europaeischen Symp. Zerkleinern, I., Frankfurt am Main 323-40, 1962 (in French).

For the agglomeration of Lorraine iron ore, particles less than 10 mm. are required with max. distribution at 0.1-6 mm. Existing secondary grinders give less than 40% on size. Tests with 7 types of rotary grinders of capacities of 50-200 tons/hr. showed that 100% on size is obtained with 22-6% less than 0.1 mm. and 5-8% between 6 and 10 mm., starting from a material between 0 and 200 mm. These results are obtained when the mill has an internal screen of 20 or 30 mm. The optimum peripheral velocity depends on the no. of hammers: a min. of 50 hits per sec. is required.

3963. Patat, F., and Langemann, H., Kinetics of grinding hard substances II: Temperature dependence of the comminution velocity, Chem. Ing. Tech. 34 15-20, 1962.

Determinations of the activation energy of comminution were made. The magnitude of the energy values would exclude the participation of lattice defects and indicates that superdislocations act as centers of fracture. Literature data are analyzed. 48 refs.

3964. Patat, F., and Langemann, H., Kinetics of grinding hard substances I, Chem. Ing. Tech. 31 561-8, 1959.

In order to relate the rate of grinding or comminution and the properties of the ground material, a method of differential grinding is proposed. Interpretation of model expts. with quartz fractions in ball mills were successful. Many diagrams and 24 references are given.

3965. Patat, F., and Mempel, G., Kinetics of grinding hard substances, IV: Ball mill grinding (In Ger.), Chem. Ingr. Tech. 37 (9) 933-9, 1965.

Expts. in a lab. ball mill of 900 cc. vol. and of 110 mm. are reported. The steel balls occupied 34% of the vol. Exptl. data were evaluated by means of the equation $\Delta G/\Delta t = -kG^n$ g./min. , where G is remaining fraction of the charge in g., n the exponential order, k the velocity const., and t the time. The conditions leading to various orders of n are discussed as a function of charge concn., mill rotation, resistance of material to comminution, and choking of the mill.

3966. Patterson, W.R., and King, D.E., Magnetic logic maximizes crusher output, Control Eng. 10 (1) 97-9, 1963.

Automatic control system of Massachusetts Broken Stone Co. Static switches based on magnetic amplifier provide high reliability and require no special power supply. Simple logic network continuously controls 2 primary variables to optimize

rock crusher's output.

3967. Patterson, W.R., and King, D.E., Set it and forget it, Rock Prod. 65 (2) 100-7, 1962.

Static control of automatic crushing system at Massachusetts Broken Stone Co. has no moving parts thus giving freedom from maintenance and environmental hazards. Static device is magnetic amplifier type using conventional 110 v a-c power source. In automated system static devices control feed rate and crushing setting. Variables in crusher performance. Design of system and flow sheet with regard for variables.

3968. Paulsen, H., Grinding media distribution in tube mills, Zement-Kalk-Gips 17 (9) 392-6, 1964.

Investigation of size distribution of mixed charge to be located at larger diameters than that of sorted charge. Formulas of F.C.Bond and M. Papakadis, by means of which size of balls for replenishing charge can be calculated, are explained.

SLA Trans. TT65-11963,

3969. Pavlov, V.A., Laws of plastic deformation and breakdown, U.S. At. Energy Comm. AEC Trans. 4513, 272-93, 1958.

A review with 57 references.

3970. Pawluschkin, N.M., Effect of dispersity and the form of starting material on the properties of sintered corundum, Freiburger Forschungsh. B 78 23-42, 1963.

Sintering temp. of corundum decreases with decreasing particle diam. down to 0.5μ av. diam., then increases again. Sintering of 0.5μ particles occurs around 1700° . Microhardness keeps increasing with decreasing particle size. Aluminas calcined at $1000-1500^\circ$ grind easily, and those over 1600° only with difficulty. Grinding time can be decreased by using a high ball-to- Al_2O_3 ratio and using heavy balls.

3971. Matouschek, F., Zement-Kalk-Gips 13 (9) 394-409, 1960. For liner wear with raw cement and clinker, Matoushek published a mathematical approach by way of statistical analysis, with many references on the subject. The ideal solution is said to be in combined effects of proper choice of alloy and surface and shape of the liners. Chrome and manganese steels are compared. Shape is less important in first raw mill chamber than in the second.

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3975. Roberts, A., E., Mineral Processing (Proceedings of the Sixth International Congress held at Cannes, May 26 - June 2, 1963). Pergamon Press, New York. 1965.

3976. Pew, John C., and Weyna, Philip, Fine grinding, enzyme digestion, and the lignin-cellulose bonds in wood, Tappi 45 (3) 247-56, 1962.

The vibratory grinding and enzyme digestion of wood was studied to obtain addnl. information on the nature of the lignin and cellulose in wood and the type of assocn. between these constituents. See CA 61 819e, 1964.

3977. Pfeifer, V.F., et.al., Size reduction of dried pellets containing serratia marcescens, Ind. & Eng. Chem. 50 (4) 627-32, 1958.

