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Past and Present Applications of Synroc

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Classes of Nuclear Waste

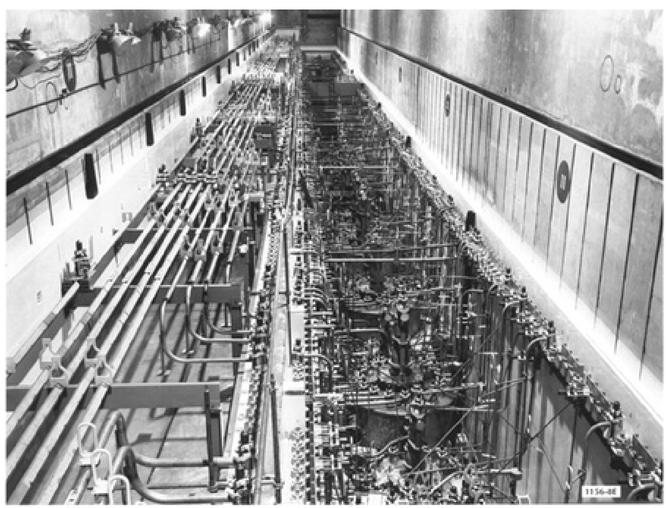
- Low-level (mining waste, hospital wastes; less than 100 MBq/L)
- Intermediate level (secondary wastes from nuclear power plant operations; more than 100M Bq/L)
- TRU= actinide-bearing waste having > 100 nCi/g (for example 1.6 ppm of ^{239}Pu or 140 ppm of ^{237}Np)

(1Ci = 37GBq)

- High-level: spent power plant fuel or reprocessing waste ~10^{13}-10^{14} Bq/L

HLW

- Spent fuel in storage (many thousands of MT from the ~400 power reactors worldwide)
- Acidic liquid wastes from reprocessing fuel (~1000 Ci/L)
- Defence wastes from Pu production (~ 1 Ci/L; millions of litres in US). Neutralised for storage in SS tanks but tank leakage can occur and gas buildup a problem-mostly process chemicals

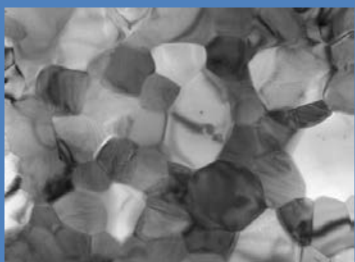


Savannah River Site -- interior of canyon

Waste Forms for HLW

- Via the addition of certain materials, produce by chemical design a near-water insoluble solid (**the waste form**) plus minimum secondary waste.
- **Requirements**:
  - Relatively easy to fabricate, even though intensely radioactive (no dust or liquid spray)
  - Low volatility losses of RN during processing
  - High waste loading
  - Nearly insoluble in a range of hot and cold groundwaters

Types of Wasteforms

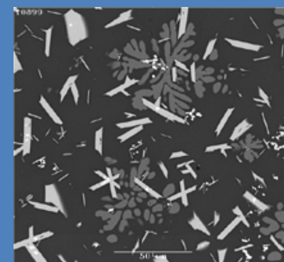


Ceramic

- HLW / ILW
- Lattice substitution
- 10^{-5} g/m²/d

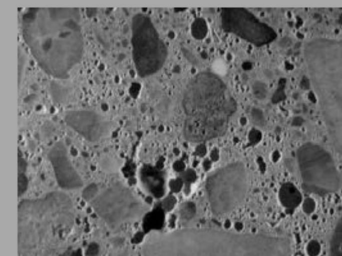
Glass

- HLW / ILW
- Glass network incorporation
- 10^{-3} g/m²/d



Glass Ceramic

- HLW / ILW
- Composite glass-ceramic
- Elements targeted to either ceramic or glass
- 10^{-3} - 10^{-5} g/m²/d



Cement

- LLW
- Continuous porosity
- Diffusion release
- Waste ions located in pore water

PAST APPLICATIONS

Synroc Titanate Minerals

Composition and mineralogy of synroc-C (20 wt%)

