BENEFITS OF MOVING BED ION EXCHANGE FOR URANIUM HYDROMETALLURGICAL FLOWSHEETS

❖ **Presented By:**

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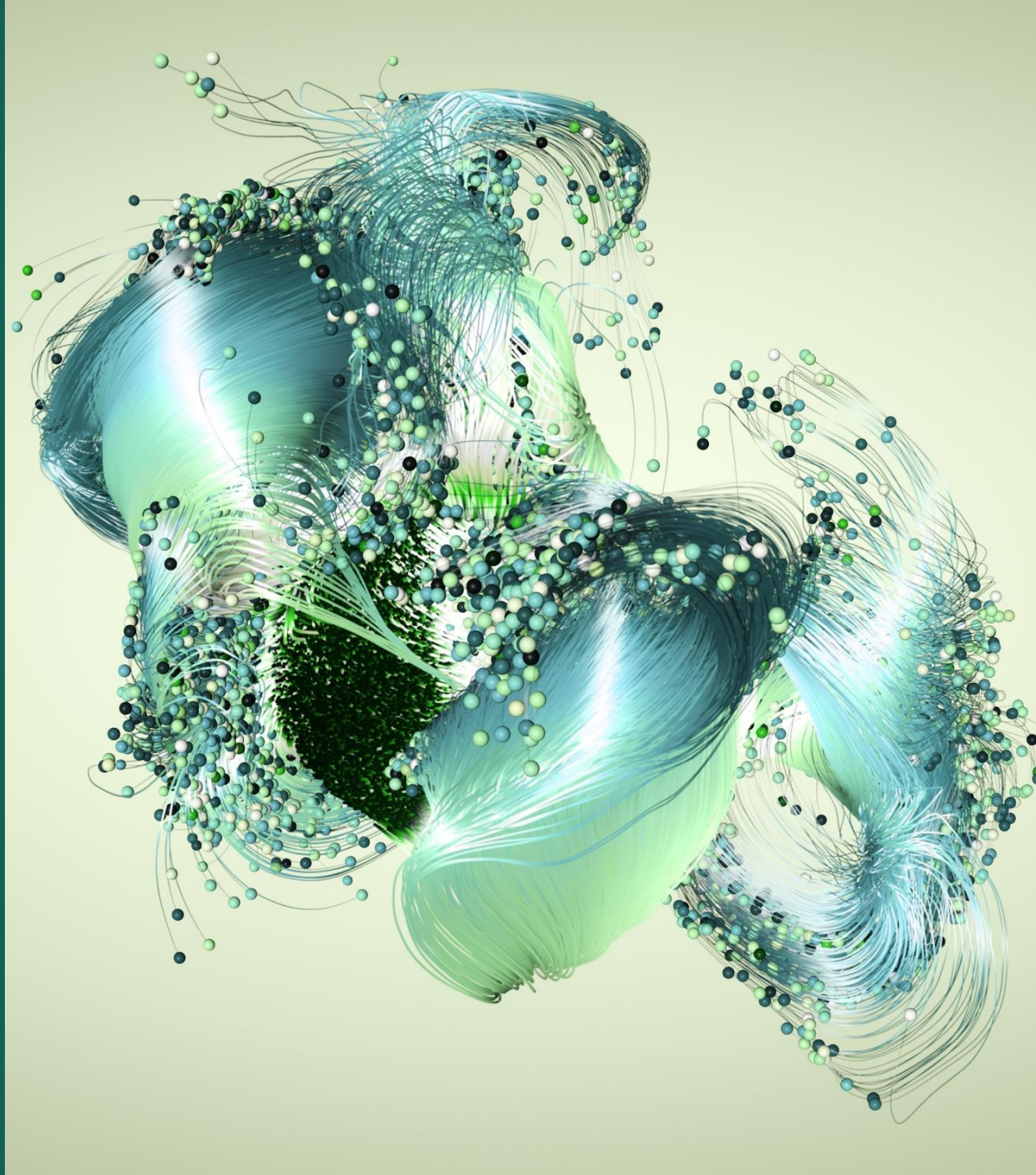
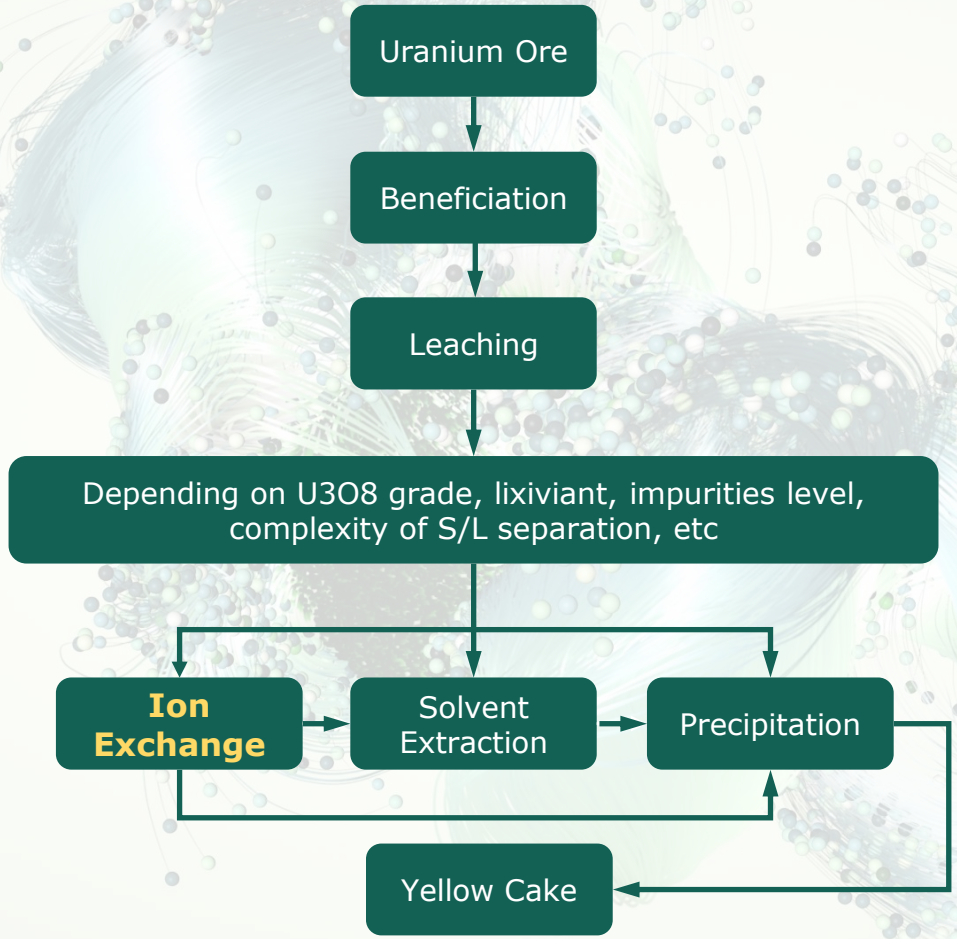