Investigation of suitable operating conditions for pulverizing dried pellets containing Serratia marcescens where powders are used for aerosol production and testing. Testing of ball mill, fluid energy reduction mill, high speed centrifugal mill. Chief factors affecting grinding of pellets were type of feed material and intensity of grinding. In general, viable cell recovery in powder depended upon particle size. High speed centrifugal mill was most satisfactory.

3978. Phelps, G.W., and Maguire, S.G. Jr., Practical particle-size analysis of clays, Am. Ceram. Soc. J. 40 399-409, 1957.

3979. Pickett, D.E., Technical advances in milling and process metallurgy in Canada during 1961, Can. Min. J. 83 (2) 148-58, 1962.

Automation, autogenous comminution and hydrocyclones for classification continue to be trends in crushing and grinding. Developments in materials handling and controls and in mill metallurgy. Progress at various ore treatment plants in Canada. Major features of ore treatment plants constructed in 1961. Research in extractive and physical metallurgy. Manufacturers information on new equipment.

3980. Pitchford, A.H., A high-speed, selective, uniform-particle-size grinder for the preparation of analytical samples, Advan. X-Ray Anal. 4 547-54, 1961.

The selective uniform-particle-size grinder grinds with an oscillatory motion whose configuration resembles 2 short cones coupled at their vertexes. Grinding of almost any sample from diamond to soft org. material is extremely rapid. Around the circumference of the grinding chamber are windows fitted with a screen of the desired mesh size. Air is pulsed through an inlet against the rear side of the screen at one end of the chamber, removing any residual powder that may be clogging or binding the screen. The air continues on through the vial and blasts the powder against the screen at the opposite end. As this is clean, particles reaching screen size are removed from the chamber. The advantages of selective over static

grinding are illustrated by comparing the av. counts in the analysis of hard clay, calcined bauxite, and a 50:50 mixt. of each, after both static grinding and selective grinding through a 400-mesh screen. The advantages of the selective grinding are illustrated by a strip chart recording for the detn. of TiO_2 in the clay, bauxite, and 50:50 mixt. by both methods of grinding. A photomicrograph illustrates the greater uniformity in the selective grinding. The advantages of the later are further emphasized with data for the analysis of basic brick for Fe, Cr, Si, and Ca, statically and selectively ground through 325- and 440-mesh screens.

3981. Bond, F.C., Engr. & Mining J. 93 (3) 82, 1960.

Bond's article on rod mills deals with an industrial example. As it was found that the energy consumption and throughput did not agree with the Bond index, close observation of the rods was made. It was found that rods wear to a certain thickness and then break. 4 tons out of 63 tons of rods were thus found to have been broken. When broken rods are taken into account, the index appeared to be correct.

3982. Planiol, Rene, Energy relations in centrifugal grinders with vacuum impacting, Congr. Intern. Prepn. Minerais, 6^e, Cannes, France 51-61, 1963 (Pub. 1964) (Fr).

Particles are ejected from the rotary blades with a trajectory speed dependent upon the blade radii, and their angular

using a condenser-type microphone with uniform response from 20 to 18,000 cycles per sec. and suitable band-pass filters. In preliminary runs, this level was detd. for optimum performance in the wet-grinding of a crude ore contg. Mn and Fe carbonates, pyrites, and quartz. The input of the mill was then maintained at this level by a servomotor mechanism which was controlled by the microphone response.

3987. Poluboyarinov, D.N., Popil'skii, R.Ya., and Chiang, Tung-Hua, The effect of preliminary thermal treatment and vibratory grinding of magnesium oxide on its dispersivity, hydration properties, and fusibility, *Ogneupory* 26 80-6, 1961. cf. Salmang, CA 43, 3156d.

With the view to obtaining data of interest to periclase technology, studies were made on the effects of preliminary calcining of tech. MgO and its vibratory grinding on the properties named in the title. For comparison a fused material from the same calcined stock was included. Specimens of this tech. MgO passing 10,000/sw. cm. were calcined at 900, 1100, 1300, 1500, 1600, and 1700° for 2 hrs.; grinding was carried out in a vibratory mill with steel balls 14-18 mm. in diam. for periods that varied up to 120 min. See CA 55 12802a, 1961.

3988. Poncelet, E.F., The mechanism of fracture propagation, *Trans. AIME* 229 161-9, 1964.

motors with enclosed reduction gears, motors and friction clutches; example on possible savings, before taxes, due to power factor (pf) improvement, if wound-rotor motors are selected as mill drives, if synchronous motors of 1.0 pf are selected as mill drives, if synchronous motors of 0.8 pf are selected for mill drives; example of possible savings, before taxes, due to higher efficiency of mill drive motors.

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3941. Reiners, E., Chem. Ing. Tech. 32 335, 1960.

Contributes interesting information from high speed camera pictures on breakage phenomenon.