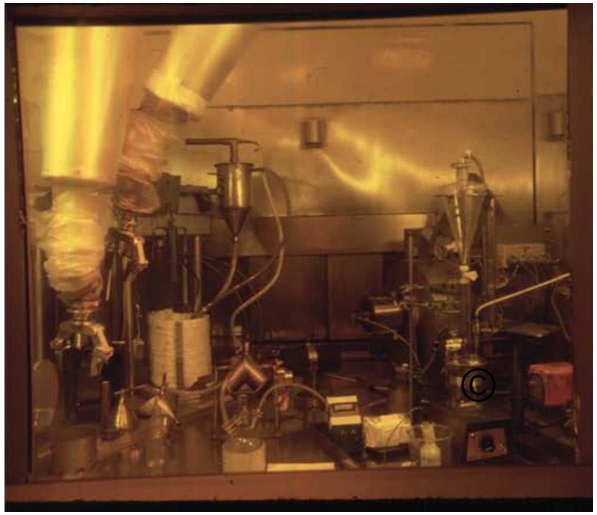
- Much more leach resistant in water than silicates and phosphates of supercalcine
- 10-100 times more resistant than borosilicate glasses in short-term MCC-1 tests

Phase	Wt.%	Radionuclides in lattice
Hollandite, $BaAl_2Ti_5O_{14}$	30	Cs, Rb
Zirconolite, $CaZrTi_2O_7$	30	RE, Zr, An
Perovskite, $CaTiO_3$	20	Sr, RE, An
Ti oxides, mostly TiO_2	15	none
Alloy phases	5	Tc, Pd, Ru, Rh, Mo, Ag, Cd, Se, Te

Synroc Titanate Minerals

- 1980s Original synroc-C and its processing technology developed
- Specifically targeted towards immobilising high level waste (HLW) from the reprocessing of spent nuclear fuel from power reactors (PUREX type PW-4b type waste)
- Synroc technology was not sufficiently mature to compete with borosilicate glass (US DOE decision in 1981 to immobilize SRNL HLW in borosilicate glass)
- Glass became the defacto baseline process for the immobilisation of HLW.

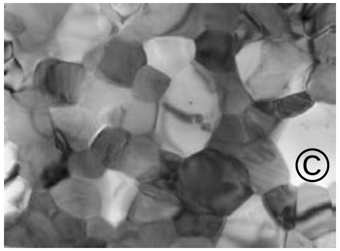
SDP – conceptual plant (1980s)



What makes waste problematic for glass

Switch in focus to "problematic" wastes

- High concentrations of refractory metal oxides like alumina and zirconia
  - → low waste loadings in pourable borosilicate glasses
- Require high processing temperature
  - → increase in volatile fission product loss
- Chemistry – viscosity / conductivity / crystallisation
- Corrosive off-gas (eg. HCl)
- High concentrations of toxic and radioactive elements
- Relatively low waste loadings achievable (plutonium / U).
- Harder to extract fissile material
- Orphan wastes where volumes are low



ANSTO Synroc – HIPing

DEMONSTRATOR HIP

Benefits from HIP route:

- Zero emissions from high temperature densification
- Significant waste volume reduction (impact on long term storage)
- High density with minimal temperature (grain size)
- Versatile - Capable of producing a wide range of waste forms
- No contact between waste and process equipment

Excess Weapons Plutonium Immobilization

- Excess impure weapons Plutonium
- Project in the 1990s with US Labs

Competitively selected by the US DOE to immobilize excess impure weapons plutonium in 1997

(*written into the Waste Acceptance System Requirements Document*)

Idaho National Laboratory Calcines

Waste Description:

- 4400 m^3 heterogeneous calcine, consisting of layered binsets (alumina, zirconia, zirconia-sodium blends reflecting different reprocessed fuel assemblies)

Alumina Calcine	Zirconia Calcine
~90% Al_2O_3	~50% CaF_2
~5% alkali	~25% ZrO_2
~3% HgO	~15% Al_2O_3
	~0-8% CdO

