ANS Annual Meeting 2020

Countdown to 2030

Framing the Nuclear Technology Agenda for the Next 10 Years

A Parametric Study of Uranium Sensitivity in an Aqueous Separations Simulation

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Savannah River Nuclear Solutions℠

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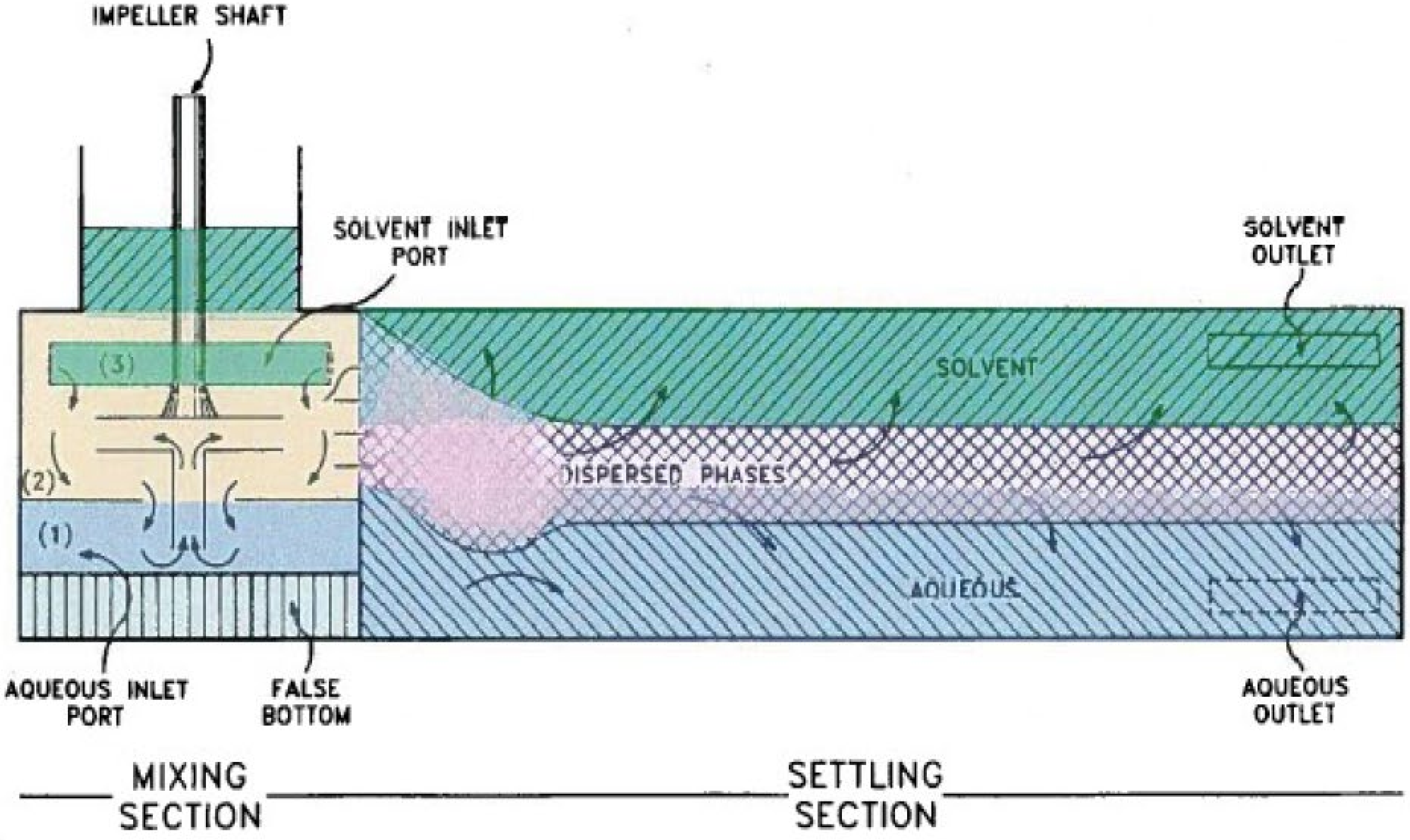
Background

- **SRS H-Canyon operates a two cycle aqueous solvent extraction system for separations and recovery of HEU**
  - First cycle partitions uranium from fission products and other actinides
  - Second cycle purifies and further decontaminates the uranium
  - Allowable ranges process stream composition and flow
- **Uranium concentration affects both the <u>criticality safety</u> and <u>economy</u> of operating the separations and purification process**
  - Fissile material location and concentration must be controlled to prevent criticality
  - Fissile material throughput affects the process run time and the need for post process decanting and evaporation
- **Simulations are performed in SEPHIS Modification 4**
  - Ease of input development
  - Rapid batch wise execution