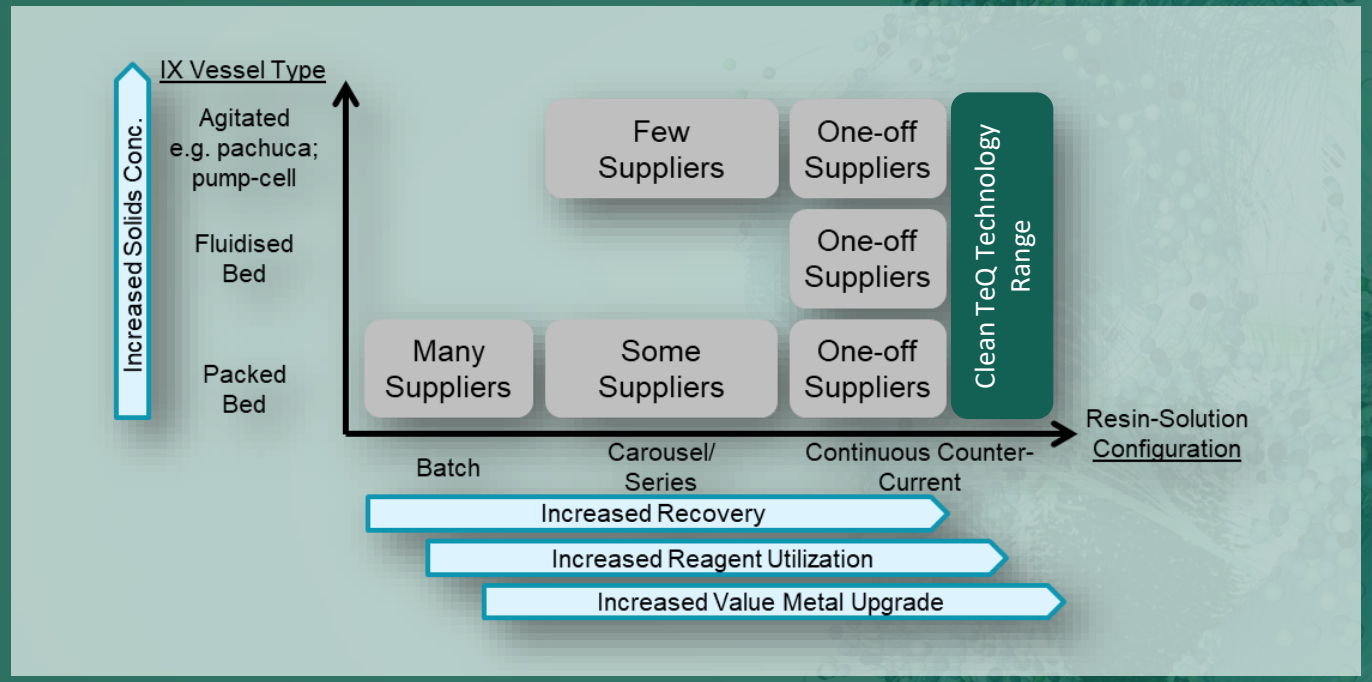
Ion Exchange In Uranium Processing

- The ion exchange process applies to the treatment of both pulps and clarified solutions in either an acid or alkaline circuit

- Challenges of ion exchange processes:
  - Solids handling
  - Reagents consumption vs resin regeneration efficiency
  - Water balance
  - Some impurities



Engineering Solutions

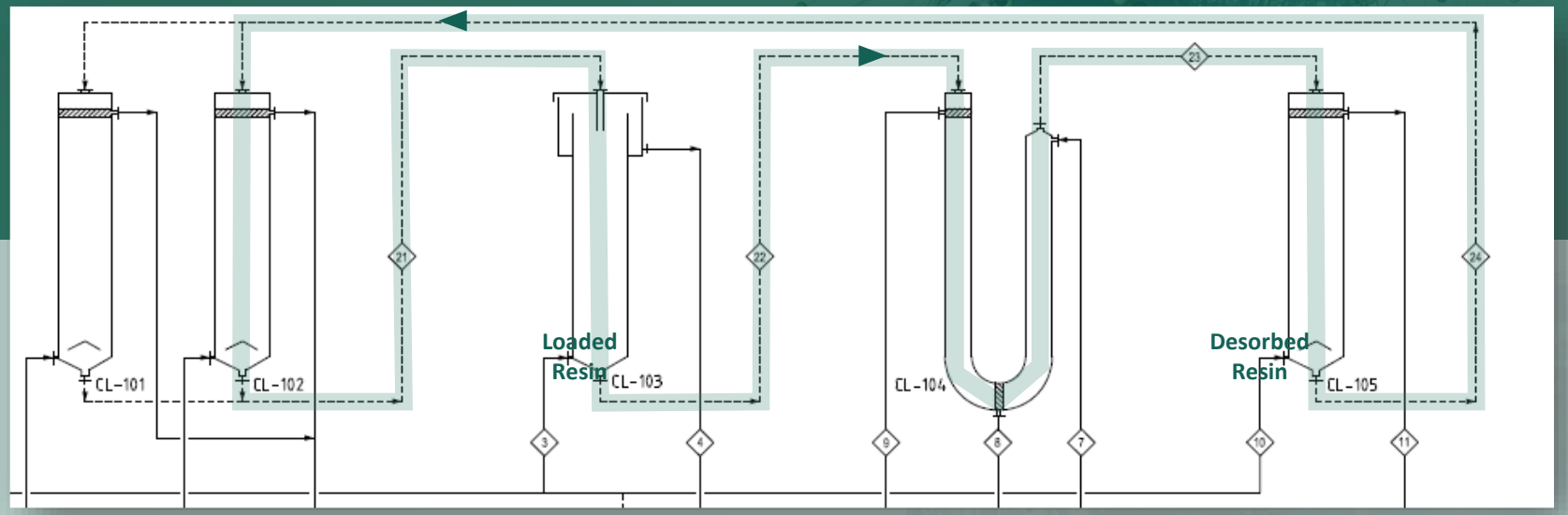


CLEAN-IX® provides a continuous, counter-current approach to ion exchange, thereby optimally exploiting ion exchange resin chemistry to deliver richer metal liquors and an improved water balance around the circuit

