Management of Research Reactor Spent Nuclear Fuel

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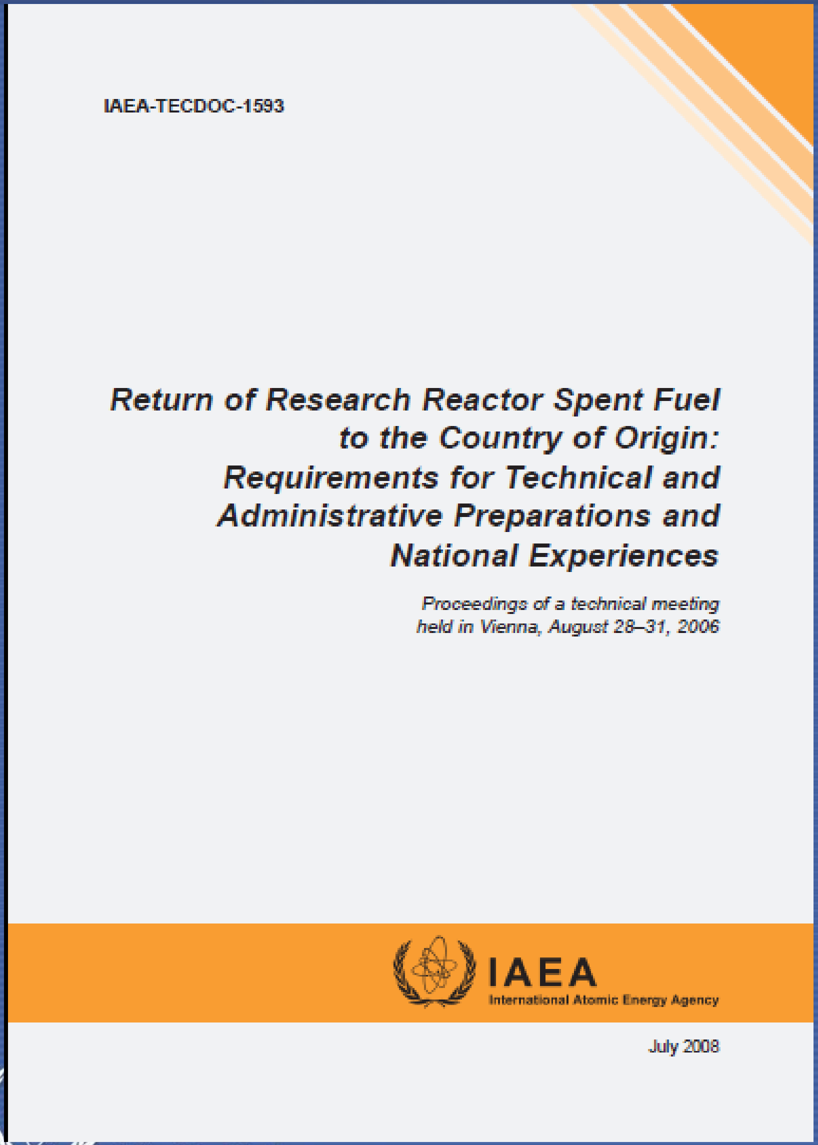
IAEA
Atoms for Peace: The First Half Century
1957–2007

Content of the lecture

- Overview of RR fuel types
- Options for management of research reactor spent nuclear fuel (RRSNF):
  - Reprocessing
  - Repatriation
  - Disposal
  - Storage
- Summary

