Solutions for Disposal of Intermediate Level Waste in the UK-16693

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Introduction

GNS mbH is a competence centre owned by of the German utilities and tasked with the management of spent fuel and nuclear waste of all activity levels arising from operation and decommissioning of the commercial German nuclear power plants.
Waste management products and methods developed by GNS over the past decades are at present the standard solutions for their respective tasks in Germany. While regulatory environments in the nuclear industry vary strongly from country to country thus limiting the one-to-one portability of such established solutions, GNS has managed to offer its services abroad, with continuously growing success. Challenges and first results of GNS' activities in the UK are the subject of this paper.

GNS in Germany and UK

GNS was incorporated in Germany in 1974, to supply the German utilities with flasks for spent nuclear fuel and intermediate level waste. The main focus in those early days was the development of flasks using a material, which was not new, but rediscovered - as it where - for the nuclear sector: Ductile (spheroidal graphite) cast iron. The resulting trademarks CASTOR®, MOSAIK®, and recently GNS Yellow Box® for different types of cylindrical and cuboidal containers have become renown for being mechanically robust and commercially competitive.

Since then GNS has grown from a small start-up to a company with more than 600 employees and, today, is the main supplier of waste management solutions for all levels of radioactive waste in Germany.
Many solutions, which were developed over the years by GNS, are suitable for waste management challenges outside Germany and sometimes can open up much more efficient disposal concepts.

In the UK, GNS technology is used for creating disposable packages of ILW since 2009. Wet and dry waste has been packaged into two types of ductile cast iron GNS containers (DCIC) – the cylindrical 450 l capacity MOSAIK® and the cuboidal $3m^3$ GNS Yellow Box®. In total, some 600 containers have been delivered and are now being filled mostly – but not only - for the decommissioning program of the British Magnox reactor fleet. A number of packages have been conditioned into a disposable state in the UK using GNS waste processing technology. They are now in the final stage of certification for storage in the Geological Disposal

Facility (GDF) after having undergone the so-called Letter of Compliance (LoC) process.

To support all those projects locally, GNS has established a local branch office in Bristol, in the south west of England. The Bristol office coordinates activities of the waste management teams active in the UK and provides a customer front end for the German sales teams and conditioning experts.

Ion Exchange Resin at Sizewell-B

Sizewell-B is located on the North Sea coast in Suffolk County, some 100 miles north east of London. With an electrical power output of nominal 1200 MW to the grid, it is the most powerful British nuclear reactor. It is also the UK's only commercial light water reactor. The design is based on a 4-loop Westinghouse *Standard Nuclear Unit Power Plant System* (SNUPPS) with some modifications to adapt it, among other things, to British grid requirements. The reactor vessel was built by Framatome and GEC Alsthom supplied the two 660 MW power generators. Construction started in 1987 and the plant was first synchronised to the grid in 1995. Since then, no further nuclear power plants have been built in the UK.
At design stage, spent ion exchange resin was stored in two tanks in a dedicated *radwaste* building. Around 2005 that capacity had to be extended with a third tank, but projections showed that by 2013 all three tanks would have reached their maximum capacity at a total of some $25m^3$. Further extension was not feasible and this would ultimately have compromised power generation.

In 2008 a *Best Practicable Environmental Option* (BPEO) study was undertaken which looked at a number of options to remove and treat this waste stream:

- Cementation (the existing plant on site is not reliable)
- Capturing in a polymer matrix
- Wet oxidation
- Pyrolysis
- Hot super-compacting
- Dewatering in thick walled containers
- Cementation of the products from wet oxidation, pyrolysis, or hot super-compacting
- Storage of the product of wet oxidation, pyrolysis, or hot super-compacting in thick walled containers

These conditioning methods were evaluated by EDF using the following criteria:

- Technical readiness level
- Commercial viability
- Mobile plant technology
- Handling of radioactive substances
- Safety of operating personnel
- Minimisation of primary and secondary waste volume
- Transportability of containers
- Robustness of containers
- Reversibility
- Cost of conditioning and storage

As a result, GNS was awarded the contract for conditioning of 25 m³ bead resin into GNS-manufactured MOSAIK®II-15 ductile cast iron containers with subsequent dewatering. Part of the deliverables was the preparation of the buffer store including processing of some solid waste which had to be removed first and the installation of resin transfer systems from the 3 existing tanks.

