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Management of Ion Exchange Resin in the Continuous Resin-in-Pulp Extraction of Uranium

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ABSTRACT

Ion exchange resins have been used extensively in the recovery of uranium, especially from low grade ores, traditionally in fixed beds. Continuous resin-in-pulp (RIP) technology was a logical development from the fixed bed technology and was first trialled in 1953 in Russia. The RIP technology was used predominantly for pulps that exhibited poor settling characteristics and involves contacting the pulp directly with the ion exchange resin, eliminating the need for solid liquid separation. Typically, the solid liquid separation requires a CCD circuit or filtration to produce 'clean' solutions which accounts for between 30 and 40 per cent of the capital cost of the uranium processing plant.

This paper describes a typical continuous RIP plant and the ion exchange resins used. The paper also addresses two of the main challenges associated with this technology which are controlling the transfer of resin, and limiting the amount of resin that needs to be replaced.

The development of the RIP is discussed with respect to resin transfer and management. Various transfer options are discussed and the impact on stage efficiency and the ability to control resin flow. The second challenge is to limit the resin replacement cost. Resin typically needs to be replaced as a result of attrition, breakage, physical loss from the system and fouling of the beads. Reported resin loss is presented to guide the designer establish a realistic resin replacement strategy.

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1. Introduction

The development of ion exchange technology in the 1950's marked a major advance in the processing of uranium. Initially, ion exchange was done in fixed bed ion exchange columns (FBIX) but the feed had to be filtered to remove particles which would otherwise result in the bed becoming blocked. Continuous ion exchange (CIX) systems were built but the pulp density tended to be limited to around 7% solids (in the west). These CIX technologies were only applied to leach solutions which showed poor filtration or settling characteristics. The development of solvent extraction in the mid-1950's in the western world saw the rapid rise in Solvent Extraction as the technology of choice for the second generation plants. Solvent Extraction currently is the dominant technology used in the recovery of uranium.

At the same time that the West were developing the first FBIX uranium extraction plants, Russia developed continuous resin-in-pulp (RIP) which used undiluted, de-sanded pulp. Some of the benefits in using RIP are:

1. The potential to dispense with a solids/ liquids separation step.
2. The ability to remove residual soluble uranium from the tailings, better than a CCD circuit.
3. Ability to treat slurries with poor filterability or settling characteristics.
4. Recovery ratios in the region of 200: 1.

This paper is intended to be of use to those designing RIP plants. There are a number of challenges which need to be addressed in the design stage in order that the process meets the design requirements. The challenges relating to the management of resin addressed in this paper are:

1. Scale-up from laboratory to full scale
2. Accurate transfer of resin, especially in sorption
3. Limiting the resin breakage and losses
4. Dealing appropriately with resin foulants and interferants

Prior to addressing the above 4 points it is useful to provide a brief history of the rise of continuous ion exchange and resin-in-pulp as there are many lessons and experiences which are directly applicable to RIP.

2. Early Development of Ion Exchange

Ion exchange was the dominant technology in the first generation uranium processing plants. This covered the period up to around 1957. The plant typically consisted of acid leaching in air-agitated pachucas, two stages of drum filtration, extraction in a fixed bed ion exchange column, elution and finally precipitation of the uranium as yellowcake, ammonium diuranate (ADU). This flowsheet is depicted in figure 1.

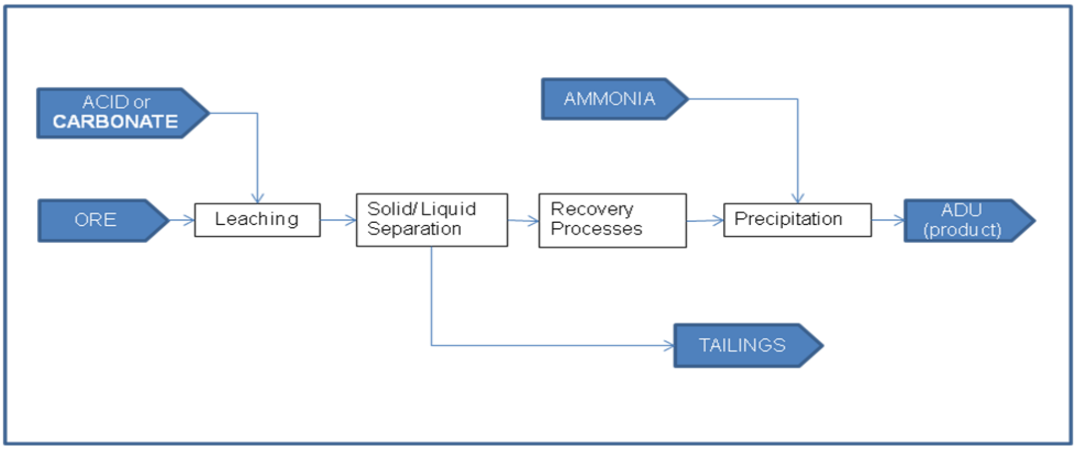


Figure 1: Block Flow Diagram of a Typical Uranium Processing Plant

The Ion Exchange Unit typically consisted of three columns manifolded such that two were on-line at any time and the third was being stripped (regenerated). When the lead column was saturated with uranium, it was taken off-line and stripped as shown in figure 2. The maximum size of the fixed bed ion exchange columns was limited and this often resulted in a number of parallel trains being required. As a result, the manifolding, valving and control was complex.

