Preconcentration of Primary Uranium Ores by Flotation

by Burt C. Mariacher

EXTRACTION of uranium from ores is being accomplished by processes which, for the most part, subject the entire ore to acid or carbonate leaching. Ore deposits with a U_3O_8 content below 0.10 pct U_3O_8 are seldom considered suitable for treatment by leaching.

A preliminary concentration that would enrich the uranium content of an ore by a simple, low cost process based on physical properties of the ore might result in some low grade deposits becoming commercial ores. In addition, the process might be employed in existing operations to reduce transportation and leaching costs and to increase capacity of existing leaching plants.

A study to attempt the development of a preliminary concentration process for primary uranium ores was undertaken by the Colorado School of Mines Research Foundation under sponsorship of the U.S. Atomic Energy Commission. The objective of this work was to produce concentrates containing 0.25 pct U_3O_8 from the low grade ores tested.

Ores Tested: The main effort was devoted to the low grade primary uranium ores from northwestern Saskatchewan. Samples were obtained from the Beaverlodge operation of the Eldorado Mining & Refining Ltd. Additional primary ores, obtained from deposits in Gilpin County, Colo., contained from 0.07 to 0.10 pct U_3O_8.

Summary of Concentration Tests: The Beaverlodge ore was tested to determine amenability of the ore to concentration by magnetic, electrostatic, gravity, and scrubbing processes. None of these produced satisfactory results. Both gravity and magnetic processes produced fairly good concentrates when closely sized fractions of the ore were treated, but on the basis of treating the total ore, recovery was poor. Preparation of sized fractions and the low capacity of equipment for suitable concentration made these methods impractical.

As flotation offered the advantage of treating the total ore without intermediate sizing, the main effort was in this direction. A flotation process was developed that fulfilled the concentration objectives as set by the AEC. Pilot plant testing was used to verify results obtained from laboratory batch testing.

Mineralogy: A petrographic examination of the Beaverlodge ore included a study of polished surfaces and identification of the radioactive mineral by autoradiograph and X-ray diffraction. Approximate quantitative mineral identification was as follows: quartz, 60 pct; orthoclase feldspar, 20 pct; chlorite, 10 pct; carbonates, 5 pct; and miscellaneous minerals, 5 pct. Included in this last group were plagioclase feldspar, pyrite, mica, chalcopyrite, pyroxene, sericite, magnetite, galena, and uraninite.

The most general occurrence of uraninite was in the form of crusts and thin coatings on limonite-stained grains of pyrite, quartz, and pyrite-quartz intergrowth. At least 90 pct of the uraninite was still attached to other minerals in a 100 by 200-mesh size fraction. The uraninite crusts were as small as 10 to 20 μ diam, and 5 to 10 μ thick.

The Flotation Process

Petrographic examinations of the Beaverlodge ore had indicated the impracticability of attempting to concentrate the uranium by floating individual grains of uraninite. Liberation of the uraninite required grinding to sizes below those suitable for flotation. However, there was preferential association of the uraninite with some minerals while others were free of uraninite attachment. The approach to the development of a flotation process was, therefore, based upon an attempt to concentrate the uraninite by floating carrier minerals. The following paragraphs discuss the various stages of the process with regard to the factors tested and the conditions under which best results were obtained.

Grinding: The most effective size range for flotation was -150 mesh $+ 13$ μ. The -13 μ material in the final concentrate had a higher U_3O_8 content than the total ore, but not as high as the average concentrate; however, rejection of slimes before flotation was prohibitive because of the loss in uranium carried in the -13 μ fraction. Grinding techniques which contributed to a minimum production of fines, such as stage grinding, were then employed.

Quartz and Silicate Depression: These minerals represented approximately 80 pct of the ore and were free to a large degree of uraninite attachment. Significant improvement in the grade of the concentrate was obtained by depression of these minerals with hydrofluoric acid or sodium fluoride.

Promoter: Selective stage flotation of uraninite carrier minerals was simplified by development of a single promoter mixture. The mixture consisted of an emulsion of a fatty acid, fuel oil, and a petroleum sulfonate and was selected after a comprehensive series of tests. It contained three parts by weight of an oleic and linoleic acid such as Emersol 300,

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three parts by weight of No. 2 fuel oil, and one part by weight of a petroleum sulfonate such as Oronite L. The mixture was emulsified in water at 20 to 25 pct reagent strength.

Rougher Flotation: The reagents and technique employed in the rougher flotation were primarily directed toward maximum recovery. The amount of promoter mixture required for acceptable recovery varied with the type of ore and ranged from 10 to 20 lb of active promoter mixture per ton of ore. Stage addition of the promoter improved recovery. Sulfuric acid was used to maintain a pH of 6.0 during flotation. A lower pH resulted in improved concentrate grade, but was not suitable because of a lower U_3O_8 recovery.