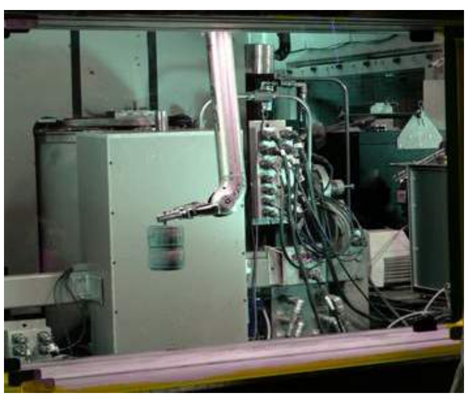
Calcine challenges for glass…

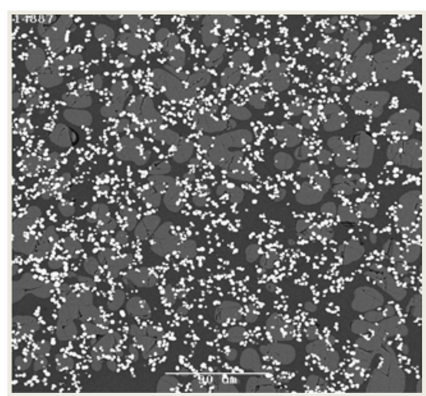
- Low solubility in glass
- Detrimental to glass properties e.g viscosity
- Corrosive to melter or off-gas system.

Impact is to significantly reduce maximum achievable waste loading for glass, What about a glass-ceramic waste form.

Idaho National Laboratory Calcines

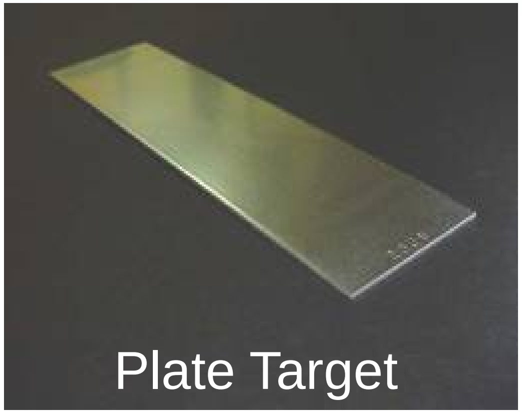
Consolidation:	HIP		JHM
Matrix:	glass-ceramic		borosilicate glass
Waste loading:	**60-90%**		**20-35%**
Durability (PCT-B):	10-100 x EA glass		10 x EA glass
Final volume: (relative to untreated calcine)	15-45% reduction		100+% increase
Temp:	1300°C	2009	1150°C
Pressure:	100 MPa		-
Off-gas:	very low		medium-high