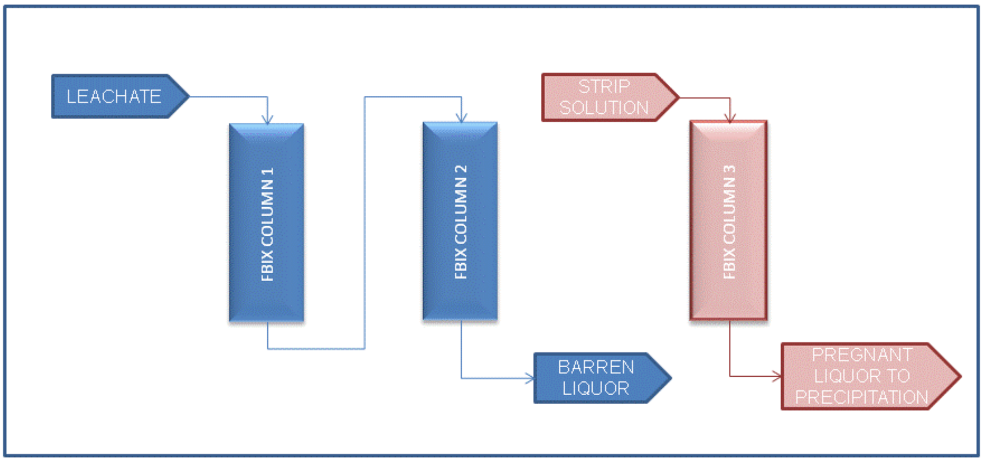


Figure 2: Fixed Bed Ion Exchange Unit

3. Continuous Ion Exchange Technologies (CIX)

The development of ion exchange post Fixed Bed Ion Exchange saw the emergence of a number of new CIX technologies which could tolerate low concentrations of solids in solution.

In Table 1 the solids contents of various feed solutions to an ion exchange plant is shown and a preliminary selection of ion exchange technologies is indicated based on the solid content.

Solution Description	Solids concentration	Solid/ Liquid separation	Applicable iX Technology
Clear solution	Negligible	Sand Filter	FBIX
Cloudy Solution	< 1,000 ppm	Belt Filter	CIX
Dilute Slurry	< 10% solids	Classifier	RIP
Concentrated Slurry	30 – 60 % solids	None	RIP

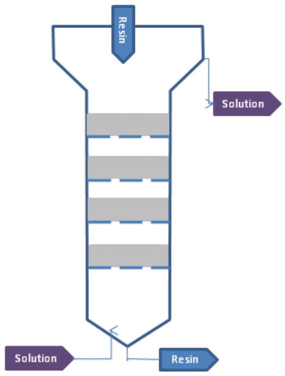
Table 1: Comparison of Feed Solids Contents for Different Ion Exchange Technologies

The CIX technologies are able to accept feed solutions that contain up to 1,000 ppm of solids. For this reason they require a solid/ liquid separation such as a belt filter or a CCD circuit to separate the solids in the feed pulp. Only the clarified solution is processed to recover uranium.

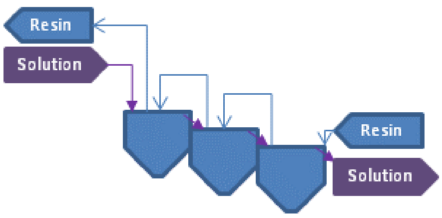
For simplicity, the available technologies have been grouped into the three main types. These are the fluidised bed, multiple tanks and pulsed column types. A brief summary of each type is provided below to distinguish them from the continuous RIP technologies.

In this section a brief overview of the three main technologies comprising CIX is provided.

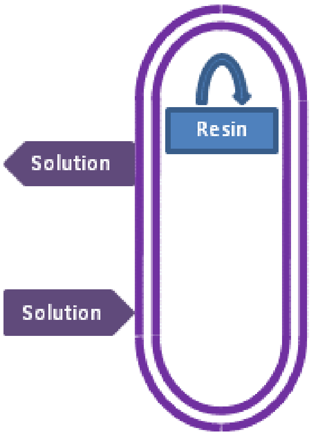
a. Fluidised Bed

	Description	The sorption column typically consisted of a number of separate beds supported on orifice plates with the feed solution flowing upwards through each bed and partially fluidising the resin. This allowed for solids contents typically around 300 ppm
	Examples	Chemwes, NIMCIX Contactor Vaal Reefs, Himsley Column.

b. Multiple Tanks (Horizontal)

	Description	The sorption section consisted of a number of fluidised bed tanks with the resin flowing counter-currently to the pregnant solution. At Rőssing the solids are typically 300 - 500ppm.
	Example	Porter, Rőssing

c. Pulsed

	Description	Closed loop system sometimes referred to as the Higgins Loop.
	Examples	Blind River, Ontario

4. Resin-In-Pulp Technologies

In contrast to the CIX (Continuous Ion Exchange) discussed in section 3, RIP technologies were developed to enable contact of ion exchange resin directly with the desanded pulp to recover the uranium. The benefits of these technologies are:

- No solids/ liquid separation required between leaching and uranium recovery processes (as shown in Figure 1). The solid/ liquid separation process typically involved either two-stages of drum filtration or a CCD circuit and represented between 20 – 40% of the capital cost.
- The loss of soluble uranium in the tailings is considerably reduced. Uranium content of < 5 ppm.

Two contacting methods for RIP are described below. These are Resin-in-a-Basket and Screen-Mix.

a. Resin-in-a-Basket

This technology was developed in the United States in the 1950's predominantly to treat pulps that had poor settling characteristics or were difficult to filter. A total of 7 plants were built. Even though there none of these are operational today, there are a number of aspects of the design relating to this technology which are relevant to today's plants.

The resin was placed in stainless steel (or alloy) baskets which were usually cube shaped. The length of the cube varied between 1 – 2 m. The cubes, containing the resin, were slowly raised and lowered in vessels containing the pulp. Typically there were 6 - 10 sorption stages in which there were up to 4 baskets per stage. The resin baskets were moved in a counter-current fashion to the pulp in a semi-continuous fashion. The pulp typically flowed by gravity between the stages. After a predetermined time the baskets in a stage were manually advanced to the next stage. When a basket reached the final stage, and was fully loaded it was transferred to the elution circuit and stripped of the uranium. The barren resin was returned to the returned to the beginning of the sorption train. A typical stage is shown in figure 3.