Mixer Settler Design and Function



MIXER-SETTLER, SINGLE STAGE

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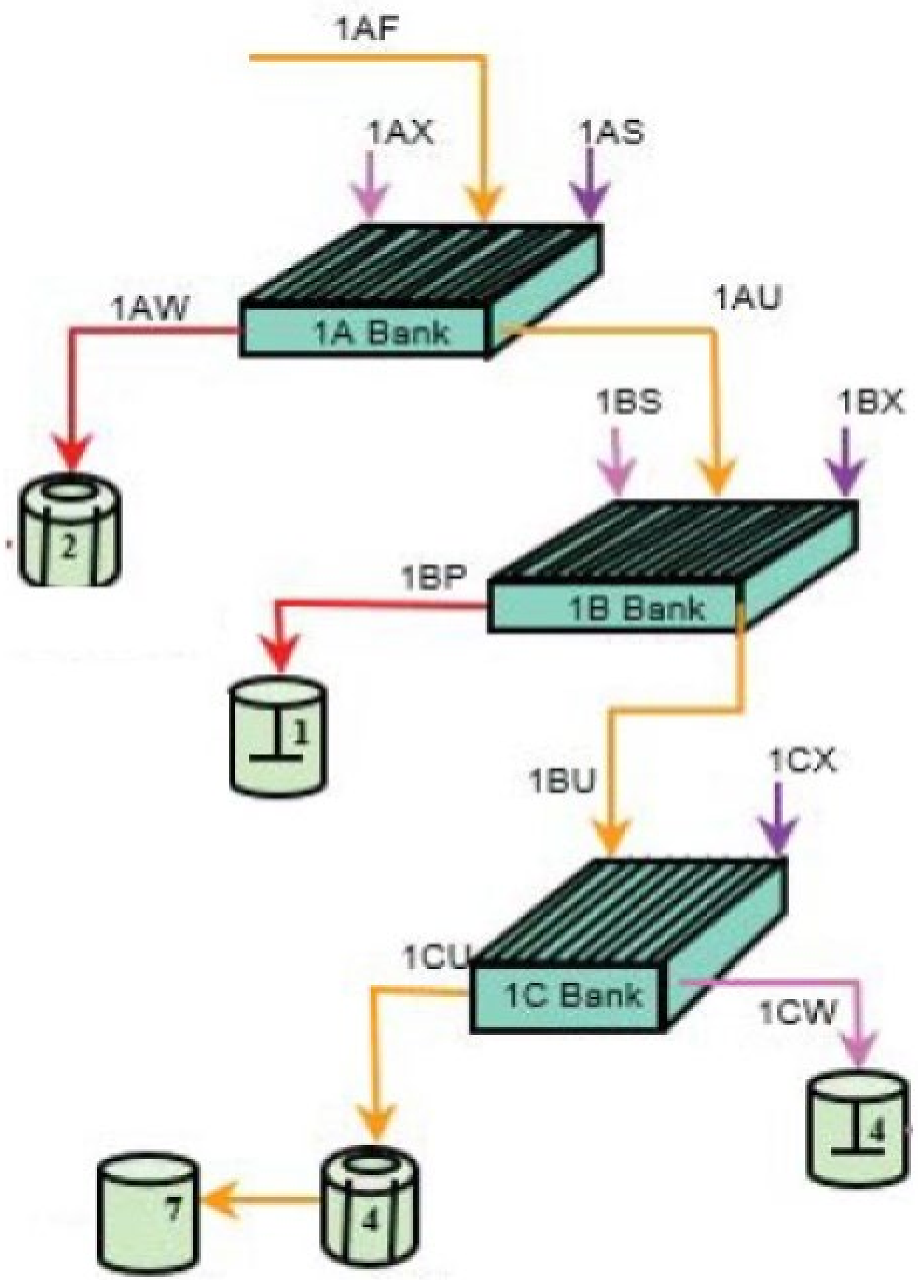
First Cycle Simulation



First Cycle Simulation

Parameter	Acceptable Range
Process feed stream	5.4 to 6.6 L/min 2.5 to 4.68 gU/L 0.00365g Pu/L 4.45 to 7.49 M acid
A-Bank acid stream	1.3 to 1.5 L/min 3.5 to 4.3 M acid
A-Bank solvent stream	10.1 to 11.6 L/min
B-Bank acid stream	6.3 to 7.1 L/min 1.5 to 1.5 M acid 0.00375 to 0.22 M reductant
B-Bank solvent stream	18.7 to 21.5 L/min
C-Bank acid stream	7.4 to 8.5 L/min 0.005 to 0.035 M acid
TBP Concentration (all solvent streams)	7.35 to 8.10 vol.%

