



The Magmont mining complex at Bixby, Mo., shows the tailings pond in the background and the fresh water supply pond in the right foreground. Reuse of water gains importance as state governments establish stricter pollution control laws.

Minerals Beneficiation in '69 Steps up Tonnage, Engineering, Environmental Control and Automation

**Size Analysis and Flotation Chemistry
Highlighted by Basic Science Researchers**

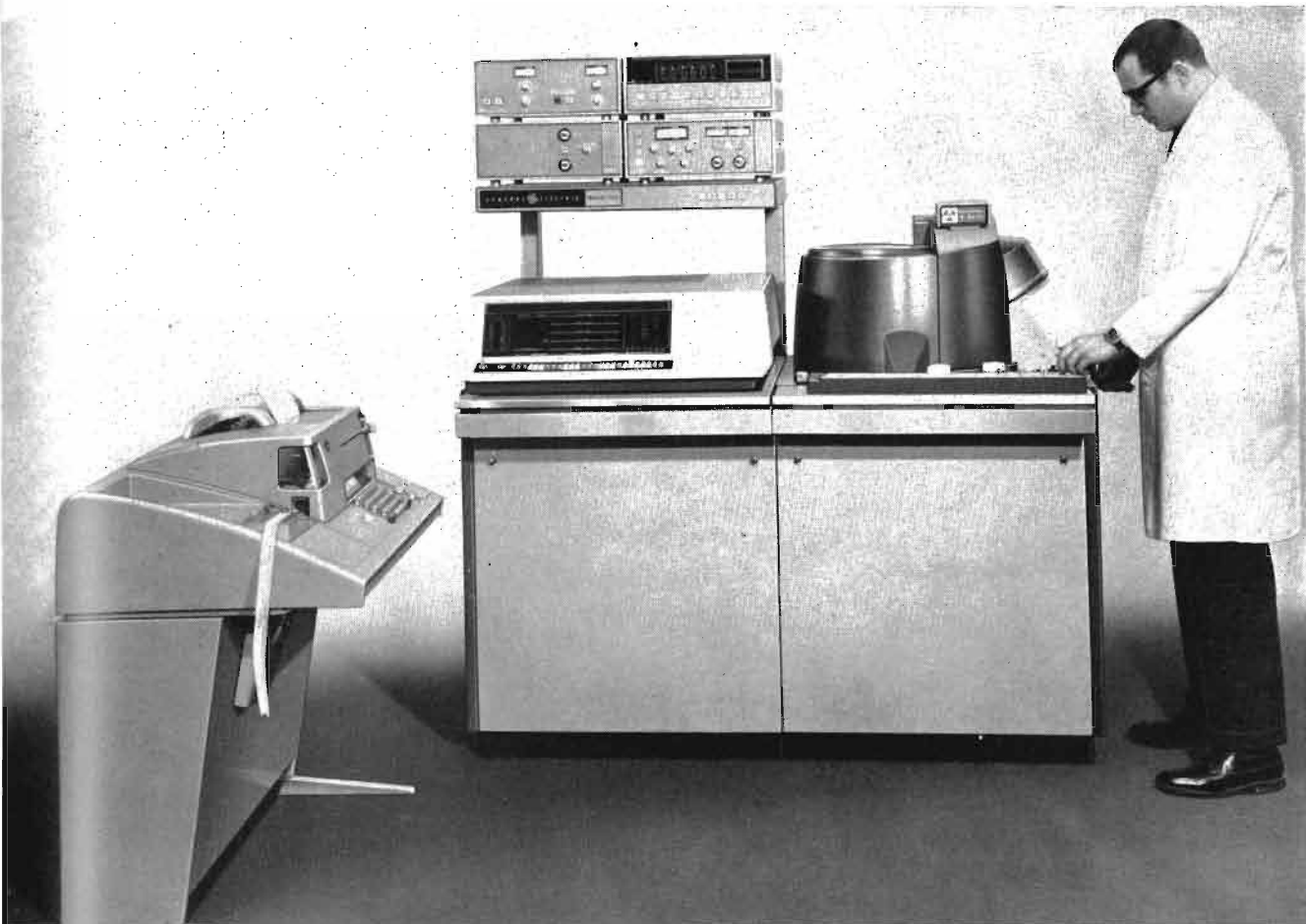
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The application of computers to the control and study of mineral processing operations such as grinding, classification and flotation has created an interest in simulation studies of these operations with mathematical models. Evidence of this interest is confirmed by papers presented at the 1969 International Computer Application Symposium held concurrently with the Fall Meeting of the Society of Mining Engineers in Salt Lake City, September 17-19, 1969. Proceed-

ings of this symposium, entitled *A Decade of Digital Computing in the Mineral Industry*, were edited by Alfred Weiss and published by SME. Two sections of this book are devoted to computer application and simulation of mineral processing operations.