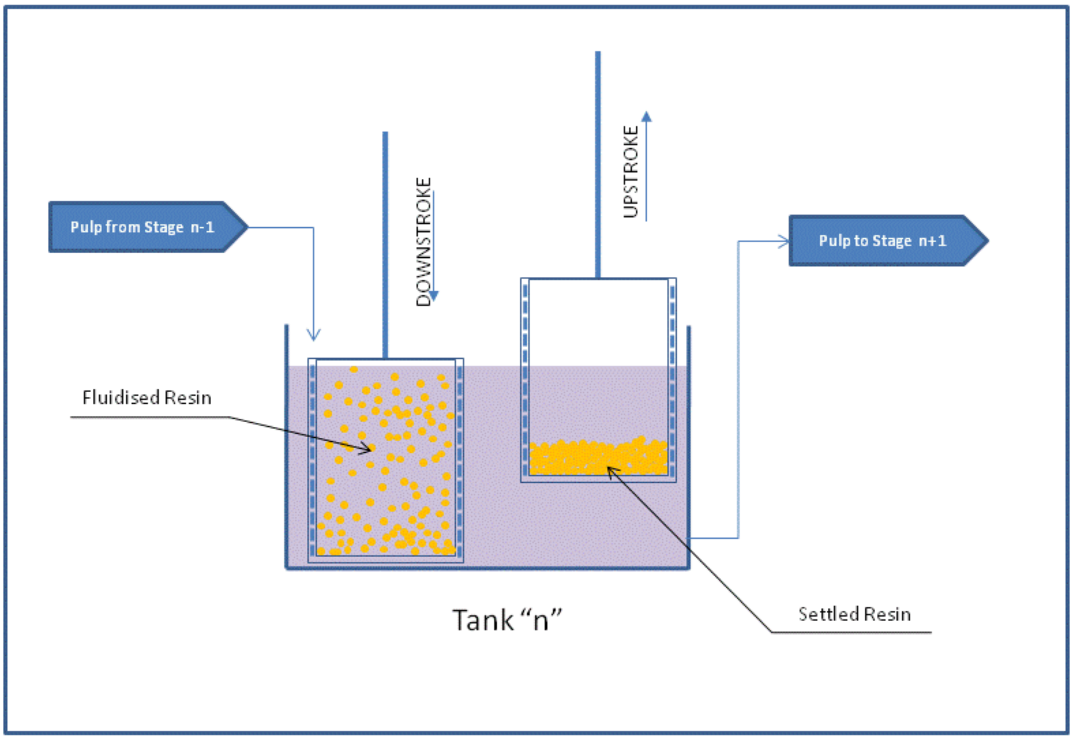


Figure 3: Schematic for Resin-in-a-Basket

A summary of the operating conditions of the process are shown in table 2.

	Units	Value
Feed solids in pulp %	wt%	7%
Maximum particle size in pulp	micron	45
Resin concentration in the pulp	vol%	3 – 3.5
Uranium Recovery	%	> 99
Total resin sorption time	min	90 -150
Loading of U_3O_8 on the resin	mg/L	56 - 72

Table 2: Resin-in-a-Basket Operating Conditions

Design issues included:

- Solids % was limited to around 7% as otherwise the resin density would be lower than the pulp density and it would float.
- Sand blocked the basket mesh apertures.
- Particles > 325 mesh (44µm) tended to cause excessive abrasion of the resin and were therefore removed.

A number of these plants were modified to a screen-mix (multiple tanks) configuration. One example was Split Rock Mill which achieved reduced operating and maintenance costs and an increase in recovery and plant capacity after making the modifications.

b. Screen-Mix Technology

This process was developed in Russia in the 1950's. In contrast to the technologies just reviewed this technology does not require solid/ liquid separation. The slurry is fed, undiluted, directly into the RIP sorption vessels as is shown in Figure 4.

The "raw" pulp entering the sorption plant is passed over a de-sanding screen. The purpose is to remove particles of a similar size to the resin as well as to prevent coarser particles settling out, especially in the first vessel. Typically the vessels are air-sparged Pachuca's with or without a draft tube used to mix the pulp with the resin. Alternatively mechanical agitation can be used, which is usually more effective from a mass transfer point of view. However, there is always the debate as to whether the mechanical agitation results in rapid attrition of the resin. This will be discussed later in the paper.

The resin and pulp move counter-currently through the sorption section. Transfer of the resin can be affected by air lift, hydrostatic pressure or pumping. The resin is typically separated from the pulp to minimise backmixing of the pulp in the previous stage. Due to the resin flow being considerably lower than that of the pulp, either the resin is transferred separately or the majority of the transferred resin is recycled back to the current pachuca.

The pulp can be transferred by pump or by gravity. In gravity systems interstage screens retain the resin in the current Pachuca while allowing the screened pulp to flow through to the next Pachuca. The screen can be air swept to prevent the screen from becoming blocked by the resin. In most cases the turbulence in the Pachuca keeps the screen clean.

Separation of the resin from the pulp is typically done over a screen. Mostly the screens are vibrated and rarely are additional mechanical means, such as a worm screw, used to convey the resin over the screen. The discharged resin from the screen should fall directly into the Pachuca below as conveying resin is difficult, as it is sticky.

Pregnant (loaded) resin is continuously washed over a discharge screen in sorption prior to being transferred into the Washing Column. The purpose is to remove the slime layer and any residual pulp associated with the resin. If this was not removed it could contaminate the pregnant solution obtained from the stripping column. Typically the column would be operated in a fluidising mode to achieve adequate washing action between the resin beads.

The clean pregnant resin is transferred continuously to the top of the stripping column. The stripping solution passes counter-currently up the column. In continuous operation the concentration of the uranium in the pregnant solution is reasonably constant. This is in contrast to Fixed Bed ion Exchange in which there is a rapid increase in concentration followed by a trailing off in concentration towards the end of elution (stripping).