Main References



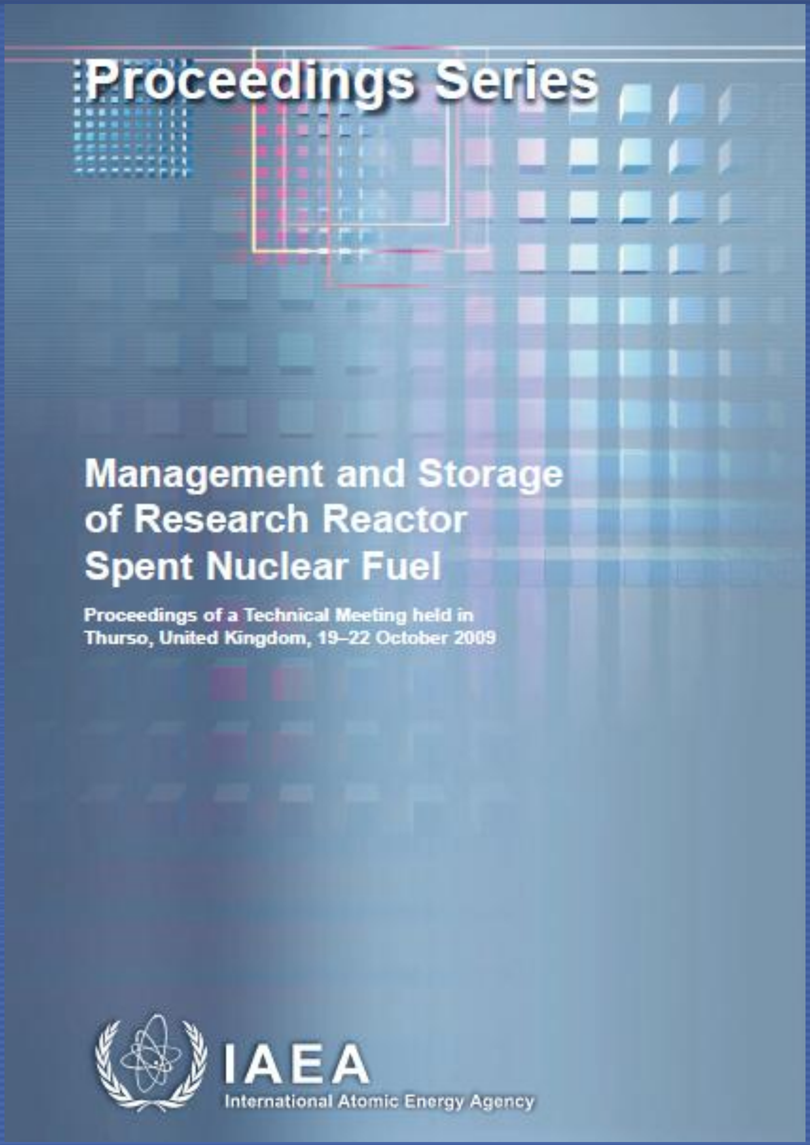
IAEA-TECDOC-1593

Return of Research Reactor Spent Fuel to the Country of Origin: Requirements for Technical and Administrative Preparations and National Experiences

Proceedings of a technical meeting
held in Vienna, August 28–31, 2006

IAEA
International Atomic Energy Agency

July 2008



Proceedings Series

Management and Storage of Research Reactor Spent Nuclear Fuel

Proceedings of a Technical Meeting held in
Thurso, United Kingdom, 19–22 October 2009

IAEA
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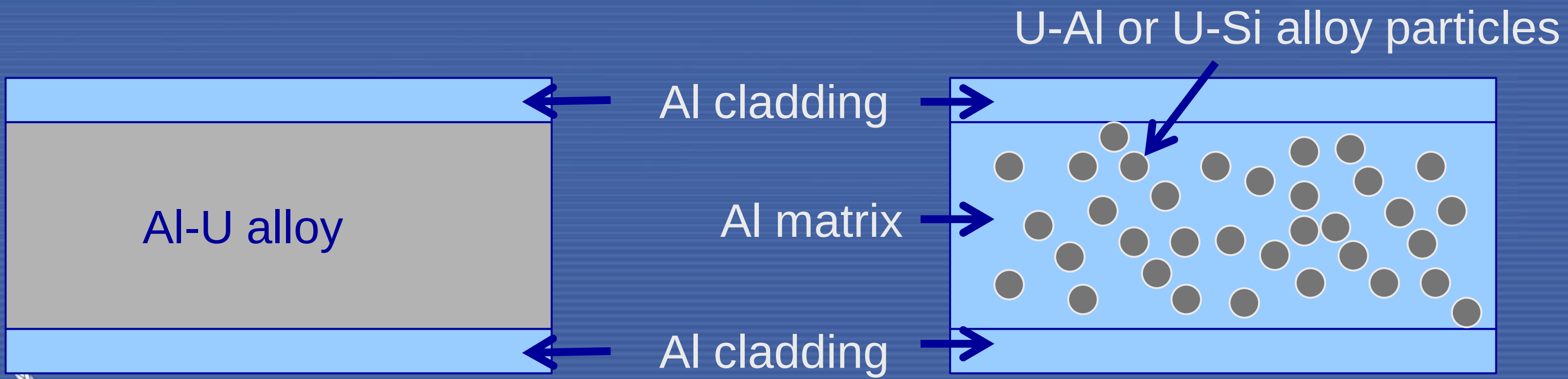
Research reactor fuel types

