and settling is an important area for fundamental research. The waste abatement plant, on the right, operated by Union Carbide Corp. is a good example of how research results pay off. This plant treats industrial wastes from one of the company's largest facilities as well as municipal sewage from a nearby community. This is how government and industry should cooperate.

Mineral Processing Fundamentals

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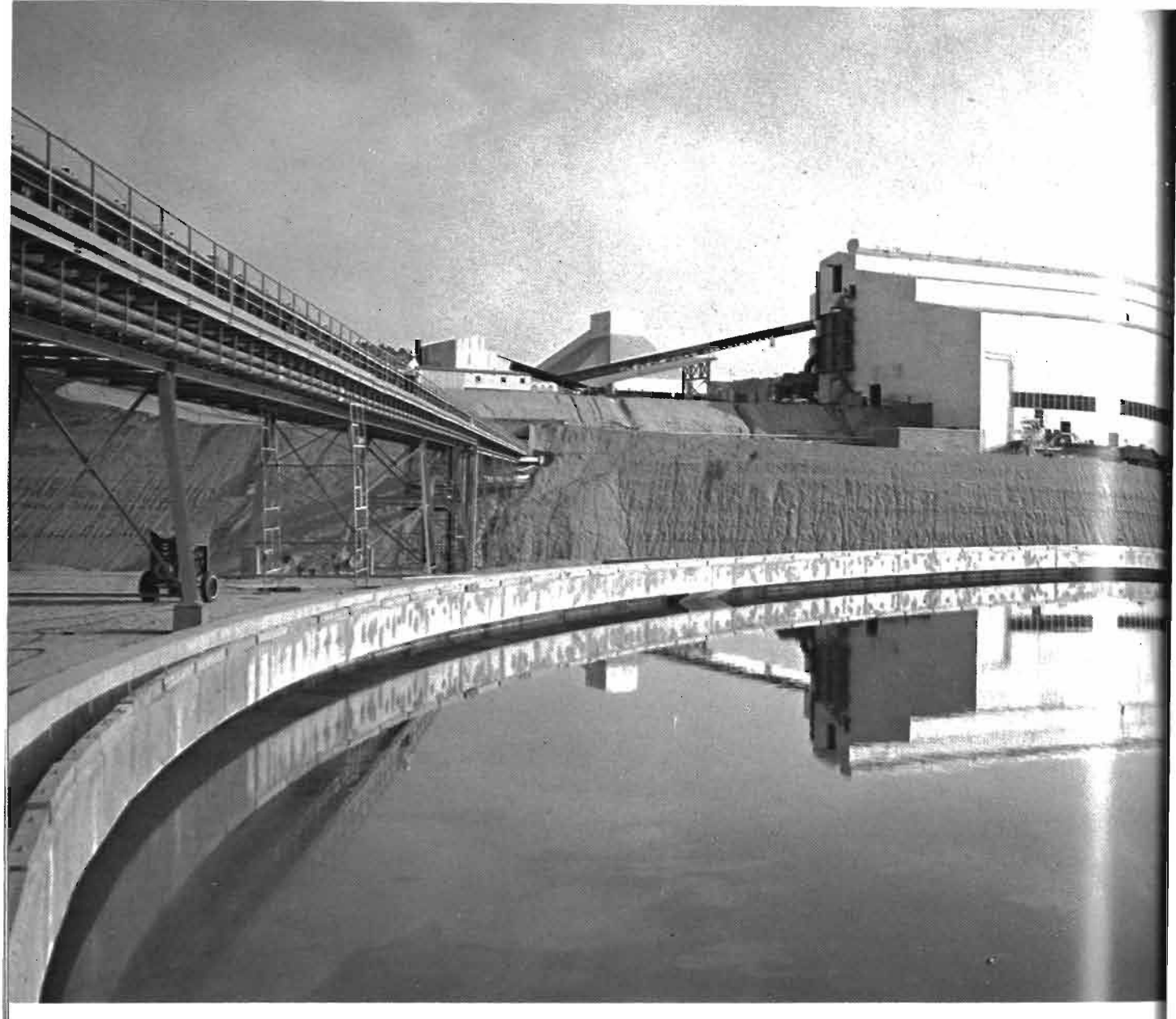
All mining companies regardless of their location are installing adequate thickeners for solid-liquid separation so they may maintain the quality of surface waters at a high level and thereby protect our heritage.