The stripped (barren) resin is transfer from the stripping column into a final wash column prior to being returned to the Sorption section. The purpose of this column is to remove any residual eluent on the resin. The wash solution leaving the top of the column contains considerable stripping solution which can be recycled back to the stripping solution tank.

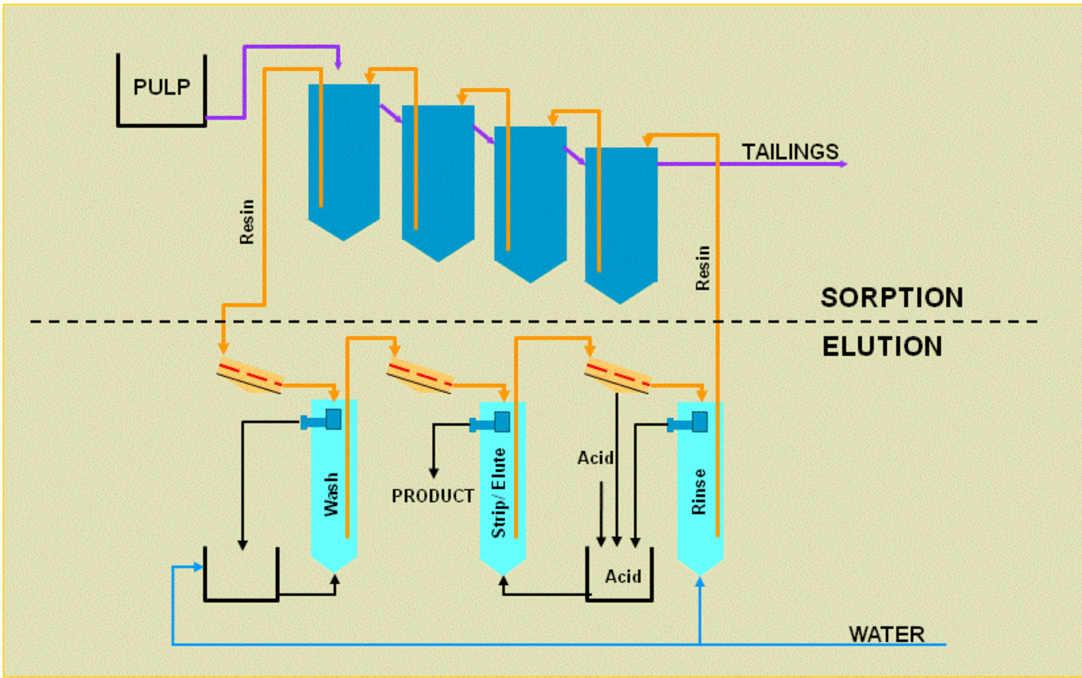


Figure 4: Schematic of a Continuous Resin-In-Pulp Plant

Typical operating conditions are provided in table 3. Every application is different but the data provided should be adequate for a first approximation of uranium recovery.

	Units	Value
Inlet feed concentration	ppm	120 - 800
Solids concentration	wt%	50 - 60
Resin : pulp ratio[volumetric flowrate]	-	1: 30 - 1: 100
Resin type		Macroporous Strong Base Anion Exchange Resin
Resin Selection		• DOWEX 21K 16/20, Dow • AMn All-Russian Research Institute of Chemical Technology • Amberlite IRA910U Cl, Rohm & Haas.
Resin size	mm	0.6 – 1.6
Resin density (hydrated)	SG	1.1
Slurry density	SG	1.5
Resin content in Pachuca	vol%	3
Pulp maximum size	mm	95% < 0.15
Resin residence time	h	10 - 72
Pulp residence time	h	3 - 6
Overall uranium recovery	%	90 - 99
Number of theoretical stages	-	2 – 4
Number of Pachucas	-	6 -10

Table 3: Typical RIP Operating Conditions

5. Resin Management Issues

As mentioned in the introduction, the successful design of a RIP plant needs to adequately address the following issues:

1. Scale-up from laboratory to full scale
2. Accurate transfer of resin, especially in sorption
3. Limiting the resin breakage and losses
4. Dealing appropriately with resin foulants and interferants

5.1 Scale-up from laboratory to full scale

In Figure 5, a typical McCabe Thiele construction is shown. The blue line is the uranium solution/ resin equilibrium line (also referred to as an isotherm) and the red line is the operating line. The figure predicts that roughly 4 theoretical stages would be required to achieve a recovery of 99% of the uranium feed. Recent work done at the Atomic Energy Organisation of Iran (1) indicates an efficiency close to 100%, based on a McCabe Thiele, could be achieved at pilot plant scale, provided that there is sufficient contact time and good agitation. This validates the equilibrium testwork that was conducted to produce the original equilibrium line, based on bottle-roll testwork or equivalent.

In scaling-up from laboratory size tanks to full-scale Pachucas (or mixing tanks), attention needs to be paid to both geometric similarity and dynamic similarity. In many cases it is not feasible to reproduce the same dynamic similarity on the larger scale. For example the capital cost of the required equipment or the impact of a higher tip speed on resin attrition may limit design options. This explains why the number of stages in a commercial plant are typically far greater than required, based on theoretical analysis.

Each system has unique properties but the Reynolds number has been found to be an important parameter in scale-up (8). [The Reynolds number is a measure of the ratio of inertial forces to viscous forces and is especially useful in the scaling-up of dynamic system in which mixing/ turbulence is a critical factor.]

Table 3 shows that the retention time required for the pulp in the Pachuca is far shorter than the time required for the resin. The pulp residence time is set by the mixing time. This is the time required to mix the feed pulp with the small amount of resin in the Pachuca. Although the reaction of the resin with the uranium on the surface of the resin bead is fast, the diffusion of the uranium from the surface into the interior of the bead is considerably slower. Consequently the resin residence time is considerably longer.