3942. Ott, Ronald L., Mechanism of the mechanical degradation of cellulose, J. Polymer Sc. Pt. A2 (2) 973-82, 1964.

High-viscosity, acetate-grade cotton linters with a no. av. degree of polymerization (D.P.) of 1710 were ground in a vibratory ball mill under N for periods of time ranging from 17 to 36 hrs. The grinding was carried out on air- and oven-dried cellulose samples alone and in the presence of cyclohexane and CCl_4 contg. I. The rate of degradation increased as the I concn. in CCl_4 and cyclohexane increased from 0 to 2.0 g./l. The I accelerated the degradation by preventing the recombination of at least some of the macroradicals formed during the milling of cellulose. See CA 60 8219b, 1964.

3943. Ottley, D.J., Size reduction symposium, Min. Mag. 106 (6) 329-33, 1962.

Topics under discussion and principal features of some of 43 papers presented at Symposium on size reduction held in Frankfurt, Germany, April 1962.

3945. Ozhigov, E.P., Qualitative analysis of local ores by grinding, Tr. Dal'nevost. Filiala, Akad. Nauk SSSR, Ser. Khim. (5) 116-24, 1961.

Zn, Pb, Sn, and Bi were detd. in a mineralogically complex ore contg. 22 elements. The change of color after grinding the sample with several reagents proved the presence of the element sought. See CA 57 9197c, 1962.

3946. Pacault, Adolphe, Marchand, Andre, Boy, Francis, and Poquet, Elizabeth, Increase in diamagnetism of natural graphite by grinding, Compt. Rend. 254 1275-7, 1962.

Grinding natural graphite by different methods increases the diamagnetism to approach that of pyrolytic graphite. Most effective is a rotary grinding in a B carbide mortar. Susceptibilities over a temp. range are given.

3947. Lin, Hsien-chih, Scientia Sinica 8 1295, 1959.

Details of movement of charge in a ball mill. Relates optimum ball charge to rotational speed.

3948. Panu, Huber and Popa, Emil, Method of calculating the capacity of ball mills, I. Rev. met. Acad. rep. populaire Roumaine 3 59-83, 1958.

Math. treatment, verified by expts. with materials such as quartz, on capacity of ball and rod mills for reducing particle size of feed product to specified limits.

3949. Panu, Huber, and Popa, Emil, Method of calculation of the capacity of crushers. I. Acad. rep. populare Romine, Studii cercetari met. 2 499-522, 1957.

A method is presented for the calcn. of the capacity of ball mills and roll crushers. Using Rittinger's Law for the crushing energy needed, a formula is derived for the capacity of such crushers as a function of their dimensions, of the increase of the specific surface of the crushed material, and of the resistance of the material to crushing as characterized by a parameter termed the "relative crushing index". This formula is rearranged to allow th calcn. of the specific surface and of the relative crushing index. In order to find the specific-surface independently, formulas are derived in terms of parameters which can be detd. by simple experimentation, such as a sieve analysis, so that the practical application of the method is not hampered by requirements for special app. The specific surface can be detd., once the screen analysis of the material is known. For the material passing through the finest sieve, a new formula for specific surface is used based on Gaudin's equation (Principles of Mineral Dressing, 1939(C.A. 34, 1605³)). The method was checked experimentally with quartz and a complex mineral from the Ruschita deposits and was found to give accurate results.

3950. Papadakis, Michel, Problems in simulation of ball mills, Rev. Mater. Construct. Trav. Publ,(572)157-62, 1963.

Relations developed predict the sp. surface obtainable in a closed-circuit ball mill after a given grinding time with given ball and mill diams. and a homogeneous material. The equations were checked exptl. with 64- and 36-cm. mill diams. and 2, 4, and 6-cm. ball diams. Grinding efficiency and sp. surface limitations depend on the coeff. of agglomeration, which is a function of the grinding body and of the type of material ground. Specific surface vs. time is linear if the ball diam. is decreased with time. In open-circuit grinding, the mill diam. or the ball diam. may be decreased with the distance from the mill feed end. The effect of material circulation is uncertain; experimentation on this factor continues. The method may be used to find the sp. surface of a material ground in an existing ball mill, or to design a ball mill for a particular material and grinding regime. .

3951. Papadakis, Michel, Grindability characteristics as applied to the analysis of ball milling, Europaeischen Symp. Zerkleiern, I, Frankfurt am Main 341-59, 1962. (In French). The coeff. B, which indicates the tendency for a material to break up, can be detd. by a compression test. The coeff. A for the agglomerating tendency must be detd. in a milling expt. Values of A are 0.02-0.03 for sand and 0.04-0.04 for clinker. Values of B are 80×10^{-7} and 78×10^{-7} cm.²/erg, resp.

Rittingers law is shown to hold if the agglomeration during milling is subtracted. The capacity of a continuous ball mill with length L and internal diam. D is $0.16 LD^2/t_s \text{ cm.}^3/\text{sec.}$, where t_s is the time required to mill to the same sp. surface area in a batch ball mill of the same diam. A formula is given to calc. the distribution of ball diams. along the length of the mill. This distribution gives a max. throughput together with a well defined surface area.

3952. Papadakis, M., Application of grindability values in investigation of mode of operation of ball mills, Zement-Kalk-Gips 16 (4) 131-4, 1963.