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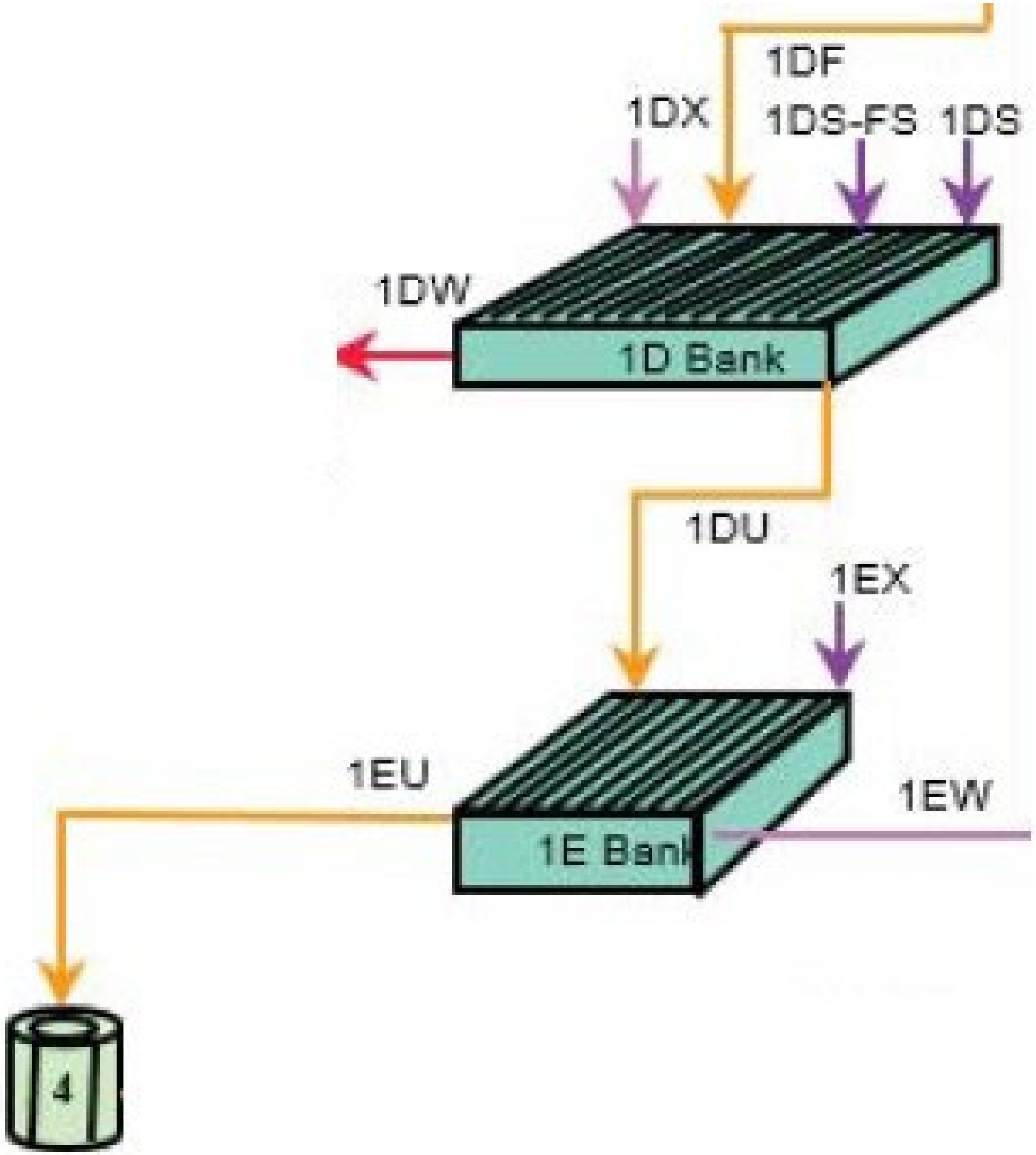
Second Cycle Simulation



Second Cycle Simulation

Parameter	Acceptable Range
Process feed stream	8.1 to 8.95 L/min 4.6 to 6.6 g U/L 3.9 to 5.8 M acid
D-Bank acid stream	3.43 to 3.79 L/min 0.825 to 1.5 M acid
D-Bank solvent stream	25.5 to 27.71 L/min
D-Bank reductant stream	0.07 to 0.08 L/min 0.02 to 0.06 M reductant
E-Bank acid stream	6.48 to 7.16 L/min 0.005 to 0.04 M acid
TBP Concentration (all solvent streams)	7.35 to 8.10 vol.%

Parameter Variation Method

- **Each of the parameters' ranges listed above is cast as a <u>uniform distribution</u> between the minimum and maximum**

- **Random perturbations of all input variables**
  - 1000 perturbations of for each cycle
  - All parameters available for perturbation are randomly perturbed within their acceptable ranges
  - Reflects reality of operation

- **Component perturbation**
  - All process parameters available for perturbation are held at their midpoint value except one which is allowed to be perturbed within its range
  - 150 random perturbations per variable

- **Results are presented for aqueous phase uranium concentration because it drives economy of the cycles and neutron multiplication of the mixer-settler banks**

- **Comparable results and analyses were performed on organic phase uranium concentration**

