SHORT COURSE

Uranium Ore Processing

Presented by

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Notes

COMMON URANIUM MINERALS

Type	Name	Composition
Oxides	Uraninite* Pitchblende*	$(U^{+4}_{1-x},U^{+6}_{x})O_{2+x}$ UO_2 to $UO_{2.25}$
Hydrated oxides	Becquerelite Gummite	$7UO_2.11\ H_2O$ Alt. product of uraninite. (May contain silicates, phosphates)
Nb-Ta-Ti Complex oxides	Brannerite* Davidite*	$(U,Ca,Fe,Th,Y)(Ti,Fe)_2O_6$ $(La,Ce,Ca)(Y,U)(Ti,Fe+^{3})_{20}O_{38}$
Silicates	Coffinite* Uranophane Uranothorite* Sklodowskite Uraniferous Zircon	$U(SiO_4)_{1-x}(OH)_{4x}$ $Ca(UO_2)_2(Si_2O_7.6H_2O$ $UThSiO_4$ $(H_3O_2)Mg(UO_2)_2(SiO_4)_2.2H_2O$ $ZrSiO_4$

Primary Minerals*

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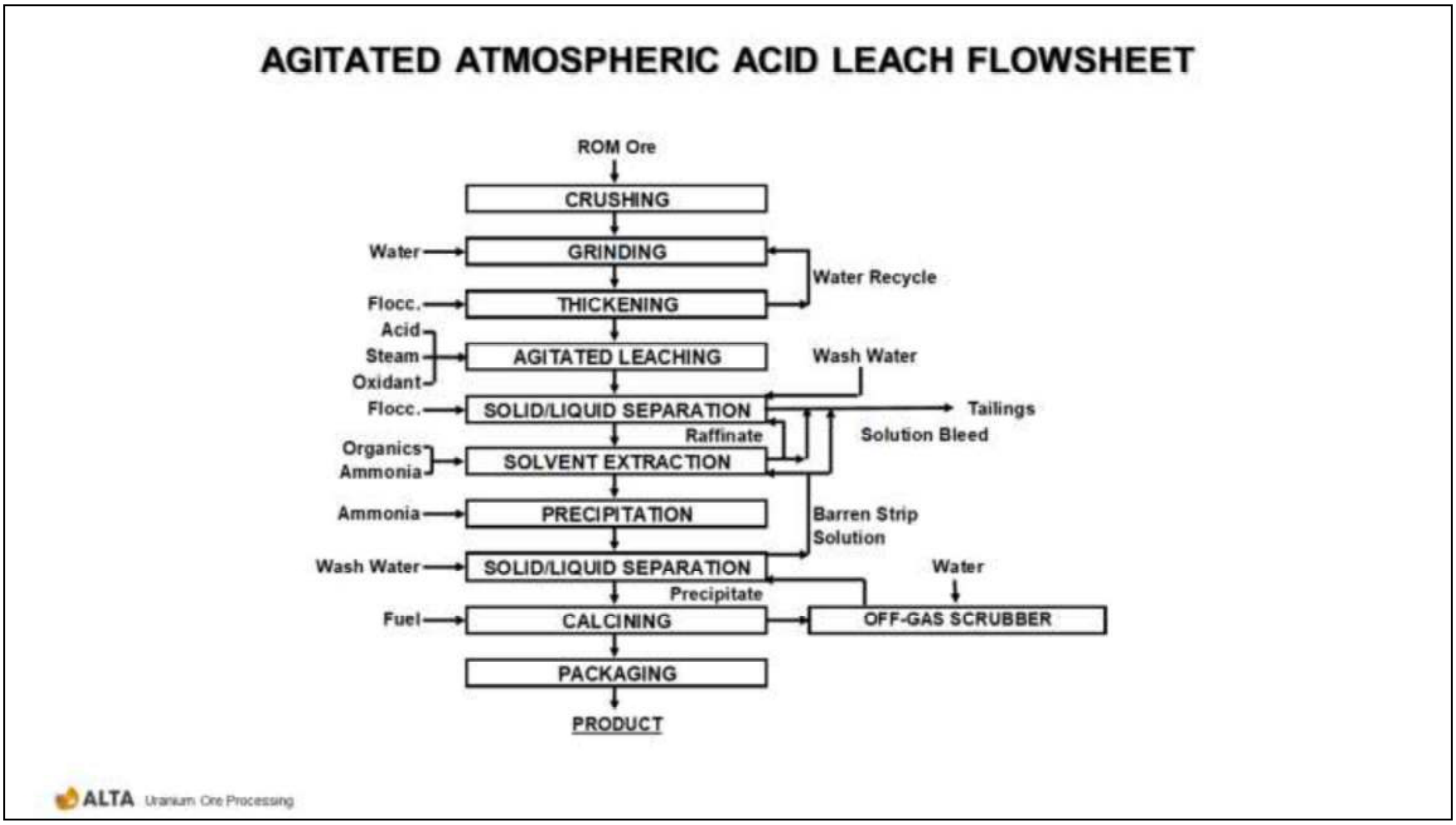
Typical Uranium Content of Economically Important Minerals