Research reactor fuels (Australia)

Reactor	Reactor Type	Fuel
MOATA 100kW	Argonaut teaching reactor Light water cooled and moderated. Shut down	60-90% HEU Al-U alloy, Al clad
HIFAR 10 MW	DIDO-type MTR Heavy water moderator & primary coolant. Shut down	60-90% HEU U-Al alloy dispersed in Al matrix & clad in Al Later converted to <20% LEU
OPAL 20 MW	Open pool light water MTR In operation	<20% LEU U-silicide dispersed in Al & clad in Al



TRIGA fuel (Indonesia)

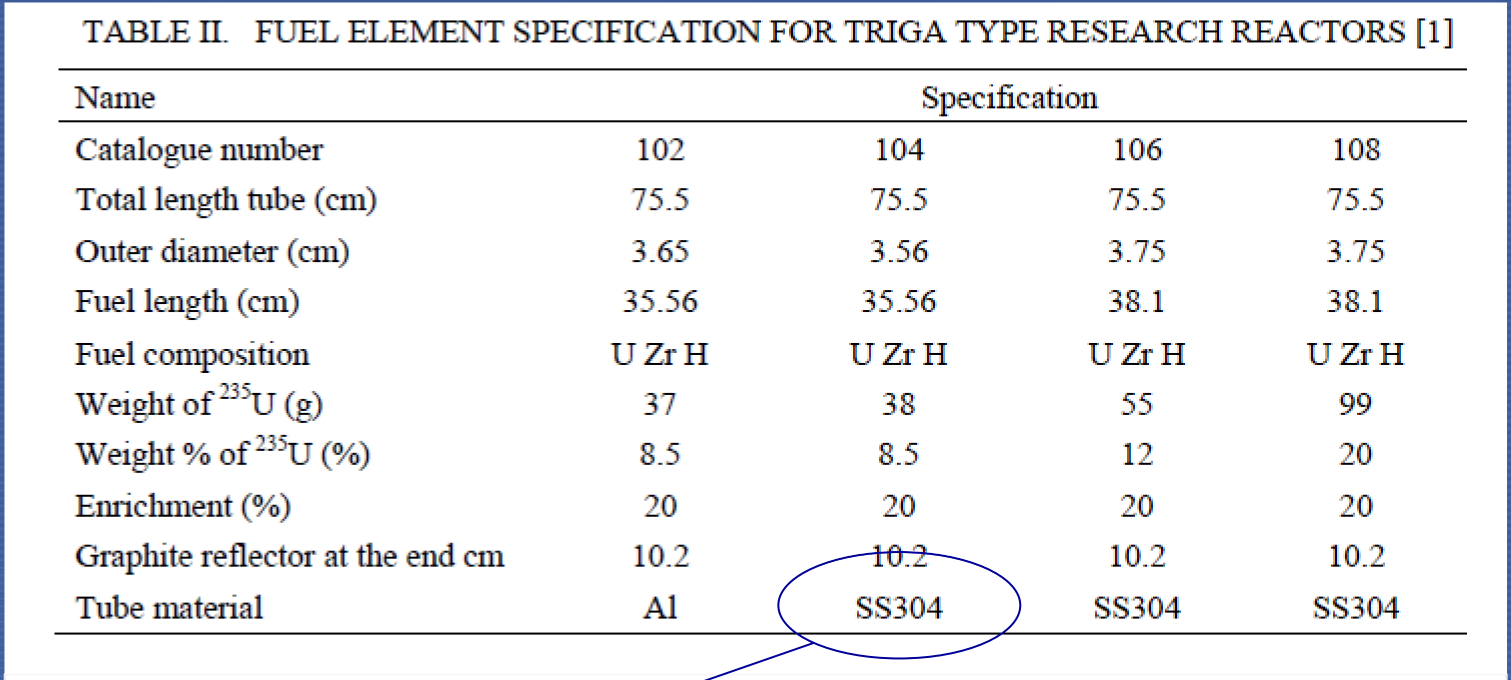


TABLE II. FUEL ELEMENT SPECIFICATION FOR TRIGA TYPE RESEARCH REACTORS [1]

Name	Specification			
Catalogue number	102	104	106	108
Total length tube (cm)	75.5	75.5	75.5	75.5
Outer diameter (cm)	3.65	3.56	3.75	3.75
Fuel length (cm)	35.56	35.56	38.1	38.1
Fuel composition	U Zr H	U Zr H	U Zr H	U Zr H
Weight of ^{235}U (g)	37	38	55	99
Weight % of ^{235}U (%)	8.5	8.5	12	20
Enrichment (%)	20	20	20	20
Graphite reflector at the end cm	10.2	10.2	10.2	10.2
Tube material	Al	SS304	SS304	SS304

304 stainless steel (18% Ni, 8% Cr)

MANAGEMENT OPTIONS FOR RRSNF

1. Reprocessing

What is Reprocessing?