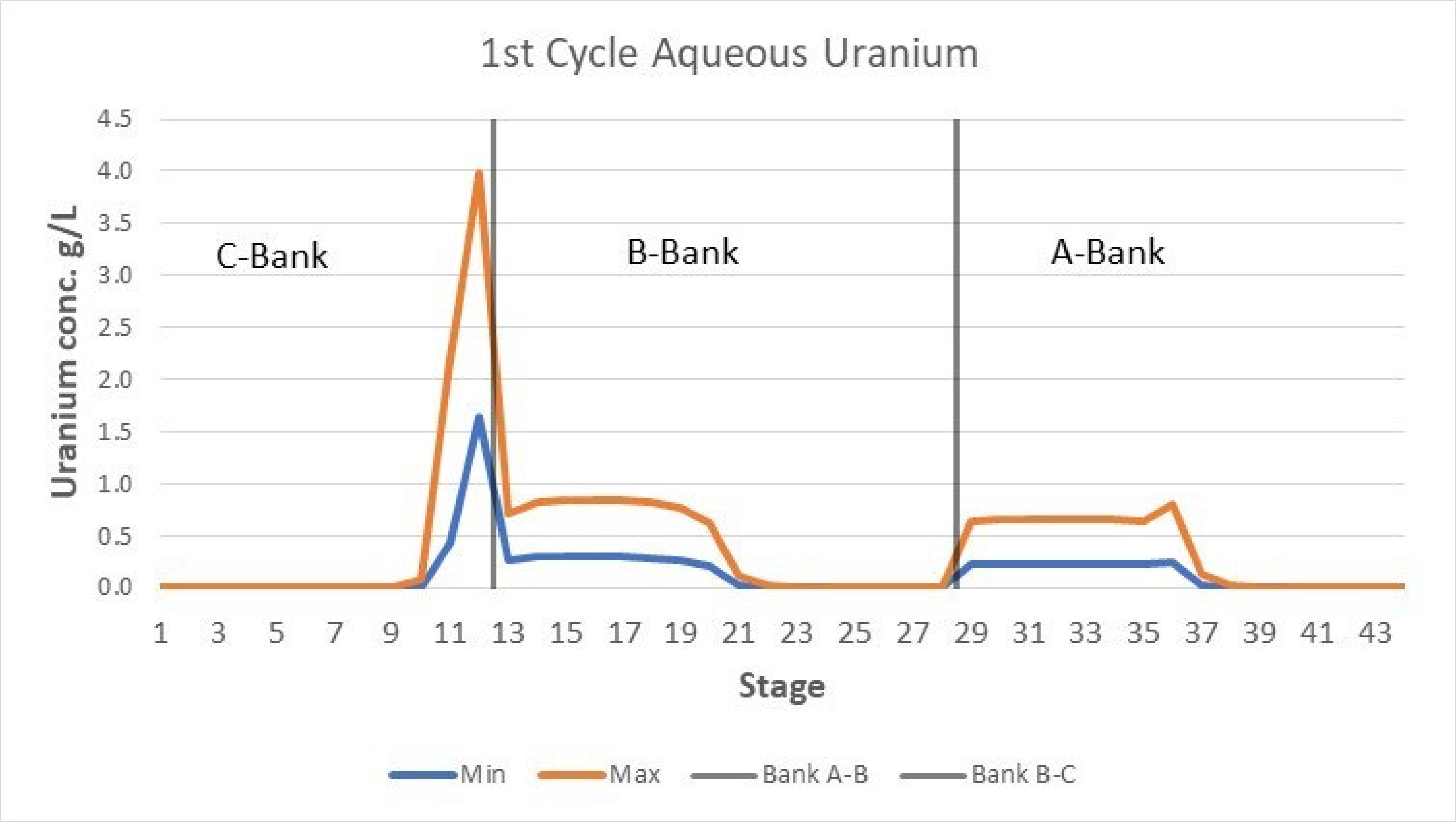
Results

- **Expected output stream ranges**
- **Output parameter distribution**
- **Component linearity**
- **Covariance correlation**