The reported claims in several Russian articles that magnetic fields change the viscosity and other basic properties of water and as a result produce beneficial effects such as increased flotation rate, improved grades and recovery, and increased settling rates, appear to be unfounded. This conclusion was reached after critical experiments had been conducted with both pure and impure water and the results failed to indicate any of the effects which had been claimed at the VII International Mineral Processing Congress.

The theoretical aspects of batch grinding continue to intrigue a number of investigators. One team of researchers using a nonlinear optimization technique determined an optimum set of selection values for batch grinding of anthracite and limestone when it was assumed that the breakage distribution function is normalizable. By suitable approximations in the batch-grinding equation, one investigator showed that the Bond Grindability and Work Index can be obtained from batch-grinding parameters. Other investigators contend that the recent batch-grinding hypotheses are suspect and that batch grinding involves something other than zero order kinetics. They suggest that batch grinding data should be plotted according to the Weibull distribution equation (a Rosin-Rammler-type plot with time located on the abscissa of the graph).

The problem of determining or estimating selection elements in continuous industrial milling is being approached by several groups. A Canadian presented a computer-search algorithm which improves the accuracy of estimating parameter values for tumbling mills. An integral part of applying grinding equations to continuous milling is the determination of residence-time distributions. Last year residence-time distributions for both liquid and solids (with quartz tracers) were determined as a function of the initial size of ore, ball diameter, hold-up weight, mill length, pulp density, ball load, and revolutions per minute. Flow characteristics of unbreakable particles and of a range of different minerals were determined. The general form of the residence-time function was not significantly altered by changes in grinding variables, but large changes in the mean residence time could occur due to induced changes in hold-up weight. The distribution of residence time in the ball mill was found to be log normal. A simple and convenient description of flow (either liquid or solid) is a time delay followed by a perfect mixer of appropriate size. In another report, modelling of a grinding classification circuit in relation to plant control with breakage and selection functions is compared with modelling by a simple multiple-regression technique.

