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LABORATORY AND ION EXCHANGE PILOT PLANT STUDIES SUPPORTING THE FIELD LEACH TRIAL AT THE HONEYMOON URANIUM PROJECT

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INTRODUCTION

The Honeymoon Uranium Project is an acid In-Situ Recovery (ISR) mine in South Australia. The project contains three deposits; Honeymoon, Jasons and Goulds Dam. The measured resource consists of a total of 6.5 Mlb U3O8 (2.9 kt U) at an average grade of 1720 ppm U3O8 (1460 ppm U), with total resources (measured + indicated + inferred) of 63.3 Mlb U3O8 (28.8 kt U) at 660 ppm U3O8.

The mine was previously operated by Uranium One for approximately 18 months, producing ˜335 t of U3O8, before being placed on care and maintenance in 2014 due to the persistently low uranium price and production issues. Boss Resources acquired the project in December 2015. As part of the plan for restarting the mine, Boss performed a successful Field Leach Trial (FLT) on an area of the deposit between August and December 2017.

In support of the FLT, ANSTO Minerals performed a comprehensive laboratory testwork program. This included a study to optimize the leaching conditions, as well as column leaching of samples taken from the FLT area. The laboratory studies also identified an ion exchange (IX) resin capable of achieving significantly higher uranium loading than conventional resins under the elevated chloride concentrations in the Honeymoon leach liquor. As a result, ANSTO Minerals constructed and commissioned an IX pilot plant that operated for a 10 week period during the FLT. The success of this pilot plant means that IX could potentially be used as an alternative to the existing solvent extraction facility.

This paper will present the results from the laboratory program, as well as highlighting the success of the FLT campaign and associated IX pilot plant operation.

LABORATORY LEACHING PROGRAM

A laboratory leaching program was performed using samples taken from the Jasons deposit, as well as samples taken from the FLT area. The program comprised two main parts, a leach optimization study, to determine the conditions for maximizing uranium extraction whilst minimizing acid and oxidant consumption, and secondly a series of column leaches simulating ISR conditions, to confirm the results from the optimization study and assess the leachability of the uranium in the FLT area.

The leach optimization study, investigating the effect of pH, ORP and Fe addition, was performed in 2 L stirred tank reactors at a solids density of 50 wt% and a temperature of 30 ℃ for a period of 24 hours. The pH and ORP set-points were maintained by the automated addition of concentrated sulphuric acid and sodium permanganate. The results from the optimization study demonstrated that uranium extraction was strongly influenced by pH, with a pH of approximately 1.5 required for maximum extraction. This pH is considerably lower than that employed by the previous operators at Honeymoon, and indicates that the uranium recovery could potentially be significantly higher or kinetics significantly faster than that historically achieved.

Tests at varying ORP set-point also demonstrated increased uranium extraction with ORP, however the effect was generally not as significant as for pH. Significantly, if the ORP was maintained at ≥475 mV (relative to a Ag/AgCl reference electrode filled with 3 mol/L KCl), then extensive oxidation of any pyrite present in the sample occurred, resulting in excessively high oxidant consumption. This demonstrates the impact

that the presence of sulphide could potentially have in practice, with any ferric iron injected potentially being reduced upon contact with the sulphide. This could result in the rate of uranium extraction being retarded until the sulphide phase is significantly oxidized, with the ferric being consumed by the sulphide before reaching the uranium mineralogy. It is also possible that solubilized uranium could be subsequently precipitated by reducing conditions upon contacting the sulphide, and would not be redissolved until the sulphide is consumed and/or liquor of sufficiently high ORP reaches the precipitate.

As a result of the leach program, the optimum conditions identified for leaching of the supplied ore samples were pH 1.5 and ORP 450 mV. In practice, it is likely that in order to minimize sulphide oxidation, it would be necessary to keep the ORP as low as possible whilst still being sufficiently high to achieve a an effective rate of uranium leaching. This could be potentially achieved by increasing the total iron concentration whilst maintain the injection ORP at 400-450 mV, meaning that uranium leaching would occur whilst sulphide oxidation would be minimal.

Uranium extractions >90% were consistently achieved in leaches under optimized conditions. The gangue acid consumption in all tests was very low, less than 11 kg H2SO4/kg U3O8, indicating the acid costs in operation would also likely be low. As noted above, oxidant consumptions were high in tests at high ORP set-point, but under optimum conditions consumptions were typically less than 4 kg equivalent H2O2/lb U3O8, or <22 kg Fe3+/kg U3O8.

COLUMN LEACHING

A series of column tests were also performed on samples taken from both the Jasons deposit and the FLT area. These tests utilized horizontal columns of 1 metre length, with ore samples crushed to -2 mm packed tightly into the columns. The packed ore was irrigated by leach liquor, gravity fed into the column to achieve a target liquor flow rate of 2 m/day through the bed.