Behavior of materials being ground in tube mill depends on fracturing behavior and agglomeration tendency. With knowledge of these variables it is possible to establish relationship governing longitudinal distribution of grinding media for maximum throughput associated with certain mill dimensions and fineness of material.

3953. Papadkis, M., Contribution to investigation of industrial ball mills, Aufbereitungs-Technik 2 (9) 353-64, 1961.

Grindability of material depends on capacity to break down and on capacity to agglomerate due to effect of impact causing breakdown. Optimum distribution of crushing bodies in open circuit ball mill.

3954. Papadakis, M., Crushing of materials, Annales des Mines 707-22, Nov. 1959.

Crushers are divided into three categories: slow, percussion, and rapid types. Ball mills of rapid type work at maximum efficiency when rate of loading by volume is in neighborhood of 0.40, and its speed is three quarters of critical speed. Theory explaining behavior of materials in ball mills. Crushability depends on breakability and agglomerability. English summary.

3955. Papadakis, Michel, Linings for ball mills, effectiveness of linings provided with projections, Rev. matériaux construct. et trav. publ. C, (518) 292-9, 1958.

These linings are more effective than smooth linings (both in power consumption and time required/ unit cement of a given fineness) only when the rotation rate and the vol. of the charge are low, $18/\sqrt{D} - 25/\sqrt{D}$ turns/ min. (D in m.) and clinker-ball ratio 20% by vol. The most efficient operation is obtained, however, at faster rates (about $30/\sqrt{D}$) and clinker-ball ratios (about 40%). Smooth linings are then more effective, but these conditions are not always realized in practice. Linings with projections are more wear resistant.

3956. Jax, Karl M., Ceramic balls for grinding mills, Ger. Pat. 1 072 179, 12/24/1959.

Wear-resistant grinding balls (sp. gr. greater than 4) consist

mainly of TiO_2 and of 2-10% Pb compds. used as a vitreous binder. An example of the compn. is TiO_2 91, Pb silicate 4, Klingenberg clay 2.5, and bentonite 2.5% by wt. The material is fabricated as usual, and preferably fired in an electric furnace in an oxidizing atm, at 1300-400°.

3957. Parfenov, L.I., and Karakula, M.V., Effect of cerium on wear resistance of G13L steel, Liteinoe Proizv. (10) 8-9, 1964. (Russ).

Up to 0.11% Ce added to 13% Mn steel deoxidized with 0.1% Al refines the grain and increases the life of crusher jaws, raising their surface hardness from 550 to 580 Brinell. More Ce reduces these properties.

3958. Paricio, Ray, Grinding problems - consider vibratory ball mill, Min. World 24 (7) 24-6, 1962.

Over 40 different materials are being efficiently processed by vibrating ball mill. Whether this new concept, using vibrating rather than rotating action, could be profitably employed depends largely on physical characteristics of ore, feed size, desired product analysis. Vibrating mill has greater versatility and offers economies over conventional mill in lower initial installation cost and weight, less required floor space, and easy maintenance. Vibrating mills of various designs, construction and application. Continuous mills. Cost of 30-in. mill is \$5000 less than ball mill.

3959. Pascu, N., Ripan, R., and Buturca, F., Determination of crushing and flotation time of gold minerals at Rosa Mountain, Studii Cercetari Met. 10 (1) 155-65, 1965 (Rom).

The flow of materials in the Au extn. plant was followed by the addn. of 3 g. radioactive ¹⁹⁸Au powder, activity 0.3 c. This procedure revealed that: mineral crushing time was 10-15 min., speed of mineral passage through the mill, 1 min., and through the classifier, 1½ min. Flotation time was 10 min. Loss of Au in the discharge fluid was 0.09 g. Au/ton.

3960. Koulen, K., Zement-Kalk-Gips 13 (4) 158-162, 1960.

Literature survey with many references on closed circuit grinding and sieving in Germany. Results are inconclusive because experiments are poorly controlled. They need statistical basis.

3961. Pasquet, Maurice and Joco, Gerard, Autogenous grinding of Lorraine iron ores for magnetic enrichment, Congr. Intern. Prepn. Minerais, 6^e Cannes, France 90-111, 1963 (Pub.1964)(Fr). Soft oolitic grains contg. approx. 50% Fe are cemented by calcite or silicates. Following grinding to 800 μ, autogenous milling gives better sepn. of the oolite grains, while hot air transport provides simultaneous drying. The Aerofall mill is preferred to the Cascade mill, since air flow speed vs. sizing is more flexible than by internal sieving. Optimum grinding time must be ensured by balancing air flow, addn. of grinding balls to assist the lateral deflectors, and venting in the

discharge chamber. An overall 80% recovery is obtained by final magnetic sepn.

3962. Pasquet M., and Pevergne, L., General considerations on the crushing of Lorraine iron ores to a suitable size for agglomeration, Europaeischen Symp. Zerkleinern, I., Frankfurt am Main 323-40, 1962 (in French).