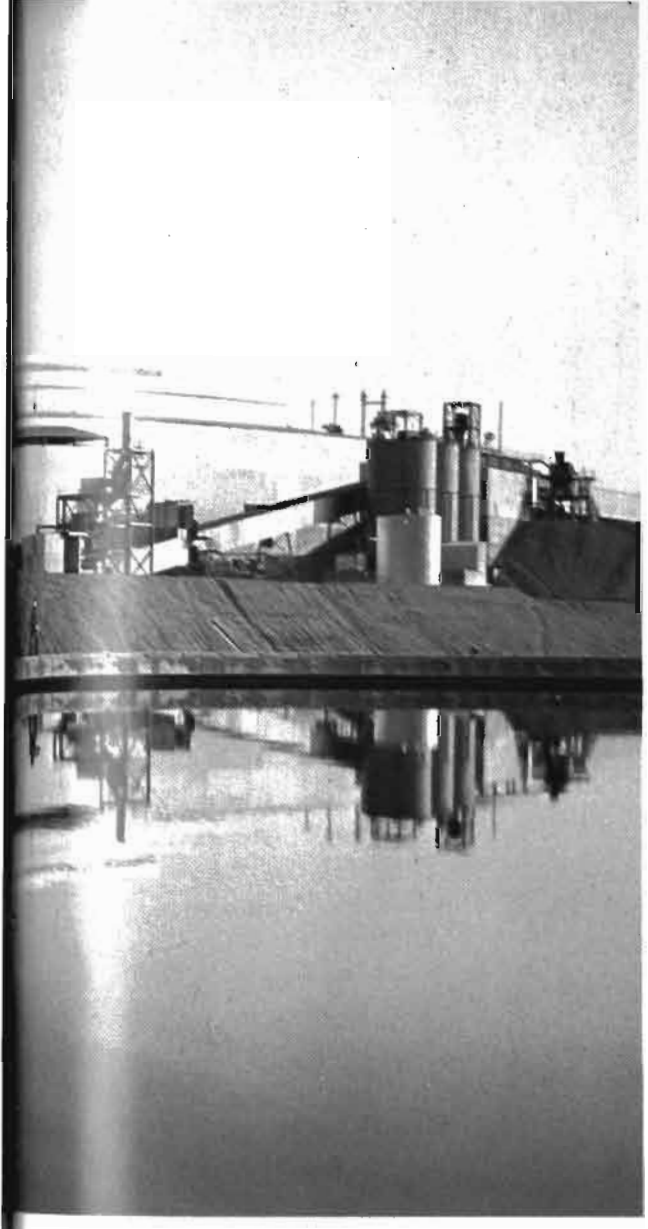


The mathematical description of continuous milling at steady state is complicated by the heterogeneity of the feed. In this respect, another research team studied the simulation of ball-mill grinding of a heterogeneous solid. A study of a more empirical nature was conducted by a lone observer, and he determined the relations between operating variables and characteristics of ground products by an experimental design technique.

The fundamental aspect of particle-particle interaction has been studied extensively this past year. In an ideal system, an approximate solution to the double-layer-interaction free energy of two charged colloidal spheres was determined by a linear superposition technique. Another team reported on two types of size-enlargement mechanisms—"free in space" and "restricted in space." The resulting agglomerated size distribution is the same for each mechanism. A study of the coagulation kinetics of two normally distributed particulate suspensions enabled the researchers to use a computer in predicting the resulting particle-size profile.

The mechanism of flocculation encountered in thickening, and the settling behavior and mechanical strength of such flocs is an important area of fundamental research. One research team found that the formation of clay sediment of a given concentration decays exponentially with time from the start of a batch test, whereas classical theory would predict it to remain constant. A sedimentation-rate constant is determined and studied as a function of operating variables. In another study, the continuous thickening behavior of pulps was confirmed as being related to floc volume. In addition, evidence is presented that the floc is dewatered by mechanical compression in the mud zone when the underflow density exceeds that of the uncompressed flocs. Recent application of flocculation has been the selective flocculation and separation of minerals. A fundamental investigation has been completed in this area in which binary and tertiary mixtures were studied. The difficulty of particle entrapment has been considered and related to the mechanism of floc formation. Steps for preventing entrapment are suggested.

The rheological properties of solid-liquid suspensions has been investigated. Two factors which previously had not been taken into consideration, suspension particle size and solid volume fraction,

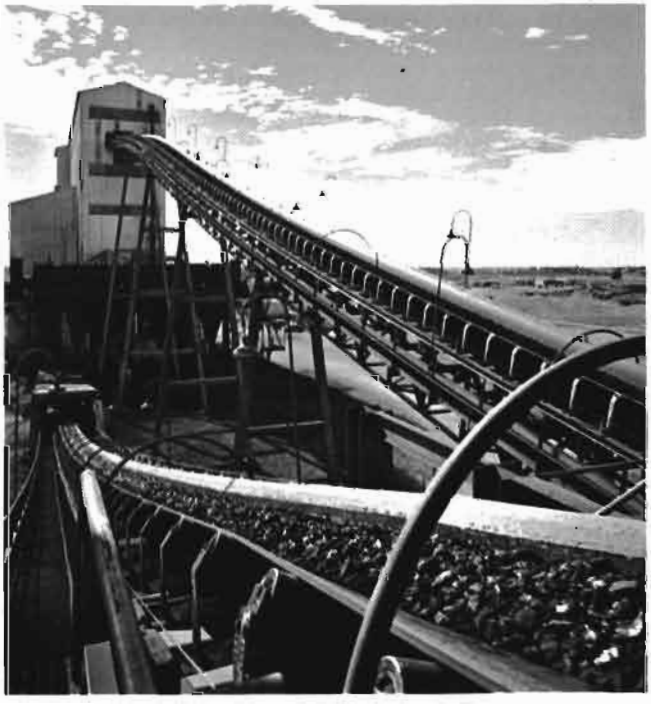


One of four 325-ft thickeners reflects the Phelps Dodge Tyrone concentrator building in its settling pool. Photograph by Ray Manley.

are incorporated in velocity-resistance relations in the turbulent flow region.