Mineral	Formula	% U
Pitchblende	UO_2 to $UO_{2.25}$	86-88
Uraninite	$(U^{+4}_{1-x},U^{+6}_{x)}O_{2+x}$	46-88
Uranophane	$Ca(UO_2)_2Si_2O_7.6H_2O$	55
Carnotite	$K_2(UO_2)_2(VO_4)_2.3H_2O)$	53-55
Subagalite	$HAl(UO_2)_4(PO_4)_4.16H_2O$	54
Tyuyamunite	$Ca(UO_2)_2(VO_4)_2.8H_2O)$	49-54
Autunite	$Ca(UO_2)_2(PO_4)_2.10H_2O)$	48-50
Torbenite	$Cu(UO_2)_2(PO_4)_2.10H_2O)$	47
Coffinite	$U(SiO_4)_{1-x}(OH)_{4x}$	40-60
Brannerite	$(U,Ca,Fe,Th,Y)(Ti,Fe)_2)O_6$	26-44
Uranothorianite	$(ThU)O_2$	<40
Betafite	$U_2(TiCb)_2O_6(OH)$	15-24
Uranothorite	$(UTh)SiO_4$	<10
Davidite	$(La,Ce,Ca)(Y,U)(Ti,Fe^{+3})_{20}O_{38}$	<5