In the area of comminution, several papers were presented at the International Computer Symposium. The size-discretized batch grinding model was described, and its application to the simulation of batch



On-stream analysis is either installed or planned for many mineral industry plants. The heart of many of these systems is an x-ray emission system, like the one shown above. Sophistication of instrumentation should lend itself to more accurate control.

grinding, locked-cycle grinding and closed circuit grinding were discussed¹. Freeh, Horst and Kellner² approached simulation using a steepest ascent parameter-fitting technique, while Schonert³ considered the dependence of the elements of the mill matrix and classifier matrix on operating conditions, especially the feed rate.

The effect of hold-up weight of calcite in wet ball milling of quartz tracer particles has been considered⁴. The first order breakage rate constants were shown to be strongly dependent on the hold-up weight. In this vein, Rauth⁵ has shown that there is a proportional relationship of mill power to charge level. The importance of structure and composition in the comminution of ferrosilicon alloys was shown by Aplan and Kirby⁶. A maximum distribution modulus of 1.5 was realized for a 15% silicon alloy.

In more idealized systems, an informative study of single fracture of brittle spheres was made⁷. The pattern of breakage was determined and the stress distribution was simulated through a photoelasticity method. In another study the full mathematical derivation of Meloy's theoretical model of comminution was presented⁸. The constraint of homogeneity has been removed and replaced by an arbitrary function which describes the rock's susceptibility to comminution. Complete experimental verification has not been achieved.

Particle size analysis is always a subject of extensive discussion, and research in this area has been

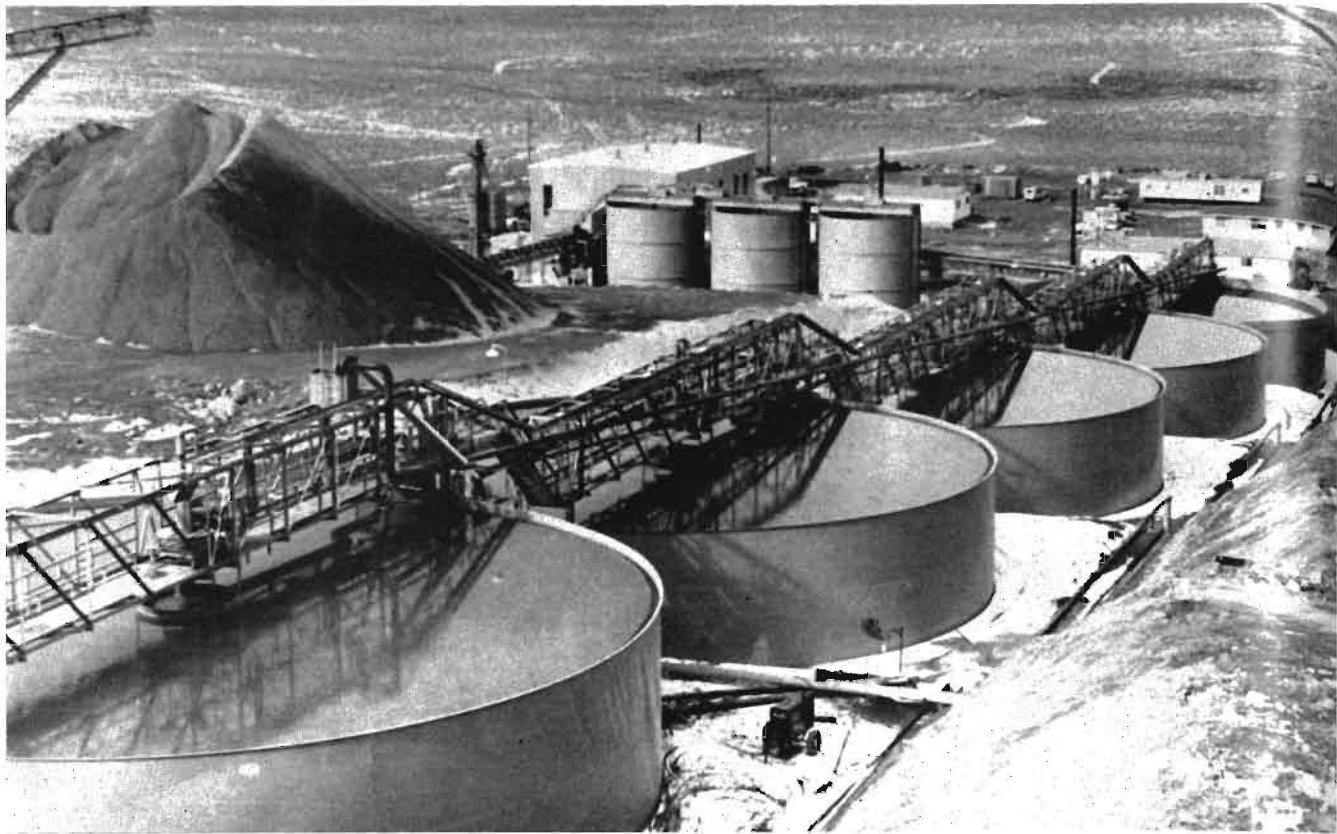
active the past year. Allen^{9,10} determined size distributions of both spherical and nonspherical particles in suspension utilizing light absorption. Good agreement was obtained between measured results and a theoretical model. Schleusener¹¹ described an automatic high-speed particle sizing apparatus consisting of a gas laser and nuclear counter.