A recent publication of some interest to those working in the area of flotation chemistry is Hydrophobic Surfaces published by Academic Press in 1969. Of particular interest is the chapter by M. A. Cook. The mechanisms of collector adsorption involved in sulfide flotation systems have attracted considerable interest. Some investigators have used an electrochemical experimental technique with sulfide electrodes in an effort to gain further understanding of the mechanisms involved. The micro-oxidation-reduction reactions which occur at sulfide surfaces seem to be of primary importance. Oxygen is an effective oxidant and appears to be operative in many of these adsorption processes. In this regard, the floatability of galena, pyrite, and chalcopyrite was studied in the presence of various amounts of oxygen with a xanthate collector. It was determined that the oxygen improved the floatability of galena and chalcopyrite only. Several papers were presented relating to sulfide flotation and it appears that the mechanisms involved are complex and different for each sulfide mineral investigated.

Ore from the primary crusher at the Mt. Newman iron-ore mine in Western Australia is crushed and screened to a finer size at the port. Amax is a 25% participant in Mt. Newman.

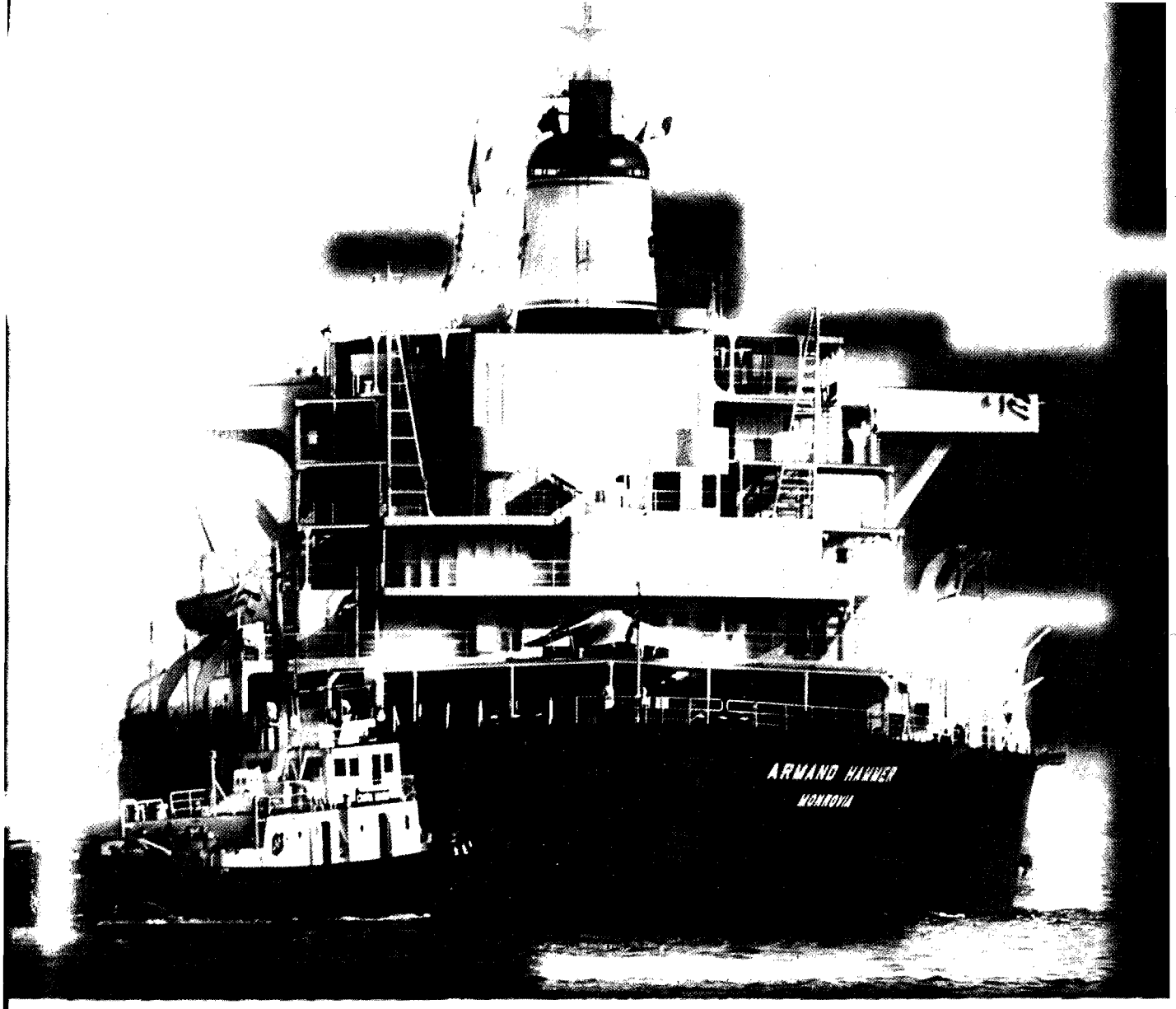


Tanker *Armand Hammer* is flagship of Occidental Petroleum Corp's. growing fleet of vessels needed to transport natural resources to harbors of the world. Ship can carry crude oil on one voyage and coal or phosphate rock on the next. The material-handling section begins on page 165.

Rutile, the vital raw material for titanium metals and chloride process titanium pigments is recovered in this floating dredge and plant at Hawks Nest, Australia. A unique process restores the beach to its original scenic beauty simultaneously with mining. Mineral Deposits Ltd. operates this facility which is 85% owned by National Lead Co.

The lack of understanding of these systems is probably best illustrated by a report on the anomalous flotation behavior of galena. It was found that galena in a tailings product had adsorbed as much xanthate as galena in the concentrate, but no one could offer a satisfactory answer for the phenomenon observed in these tests.

The chemistry of oxide flotation systems continues to receive considerable study. During the past two decades, extensive fundamental effort has been directed toward developing a complete understanding of oxide flotation systems by such experimental techniques as electrophoresis, infrared spectrophotometry and adsorption-density measurements. The effects have been well characterized in systems of industrial importance, but generally the results have failed to effect major changes in industrial practice. In order for flotation to enjoy the success it has achieved in sulfide systems, selective economical collectors must be developed for oxide flotation systems. The most recent and most promising work in this area has been the flotation of iron ore with hydroxamate as a promoter-collector.