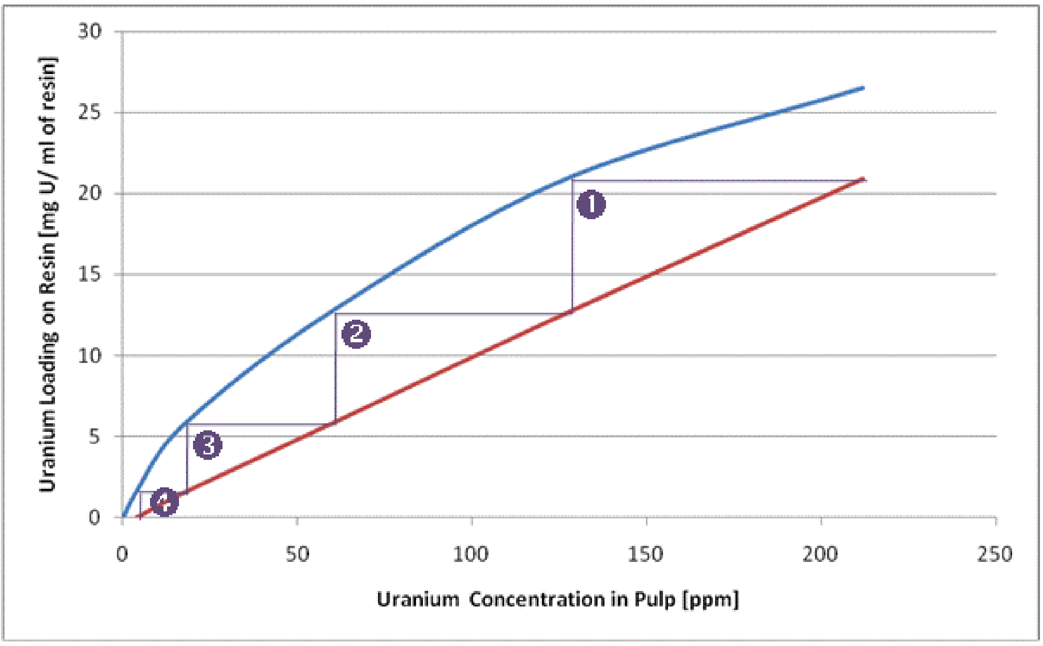


Figure 5: McCabe Thiele construction for a Uranium sorption isotherm indicating that 4 theoretical stages are required.

Typically mixing in the Pachuca is achieved by an air draft tube. This minimises resin attrition but does not impart the same mixing intensity compared with a mechanically assisted draft tube.

The injection of air into the pulp has the effect of reducing the apparent pulp density and aiding in the mixing.

The design of the draft tube, air lift or mechanical assisted, needs to find a balance between:

- Preventing the largest particles from settling out in the bottom of the Pachuca or mixing tank,
- Conveying the largest particles to the top of the draft tube, and
- Fully mixing the resin with the pulp as it typically would float as the barren resin is considerably less dense compared with the pulp.

5.2 Accurate Transfer of Resin

5.2.1 Standard Methods of Transferring Resin

Figure 4 shows the standard methods of transferring resin containing pulps or fluids. These are by air-lift, blowing, recessed impellor pump and eductor. Each of these is briefly described.

Air-lift is the most common method. The device has no moving parts and typically operates in a slug flow regime. The lift that can be achieved is dependant on the submergence. For low lift applications the required submergence is typically around 60%.

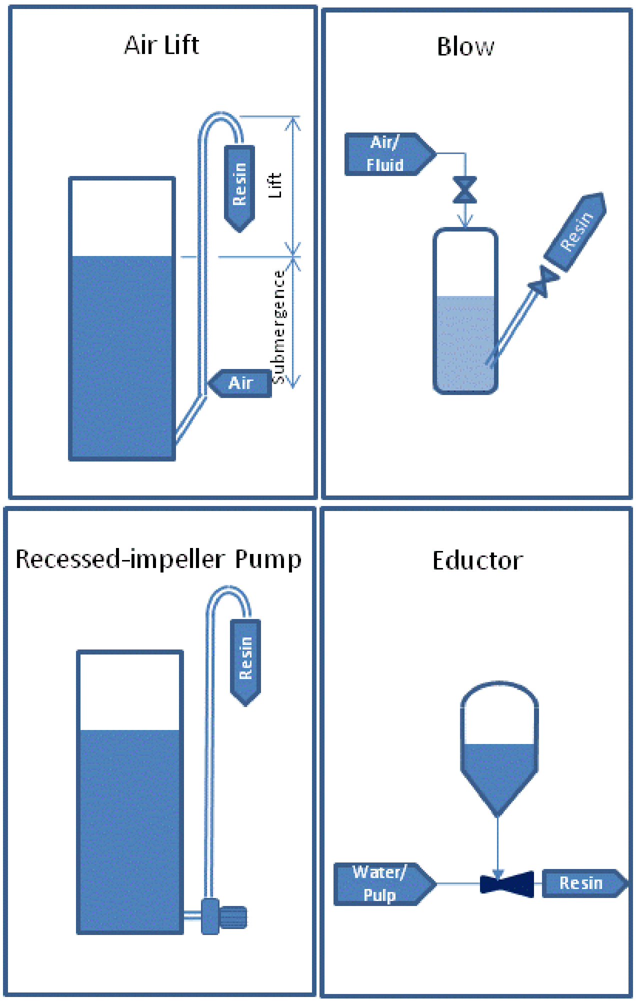


Figure 6: Methods of Transferring Resin

Blow tanks are typically used in batch applications where the full contents of the vessel are transferred. Sufficient water/ fluid needs to be in the vessel, a head of water/ fluid above the resin, prior to starting the transfer as the settled resin solids% is greater than the % solids when being transferred and if enough water is not available the resin will be dewatered and will not transfer.