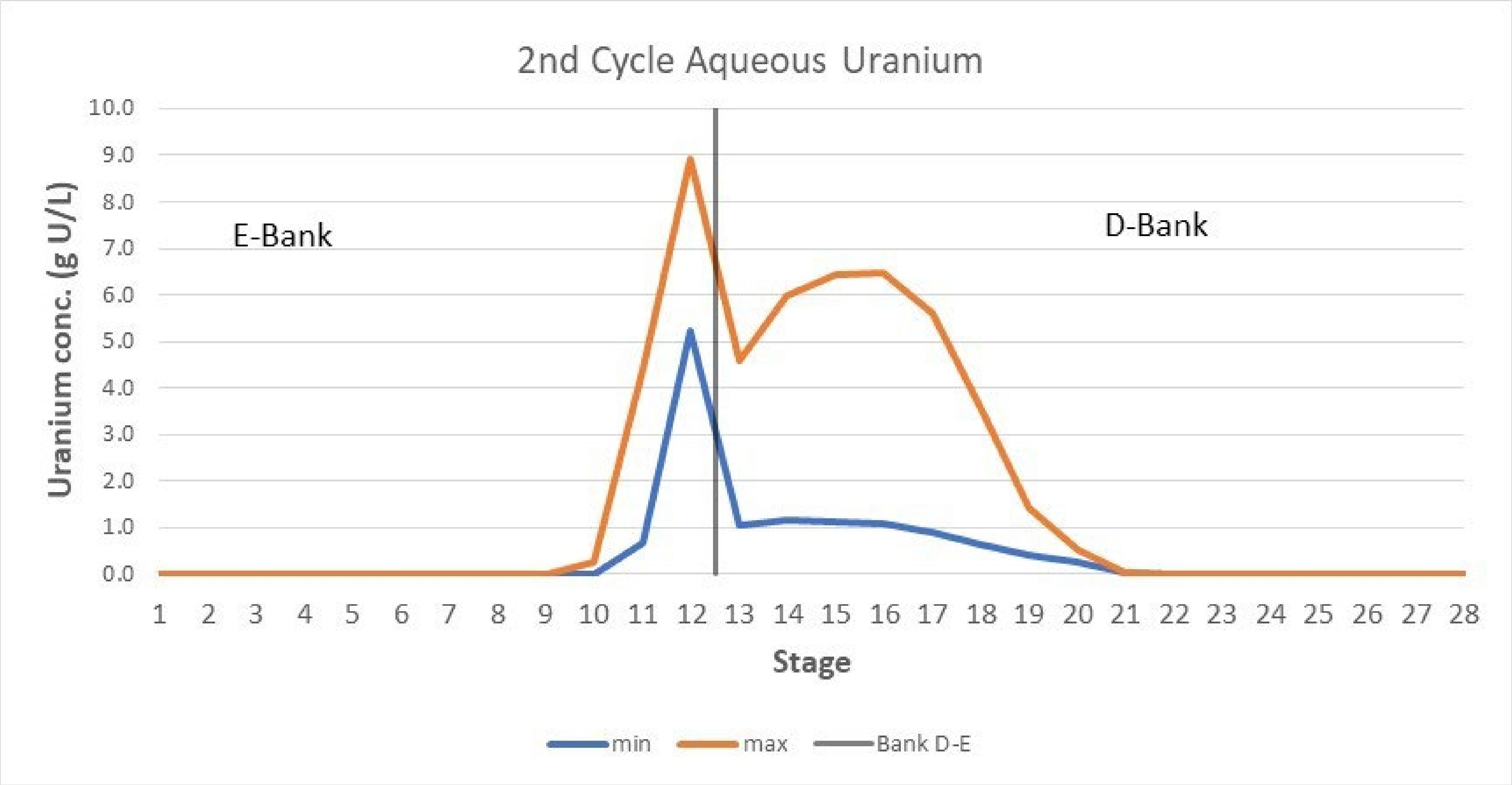
Results –Output Stream Concentration

- **First Cycle product stream had a range of 1.635 to 3.977 g U/L.**
- **Second Cycle product stream had a range of 5.250 to 8.916 g U/L.**
- **This is the most practical result of this study.**
- **Product streams are the highest or near highest concentration in the mixer settler**
- **Product stream concentrations affect the need for product evaporation**