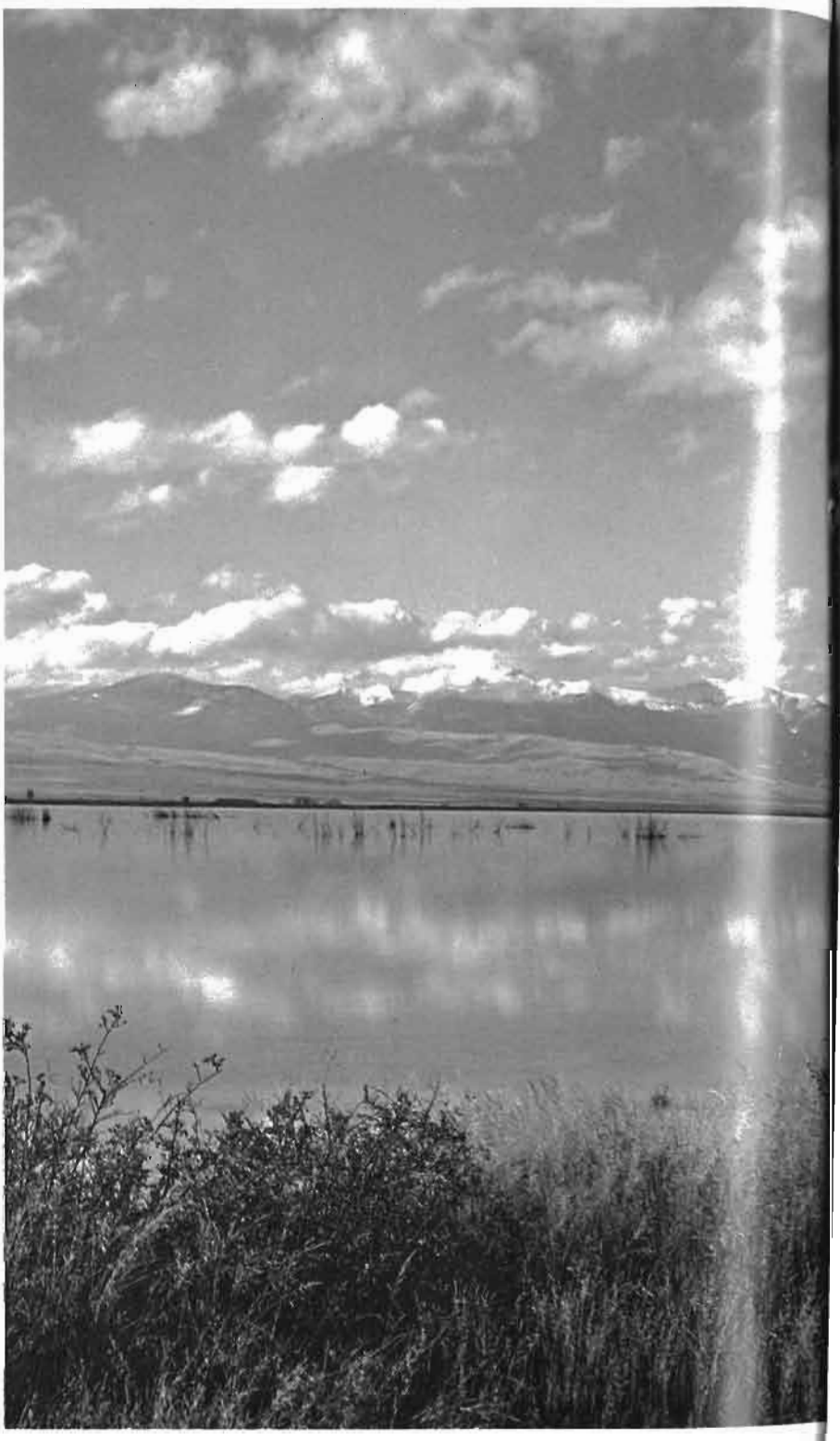


Because of the lack of selective collectors and other important factors, many oxide flotation systems require emulsion flotation to enhance recovery of valuable oxide minerals. Such is the case for manganese and phosphate ores. An important parameter of emulsion flotation is the energy input during the conditioning step. Recent work suggests that the reason for this criticality is that surface attrition must be effected in order to achieve selective separations by emulsion flotation.

A study of the electrochemical potential at the ZnO-solution interface revealed that the zero point of charge (zpc) depends both on the method of preparation of ZnO and the nature of the supporting electrolyte. A solubility diagram was presented which correlates with the zpc. Variations in the zpc were explained on the basis of impurity anions. Elsewhere, the adsorption isotherms of sodium oleate on cupric and ferric hydroxides were found to be described by Freundlich's adsorption equation. The authors suggest that oleate is chemisorbed. This conclusion was reached by another research team when it investigated hematite.

The mathematical description, both on a microscopic and macroscopic basis, of particle-bubble interaction and of the flotation process in general is an important area of study. The thermodynamics of bubble-particle collision and the change in thickness of the water layer between bubble and solid during attachment was studied.

On a macroscopic scale, the state of the art has been established and a team of investigators considered the effect of baffle designs upon liquid mixing in a bank of flotation cells. Another team has made a kinetic analysis of quartz flotation in a bank of flotation cells. It has been found, with high speed photographic and stroboscopic techniques, that bubble generation in flotation cells is brought about by flow separation, formation of a ventilated cavity, and vortex shedding. These studies may open up new areas and make it possible to improve impeller design and power consumption. A mathematical model of flotation in a Flotation Column has also been investigated. Finally, a review of the electrical methods of separating minerals by both magnetic and high-voltage systems, has been made.



The Anaconda Co. chose its Anaconda, Mont., waste settling ponds as the site of a state waterfowl restoration project. Anaconda's program for dealing with environmental problems extend over a 50-year span. In 1965 the company established an environmental engineering department. Anaconda was one of the first large industrial organizations to direct responsibility for air and water quality and for land use to a single department. The pond shown above is a typical environmental quality program carried out by this new department. Some $250,000 was spent to improve the 700 acres contained in the settling ponds and to provide for diversion of natural runoff waters around the ponds into natural streams.