- When uranium fissions it produces energy and fission products. Some of these FPs are so-called “neutron poisons”
- These prevent further fission from occurring by absorbing neutrons that would otherwise sustain the chain reaction
- Consequently, when a fuel core is exhausted much of the U-235 and almost all of the U-238 remains intact
- Reprocessing is the means by which uranium and plutonium (which is produced in reactor from U) are removed so that they can be reused
- This is done by dissolving the fuel in hot acid and then separating the uranium and plutonium chemically
- The remaining FPs are left in solution as HLW. This is usually evaporated to dryness and then dissolved in borosilicate glass

Reasons for Reprocessing

- 40-50 years ago it was assumed that, by 2000, there would be thousands of NPPs. This would increase the demand for uranium and, given a limited supply, it would increase the price
- Reprocessing was seen as a strategy against this
- Reprocessing also produces plutonium which could be used to fuel fast reactors. Fast reactors can be "tuned" to produce more fuel than they consume (hence the alternative name "breeder reactor")
- Anticipating these developments, reprocessing plants were constructed
- In the event:
  - The expected expansion of nuclear power did not happen
  - Fast reactor technology was found to be difficult and expensive and, in addition, there were fears over security and possible proliferation of nuclear weapons
  - To avoid an accumulation of plutonium in storage, some of it was put into MOX fuel as a substitute for U-235. This requires modification of NPPs, raises additional safety and security concerns and is more expensive than standard once-through fuel

Sellafield reprocessing plant and vit-HLW

Reprocessing of RR SNF

- Available for NPP fuel and standard types of MTR fuel but rarely for RR fuel e.g. TRIGA fuel has only been reprocessed at demonstration scale
- Political and economic issues related to export/ import of fuel and wastes be very difficult to overcome
- Even if it were possible, what would be done with the resulting HLW?
- Transportation costs (for fuel and waste) may be prohibitive and controversial

Key questions to ask

- Assuming that reprocessing and transportation are available and affordable, two key questions to be addressed are:
    - What is to be done with the reprocessed fissile material (uranium and plutonium)? Can it be used for the fabrication of new research reactor fuel elements or sold for other peaceful uses, and will the reactor owner get a credit for it?
    - The volume of the resulting HLW from the reprocessing will be significantly less that that of the original fuel. What is to be done with it?
        - kept by the reprocessor?
        - returned to the reactor owner? Is this legally possible?
        - Is there suitable storage available? What about disposal?
- Conclude from all this that reprocessing will seldom be a practical option

2. Repatriation

- return to the vendor country
or the country where the fuel was enriched

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Repatriation - return of RR SNF to the country where it was enriched

- two international RRSNF take-back programmes exist:
  - the USA Foreign Research Reactor Spent Nuclear Fuel (FRRSNF) acceptance programme and
  - Russian Research Reactor Fuel Return (RRRFR) programme.
- major goal is to eliminate inventories of Highly Enriched Uranium (HEU) and have been very successful in this respect
- only available for USA and Russian origin fuels plus fuels classified as “gap material”. These routes are not available if the uranium was not enriched in USA or RF
- Not unusual for countries to wet store RRSNF for more than 20 years pending an expected political decision that could allow the inclusion of the material in one of the two take-back programmes.
- no established deadline for the RF programme
- US take-back programme will cease in May 2016; could be extended but certainly not indefinitely
- **clear that many countries will face the problem of finding their own solutions**

Repatriation – lessons learned

- Must identify, from the beginning, the relevant decision-making authorities and establish a very good communications;
- Special attention needed to “non technical” issues such as negotiation of contractual matters, safeguards, managerial activities, security, budget, cost scheduling and public relations;
- Important to have strong coordination and collaboration between the local Organization and staff of receiving body;
- Need for centralized and vertically organized scheme – someone in overall charge
- Integrate shipments whenever possible – reduces organizational and transport costs
- **Most of all – start early!**