The column tests investigated the impact of increasing uranium concentration in the feed on the rate of uranium extraction, simulating the effect of solution recycle (also known as solution stacking). Tests were also performed to confirm the effects of pH and ORP observed in the stirred tank tests, and also to confirm the optimum leaching conditions.

The column tests utilizing feed liquors with varying uranium concentration (between 0 and 200 g/L U) showed a small decrease in the rate of uranium extraction with increasing concentration. The impact of pH and ORP on uranium extraction in the column leaches was variable, however extractions of >90% were consistently achieved throughout the tests, again demonstrating the amenability of the uranium mineralogy to leaching. Significantly, the calcium contents of the ore samples were very low, and there was no evidence of the precipitation of gypsum or any other calcium salts in the column tests.

FIELD LEACH TRIAL

The FLT was performed on site from mid-August until early December 2017, and utilized a wellfield approximately 1:10 the size of a typical production wellfield. This comprised of two well patterns with a total of 8 production wells and 2 extraction wells. The primary objectives of the FLT were to determine the necessary conditions required for effective uranium leaching (pH, ORP, Fe3+ concentration), the resultant reagent consumptions and to evaluate the effect of solution recycle in order to increase uranium tenor feeding IX.

The wellfields were initially injected with liquor at pH 1.6 with 1.2 g/L Fe3+ added as FeCl3, resulting in an injection ORP of approximately 650 mV. Due to the unusually high pyrite content of the FLT area, the oxidant consumption was high, resulting in the Fe3+ addition being increased to approximately 2.5 g/L and an ORP of approximately 700 mV. This resulted in an increased rate of pyrite oxidation, allowing the uranium leaching rate to also increase. After the increase in Fe3+ addition, a stable U3O8 tenor of 75-85 mg/L was achieved as leaching continued at a steady rate for the remainder of the trial. Towards the end of the campaign, a role reversal was performed (where the injection and extraction wells were reversed), resulting in a maximum U tenor of 375 mg/L, the highest recorded at Honeymoon.

Following the initial injection of liquor into the wells when the readily available acid consuming phases reacted, the pH of the liquor from the extraction wells stabilized at approximately pH 1.5. This confirmed the low acid consumption observed in the testwork program, and also demonstrated the effectiveness of uranium leaching at this pH. Similarly, calcium concentrations remained low in all extraction liquors throughout the campaign, and no issues were observed with gypsum precipitation throughout the operation.

The successful FLT supported the observations and conclusions from the ANSTO Minerals leaching testwork. In addition to confirming the requirement for a lower pH than previously utilized, as noted above, the FLT also showed that localized regions of high sulphide content can impact on the consumption of Fe3+/oxidant and subsequently the rate of uranium extraction. Increasing the rate of uranium extraction was achieved by increasing the Fe3+ addition.

ION EXCHANGE PILOT PLANT

Laboratory testwork performed at ANSTO Minerals identified and tested a commercially available resin capable of high uranium loadings from liquors at the elevated chloride concentrations in Honeymoon groundwater. The successful results from this study allowed Boss Resources to evaluate the use of IX for the concentration of uranium from ISR liquors by operating an IX pilot plant campaign over a 10 week period during the FLT. The pilot plant was designed, constructed and commissioned by ANSTO Minerals personnel, and subsequently operated by Inception Consulting Engineers for Boss Resources.

The pilot plant consisted of 21 fluidized column contactors divided between 3 modules of 7 contactors each. The function of each contactor (feed, wash or elution) was changed by relocation of feed and outlet hoses, resulting in the resin effectively flowing incrementally in the opposite direction of the liquor. The 21 contactors were divided into 14 loading and 7 elution contactors, representing this number of stages for each. Elution was performed using NaCl/HCl solution. A total number of 312 cycles were performed over the 10 week operating period.

The adsorption circuit yielded excellent results, achieving 97% extraction from the PLS, with resin loadings under base case conditions averaging 26 g/Lwsr (wet settled resin) U3O8, with feed and barren concentrations of 50 and 1 mg/L U3O8, respectively. The elution circuit also produced good results, with eluted resin consistently below the target of 2 g/Lwsr U3O8, corresponding to 95-99% elution, during stable periods of operation. The maximum eluate concentration achieved was 2.4 g/L U3O8, corresponding to a resin loading of 28 g/Lwsr U3O8.

The IX pilot plant performance overall was in agreement with the bench scale testwork carried out on synthetic liquors, for the PLS chloride concentration and acidities that were tested in the laboratory. Modelling of the IX circuit, based on results from the laboratory results, was validated by the uranium concentrations measured in the barrens and in the loaded resin.

The success of the IX pilot plant campaign means that in future operation the existing solvent extraction facilities at Honeymoon could be replaced or supplemented by IX. The use of IX for uranium in elevated chloride liquors is a significant new development in the industry.

Country or International Organization

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