The problem of characterizing particle sizes has been dealt with by McAdams¹², who feels that particle size can be most conveniently described by induced probability space. Meloy¹³ has considered how particle shape and variation in particle shape affect screening information. A new method for determining the parameters of the 3-parameter size distribution equation has been suggested¹⁴.

Recent research on sieving includes the work of Daeschner¹⁵ who studied wet sieving with electroformed sieves in the size range of 6-150 microns. Also, a theoretical model of sieving has been proposed¹⁶. The model allows for three possible rate controlling mechanisms.

Air classification as a technique for particle size analysis has been considered recently by Leschonski and Rumpf¹⁷. Flow patterns are discussed and considered from a theoretical standpoint, and two new air classifiers are described with theoretical background. An oscillating air column has been described for separating subsieve particle sizes¹⁸.

Attention has also been given the theory of mixing^{19,20}. The mixing process is considered by these



Chemical adsorption on minerals and the affect of dissolved salts on leaching and flotation systems have taken on greater importance since the advent of zeta potential measurement. Better chemical usage can be obtained in circuits like this CCD system through the use of zeta potential.

authors to be controlled by diffusion, and hence, the systems were analyzed on the basis of Fick's first law.

Considerable insight into the chemistry of flotation processes has been obtained in recent years, and extensive research was conducted in this area during this past year. In sulfide flotation the importance of the xanthate-dixanthogen couple has been realized. Recent work in the galena system showed that oxidation during the induction period resulted in the formation of elemental sulfur at the surface²¹. The authors conclude that adsorption of xanthate is probably not via surface lead salts such as PbS_2O_3 or $PbSO_4$.

In an investigation of the mechanism of collector adsorption on copper sulfides and iron sulfides, Fuerstenau, Elgillani and Kuhn²² report that only the oxidized species of xanthate and dithiophosphate are capable of floating pyrite.

The adsorption of metal ions on oxide surfaces has attracted considerable attention, especially with regard to metal ion activation of quartz. Electrokinetic results determined by Mackenzie and O'Brien²³ in the cobalt, nickel-quartz system correlate well with the electrokinetic and adsorption results of Fuerstenau and Rice²⁴, and Fuerstenau, Elgillani and Miller²⁵ who explain the mechanism of adsorption on both quartz and alumina via water formation which is independent of surface charge. Matijevic²⁶, however, disagrees with this mechanism. Also, the effect of copper sulfate on the flotation of methylated quartz has been explained on the basis of hydroxy complexes²⁷.

Electrokinetic study of mineralogical systems has

continued. Parks, Smith and Paces²⁸ have explained the variability of the point of zero charge of alumina in terms of its time dependence, thermal history and structural or compositional defects. Fuerstenau, Lai and Ball²⁹ found that the points of zero charge of oxides decrease with increasing temperature and developed a model describing this phenomenon.

In the area of semisoluble minerals, the zeta potential of apatite was affected by phosphate and fluoride ions at all pH values³⁰. Calcium ions had a significant effect only above the isoelectric point. In addition, the electrokinetic behavior of coal, anthracite and bituminous lithotypes, has been reported as a function of pH³¹.