3. Disposal

Disposal of RR SNF

- RR SNF (or HLW if reprocessed) is long lived and heat producing - will require geological disposal
- SNF/ HLW volumes are no more than a few cubic metres, often, very much less. Disposal in a dedicated geological repository is probably uneconomic and affordable by few countries
- No countries are currently planning to dispose of HEU – it will be new technology. Disposal of aluminium cladding and metallic uranium could be problematic because of gas generation
- Deep borehole disposal is a possibility but the technology is not well developed (IAEA Borehole Disposal Concept is unsuitable for SNF)
- Another long-term possibility is a regional or multi-national repository – many countries are hoping for this option and work is ongoing but there are many obstacles to be overcome

4. Storage

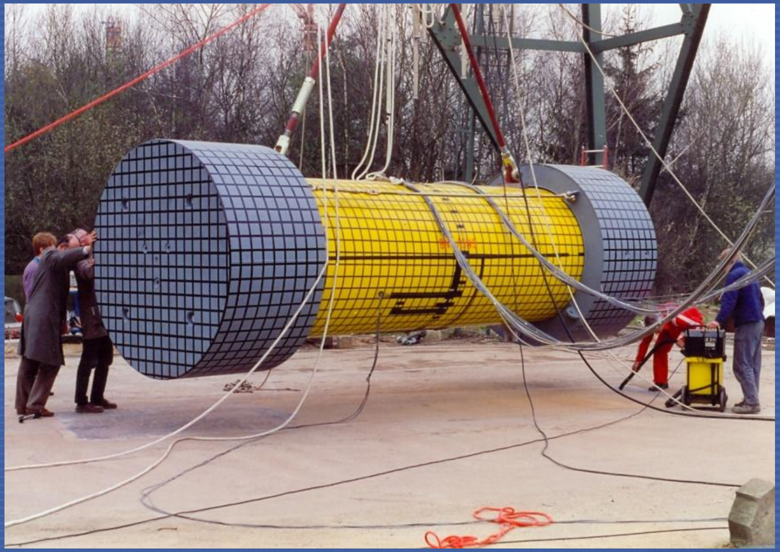
Storage – general points

- All storage is “interim”
- All storage should be retrievable – preferably, easily retrievable
- Fuel will need some form of treatment prior to disposal eg overpacking
- An important aim in storage is to preserve the integrity of the fuel (and its storage vessel if one is used) throughout the storage period. Failure to do this could make the fuel non-retrievable or else unsuitable for future packaging steps. This means that environmental conditions during storage are likely to be crucial
- We consider three forms of storage:
  - Dry
  - Wet and
  - Semi-dry

Dry storage of RR SNF

- Fuel may be held in vaults or casks
  - Vaults consist of reinforced concrete buildings (or modules) containing arrays of storage cavities
  - A cask is a sealed metal cylinder containing the spent nuclear fuel, and which may or may not be suitable for transport.