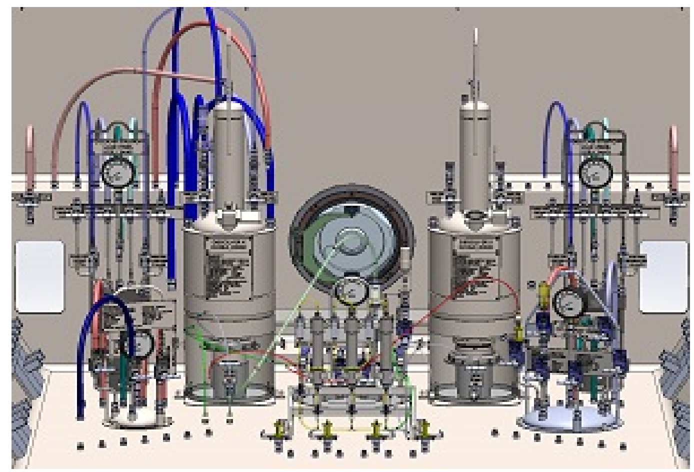




PRESENT APPLICATIONS

ANM Production Cycle





Dissolution, Filtration and Initial Ion-exchange Purification: ILLW

Synroc Intermediate Level Liquid Waste Treatment Plant Project

~5000L/yr of ILW to treat

necsa

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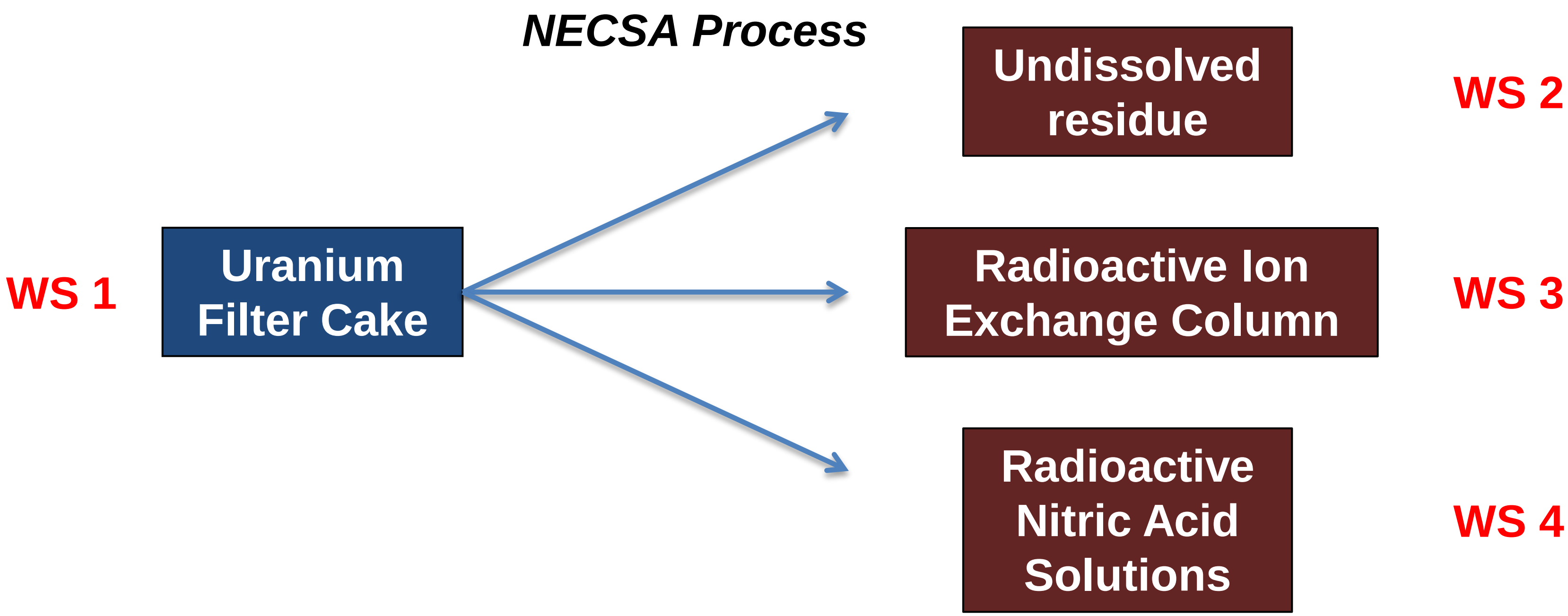
ANSTO Synroc – NECSA Project

- Funded by U.S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA)
- The demonstration of practical and economically feasible technologies to treat the waste arising from Mo-99 production
- Nearly all of the Mo-99 is produced in reactors by irradiation of HEU targets
- Provide an additional incentive for conversion to an LEU process
- NECSA
    - Legacy HEU wastes arising from the Mo-99 recovery process that meets the NNSA's non-proliferation objectives
- ANSTO Synroc
    - Extensive waste form expertise
    - Knowledge and capability waste treatment technologies

ANSTO Synroc – NECSA Project



ANSTO Synroc – NECSA Project

Work Order 1

- Benefitted from differing expertise

Waste Characterisation → Wasteform Design

Work Order 2

- Phase 1:

    Over 100 small scale samples fabricated

    All characterised

    Measured against pre-established evaluation criteria

    ~ 15 formulations recommended for scale-up

ANSTO Synroc – NECSA Project

Work Order 2

- Phase 2:

  Up-scale to ~ 1 L (up to 6 L)

  All characterised and evaluated

  Some up to 80 wt.% waste loading

  and 60% volume reduction

  U-extraction from final HEU-bearing

  wasteform

Only feasible technology to process all Mo-99 wastes is either HIP or vitrification.

CURRENT RESEARCH PROJECTS

- FLiNaK pyroprocessing waste
- AgI sodalite (with NNL) and CuI
- CRADA
- Engineered waste form for spent fuel
- HIPed wasteform revisit from 1990s PIP project

Conclusion

- Focus on waste that is problematic for vitrification
- Working toward cost estimates for Mo-99 production wastes using LEU.
- Substantial progress is being made in several projects, notably immobilisation of ANM waste

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Thank you