Best Engineering Solution For Each IX Stage

IX Stage	Equipment Options	Benefits / Function
Adsorption	Moving Bed	Efficiencies & residence time comparable to fixed bed Can handle suspended solids
	Resin-in-Pulp	True continuous counter-current, up to 50% w/w solids
Washing	Moving Bed	Efficient recovery of entrained solution, minimized water consumption
	Trommel/screens	Resin/pulp separation, entrained solution recovery (including reagents)
	Fluidised Column	Elutriation - solids removal, entrained solution removal
Elution/ desorption	Moving Bed	Minimal value metal dilution, no holding tanks and internal recycles
	U-column	Rejection of some impurities and metal upgrade into eluate
	Pachuca	Can accommodate formation of solids or gases during regeneration process

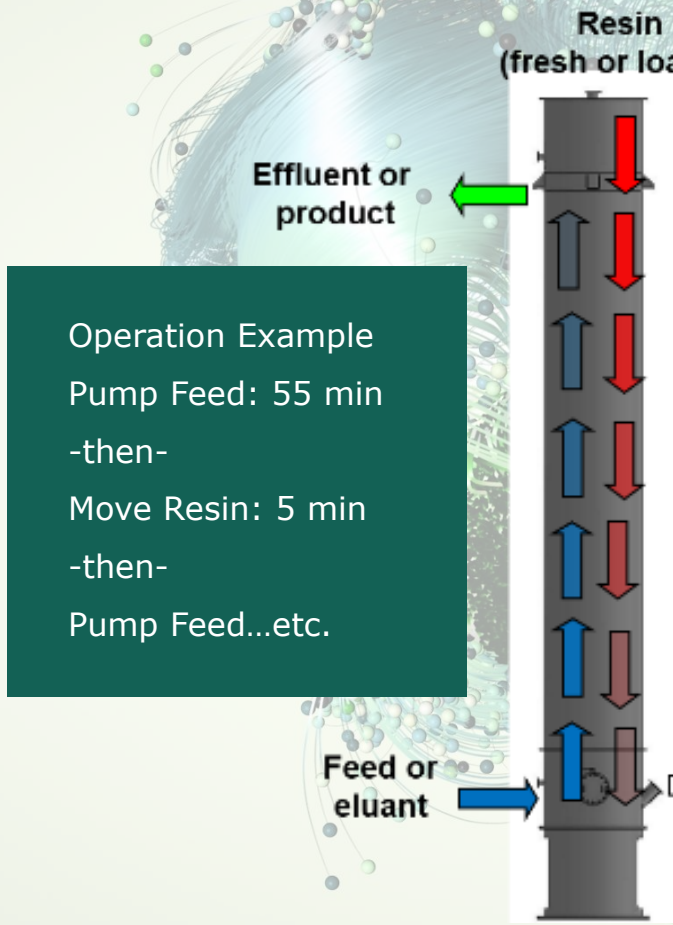
Ion Exchange Flowsheet for Uranium Recovery From Clarified Solutions



ADSORPTION	LOADED RESIN WASH	ELUTION (+SCRUB)	ELUTED RESIN WASH
In: PLS **Out**: Raffinate	**In**: Process Water **Out**: Dilute Leachate	**In**: Eluant **Out1**: Scrub Waste **Out2**: Eluate	**In**: Process Water **Out**: Dilute Acid