For the agglomeration of Lorraine iron ore, particles less than 10 mm. are required with max. distribution at 0.1-6 mm. Existing secondary grinders give less than 40% on size. Tests with 7 types of rotary grinders of capacities of 50-200 tons/hr. showed that 100% on size is obtained with 22-6% less than 0.1 mm. and 5-8% between 6 and 10 mm., starting from a material between 0 and 200 mm. These results are obtained when the mill has an internal screen of 20 or 30 mm. The optimum peripheral velocity depends on the no. of hammers: a min. of 50 hits per sec. is required.

3963. Patat, F., and Langemann, H., Kinetics of grinding hard substances II: Temperature dependence of the comminution velocity, Chem. Ing. Tech. 34 15-20, 1962.

Determinations of the activation energy of comminution were made. The magnitude of the energy values would exclude the participation of lattice defects and indicates that superdislocations act as centers of fracture. Literature data are analyzed. 48 refs.

3964. Patat, F., and Langemann, H., Kinetics of grinding hard substances I, Chem. Ing. Tech. 31 561-8, 1959.

In order to relate the rate of grinding or comminution and the properties of the ground material, a method of differential grinding is proposed. Interpretation of model expts. with quartz fractions in ball mills were successful. Many diagrams and 24 references are given.

3965. Patat, F., and Mempel, G., Kinetics of grinding hard substances, IV: Ball mill grinding (In Ger.), Chem. Ingr. Tech. 37 (9) 933-9, 1965.

Expts. in a lab. ball mill of 900 cc. vol. and of 110 mm. are reported. The steel balls occupied 34% of the vol. Exptl. data were evaluated by means of the equation $\Delta G/\Delta t = -kG^n$ g./min. , where G is remaining fraction of the charge in g., n the exponential order, k the velocity const., and t the time. The conditions leading to various orders of n are discussed as a function of charge concn., mill rotation, resistance of material to comminution, and choking of the mill.

3966. Patterson, W.R., and King, D.E., Magnetic logic maximizes crusher output, Control Eng. 10 (1) 97-9, 1963.

Automatic control system of Massachusetts Broken Stone Co. Static switches based on magnetic amplifier provide high reliability and require no special power supply. Simple logic network continuously controls 2 primary variables to optimize

rock crusher's output.

3967. Patterson, W.R., and King, D.E., Set it and forget it, Rock Prod. 65 (2) 100-7, 1962.

Static control of automatic crushing system at Massachusetts Broken Stone Co. has no moving parts thus giving freedom from maintenance and environmental hazards. Static device is magnetic amplifier type using conventional 110 v a-c power source. In automated system static devices control feed rate and crushing setting. Variables in crusher performance. Design of system and flow sheet with regard for variables.

3968. Paulsen, H., Grinding media distribution in tube mills, Zement-Kalk-Gips 17 (9) 392-6, 1964.

Investigation of size distribution of mixed charge to be located at larger diameters than that of sorted charge. Formulas of F.C.Bond and M. Papakadis, by means of which size of balls for replenishing charge can be calculated, are explained.

SLA Trans. TT65-11963,

3969. Pavlov, V.A., Laws of plastic deformation and breakdown, U.S. At. Energy Comm. AEC Trans. 4513, 272-93, 1958.

A review with 57 references.

3970. Pawluschkin, N.M., Effect of dispersity and the form of starting material on the properties of sintered corundum, Freiburger Forschungsh. B 78 23-42, 1963.

Sintering temp. of corundum decreases with decreasing particle diam. down to 0.5μ av. diam., then increases again. Sintering of 0.5μ particles occurs around 1700° . Microhardness keeps increasing with decreasing particle size. Aluminas calcined at $1000-1500^\circ$ grind easily, and those over 1600° only with difficulty. Grinding time can be decreased by using a high ball-to- Al_2O_3 ratio and using heavy balls.

3971. Matouschek, F., Zement-Kalk-Gips 13 (9) 394-409, 1960.

For liner wear with raw cement and clinker, Matoushek published a mathematical approach by way of statistical analysis, with many references on the subject. The ideal solution is said to be in combined effects of proper choice of alloy and surface and shape of the liners. Chrome and manganese steels are compared. Shape is less important in first raw mill chamber than in the second.

3972. Peck, W.C., Vibration mills and vibration milling, Indus. Chemist 38 (447) 223-5, 1962.

Vibration ball milling is used to prepare tungsten carbide, for grinding graphite or sugar carbon used to produce tungsten carbide, and for mixing and coating tungsten carbide with cobalt prior to sintering. Application of dimensionless analysis.

Importance of rate of milling. Reviews Rose & Sullivan.
Problem to make full-sized mills continuous and provide cooling to dissipate the heat of milling.

3973. Halbart, J., and Freymann, V.F., Zement-Kalk-Gips 13
(1) 17-23, 1960.

Halbart and Freymann discussing Davies and Ugglia's theory on the movement of the charge within a mill, conclude that the space in between liner bars is essentially connected with ball diameter. Ball packing geometry is considered, a thing that is overlooked by many authors. A liner construction is proposed in which the distance between bars is smaller toward the discharge of the mill. This causes worn (smaller) balls to move towards the finer milling zone. Proper attention is also given to the coefficient of friction between different rows of balls. See 3606 for translation.