Results –Output Stream Concentration



Results –Output Stream Concentration



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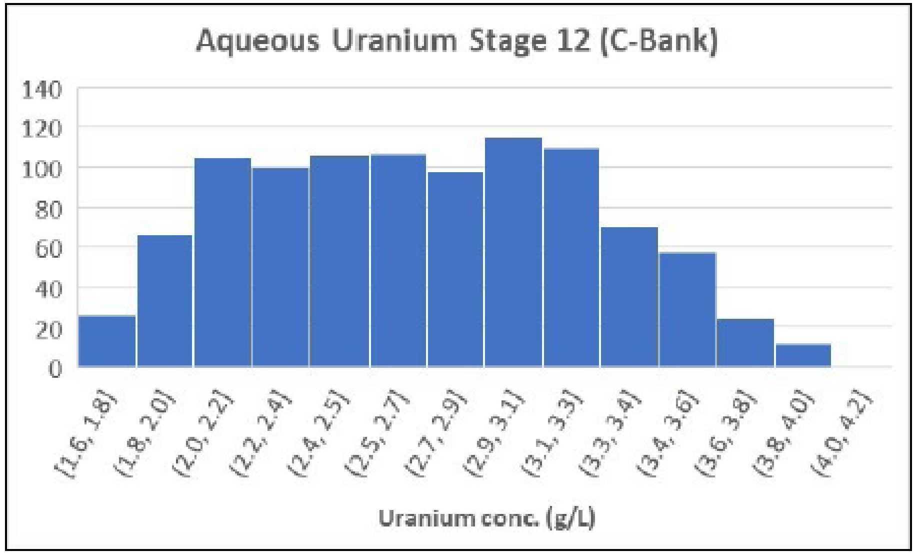
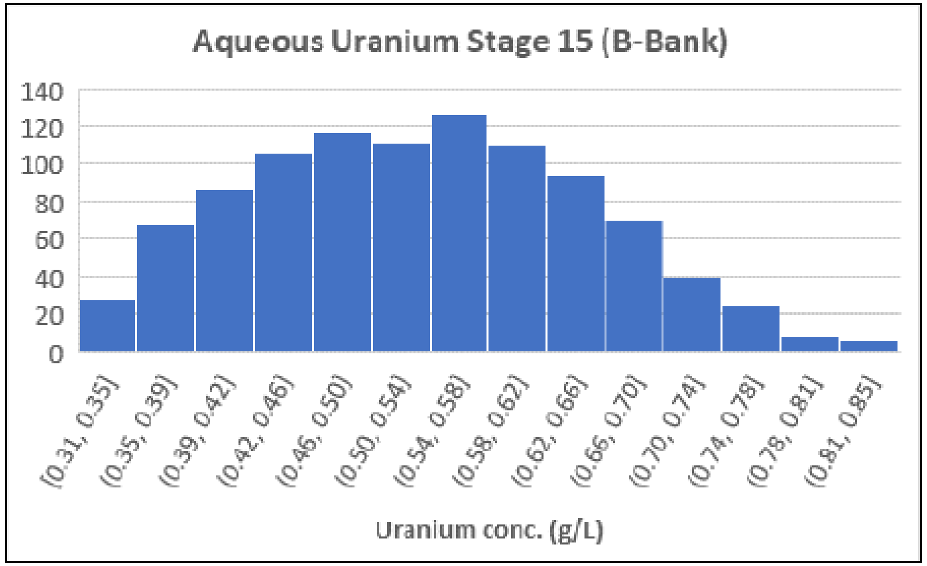
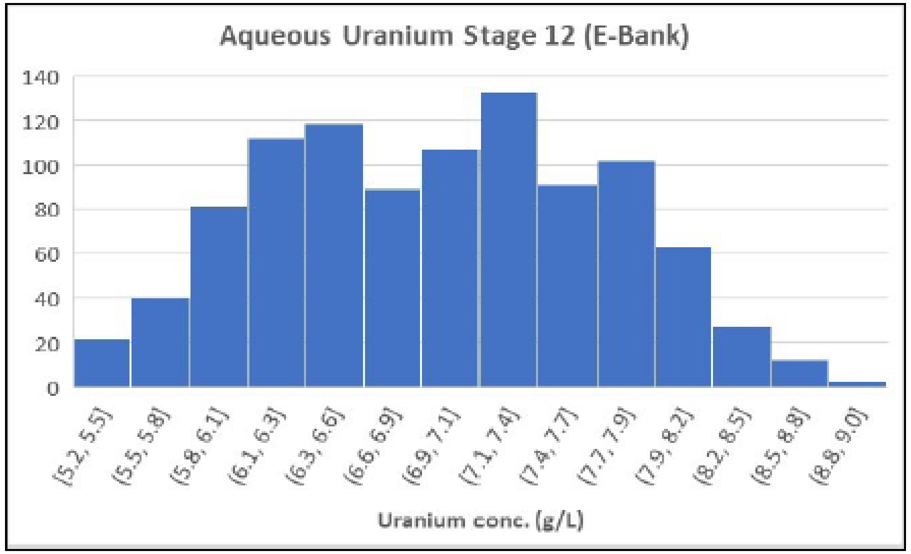
Results –Output Parameter Distribution

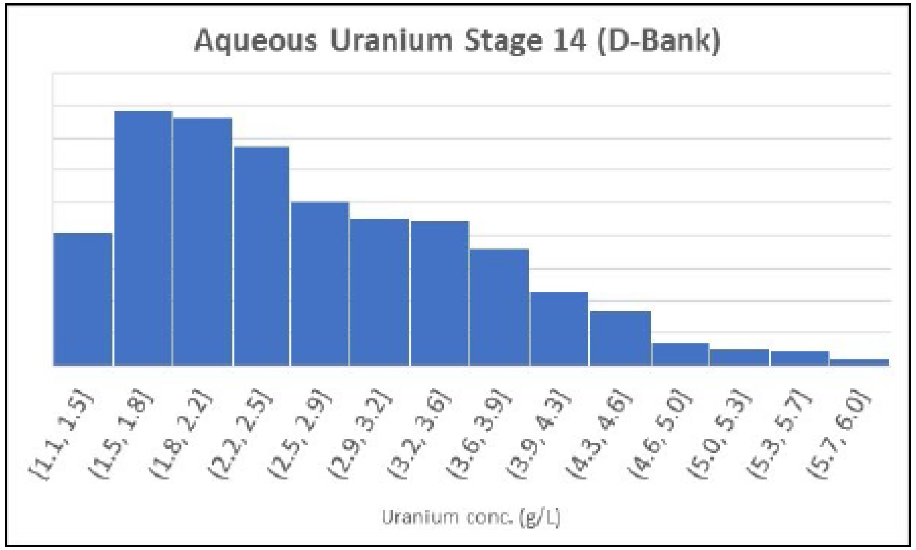
- **Uniform distribution inputs**
- **Output distributions were not uniform**
  - One of the distributions appeared close to being normal was subjected to statistical test and was found not to be normal.
  - One of the distributions appeared to have a skewed (higher order) Weibull distribution but did not exactly fit
- **Simulation is non-linear and involves higher order relationships**
  - Expected due to chemistry involved
  - No simple correlation of inputs to outputs