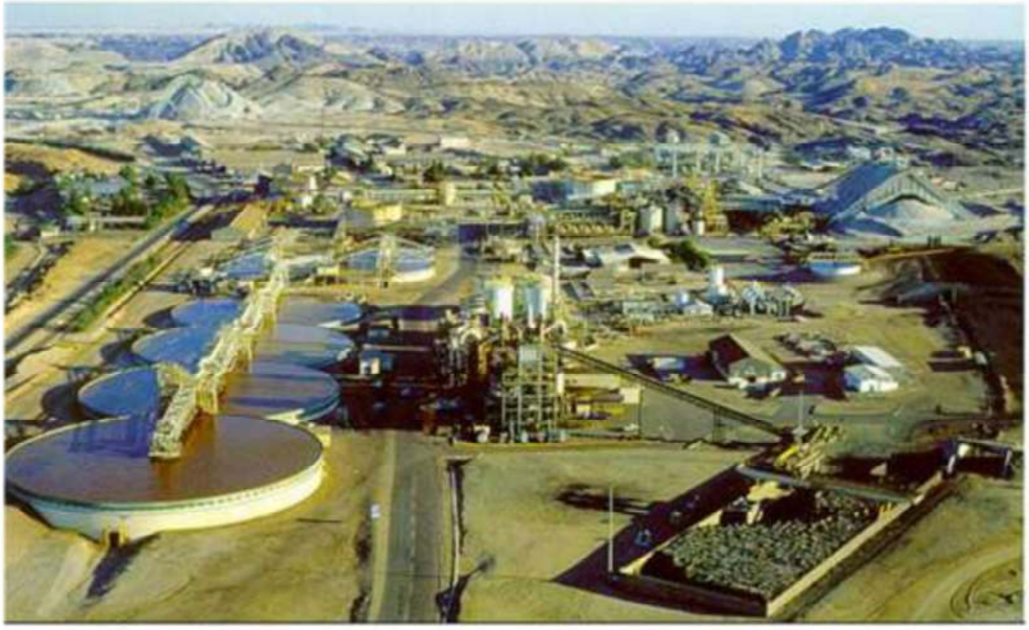


Notes

1. A thickener is generally included after grinding to increase the pulp density ahead of leaching. Alternatively, a filter may be used depending on the overall water balance.
2. Most acid leaching operations incorporate a CCD or filtration step for solid-liquid separation, followed by solvent extraction using a tertiary amine.
3. Mixer-settlers are still the most common SX equipment though pulsed columns are gaining acceptance. The solvent extraction system frequently includes one or more scrub stages to deal with particular impurities.
4. The ammonium sulphate stripping process has been widely applied, followed by ammonia precipitation and calcining in a multi-hearth furnace. The alternative of strong sulphuric acid stripping and precipitation with peroxide can have process and environmental advantages.
5. The acid leaching-CCD-solvent extraction route has been commonly adopted for plants in Australia including the currently operating Ranger and Olympic Dam facilities.
6. Ion exchange has been used in some cases instead of solvent extraction, especially for lower grade ores. Ion exchange can be particularly useful for systems with difficult solid liquid separation characteristics, either by operating with unclarified solution or as a resin-in-pulp system. Ion exchange has been commonly followed by solvent extraction to form an Eluex arrangement. A current example is the Rossing plant in Namibia, where coarse material is split off from the leached pulp and washed. The pregnant leach solution containing fines is treated in a multi-stage ion exchange circuit followed by solvent extraction. Resin-in-leach has been applied in Russia.
7. There are a number of alternatives to ammonia sulphate stripping. For example sodium chloride is often used when molybdenum is present. Also, a strong acid strip has been applied in Canada to avoid the release of ammonia to the environment.

ROSSING URANIUM AGITATED ACID LEACH OPERATION, NAMIBIA

(Ref: Cognis presentation, ALTA 2009)



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1. Rossing Uranium Limited is a member of the Rio group of companies.
2. Plant started up in 1976, and produces 4,000 tons per year of U_3O_8 from 13 million t/a of ore with a grade of about 0.03% U_3O_8.
3. Ore is crushed, ground and leached in dilute sulfuric acid. Uranium is extracted from unclarified CCD overflow solution with a multi-stage Porter fluidized bed CIX system followed by amine SX. U_3O_8 is produced by conventional ammonia precipitation followed by dewatering and calcining.

HEAP LEACH OPERATION, NIGER

(Ref: Areva presentation, ALTA 2012)

