Management and surveillance of aging underground storage site and aging Al-clad metallic uranium legacy fuel

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Norway is in the process of decommissioning storage sites with chemically unstable Al-clad metallic uranium legacy fuel and is doing preparatory steps for final deposition of the fuel.

Since the mid-60s IFE manages an underground storage site for canisters with spent, legacy fuel elements. The fuel was used from 1951 to 1967 in the first Norwegian research reactor JEEP I. JEEP I is decommissioned many years ago and has been replaced by other Norwegian research reactor. Documentation and knowledge of the legacy fuel are original design drawings with material specifications as well as in- and out-of-pile visual inspection records. Each JEEP I legacy fuel element consists of 2 Al-clad, metallic uranium fuel rods. Records give written information on each fuel element, namely on time in-pile, burn-up (<600 MWd/tU) and fuel element status as observed by visually during biannual interim inspections and after discharge. In the 50s and early 60s discharged JEEP I fuel elements were placed in a cooling pond. In the mid-60s the elements were transferred to dry canisters and placed in steel clad vertical pits in an underground storage site, where they are kept until today. One canister in each pit. In the early 80s, some pits and open Al-canisters were subjected to water ingress. Subsequently, the pits were dried and painted. Further, after >20 years storage all elements were cold and were repacked into new, dry, gas-tight stainless steel canisters with screw lid. The pits were kept sealed by IAEA until about 2008.

Figure 66: Spent fuel storage pits and example canister.

The main risks associated with storage of spent, chemically unstable Al-clad natural U metal fuel with graphite end plugs are:

- Radiation, if canister is lifted up from underground storage position.
- Contamination of surrounding environment by leakage from canisters, if water ingresses into defect canisters and fuel elements.
- Fire, if a (defect) fuel element is exposed to high temperatures, friction, mechanical shock, and free access of oxygen (to the U metal or UH_3).
- Explosion, if a critical amount of hydrogen gas is released instantly from a canister.

After the seal was taken off, a storage site inspection programme was performed including a full non-destructive and destructive examination of a stored fuel element. The fuel element selected had documented small defects caused by uranium metal corrosion. The fuel rod sample showed as expected in the uranium metal some small corrosion spot with oxidised uranium hydride UH_3.

Recognised issues to be worked on in the underground storage site after long time storage were:

- Unknown integrity of black-steel clad pits – unknown number of intact pits.
- Unknown integrity of stainless steel storage canisters, corrosion marks on their exterior, their interior atmosphere and leak tightness for hydrogen and uranium.
- Unknown number of canisters containing defect fuel elements.
- Unknown dose-rate profile alongside the canister axis.
- Unknown integrity of defect fuel elements and unknown fraction/percentage of corrosion product UH_3 present in defect Al-clad fuel elements. UH_3 formed at higher temperatures e.g. in-pile or in the early stages of fuel storage.
- Unknown amount of hydrogen in fuel canister from ongoing anaerobic corrosion/oxidation of metallic Uranium fuel, Aluminium cladding and from ongoing anaerobic oxidation of UH_3. (e.g. at lower temperatures during storage). During the long time “dry” storage a thin protective oxide layer formed, namely underneath the Al cladding on the reactive uranium and on the UH_3 corrosion products.
- Unknown extended of Wigner effect / fire in the irradiated graphite end plug.

The actual management programme for the storage site and the stored fuel includes:

- Maintenance and improvements to the infrastructure of storage site itself
  - maintenance of cracked concrete floor, crane, installation of air conditioning (temperature and humidity), ventilation, outlet filters, fire alarms, fire extinguisher,
- Surveillance and radiological monitoring of the air and ground in and around the storage site
  - radiation monitors, water sampling and radioisotope analyses,
  - environment analyses

- Characterisation and maintenance of storage pits
  - Check movability of canister in pits
  - Make canister movable in pits
  - Control water ingress
  - Wipe outer surface of canister clean and dry
  - Cleaning of pits for rust and removal of natural condensed water in the pits
- Characterisation and monitoring the dry storage itself, namely the canisters
  - Control all canisters with regard to leak tightness (pressure test/leak test) and corrosion (visual inspection)
  - Analyze environment inside the canister with respect to humidity and hydrogen (gas-sampling)
- Characterisation and monitoring of the fuel elements
  - Dose rate measurements and X-ray examination of the entire length of all fuel canisters to document the entire fuel element on integrity, corrosion attacks of the U-metal, and dose rate profile.

What are next treatment steps of the stored fuel? As known, the U metal fuel is chemically unstable. Uranium metal reacts with water and air and therefore cannot be placed in a repository without stabilization measures. The goal of all U-metal-fuel treatment and stabilization measures is to make the U-metal-fuel fit for final depository by transforming/oxidising chemically unstable U-metal and UH_3 into stable U-oxide. Stabilization can be achieved in a slow gas treatment (oxidation) or by wet chemical processing. Necessary preparatory steps prior to a transport abroad for stabilisation or reprocessing are

- Qualitative and quantitative documentation of the fuel inventory and defects in fuel and cladding, their location, volumes and sizes.
- Atmosphere control in canisters (dry storage). When ongoing corrosion with hydrogen production is observed the atmosphere in the canisters and fuel element has to be dried (vacuum dried) and changed into a slightly oxidizing atmosphere.
- Dismantling elements and perform size reduction measures of fuel rods in a controlled atmosphere (glove box or hot-cell).
- Repacking of fuel segments for transport.

The presentation shares experiences from characterisation techniques e.g. pressure testing, hydrogen measurements and x-ray examination of fuel elements.

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