Recessed pumps have been used extensively in gold CIP plants. The pumps are not very efficient and the maximum head developed is typically limited to 15m.

Eductors have typically not been popular. The amount of damage to the resin is reported to be higher than that for an air-lift and the devices are prone to blockage. Consideration also needs to be given to the source of the motive fluid and secondly the amount required to transfer the resin. The amount of fluid required can be significant and may have an impact on the plant water balance.

5.2.2 Resin Transfer Configurations

There are a large number of different technologies which have been used to transfer the resin and pulp. In this paper four scenarios are considered, namely:

1. Pumping the pulp and resin separately,
2. Combined pumping of pulp and resin and recycling excess resin,
3. Transferring the pulp by gravity and pumping the resin and
4. Carousel.

Pumping the pulp and resin separately (Russian)

This configuration is shown in figure 7a. In this configuration the pulp/ resin mix is airlifted at a set flowrate and dumped onto an internal screen. The pulp passes through the screen and flows by gravity to the next stage (stage n+1). The resin is returned to the vessel.

The resin is airlifted separately and dumped on the screen of the (n-1) stage and the pulp transferred with the resin and is returned to the original stage (n).

This is essentially the configuration described in the Russian literature.

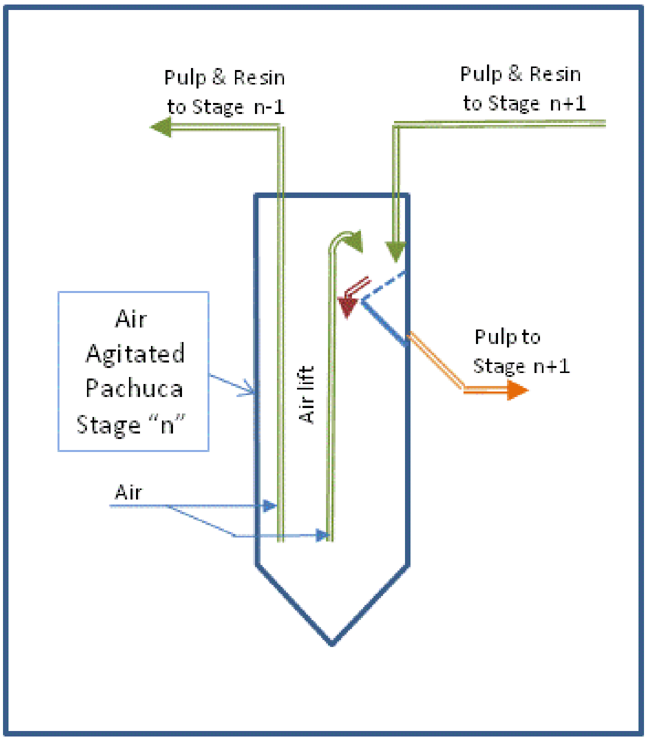


Figure 7a: Russian Resin Transfer Configuration

Combined pumping of pulp and resin and recycling excess resin

This configuration is shown in Figure 7b. In this configuration a single air lift pumps a set amount of resin and pulp and dumps it onto a screen. The pulp passing through the screen flows under gravity to stage (n+1). The majority of the resin is recycled to the current stage (n) and the remainder passed to a mix tank where it is combined with pulp from stage (n-2) prior to flowing by gravity to stage (n-1). This configuration is known as Screen-Mix.

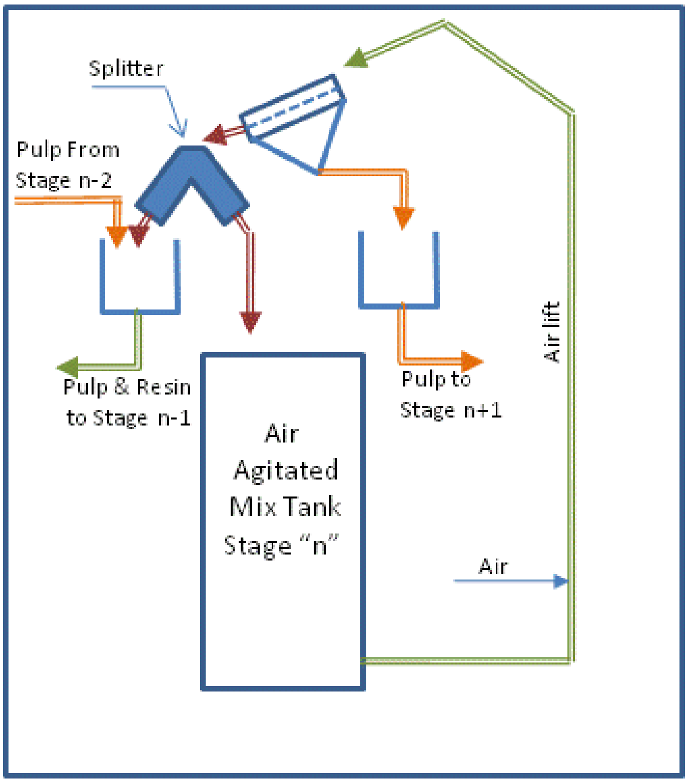


Figure 7b: Screen-Mix Resin Transfer Configuration

Transferring the pulp by gravity and pumping the resin

This configuration is shown in Figure 7c. This configuration shows the pulp passing through an interstage screen and flowing by gravity to the next stage (n+1). The resin is retained in the current stage (n). Depending on the properties of the pulp and its tendency to agglomerate the resin, cleaning of the interstage screen may be required. Typically this is done using a wiper or using compressed air.

The resin is transferred either by airlift or an eductor as shown in Figure 6c (essentially the Bateman Metrix process). Pulp is used as the motive fluid to minimise the requirements for additional water. This pulp should be separated by screen as shown to minimise the backmixing of the pulp in the previous stage.