3974. Pendleton, A.G., Fluid energy milling, Chem. & Proc. Eng. 44 (12) 733-9, 1963.

Evolution of various types of fluid energy mills and their characteristics. Advantage of this system is that fluid energy milling can also perform other operations such as dehydration, de-agglomeration and simple chemical reactions. Joule-Thomson effect enables fluid energy mill to be used for reduction of heat-sensitive materials. Narrower size-distribution range is obtained with fluid energy milling.

3975. Roberts, A., E., Mineral Processing (Proceedings of the Sixth International Congress held at Cannes, May 26 - June 2, 1963). Pergamon Press, New York. 1965.

3976. Pew, John C., and Weyna, Philip, Fine grinding, enzyme digestion, and the lignin-cellulose bonds in wood, Tappi 45 (3) 247-56, 1962.

The vibratory grinding and enzyme digestion of wood was studied to obtain addnl. information on the nature of the lignin and cellulose in wood and the type of assocn. between these constituents. See CA 61 819e, 1964.

3977. Pfeifer, V.F., et.al., Size reduction of dried pellets containing serratia marcescens, Ind. & Eng. Chem. 50 (4) 627-32, 1958.

Investigation of suitable operating conditions for pulverizing dried pellets containing Serratia marcescens where powders are used for aerosol production and testing. Testing of ball mill, fluid energy reduction mill, high speed centrifugal mill. Chief factors affecting grinding of pellets were type of feed material and intensity of grinding. In general, viable cell recovery in powder depended upon particle size. High speed centrifugal mill was most satisfactory.

3978. Phelps, G.W., and Maguire, S.G. Jr., Practical particle-size analysis of clays, Am. Ceram. Soc. J. 40 399-409, 1957.

3979. Pickett, D.E., Technical advances in milling and process metallurgy in Canada during 1961, Can. Min. J. 83 (2) 148-58, 1962.

Automation, autogenous comminution and hydrocyclones for classification continue to be trends in crushing and grinding. Developments in materials handling and controls and in mill metallurgy. Progress at various ore treatment plants in Canada. Major features of ore treatment plants constructed in 1961. Research in extractive and physical metallurgy. Manufacturers information on new equipment.

3980. Pitchford, A.H., A high-speed, selective, uniform-particle-size grinder for the preparation of analytical samples, Advan. X-Ray Anal. 4 547-54, 1961.

The selective uniform-particle-size grinder grinds with an oscillatory motion whose configuration resembles 2 short cones coupled at their vertexes. Grinding of almost any sample from diamond to soft org. material is extremely rapid. Around the circumference of the grinding chamber are windows fitted with a screen of the desired mesh size. Air is pulsed through an inlet against the rear side of the screen at one end of the chamber, removing any residual powder that may be clogging or binding the screen. The air continues on through the vial and blasts the powder against the screen at the opposite end. As this is clean, particles reaching screen size are removed from the chamber. The advantages of selective over static

grinding are illustrated by comparing the av. counts in the analysis of hard clay, calcined bauxite, and a 50:50 mixt. of each, after both static grinding and selective grinding through a 400-mesh screen. The advantages of the selective grinding are illustrated by a strip chart recording for the detn. of TiO_2 in the clay, bauxite, and 50:50 mixt. by both methods of grinding. A photomicrograph illustrates the greater uniformity in the selective grinding. The advantages of the later are further emphasized with data for the analysis of basic brick for Fe, Cr, Si, and Ca, statically and selectively ground through 325- and 440-mesh screens.

3981. Bond, F.C., Engr. & Mining J. 93 (3) 82, 1960.

Bond's article on rod mills deals with an industrial example. As it was found that the energy consumption and throughput did not agree with the Bond index, close observation of the rods was made. It was found that rods wear to a certain thickness and then break. 4 tons out of 63 tons of rods were thus found to have been broken. When broken rods are taken into account, the index appeared to be correct.

3982. Planiol, Rene, Energy relations in centrifugal grinders with vacuum impacting, Congr. Intern. Prepn. Minerais, 6^e, Cannes, France 51-61, 1963 (Pub. 1964) (Fr).

Particles are ejected from the rotary blades with a trajectory speed dependent upon the blade radii, and their angular

displacement. At higher speeds, the particle impact upon the target resulting in comminution to as low as $1\ \mu$ is in accord with Rittinger's law. Calcns. show power efficiencies of 33%. Heterogeneous minerals sometimes may be differentially comminuted due to differences in grindability. See 3975.

3983. Planiol, Rene, Vacuum centrifugal grinders, Rev. Mater. Construct. Trav. Publ. 557 42-9, 1962.

An ore or clinker crusher consists of a vertical cylinder that contains a fan-type rotor. The particles are fed from the top, enter the cylinder along the axis, and are driven spirally from the center, colliding with vanes ranged around the periphery. The crusher is 25% more efficient than a ball mill.