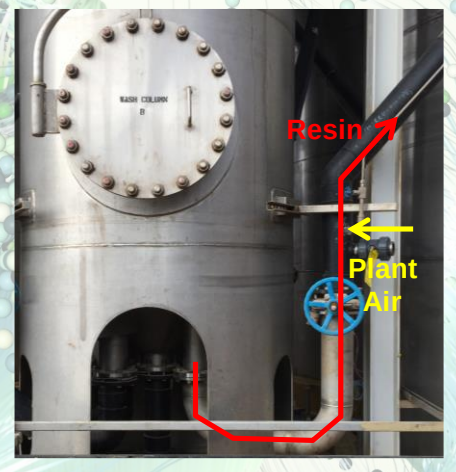
Counter-current Approach: Adsorption

- **Operates like a packed-bed system BUT:**
  - Resin moves periodically (column can be "divided" into 10^{+} sections in "lead-lag-polish-…-polish" configuration)
  - Full resin capacity utilisation
- **Due to periodical resin movement:**
  - Can tolerate suspended solids
  - Risk of column blockages is minimized

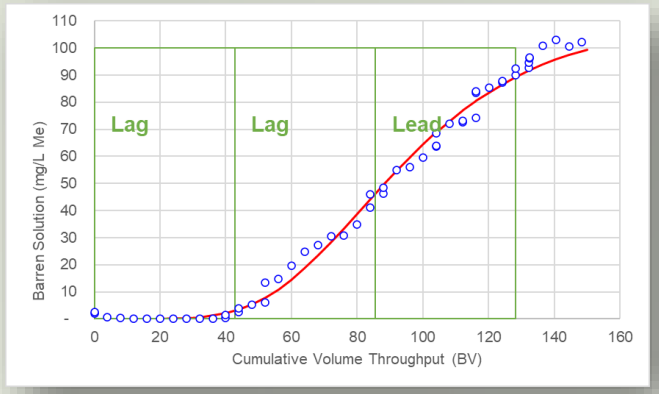


Operation Example
Pump Feed: 55 min
-then-
Move Resin: 5 min
-then-
Pump Feed…etc.

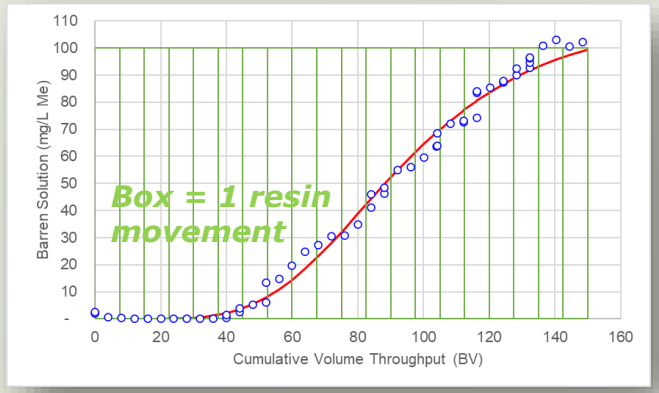
Airlift Example



Benefits for uranium adsorption



Fixed Bed



Moving Bed

Metal concentration @ transfer mg/L		
Column	Liquor avg.	Resin
Lead	69	8.4
Lag	20	6.0
Polish	0.5	2.1

NEAR-COMPLETE RECOVERY

+7% LOADING

Fixed Bed:

~3+ stages for recovery

(lead-lag polish)

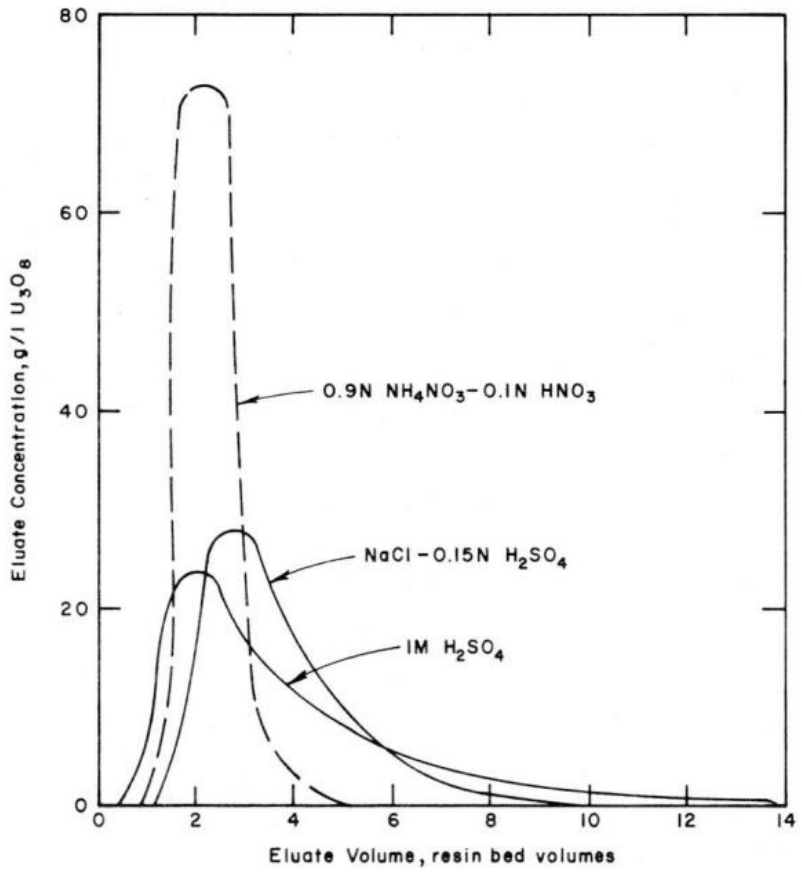
Metal concentration @ transfer mg/L		
Sub-sections	Liquor avg.	Resin
1	98	9.0
2	95	9.0
3	86	8.9
10	26	6.7
11	18	6.1
12	11	5.4
13	5	4.0
18	0.04	1.8
19	0	1.0
20	0	0.3