In the area of oxide flotation systems, Wottgen³² studied the adsorption of phosphoric acid on cassiterite. Maximum adsorption of collector occurs near pH 2 and is explained by exchange for surface hydroxyl ions. The flotation response and adsorption properties of beach sand minerals have been studied with sodium oleate³³. Iwasaki, Carlson and Parmeter³⁴ have studied the adsorption properties of starch and starch derivatives on iron oxides. They relate this adsorption to the action of these reagents as depressants and flocculants. Of a more general nature, it has been shown that the induced polarity of alkyl groups affects the surface tension, contact angle, critical micelle concentration and solubility of a given system³⁵. Finally, success in the precipitate flotation of silver, uranium and gold has been achieved³⁶.

The flotation kinetics of calcite has been studied under semibatch conditions and was shown to be approximately second order³⁷. An extensive investi-



Flotation technology advances with larger equipment (up to 400 cu ft units) and the use of simpler rotors and stators. Concurrently, reagent manufacturers are developing more specific chemicals for the various minerals. Better recovery and grade have resulted.

gation of the hydrodynamics of flotation cells has been made by Arbitrer, Harris and Yap³⁸.

References

- ¹Grandy, G. A., Gumtz, G. D., Herbst, J. A., Mika, T. S., and Fuerstenau, D. W., "Computer Techniques in the Analysis of Laboratory Grinding Tests," *A Decade of Digital Computing in the Mineral Industry*, A.I.M.E., 1969, p. 765.
- ²Freeb, E. J., Horst, W. E., and Kellner, R. C., "Digital-Computer Development of Process Models," *A Decade of Digital Computing in the Mineral Industry*, A.I.M.E., 1969, p. 747.
- ³Schonert, K., "The Influence of Classifier Characteristics on the Stability of Closed Circuit Grinding," *A Decade of Digital Computing in the Mineral Industry*, A.I.M.E., 1969, p. 677.
- ⁴Kelsall, D. F., Reid, K. J., and Restarick, C. J., "Continuous Grinding in a Small Wet Ball Mill—A Study of the Influence of Hold-up Weight," *Powder Technology*, 2, No. 3, 1969, p. 162.
- ⁵Rauth, A. A., "Maintaining an Optimum Grinding Charge," *Trans. SME/AIME*, 244, 1969, p. 82.
- ⁶Alpan, F. F., and Kirby, G. M., "The Influence of Structure and Properties on the Grinding of Ferrosilicon," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ⁷Arbitrer, N., Harris, C. C., and Stamboltzis, G. A., "Single Fracture of Brittle Spheres," *Trans. SME/AIME*, 244, 1969, p. 118.
- ⁸Meloy, T. P., and Gumtz, G. D., "The Fracture of Single Brittle, Heterogeneous Particles—Statistical Derivation of the Mass Distribution Equation," *Powder Technology*, 2, No. 4, 1969, p. 207.
- ⁹Allen, T., "Determination of the Size Distribution and Specific Surface of Fine Powders by Photoextinction Techniques I. Theoretical Estimate of Variation in Extinction Coefficient with Particle Size Using a White Light Source," *Powder Technology*, 2, No. 3, 1969, p. 133.
- ¹⁰Allen, T., "Determination of the Size Distribution and Specific Surface of Fine Powders by Photoextinction Methods II. Comparison Between Wide Angle and Narrow Angle Photosedimentometers and Experimental Determinations of Extinction Coefficients," *Powder Technology*, 2, No. 3, 1969, p. 141.
- ¹¹Schleusener, S. A., "Automatic High-speed Particle Sizing Using a Gas Laser and Nuclear Counter," *Powder Technology*, 2, No. 6, 1969, p. 364.
- ¹²McAdams, H. T., "Probability Foundations of Particle Statistics," *Powder Technology*, 2, No. 5, 1969, p. 260.
- ¹³Meloy, T. P., "Screening," presented at the AIME Annual Meeting, Washington, D. C., February, 1969.
- ¹⁴Harris, C. C., "A Method for Determining the Parameters of the 3-parameter Size Distribution Equation—Technical Note," *Trans. SME/AIME*, 244, 1969, p. 187.
