TOPICAL REPORT WIN-19

DESCRIPTION OF ALKALINE LEACH PILOT PLANT
AT GRAND JUNCTION, COLORADO

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ABSTRACT

The pilot plant facilities at Grand Junction, Colorado, for testing the amenability of domestic uranium ores to the carbonate leaching process are described. The chemistry of uranium dissolution in carbonate solutions and its precipitation with NaOH is discussed briefly.
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INTRODUCTION

At the request of the Atomic Energy Commission early in 1954, the Battelle Memorial Institute designed a pilot plant for the alkaline leaching of domestic uranium ores. Throughput for the plant was to be 12 tons of ore per day with provision in the design for oxidation of quadrivalent uranium to the more soluble hexavalent state. Oxidation would be accomplished by roasting the ore in a Dorr Fluosolids reactor before leaching and/or by aeration of the pulp in four 45 foot high Pachuca leach tanks.

The chemistry of the process is relatively simple. Uranium minerals are soluble in hot carbonate solution according to the following reactions:

\[
2\text{UO}_2 + 6\text{Na}_2\text{CO}_3 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{Na}_4\text{UO}_2(\text{CO}_3)_3 + 4\text{NaOH}
\]

\[
\text{UO}_3 + 3\text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \rightarrow \text{Na}_4\text{UO}_2(\text{CO}_3)_3 + 2\text{NaOH}
\]

Since reprecipitation of the uranium may occur due to the formation of sodium hydroxide, an excess of sodium bicarbonate is usually maintained in the carbonate solution.

\[
\text{NaOH} + \text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}
\]

\[
2\text{UO}_2 + 2\text{Na}_2\text{CO}_3 + 4\text{NaHCO}_3 + \text{O}_2 \rightarrow 2\text{Na}_4\text{UO}_2(\text{CO}_3)_3 + 2\text{H}_2\text{O}
\]

\[
\text{UO}_3 + \text{Na}_2\text{CO}_3 + 2\text{NaHCO}_3 \rightarrow \text{Na}_4\text{UO}_2(\text{CO}_3)_3 + \text{H}_2\text{O}
\]

After separation from the insoluble residue the soluble uranium complex is precipitated from the carbonate-bicarbonate solution as a mixture of sodium metauranate and diuranate by the addition of an excess of sodium hydroxide.

\[
\text{NaHCO}_3 + \text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}
\]

\[
\text{Na}_4\text{UO}_2(\text{CO}_3)_3 + 4\text{NaOH} \rightarrow \text{Na}_2\text{UO}_4 + 3\text{Na}_2\text{CO}_3 + 2\text{H}_2\text{O}
\]

\[
2\text{Na}_4\text{UO}_2(\text{CO}_3)_3 + 6\text{NaOH} \rightarrow \text{Na}_2\text{UO}_7 + 6\text{Na}_2\text{CO}_3 + 3\text{H}_2\text{O}
\]

After removal of the uranium precipitate the caustic-carbonate solution is reacted with carbon dioxide gas to regenerate bicarbonate in the carbonate solution. More uranium can then be solubilized with this solution.
2NaOH + CO₂ → Na₂CO₃ + H₂O
Na₂CO₃ + CO₂ + H₂O → 2NaHCO₃

The plant was erected on the grounds of the Grand Junction Operations Office of the Atomic Energy Commission under the supervision of the National Lead Company, Inc. The National Lead Company, Inc. operates the pilot plant for the Atomic Energy Commission under Contract AT(49-6)-924.
FLOWSHEET AND EQUIPMENT

A diagrammatic flowsheet of the Alkaline Pilot Plant is shown in Figure 1 on page 7. Three photographs showing the general arrangement of equipment in the plant are also included as Figures 2, 3 and 4, shown on pages 8, 9, and 10.

The following units in sequence, comprise the ore solids flow-sheet; crushed ore bin, FluoSolids reactor, ball mill, classifier, thickener, Pachuca leach tanks and vacuum drum residue filters. The solution flow sheet equipment consists of unclarified pregnant storage tank, clarification filter press, clarified storage tank, uranium precipitation agitators, uranium product filter press, barren storage tank, Peabody and pack-tower bicarbonating units and bicarbonated solution storage.

Ore Solids Flowsheet

Grinding

The ore, crushed to 3/16" at the Pilot Plant Feed Preparation Plant, is fed to a 3' x 2' Marcy ball mill operated at 75 per cent of critical speed. A graduated charge of steel balls is used in the ball mill. The ball mill is operated in closed circuit with a 13' x 16" Dorr rake classifier with classifier overflow pumped to a thickener. Recycled carbonate-bicarbonate solution is used to maintain the desired dilutions in the circuit.

Thickener

For ores with good settling characteristics, a 12-foot diameter by 8-foot deep thickener is operated in closed circuit with the grinding unit in order to decrease the pulp volume to the leach tank and provide mill solution. An 18-foot thickener provides additional area if needed.