Moving Bed:

- More "stages" possible
- Maximises resin metal loading
- Maximises recovery
- Decreases resin inventory for a given extraction/removal extent

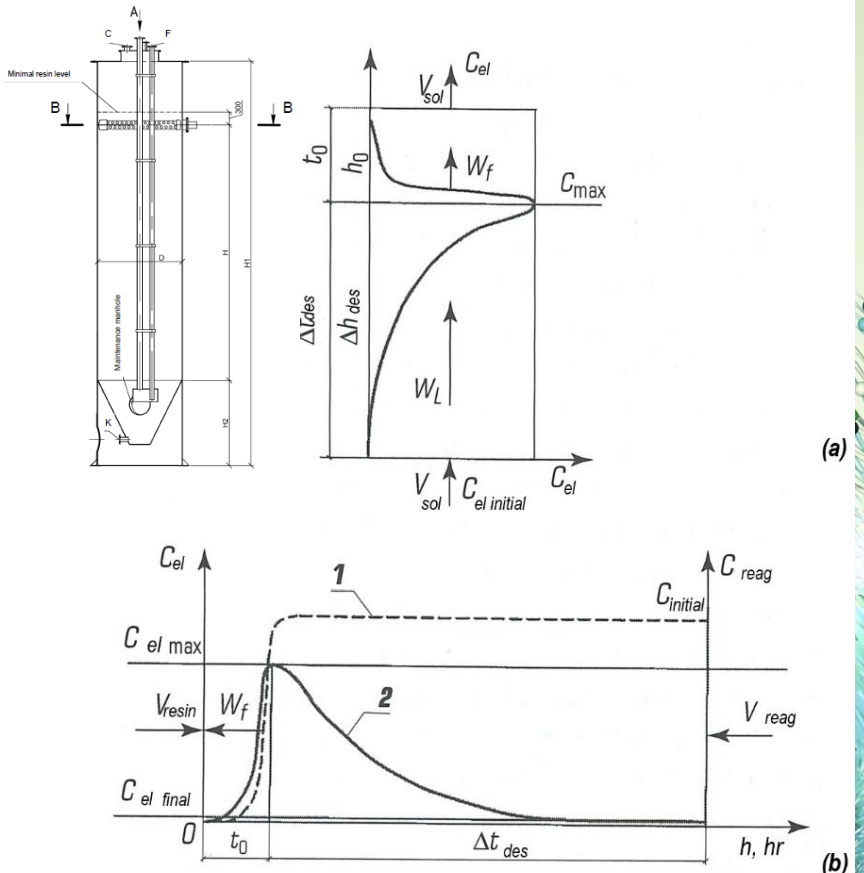
Uranium Elution

- Nitrate > chloride > sulphuric acid or bicarbonate
- Resin must be converted back to the sulfate (or carbonate) form before going back to adsorption
- Some impurities (Fe, Th, V, and others) can interfere with downstream processing, impact the purity of the yellow cake