3984. Planiol, R., Centrifugal impact mill under vacuum, Aufbereitungs-Technik 3 (10) 447-50, 1962.

Electric motor with vertical shaft drives rotor; washer which is tightly fitted around shaft permits its use under vacuum. Particles are projected individually against wall lining in grinding chamber and are crushed by single shock in time lapse of 10^{-3} to 10^{-8} sec. English summary.

3986. Polacek, J., and Kolar, O., Automatic regulation of the output of the (ore-grinding) mill of the Chvaletice works, Freiburger Forschungsh. A316 175-82, 1964 (Ger).

The noise level of the ball mill was recorded electronically

using a condenser-type microphone with uniform response from 20 to 18,000 cycles per sec. and suitable band-pass filters. In preliminary runs, this level was detd. for optimum performance in the wet-grinding of a crude ore contg. Mn and Fe carbonates, pyrites, and quartz. The input of the mill was then maintained at this level by a servomotor mechanism which was controlled by the microphone response.

3987. Poluboyarinov, D.N., Popil'skii, R.Ya., and Chiang, Tung-Hua, The effect of preliminary thermal treatment and vibratory grinding of magnesium oxide on its dispersivity, hydration properties, and fusibility, *Ogneupory* 26 80-6, 1961. cf. Salmang, CA 43, 3156d.

With the view to obtaining data of interest to periclase technology, studies were made on the effects of preliminary calcining of tech. MgO and its vibratory grinding on the properties named in the title. For comparison a fused material from the same calcined stock was included. Specimens of this tech. MgO passing 10,000/sw. cm. were calcined at 900, 1100, 1300, 1500, 1600, and 1700° for 2 hrs.; grinding was carried out in a vibratory mill with steel balls 14-18 mm. in diam. for periods that varied up to 120 min. See CA 55 12802a, 1961.

3988. Poncelet, E.F., The mechanism of fracture propagation, *Trans. AIME* 229 161-9, 1964.

3989. Pons, Louis, Chevillon, Jac, and Steff, Philippe, Surface embrittlement of tungsten carbide media as the result of grinding, Compt. Rend. 255 2100-2, 1962 (in French).

The surface embrittlement of WC frits alloyed with Co. was studied. Examn. was made with an optical microscope of the progressive deterioration of the surface of the WC media in the form of cylindrical rods after grinding soft (calcite) and hard (quartzite) mineral disks.

3990. Pownall, J.H., and Barnes, J.D., Optimization of mineral treatment processes, Trans. Inst. Chem. Engrs. (London) 40 (6) 385-416, 1962.

The unit processes which respond to optimization are closed-circuit grinding, froth flotation, ore leaching, and recovery of materials from solvent extns. and plants. A method of finding optimum control for the whole integrated plant was developed. The pilot plant results on a 2-stage concn. process (gravity concn. and flotation) for V oxide and Fe oxide recovery from various feed concns. for a 90% recovery of V oxide are reported.

3991. Prasher, Charles L., Ball mill grinding, Brit. Pat. 832 404, 4/13/1960.

In a study of the design and operating criteria of ball mills it is shown that $T = kJLD^{2.5}$, where T is the output of the mill in tons/hr. of coal of a particular fineness, k is a const., J is the fraction of interior vol. of the casing occupied by

the charge, and L and D are the interior length and diam. of the casing, resp. This relation is valid for a mill operating at a const. fraction C of the crit. speed, which is the min. speed at which a very small particle would centrifuge. In an example of improved design, for a conventional mill having a J value of 0.2 and diam. 9.5 ft., there could be substituted a mill having a value of J equal to 0.08 and a diam. of 17 ft. to give the same value of $T/L = 0.6$, with a power saving on the order of 12%. An improved method of pulverizing coal is shown in a diagram, and the design criteria are discussed in detail.

3992. Pryor, E.J., Mineral Dressing: old and new, Mining Mag. (London) 101 (6) 297-308, 1959.

This review on the art of mineral dressing covers 50 years of developments in methods of crushing and grinding, sizing, classification, gravity concn., magnetic concn., and flotation. Describes Royal School of Mines pilot plant of 1910. Important crushers were Blake, roll, and gyratory suspended from gearing below. An important development was overhead suspension, allowing longer gyratories. Development of moving screens; Trommel screens were widely used. Concentration was done by gravity only, depending on different density of ore. The ore had to be coarse-grained. The squirrel-cage mill was the forerunner of the Aerofall mill. Classifiers: free-settling was replaced by the rake and spiral. These in turn were replaced

by hydrocyclones. Dense media separation used the Humphreys Spiral. Example was Swedish Strippa iron ore machine. Magnetic separation: Swedes used the wet drum in 1899. Flotation developed slowly. The Elmore patent (1898) separated silica from sulfides with oil. Acids were used in 1901. The first froth flotation was patented by Potter (Broken Hill Co.) in 1901, using gas. Sulman and Pickard first used agitation with oleic acid in 1905. Chemical leaching. Electrostatic separation has been slow to develop. Mechanical improvements have been great. Improvements in mill design allow a modern mill to handle large tonnage with a few men.