Results –Output Parameter Distribution









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Results –Output Linearity Analysis

- **Simple linearity test:**
  - For any output in any stage the result of perturbing each individual stream should sum to the result where all streams are perturbed simultaneously.
  - If the model is weakly non linear, this would be expected to sum to within a few percent.
- **Highly non-linear, competing effects exist within the chemical process**

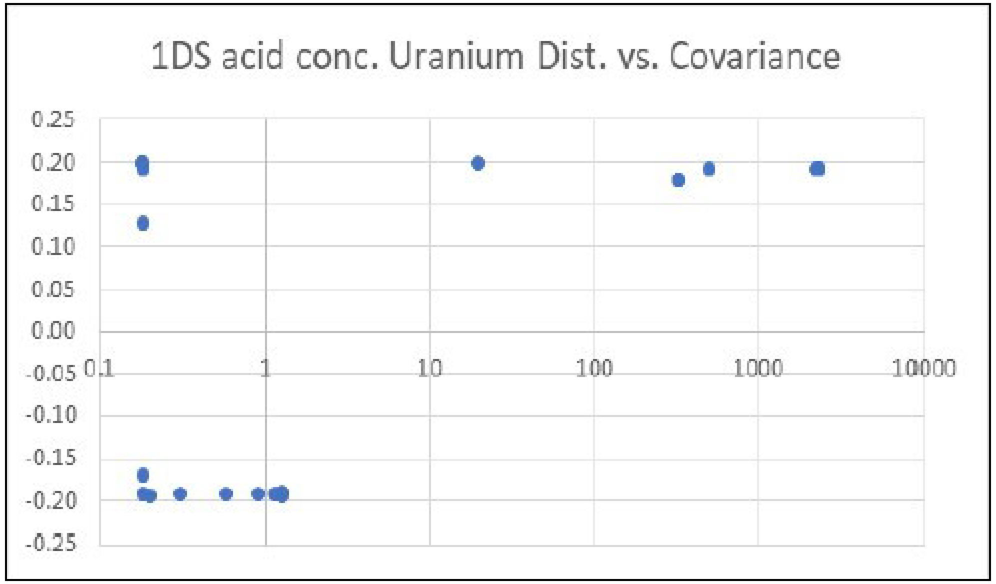
Results –Output Normality Evaluation

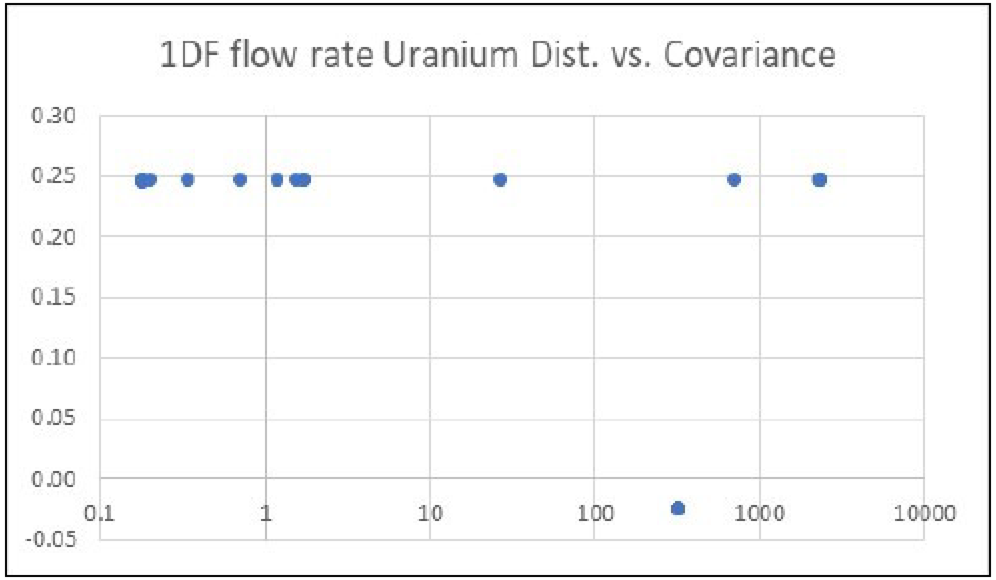
Bank -Stage	All perturbed case	Sum of top contributors	Sum of squares of top contributors
A-3	0.0568	0.4336	0.2898
A-4	0.0568	0.4512	0.3005
A-5	0.0563	0.4517	0.3008
A-6	0.0553	0.4518	0.3009
A-7	0.0529	0.4518	0.3008
A-8	0.0600	0.4518	0.3004
D-4	5.380	6.074	3.710
D-5	4.718	4.834	2.725
D-6	2.9231	2.6293	1.3354
D-7	1.0141	0.9133	0.4453
D-8	0.2505	0.2735	0.1717
D-9	0.02987	0.03044	0.01669