Approaches For Uranium Elution

- Fixed bed systems typically have a single elution vessel (but may use some solution cycling)
- Carousel/multiple vessels approach resembles desorption in moving bed straight column
- Moving bed CNQ column:
  - Results in more concentrated product liquor (eluate);
  - More efficient reagent utilisation
  - Minimises value metal dilution into the product stream



Distribution of the element during desorption/ mass transfer zone (MTZ) formation

(a) – concentration profile inside of the desorption column; (*b*) – elution curve *1* – adsorption profile of eluting reagent; *2* – desorption curve of metal

Straight Moving Bed Transition To U-shaped Column

Straight Column

Eluant-to-Resin volumetric flow ratio reduced

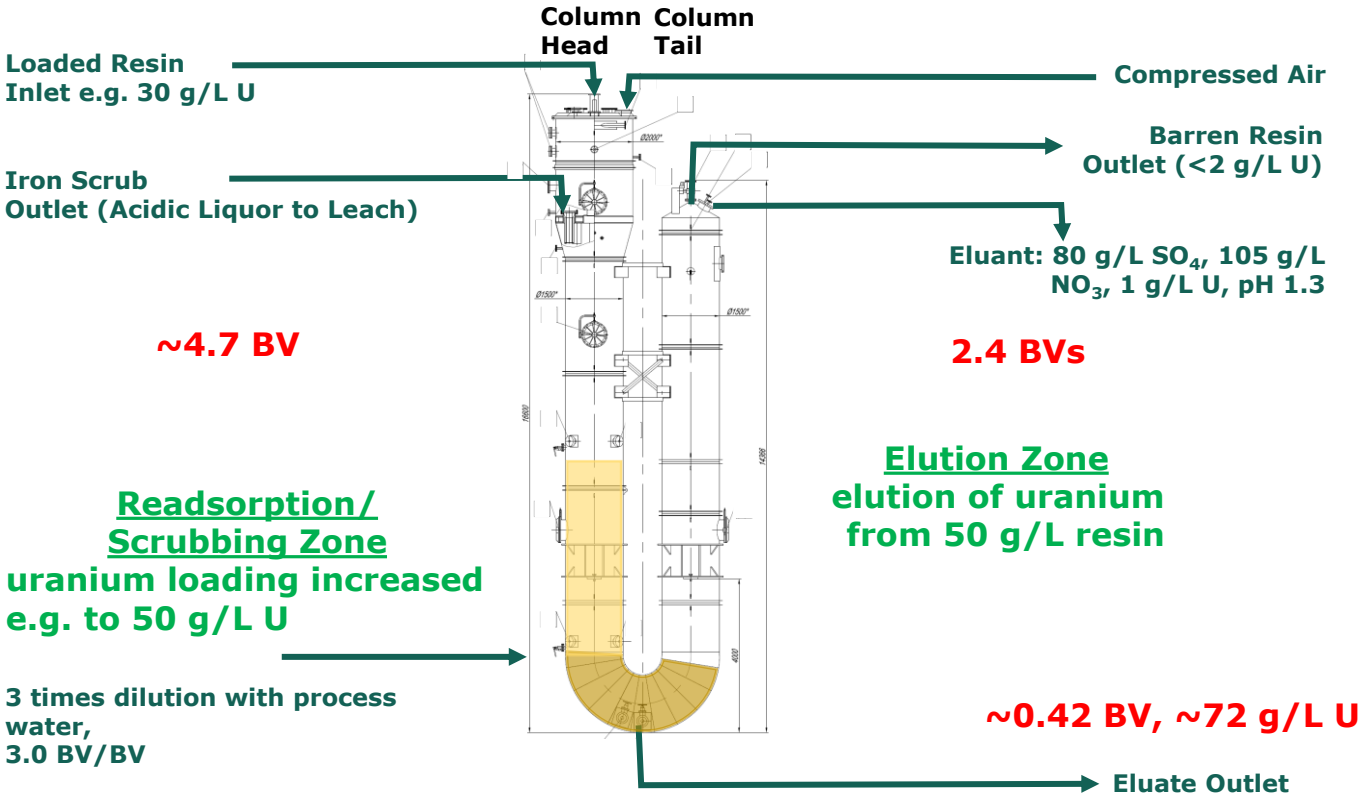
When…

- Eluate is transported to the refinery;
- The size of downstream processing circuits must be minimised;
- Scrubbing of co-loaded impurity metals is desirable