Pachuca Leach Tanks

The underflow from the thickener is pumped to the top of the first of four 4-foot diameter by 47-foot high Pachuca leach tanks. A total of 96 hours contact time for 12 tons of ore per day at 50
Figure 1
NATIONAL LEAD CO., INC.
Alkaline Leach Pilot Plant
Grand Junction, Colorado

Figure 2

Outside arrangement of 12' x 8' Thickener
4' x 47' Pachuca Leach Tanks and Solution
Storage Tank.
NATIONAL LEAD CO., INC.
Alkaline Leach Pilot Plant
Grand Junction, Colorado

Figure 3

General inside view of plant-precipitation section on left; ball mill circuit on lower right.
4' x 8' continuous vacuum drum filters with repulp mechanism and auxiliary vacuum, steam and solution pipes.
per cent solids is available in the four tanks. Pulp from the first tank flows to the second through a connection near the bottom, from the second to the third near the top, from the third to the fourth at the bottom and from the top of the fourth to the filters. Each Pachuca is provided with steam lines to heat the pulp and the sides are insulated with 1" fiberglass to conserve heat. The top is also covered for the same reason. A center airlift in the Pachuca provides agitation and some aeration to the pulp. Further aeration for oxidation of the quadrivalent uranium is supplied by four pipes in each tank discharging air at the bottom.

Residue Filters

The leached pulp from the fourth Pachuca leach tank flows by gravity to the first of three Eimco vacuum drum filters operated in series. Each filter is eight feet in diameter by four feet wide and provides 100 square feet of area per filter. A nylon cloth (Eimco No. NY521F) is used as filter media for the No. 1 and No. 2 filters. Visually, this cloth looks like that used as shirt material. Heavier, more abrasive resistant twill weave nylon (NFM 1200-S) is used on the No. 3 filter. Pregnant liquor, containing the solubilized uranium, is drawn by vacuum through the filter cloth of the number 1 filter and pumped to storage. Low grade uranium filtrate from the No. 3 filter is sprayed on the cake as the filter drum revolves, partially displacing the pregnant liquor. The filter cake, containing approximately 25 per cent moisture, is then discharged into a repulper to which additional filtrate from the No. 3 filter is added to make a slurry of approximately 50 per cent solids. This slurry is fed to the No. 2 filter and the filtration process repeated. The filtrate from the number 2 filter is recycled to the grinding circuit. The displacement wash liquor used on the number 2 filter is bicarbonated recycle liquor from the precipitation section and the cake discharge is repulped also with this liquor to 50 per cent solids. This slurry is fed to the No. 3 filter and the filtrate, as previously described, is used on the No. 1 filter. Water is used as the displacement wash on the last filter. The cake discharge is repulped with water and pumped to the tailing disposal area.

Solution Flowsheet

Clarification and Precipitation

Pregnant liquor from the No. 1 drum filter containing approximately one-half of one per cent ore slimes is pumped through a 24"
plate and frame filter press. Each plate is covered with a twill weave nylon cloth over which is placed a covering of industrial filter paper. At intervals, approximately 10 volume tons of liquor is pumped to the uranium precipitation tank where a calculated quantity of a 25 per cent solution of sodium hydroxide is added and the solution agitated for several hours. The uranium product is filtered from the resultant slurry on a 30" plate and frame press. Each plate of this press is also covered with the twill weave nylon and paper. Several batches are filtered through the press before it is opened and the "yellow cake" removed. The barren liquor from the press is stored and from there it is metered continuously through the bicarbonation system.

**Bicarbonation System**

The caustic barren liquor passes first through a 2 ft. dia. x 35 ft. high packed-tower containing a load of beryl saddles for high surface contact and then through an 18 in. dia. x 15 ft. high Peabody Scrubber. Countercurrent to the solution flow a gas flow containing carbon dioxide is sent through the two towers to convert the sodium hydroxide in the liquor to sodium bicarbonate. In the pilot plant a Dorr FluoSolids reactor is provided for roasting the various ores. The waste gas from the combustion of the fuel oil in the reactor burner is used for its carbon dioxide content to bicarbonate the caustic barren solution. During periods when the ore is being leached "raw" the reactor burner may be operated only to provide the carbon dioxide. In a commercial operation, if no roasting is required, waste gas from the pulp heating plant would be used.

The bicarbonated solution is used on the residue filters and in the grinding circuit as previously described.
PILOT PLANT OPERATION

Sampling

The ore from the feed preparation plant is trucked to the alkaline leach plant bin and is weighed enroute on truck scales. This is the official weight of wet ore received. The ore discharges from the bin onto a belt conveyor and is transported to the ball mill grinding circuit. Every hour a two-foot section of the ore on the belt is weighed for tonnage control. This sample is split to give samples for uranium and moisture determinations. The uranium assay and the truck weights, corrected for moisture, give the uranium input to the pilot plant.

The final residue from the No. 3 drum filter is sampled by hand once an hour by stripping small portions of the cake as it discharges from the filter cloth. From this sample, assayed for water soluble and insoluble uranium, is determined both the soluble loss from the filters and the plant leach extraction. All spills in the plant sumps and the final filter residue are repulped together and sampled automatically every ten minutes. This is the mill tail sample and indicates the total uranium loss not available for the "yellow cake" precipitation.

Each press load of "yellow cake" is carefully dried in a gas-fired oven, weighed on platform scales and hand sampled for uranium assay.

With the knowledge of the ore weight and uranium assay, the "yellow cake" weight and assay and the mill tail assay plus the previously described inventories, a metallurgical balance can be made.

Operating Personnel

To operate the Alkaline Pilot Plant three men and a shift foreman are required on each shift. One operator is used on the ore feed and grinding section, another operates the thickener, and Pachuca leach tanks and does most of the sampling. The third man operates the residue filters. Besides these men a general foreman is on duty during the day shift. Also on day shift is a uranium precipitation operator and a general purpose man for clean-up and helping where necessary. Each operator is responsible for the collection of data pertaining to his section as well as the operation of the equipment. Everyone is charged with keeping his working place clean and orderly.