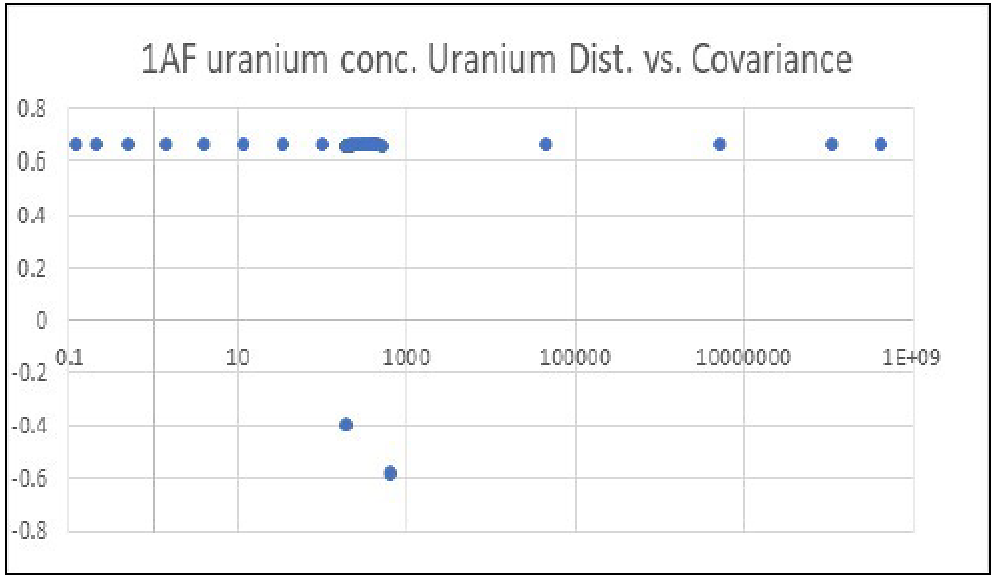
Results –Output Correlation to Covariance

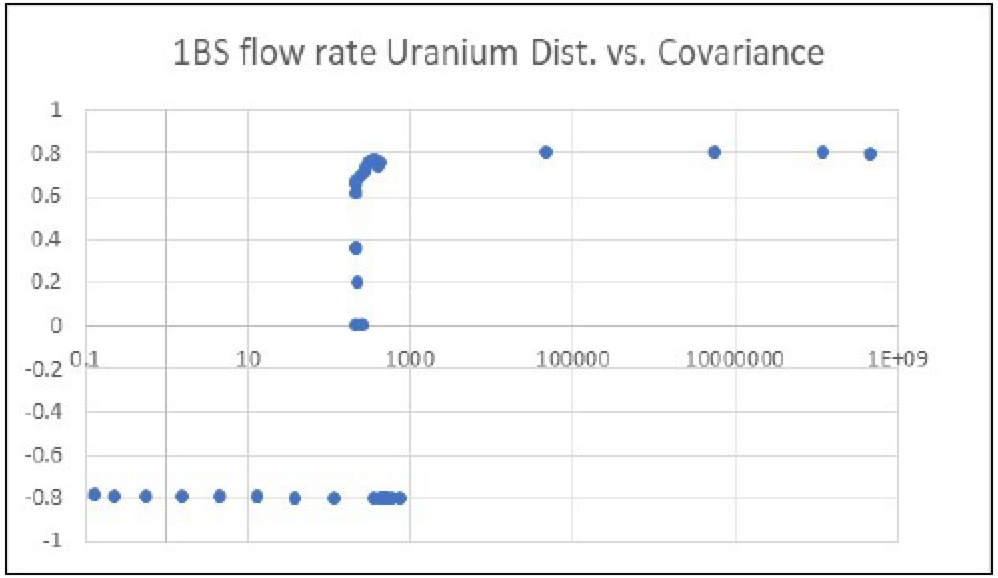
- **Can the covariance between a key input and a key output be correlated to a fundamental physics parameter?**
  - Distribution of the uranium between the two phases is a function of acid, reductant, TBP, and uranium concentrations.
  - It is a chemical property that is part of the nature of the process.
- **An attempt was made to search for a dependence on the covariance between an output and an input parameter with respect to the distribution coefficient.**
  - For example, given aqueous uranium concentration outputs for perturbing feed flow, the distribution coefficient of uranium in each bank stage was calculated for each case.
  - Using the standardized covariance function in Excel the covariance of aqueous uranium concentration with respect to feed flow was plotted versus the distribution coefficient.
- **No Correlations Found**

Results –Output Correlation to Covariance









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Conclusions

- **Practical results of knowledge of the product concentration ranges during normal operations was obtained**
  - Available for both organic and aqueous phases throughout process
- **Chemistry simulation was confirmed to be highly non-linear**
- **Parameter output distribution did not follow any known distribution correlation**
- **No mathematical correlations could be concluded**

Acknowledgements

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Questions?