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BEVERLEY ISL OPERATION SA

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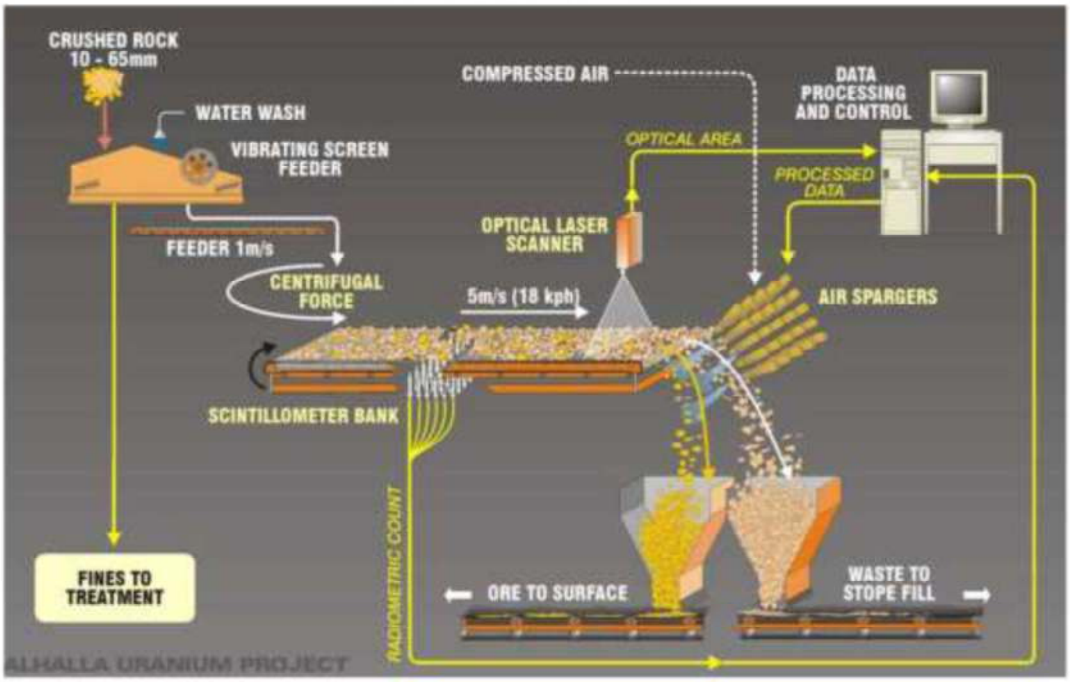
1. Located in far north of South Australia, Heathgate Resources (General Atomics, USA)
2. Sandstone type deposit; three ore lenses in unconsolidated sands; 100-300 m depth over 4 km of paleochannel.
3. Grade 0.18% U_3O_8;; at least 21,000 t recoverable U_3O_8.
4. Water in aquifer is too saline for animal or human consumption.
5. Field trial and EIS in 1998; construction in 1999; operational in 2000.
6. 2004 Production 1084 tonnes U_3O_8; 1,500 projected from 2009.
7. Acid leach at pH 2 with peroxide oxidant. Recovery is by IX in fixed bed columns, then elution with sodium chloride-sulphuric acid, followed by peroxide precipitation, dewatering then drying. Product is hydrated uranium peroxide ($UO_4.2H_2O$).
8. Leach solution 75-250 ppm U, 5.5 g/L Cl.
9. Process solution bleed is re-injected into approved disposal wells in a depleted portion of the deposit.
10. Satellite ISL operations have been established at Beverley North and loaded resin is transported to Beverley for final processing..
11. Beverley also Treats loaded resin from the nearby Four Mile acid ISL project, owned by affiliate Quasar Resources.