- ¹⁵Daeschner, H. W., "Wet Sieving with Precision Electroformed Sieves," *Powder Technology*, 2, No. 6, 1969, p. 349.
- ¹⁶Hudson, R. B., Jansen, M. L., and Linkson, P. B., "Batch Sieving of Deep Particulate Beds on a Vibratory Sieve," *Powder Technology*, 2, No. 4, 1969, p. 229.
- ¹⁷Leschonski, K., and Rumpf, H., "Principle and Construction of Two New Air Classifiers for Particle Size Analysis," *Powder Technology*, 2, No. 3, 1969, p. 175.
- ¹⁸Suhm, H., "Oscillating Air Column Method for the Dry Separation of Fine Subsieve Particle Sizes," *Powder Technology*, 2, No. 6, 1969, p. 356.
- ¹⁹Cahn, D. S., and Fuerstenau, D. W., "A Probabilistic Model of the Diffusional Mixing of Particulate Solids," *Powder Technology*, 2, No. 4, 1969, p. 215.
- ²⁰Hogg, R., Mempel, G., and Fuerstenau, D. W., "The Mixing of Trace Quantities into Particulate Solids," *Powder Technology*, 2, No. 4, 1969, p. 223.
- ²¹Eadington, P., and Prosser, A. P., "Oxidation of Lead Sulphide in Aqueous Suspensions," *IMM*, 78, 1969, p. C74.
- ²²Fuerstenau, M. C., Elgillani, D. A., and Kuhn, M. C., "Selectivity in Dithiophosphate vs. Xanthate Flotation of Copper Sulfide Ores," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ²³Mackenzie, J. M. W., and O'Brien, R. T., "Zeta Potential of Quartz in the Presence of Nickel (II) and Cobalt (II)," *Trans. SME/AIME*, 244, 1969, p. 168.
- ²⁴Fuerstenau, M. C., and Rice, D. A., "Chemisorption on Oxide and Silicate Systems," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ²⁵Fuerstenau, M. C., Elgillani, D. A., and Miller, J. D., "Adsorption Mechanisms in Nonmetallic Activation Systems," presented at the A.C.S. Meeting, Minneapolis, Minn., April 1969.
- ²⁶Matijevic, E., "Interactions of Complex Ions with Charged Interfaces," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ²⁷Iskma, J., and Lakowski, J., "Copper Ions in the Flotation Process; Effect of Copper Sulfate on Flotation of Methylated Quartz," *IMM* 78, 1969, p. C91.
- ²⁸Parks, G. A., Smith, R. W., and Paces, T., "Variability of the Point of Zero Charge of Alumina," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ²⁹Fuerstenau, D. W., Lai, R., and Ball, B., "The Effect of Temperature on the Electrical Double Layer at Oxide-Water Interfaces," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ³⁰Somasundaran, P., "Further Streaming Potential Studies on Apatite in Inorganic Electrolytes," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ³¹Campbell, J. A. L., and Sun, S. C., "The Electrokinetic Behavior of Anthracite," presented at the AIME Annual Meeting, Washington, D. C., February 1969.
- ³²Wottgen, E., "Adsorption of Phosphonic Acids on Cassiterite," *IMM*, 78, 1969, p. C91.
- ³³Dixit, S. G., and Biswas, A. K., "pH-Dependence of the Flotation and Adsorption Properties of Some Beach Sand Minerals," *Trans. SME/AIME*, 244, 1969, p. 173.
- ³⁴Iwasaki, I., Carlson, Jr., W. J., and Parmerter, S. M., "The Use of Starch and Starch Derivatives as Depressants and Flocculants in Iron Ore Flotation," *Trans. SME/AIME*, 244, 1969, p. 115.
- ³⁵Takahashi, K., and Iwasaki, I., "Inductive Effect of Polar Groups on Methyl Stretching Vibrations of Alkyl Groups and Its Implication in Flotation Chemistry," *Trans. SME/AIME*, 244, 1969, p. 66.
- ³⁶Mahne, E. J., and Pinfold, T. A., "Precipitate Flotation IV. Flotation of Ag, U, and Au," *Journal of Applied Chemistry*, February 1969, p. 52.
- ³⁷Tewari, S. N., and Biswas, A. K., "Flotation Kinetics for Calcite in a Semi-Batch System," *Journal of Applied Chemistry*, June 1969, p. 173.
- ³⁸Arbitrer, N., Harris, C. C., and Yap, R. F., "Hydrodynamics of Flotation Cells," *Trans. SME/AIME*, 244, 1969, p. 134.