3993. Puckett, J.E., Pinched for production, Rockydale quarries modernizes, Rock Prod. 68 (2) 72-4, 1965.

Addition of roller-bearing primary jaw crusher to quarrying operation at Roanoke, Va. has increased output by 25% and reduced secondary blasting costs by 35%. Other crushing facilities include 4½ ft. cone crusher, which reduces minus 7 in. stone to minus 3 in., and three shorthead cone crushers which produce sizes ranging from minus 1 in. to dust. Included also are 54 in.-gyrodisc and Hercules mill which produce all fine sizes including 200 mesh agricultural lime. Pit equipment includes 2 cu. yd. and 1½ cu. yd. shovels and 5 cu. yd. loader.

3994. Puffe, Edgar, Estimating particle size distribution as an economic problem, Europaeischen Symp Zerkleinern, 1., Frankfurt am Main, 669-79, 1962.

The possibility of estimating the product particle sizes is given for various mills. Comminution expts. on pit coal were carried out on a double-roll crusher. The fraction of fine coal can be decreased by a low content of shale, by a step-wise comminution with intermediate screening, by lowering the circumferential speed, by decreasing the feed, and by increasing the gap between the crusher rolls. The optimum gap and circumferential speed for new products must be found by expt. General rules cannot be given.

3995. Puffe, E., Selective impact crushing as means of reducing costs and increasing throughput in preparation plants, Glueckauf 96 (1) 20-30, 1960.

Theoretical and practical aspects of impact crushing. Possibility of selective crushing. Application of method in treatment of sedimentary lead-zinc ore, iron ore, titanium ore, ores of magnamtic origin, salt, anhydride, limestone, asbestos, and coal.

3996. Quatinetz, Max, Schafer, Robert J., and Smeal, Charles R., Production of submicron metal powders by ball milling with grinding aids, Ultrafine Particles 271-96, 1963.

Most of the expts. consisted in varying the grinding aid and

were run by using Ni powder (Inco Carbonyl grade B) initially $2.5\ \mu$, and 200-proof EtOH as the fluid, because alc. has both polar and nonpolar characteristics. A more polar liquid, distd. H_2O , and less polar media, cyclohexane, n-heptane, and methylene chloride were also used. The ball-mill jars were 3-pint capacity and contained $\frac{1}{2}$ in. diam. type 410 stainless steel ball bearings. Cr, Cu, Fe, Ag, and Ni powders were also ground with EtOH as a fluid. All mill charges contained 399 ml. liquid and 3000 g. of balls. When inorg. salts were the grinding aid, 70 g. salt and 210 g. metal powder were added, and with surfactants 6 g. grinding aid and 300 g. powder. After 2, 4, 8, and 15 days of grinding at 48 r.p.m. a 40-g. sample was removed for evaluation. Of 22 salts selected, 16 produced final particle sizes less than the original $2.5\ \mu$, and of these 12 were less than $1\ \mu$. Powders ground with 11 of the most effective salts were in the submicron range in 4 days. The smallest particle size noted, $0.1\ \mu$, was obtained with $Ce(NO_3)_3 \cdot 6H_2O$ and $Al(NO_3)_3 \cdot 9H_2O$ in grinding a $7.3\text{-}\mu$ Fe powder. One run with cetyl alc. as a surfactant gave a final particle size greater than the $8.2\text{-}\mu$ standard. All powders in one group except Cr were reduced in size to the submicron range within 5 days. With an attritor mill (rotates the balls with a stirring arm instead of rolling them), $1.0\text{-}\mu$ powder was produced in 10 hrs. and $0.1\text{-}\mu$ powder in 72 hours, a redn. in milling time of 80-90%. H_2O contamination of the EtOH had no effect on the alc, as a grinding fluid. Better grinding efficiency obtained in

some nonpolar media with the H_2O -sol. salts as grinding aids may be due to better conditions for ion adsorption, despite low salt soly. There was no correlation between salt hardness (Mohs' scale) and grinding efficiency. A progressive increase in C and N retention with grinding time with $K_4Fe(CN)_6 \cdot 3H_2O$ may be assocd. with increased ion sorption or compd. formation with increased surface area. 18 references.

3997. Quatinetz, M., et.al., Production of submicron metal powders by ball milling with grinding aids, Metal Prog. 82 160+, August 1962.

3998. Quesnel, G., Utilization of rod and ball mills at supercritical speeds, Revue de l'Industrie Minerale 42 (9) 749-75, 1960.

Tests were conducted below critical speed and without feed; centrifugal action is possible only by preventing load from sliding by means of efficient lifting paddles. Power peaks rise with load, but occur at progressively lower speeds. Maximum possible speed for mill depends on weight of load.

3999. Quintino, Rogado J., Principle of superposition, Tecnica 38 (324) 243-67, 1963.

Analysis of relationship between work input and particle size distribution. General relation is deduced for evaluation of energy necessary to perform fragmentation.