TYPICAL SYSTEM



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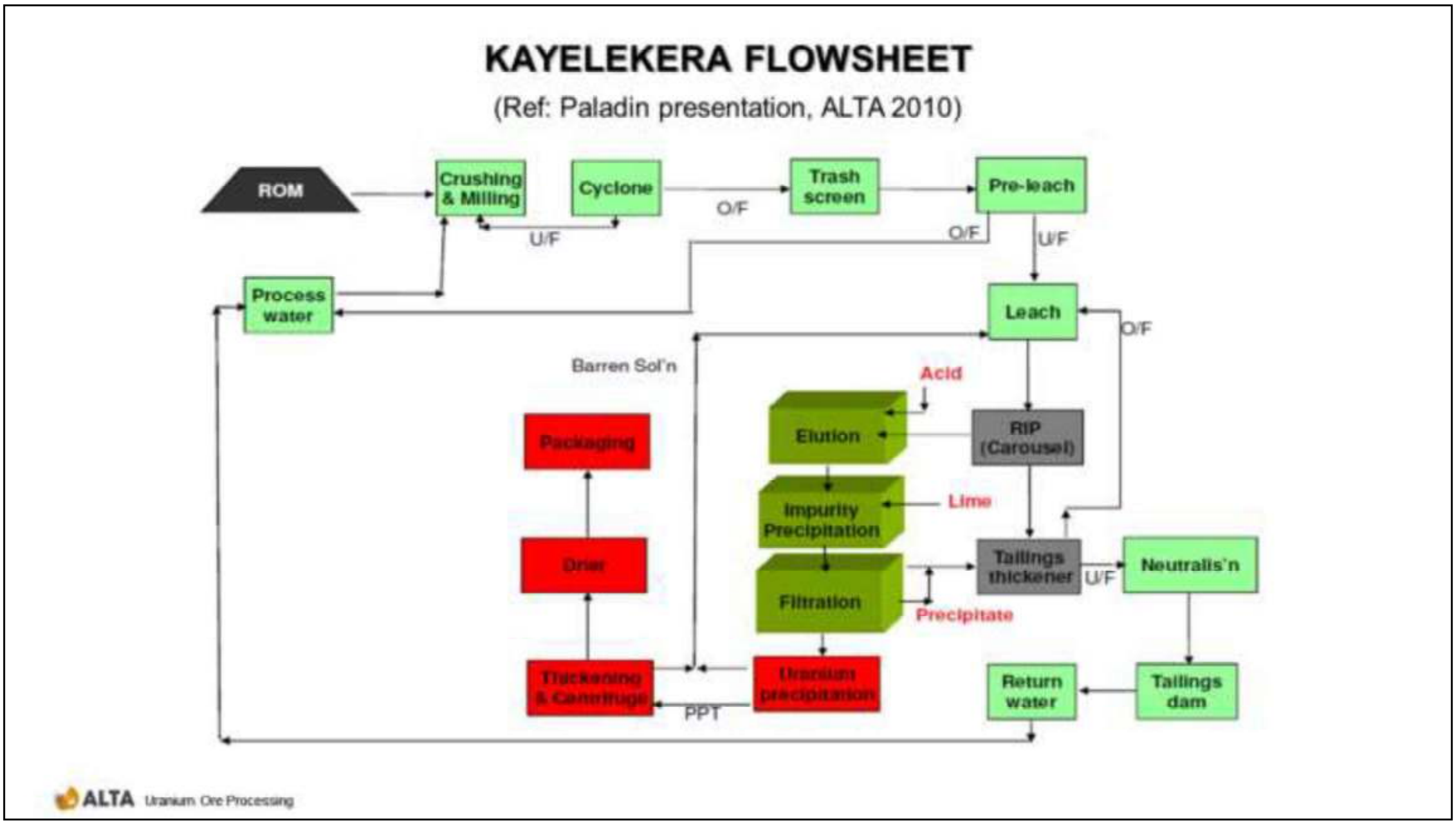

Notes

1. The Kayelekera plant comprises 10 such Kemix Pumpcell RIP units with 8 on-line at any one time. The two additional units would be off line and isolated, one of these would be in the process of transferring loaded resin to the elution circuit, while the second tank would be on standby for the receipt of barren resin. Once full of barren resin, this contactor is on standby to become the tail column.
2. When the resin in the head contactor is sufficiently loaded, that contactor is isolated and taken off line. The entire content of this contactor is pumped over a screen to clean and recover the resin which is then directed to the elution circuit for uranium recovery. The second contactor in the carousel sequence becomes the new head contactor and the contactor on standby containing barren resin is brought on line as the tail contactor.
3. Elution is carried out in a multi staged, counter current agitated tank system in a carousel arrangement. Eluant passes by gravity flow through the series of vessels.
4. Product recovery is by direct precipitation with peroxide after removal of some impurities by precipitation with lime. This is followed by thickening, centrifuging and drying in an indirect oil heated screw dryer. The dryer is maintained under negative pressure with the off gases routed to a condenser and dust collector system for product recovery.
5. Dried product gravitates into a product hopper situated underneath the dryer discharge screw. From there it is fed into 210 litre drums using a rotary feeder. The drums are sealed, weighed, cleaned, numbered and combined in batches of six and a composite sample is made for each batch.
6. A world first nanofiltration system designed by BMS Engineers, Perth, was added in 2013 for recovering acid from eluate prior to precipitation. An average of 56% of the acid is recovered and the consumption of neutralizing agent reduced by over 58%.