Concentrate Cleaning: The rougher concentrate was cleaned without additional reagents other than sulfuric acid for the regulation of pH. By variation in the pulp density and number of flotation cleaning steps, it was possible to select the grade of concentrate desired between 0.22 and 0.28 pct U_3O_8 with corresponding recoveries of 85 and 78 pct of the U_3O_8.

Reagent Additives: The promoter mixture had strong collecting properties and tended to float the slimes *en masse* in a voluminous, tough froth. Some degree of success was obtained in modifying the froth properties by adding Ucon 75-H-1400, a synthetic lubricant, to the promoter emulsion in the amount of one part to ten parts of active promoter mixture. Although a sodium ligno-sulfonate type of dispersant such as Marasperse CB was found to improve the grade of the concentrate, it lowered recovery.

Pilot Plant Operation

A pilot plant test was conducted to evaluate the process under continuous operation. The plant was equipped for a feed rate of about 40 lb per hr. The grinding circuit consisted of a ball mill in closed circuit with a classifier. Rougher and cleaner flotation machines each consisted of a 6-cell unit of Denver Sub-A, No. 5 cells.

The rougher concentrate was the combined float products from the six rougher cells operating in series. Stage addition of promoter was accomplished by a primary addition in a separate conditioner preceding flotation and subsequent addition to intermediate cells in the series.

Cleaner cells were operated with a counterflow of tailings and concentrate with progressive cleaning of the float product. The cleaner tailing was returned to conditioning ahead of rougher flotation. Table I presents data typical of the metallurgical results obtained by the process in the pilot plant test treating the Beaverlodge ore.

The close association between uraninite, limonite, and quartz presents a major problem in the flotation process. Presumably, further depression of quartz would result in a substantial loss in recovery of uraninite because of the limonite-quartz-uraninite intergrowths. Conversely, higher uraninite recovery could only be obtained by sacrifices in grade of concentrate and ratio of concentration.

Table I. Pilot Plant Flotation Data

Heads	U_3O_8, Pct Cleaner Concentrate	Rougher Tailing	U_3O_8 Recovery, Pct	Ratio of Concentration
0.096	0.219	0.023	85.0	2.7 to 1
0.099	0.288	0.030	77.8	3.7 to 1
0.103	0.225	0.026	84.6	2.6 to 1

Colorado Ores

Only cursory petrographic studies were made of the Colorado ores. The Highlander ore was essentially pink microcline and quartz with pyrite coating. Other minerals in significant quantity were orthoclase, muscovite, biotite, plagioclase, chlorite, and pyrite. The uranium mineral was too disseminated for detailed study but was assumed to be pitchblende. The Carroll ore was essentially an altered, kaolinized silicious vein material with pyrite crystals, sphalerite stringers, and occasional cleavages of galena. Other minerals in significant quantity were illite, quartz, microcline, orthoclase, plagioclase, muscovite, and apatite. Stringers of soft pitchblende, averaging about 30 μ wide, were detected in a groundmass of quartzose material.

The flotation process developed for the Beaverlodge ore was employed for tests on these Colorado ores. They were not tested in the pilot plant, but batch tests produced more effective concentration than was obtained from the Beaverlodge ore.

The U_3O_8 content of the rougher concentrate was within the objective of the work. Significant improvement in the grade of the concentrate was obtained in the cleaner flotation, but without pilot plant testing it was not possible to determine definitely the effect of the recirculated cleaner tailing. An assumption that the cleaner concentrate and rougher tailing obtained in batch tests could be maintained in continuous operation was reasonable because of the experience with the Beaverlodge ore.

Typical batch test results are given in Table II.

Table II. Representative Batch Test Results

Material	Highlander U_3O_8, Pct	Highlander Distribution, Pct	Carroll U_3O_8, Pct	Carroll Distribution, Pct
Feed	0.096	100.0	0.078	100.0
Rougher concentrate	0.274	81.3	0.219	75.3
Rougher tailing	0.025	18.7	0.026	24.7
Cleaner concentrate	0.570	56.8	0.338	61.5
Cleaner tailing	0.124	24.5	0.085	13.8

Conclusions

The conclusions which can be drawn from this investigation are as follows:

1) Preconcentration by flotation was effective in three out of four ores tested and its use should be considered in processing primary uranium ores.

2) In the case of ores containing finely disseminated uraninite, significant concentration may still be obtained by employing flotation of carrier minerals.

3) Evaluation of the benefits from preconcentration for an individual ore can be made by comparatively simple pilot plant operation.

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