U-Column

U-column currently operating outside Australia

- PLS contains 80 mg/L U, pH 1.8
- In-column dilution (left leg) used to promote additional resin loading with U
- Scrubbing of impurities



Examples of the U-Column Performance

Lixiviant	Sulphuric acid			$Na_2CO_3/NaHCO_3$
Uranium in feed, g/L	0.08	0.9	0.4	0.6
Uranium on resin to elution, g/L	30	43.8	32	18
Uranium on resin out of elution, g/L	2	0.5	1	1.5
Eluant	NH_4NO_3	NaCl	H_2SO_4	$NaHCO_3$
Product flow, m^3/m^3	0.41	1.5	1.72	2.5
Uranium in IX product stream, g/L	72	28	18	6.6
Impurities rejected	n/a	Fe^{3+}	Fe^{3+}, Th^{4+}	HVO_4^{2-}
In column dilution or neutralisation	✔	✖	✖	✔

Examples of U-Column Performance

Element	Sulphuric acid elution circuit			
	Metal concentrations, mg/L		Uranium-to-Impurity Ratio	
	Resin	U-column product	Resin	Eluate
Fe	1000-1300	0.2	23-26	109000
P (phosphates)	230	71	135-146	307
Si	~6000	28.4	5.6	905
Th	<500	4	<61	5450
U_3O_8	~34 000	25708	-	-
Zr	<10	6.4	<3000	4017
Chlorides	~2000	1390	15	18
Nitrates as NO_3	n/a	615	n/a	42

Benefits of iron rejection from the product:

- No organic freeze if Solvent Extraction is considered downstream
- Minimised scaling issues if NF is considered
- Minimum or no requirement for iron removal circuit before yellow cake precipitation

Comparison of fixed bed multi-column vs CIX

- Better resin capacity utilisation
- Better resin elution efficiency
- Smaller and purer uranium-containing liquor flow for downstream processing
- More efficient reagents utilisation
- Improved water balance

Parameter	Unit	Fixed bed	CIX
Processing flowrate	m^3/hr	655	655
U_3O_8 in feed	g/m^3	250	250
U_3O_8 in barren	g/m^3	5.0	5
U_3O_8 in resin loaded	kg/m^3	**28**	**34**
U_3O_8 in resin eluted	kg/m^3	**2.0**	**0.5**
Resin flowrate	m^3/hr	6.7	4.9
Uranium delta	kg/m^3	**24.0**	**33.1**
Resin flow	m^3/hr	6.2	4.85
NaCl in eluate	g/L	82	82
H_2SO_4 in eluate	g/L	23	50
Eluate to downstream	m^3/m^3	3	1.5
U_3O_8 in the product	g/L	8.0	22.1
$NaCl/U_3O_8$	kg/lbs	4	2
H_2SO_4/U_3O_8	kg/lbs	1.2	1.03
Eluate flow to downstream	m^3/hr	18.54	7.28

Conclusion

- Organization of uranium processing in a continuous counter-current manner provides several benefits in comparison to simulated moving bed or fixed bed approaches like better water balance, more efficient reagents utilisation, higher tolerance to the solids, etc

- Elution in U-column benefits uranium processing in several ways:

- Concentrates uranium to the smaller and purer stream

    - Small, concentrated stream decreases the size of downstream circuits (CAPEX)
    - Improved water balance (OPEX)

Conclusion

- Improved separation efficiency between uranium and impurities
  - Minimises value metal loss (REVENUE)
  - Minimises uranium recycling upstream (CAPEX, OPEX)
  - Reduces or avoids the impact of impurities on downstream processing

  (operability, OPEX)

- Reduced reagent demand within the ion exchange circuit (OPEX)
- A U-column can be integrated with various moving bed IX configurations (e.g. CIX, NIMCIX, Resin-in-Pulp)

Clean TeQ General Capabilities

Assistance in flowsheet development → Support test work programs

Mini-pilot, Pilot and demonstration scale equipment supply → Process economics, trade-off, PFS and DFS studies → Custom tailored IX equipment designs and manufacturing

Commercial scale plant delivery (LSTK packages, EPCM, etc.) → Commissioning and circuit optimisation support

Open to various Modes of collaboration (resin suppliers, engineering companies) → Hydrometallurgical laboratories, start-ups, existing operations, etc.

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