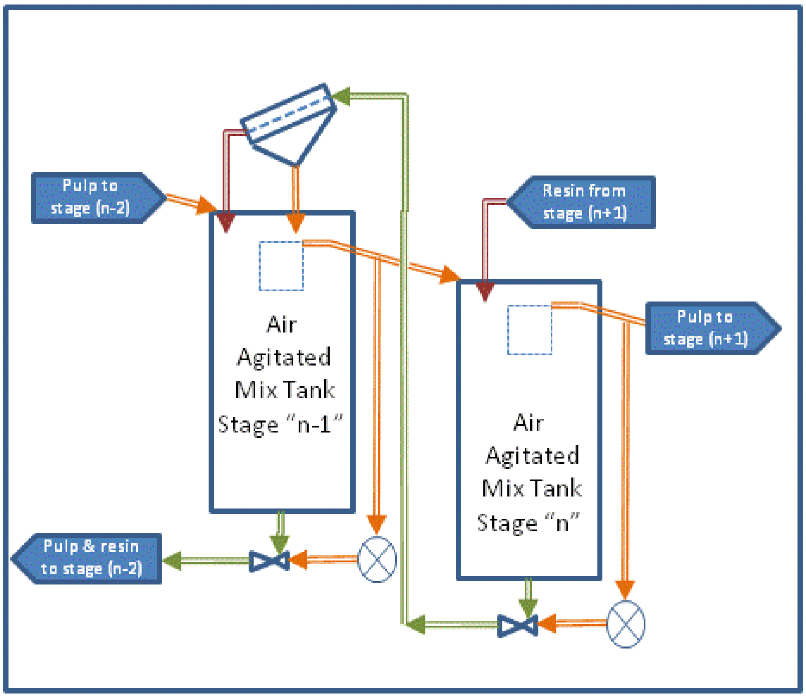


Figure 7c: Eductor Resin Transfer Configuration

Carousel

The Carousel RIP plant also consists of a series of sorption tanks but the resin is retained in a vessel as shown in Figure 7d. As shown in Step 1, feed pulp is shown entering the first vessel and passing sequentially through vessels 2 and 3 prior to disposal of the barren pulp to tailings.

After a period of time the resin in vessel 1 is fully loaded with uranium. The feed is re-directed to vessel two as shown in Step 2. Vessel 1 is emptied and the resin/ pulp mixture is passed over a screen to recover the resin. The resin is stripped of the uranium in the elution section of the plant and the barren resin is returned to vessel 1 ready for sorption in Step 3.

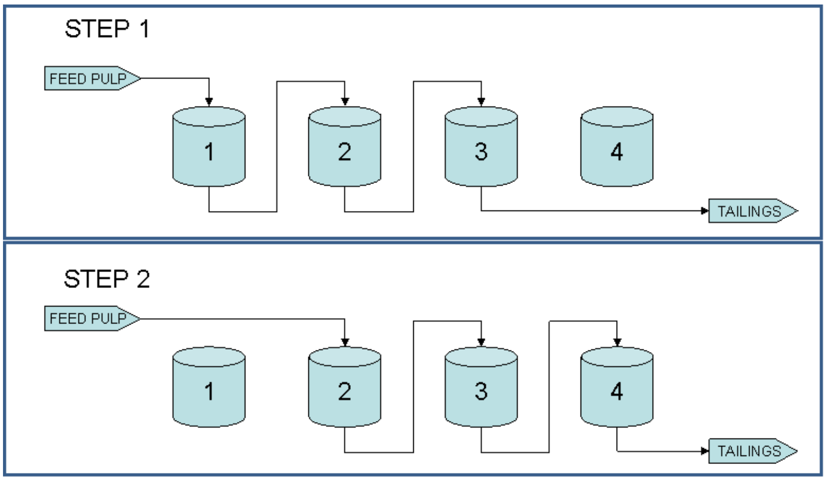


Figure 7d: Carousel Configuration

This configuration has the advantage of minimising the resin handling and damage to the resin. However there is significant time required to drain the tanks, strip the resin and transfer it back to the original vessel. This can be longer than the cycle time of the process. This configuration also has added complexity compared with the configurations mentioned previously.

5.2.3 Measurement of Resin Flow

Measurement of the resin flowrate does not appear to have been done. Instead the resin concentration in the vessel is commonly measured. This involves taking a grab sample of resin and pulp and washing the sample over a screen. The resin concentration was calculated based on the volume of sample taken and the amount of resin in the sample. This is the same type of testing as done for gold CIP.

Bateman has developed an instrument which essentially does the same test automatically. The analysis is extremely useful in predicting trends rather than absolute resin concentrations. The reason for this is due to variations of the homogeneity of the resin/ pulp in the vessel.

Mintek (4) developed an ultrasound method to measure resin concentration is an air-agitated vessel in 1986. The results were promising provided that the pulp density could be maintained within close range and there was no change to the air diffusion pattern.

In most plants there are typically 6 -10 stages. “Small variations” in the amount of resin in a stage will not have a noticeable effect on the overall sorption efficiency.

5.3 Limiting the resin breakage and losses

The amount of resin which needs to be replaced continues to be a topic of considerable discussion. Due to its cost, operators are keen to minimise the amount of resin which needs to be replaced. This has put considerable pressure on resin suppliers to provide a resin which is more robust than competitors and also to justify Ion Exchange being selected in preference to Solvent Extraction. It also may explain the difference in supplier's quoted resin losses versus the actual losses reported by operators. Table 4 summarises some of the data which has been published on resin losses in operating plants or pilot plants. Due to differences in the resins used, the solids contents and other factors there is a wide range in reported resin loss.