HLW store Sellafield



Pollux Flask

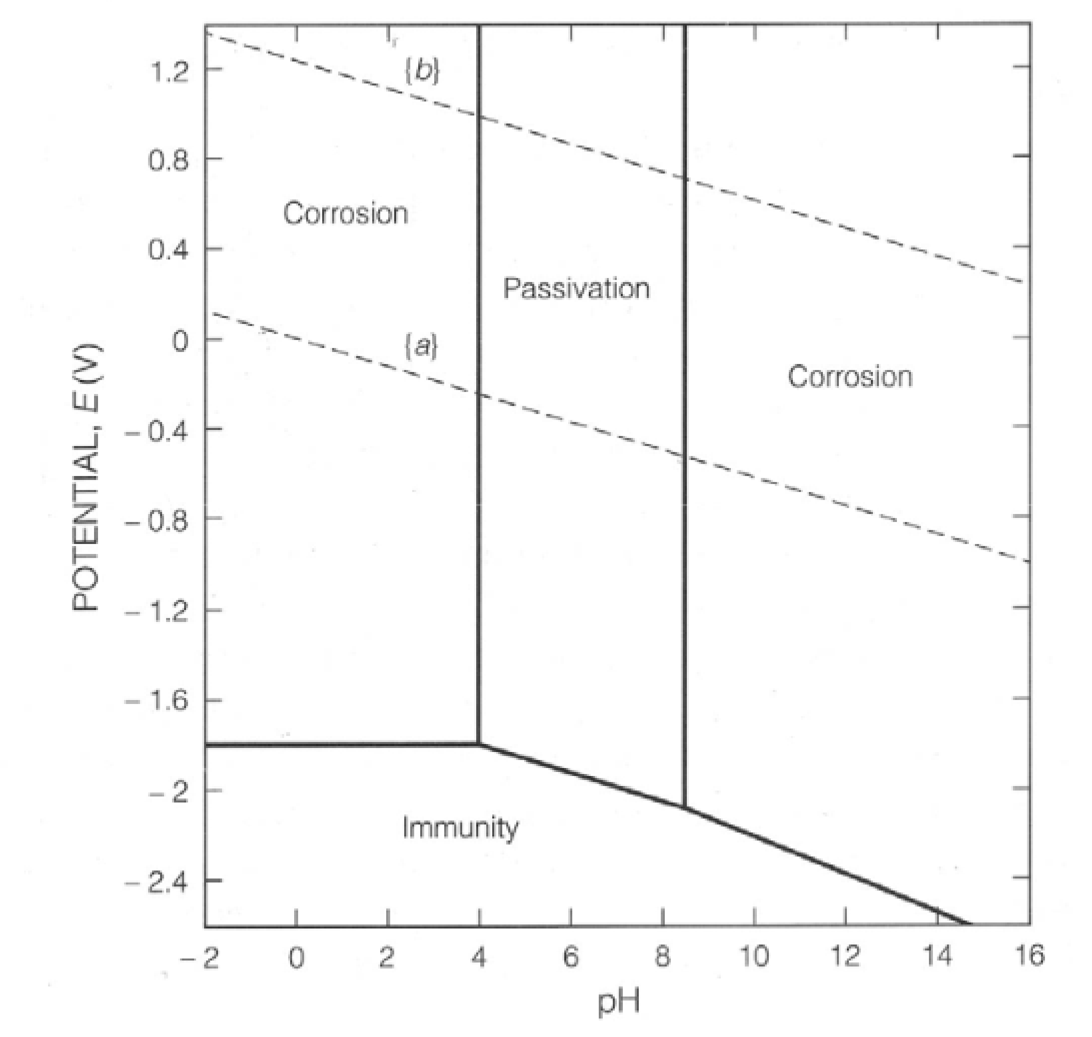
Dry storage of RR SNF

- Can require less active management through use of naturally circulating air – is thus more passively safe
- If the fuel is kept dry, corrosion should be minimal. Difficulties may come due if fuel is fragile or inadequately dried – a particular problem with aluminium cladding which forms oxy-hydroxides containing bound water.
- Hydrogen can be produced by radiolysis of water or by metal corrosion under anoxic conditions – may lead to pressurization of casks
- Casks must be resistant to gas pressurization, radiation damage over periods of 50+ years. Qualification of casks (eg drop tests) is expensive
- Facilities tend to be complex and difficult to justify when the amount of fuel is small (say less than 10 fuel assemblies per year).

Wet storage of RR SNF

- Most research reactor storage pools were designed as service pools where the fuel would be kept only for about 10 years, in the expectation that another option would be available after that time.
- Nevertheless, in good conditions, aluminium clad fuel and aluminium pool liners have lifetimes in excess of 30 years of exposure to the water in the pool.
- To achieve this, good water quality is essential - conductivity, pH and ion concentrations must be controlled continuously
- Also need appropriate pool design and operation – good choice of racking materials, water circulation to avoid stagnant regions and water filtering to produce low solids content (eg airborne dust, corrosion products and precipitated salts) to avoid localised corrosion
- There are many cases reported of severe degradation of the fuel cladding due to poor water quality

Pourbaix diagram for aluminium (aqueous environment)



Semi-dry storage of RR SNF

- Fuel is removed from storage pool, dried and loaded into capsules – typically a stainless steel or aluminium tube
- Filled with inert gas, sealed by welding and leak tested
- Encapsulated fuel is returned to the pool for storage under water (hence the name “semi-day”)
- 50 years safe storage claimed even for fuel that previously exhibited significant corrosion
- Norway, Poland and Hungary have used this technology
- - is essentially a variant of dry storage and, like dry storage, requires hot cells for drying and encapsulation

Summary

Summary

- RR fuel is diverse and often clad with aluminium
- Four options for long-term management
  - Reprocessing - unlikely to be a practical option – expensive, produces new wastes that need to be managed and, in any event, not usually available for RRSNF
  - Repatriation - the preferred solution but often not possible
  - Disposal - the only true long-term solution but currently uneconomic
  - Ongoing storage - the default position but requires active management including, for wet storage, continuous control of water chemistry.

    Dry or semi-dry storage is more passive

    All forms of storage are temporary