Reference	Solids%	Resin Type	Annual Breakage %
Relix (3)	61	Dowex 21K	36 – 168
Rőssing (2)	7	Dowex 21K	8
Maybell (5)	30 - 35	Not known	20 - 30

Table 4: Reported Resin Consumption

There are a couple of reasons for the discrepancies between the resin supplier data and the losses reported in operating plants. The first reason is that there are number ways in which resin may be lost, of which attrition is one mechanism. The mechanisms by which resin is lost from the system include:

1. Mechanical damage during resin transfer and screening
2. Attrition in sorption
3. Osmotic shock (mainly in elution)
4. Physical loss from the system

A second reason for the discrepancy is the lack of a proven test method to quantify resin attrition. A number of test apparatus have been tried including a ball mill and hydraulic cylinder. Further work needs to be done to develop a test which provides meaningful attrition data applicable for RIP.

To limit the mechanical damage in resin transfer, the air lift has been widely used. This is preferred to centrifugal pumping and eductors. The disadvantage of the air lift is cost. Typically an air lift efficiency is only around 30%.

The recessed impellor pump has been used and typically the impellor speed has been limited to below 1,000 RPM to minimise resin attrition.

The separation of the resin from the pulp is typically done over a screen. The screen is typically a vibratory inclined type and no additional water is added. Indications in the literature are that the attrition on the screen may, in certain circumstances, be significant. For this reason it may be more beneficial to increase the amount of resin in each stage rather than increase the frequency of resin transfer between stages.

There are a number of resins now available which are reported to be more robust compared with older style resins. To limit the attrition a resin should be selected which has the highest abrasion/ attrition resistance while still having adequate adsorption capacity for uranium. In general, a smaller resin bead size is more robust and offers better kinetics but is more difficult to separate from the pulp due to the smaller difference in size between the resin beads and the pulp particles.

To summarise the resin loss issue the following points are useful:

1. Resin is a consumable and will need to be replaced. It is no different to any other reagent used in the plant.
2. In fixed bed systems resin could potentially last for a considerable amount of time but there would be a gradual reduction in the loading capacity. Some sources report a reduction of 10% per year.
3. Resin-in-pulp will result in higher attrition. It is recommended that sensitivity analysis be run for resin losses in the range of 20 – 50% per annum(6).

5.4 Dealing appropriately with resin foulants and interferants

It is necessary to distinguish between fouling and interference. Foulants are compounds that adsorb or coat the resin and are not easily removed by the normal regeneration procedures and lead to a reduction in the overall capacity of the resin.

Interferants are ions or molecules which compete for exchange sites. They may be more selectively adsorbed compared with the uranium ion or in significant levels. Common interfering anions include:

- Chloride
- Carbonate/Bicarbonate
- Sulfate/Bisulfate

A typical series of ion exchange selectivity for anionic complexes in acid leach solution is shown below. These complexes are ranked from the greatest affinity to lowest affinity.

$V_2O_7^{-4}$ > $Mo_8O_{26}^{-4}$ > $UO_2(SO_4)_3^{-4}$ > $UO_2(SO_4)_2^{-2}$ > $Fe(OH)\ (SO_4)_2^{-2}$ > SO_4^{-2} > $Fe(SO_4)_2^{-1}$ > NO_3^{-1}

At the adsorption conditions under which the selectivity data was collected, uranium is not the most selectively removed. However by changing the amount of free acid, pH or temperature, for example, the selectivity for ionic species is likely to change. Ideally the selectivity for uranium should be highest and the selectivity for the interfering ions should be low.

Foulant	Remedy to reduce fouling	Remedy to remove foulants
Iron (Fe3+)	Reduction to ferrous which does not generally interfere with the resin.	In the event of complex salt or scale formation acid wash usually successful at removing the iron.
Silica	Keep pH < 4 to prevent ion exchange mechanism within resin.	Aggressive contacting with caustic solution may be useful.
Molybdenum	Can be removed using activated carbon or a suitable resin.	Fouls the resin over time due to precipitation of complex molybdenates within the resin matrix
Organics	Organics can adsorb onto and into the resin, making them hydrophobic and reducing loading capacity.	Clean with non-ionic surfactants, alternatively a mixture of brine and caustic soda.

Table 5: Typical Foulants of Ion Exchange Resin in Uranium Applications

In table 5 some of the common foulants of uranium ion exchange resin are presented. By appropriate treatment of the feed slurry to RIP, many of the potential foulants can be either eliminated or their effect reduced. Over time there is likely to be a reduction in resin capacity as a result of resin fouling. Table 6 provides an initial indication of how these foulants may be removed from the resin.

6. Summary

The use of Ion Exchange in Uranium recovery has been used since the first commercial plants were constructed in the 1950's. Due to its perceived benefits, Solvent Extraction has largely become the technology of choice even though Ion Exchange Plants have in certain instances been shown to have a lower capital cost.

With the renewed interest in uranium, there has been a renewed interest in ion exchange. A brief history of development of uranium extraction technologies is provided, including CIX (Continuous Ion Exchange) and RIP (Resin-in-Pulp). Compared with the other ion exchange technologies, RIP has two major advantages.

1. not requiring a solid/ liquid separation step which could result in a reduction of between 20 – 40% of the capital cost,
2. reduction of the uranium in tailings to below 5 ppm.

This paper discusses the four main design issues for a RIP plant. These are:

1. The importance of achieving geometric and dynamic similarity in the scaling up from pilot plant size to full scale plant.
2. Accurate transfer of resin, especially in sorption. This involves selecting the best method to transfer that limits resin damage but achieves a reliable transfer.
3. Limiting the resin breakage and losses by choosing the best resin for the application. The paper proposes that a standard method be adopted for the testing of resin attrition which is meaningful in the design of a RIP plant. This should produce reliable data from which sensitivity analysis can be run.
4. Dealing appropriately with resin foulants and interferants.

With recent developments in resins and RIP technology

Acronyms

Acronym	Description
CCD	Counter-Current Decantation
CIX	Continuous Ion Exchange
iX	Ion Exchange
RIP	Resin-in-Pulp
FBIX	Fixed Bed Ion Exchange

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