Based on the received activity data a MOSAIK®II-15 as IP-2 type flask without Pb-shielding was selected. To condition all 25 m³ of material, 55 containers were needed.


Sizewell-B


FAFNIR® Control Panel


Docking onto FAFNIR®


55 MOSAIK® in Interim Storage

The necessary modifications and extensions to the resin transfer system were designed and installed successfully towards the end of 2013. To clear the buffer storage area some legacy waste was sorted into stainless steel drums. For this task a remote handling facility was installed in the *radwaste* building. After installation of the mobile GNS plants FAFNIR® and NEWA®, all 55 MOSAIK®II-15 were filled and dewatered. Suitability for final disposal was successfully demonstrated to the disposal authority RWM Ltd.

FAFNIR® and NEWA® have since been packed into their 20' ISO freight containers and returned to Germany where they continue their work, treating operational waste in generating nuclear power plants and spent resin from full system decontamination of plants being decommissioned. But meanwhile, the extensions to the Sizewell-B transfer system remain permanent and Sizewell-B is thus ready to receive the mobile GNS plants for future batches of spent resin, then without any lengthy preparation work. We'll be back.

Drying of wet Intermediate Level Waste at Bradwell NPP

And so on to Bradwell. Some 50 miles down the coast south of Sizewell is one of the first commercial nuclear power plants ever built. Bradwell NPP is a station with two CO_2 cooled, graphite moderated reactors, fuelled with natural, metallic uranium. The non-oxidising magnesium-based cladding used for the fuel elements gave this type of reactor its name: Magnox.
Bradwell was first synchronised to the grid in 1962 after just five years of construction. At the time, it was one of only a handful of nuclear power plants worldwide. Its sibling Calder Hall had been the second commercial reactor on the planet only six years earlier. Bradwell then operated for 40 years without any noteworthy incident -- a safety record rather typical for the eleven Magnox plants built in Britain.
The station was shut down for the last time in 2002, defuelling completed in 2006 and it is now steadily moving towards safe enclosure, at present envisaged for late in the year 2017. At that time, all radioactive waste will have been packaged and all structures demolished, except for the two huge graphite blocks and the twelve boilers in their respective housings, all of which will be finally removed after a planned, maintenance free, 80-year decay period.

On the way to the safe enclosure state, GNS, among others, plays an important role in packaging and treating ILW for interim and - later - final storage. To reduce unwanted interactions between waste and containers as well as gas generation through chemical reactions or radiolysis, water has to be removed as far as possible.

FAVORIT® installed in Circulator Hall 1

The mobile GNS plant FAVORIT® does this using a heat assisted vacuum-drying process. Liquid waste is pumped into a shielded dosage tank inside the plant and then, in a second step, vacuum-lifted into six cylindrical flasks of type MOSAIK®. Part three of the process is the drying inside the flasks, via six independent, powerful vacuum-condenser units. An iterative top-up and dry process repeats these three steps until all MOSAIK® are sufficiently filled.

Extensive preparation work had to be undertaken on the designated location for installation of the GNS plant, one of the former circulator halls from where huge compressors had once pumped CO_2 into the reactor cavity. When the compressors, their concrete slabs, and all pipework had been removed and a new reinforced concrete floor had been poured, FAVORIT® moved in to begin its commissioning run in May 2013.
It was planned to condition some 40m^3 of sludge and ion exchange material (IEX) using FAVORIT®. To demonstrate achievement of a sufficiently dry end-point, a number of trial runs with inactive waste simulant were undertaken. In November 2013, trials concluded successfully and drying of the first active waste stream could begin. For sludge, a dryness end-point of less than 1% weight of residual moisture was achieved throughout the waste package, an important value below which microbial activity (a potential issue with that waste stream) largely ceases. IEX is dried until only chemically bound water remains, some 40% relative weight. Based on this evidence the LoC process for demonstration of disposability could be progressed to a point where all questions of the competent authority (RWM Ltd.) have been answered and the final letter of compliance is expected shortly.
In the second half of 2014 all sludge had been processed and at present (February 2016) IEX drying is still progressing.
By late 2015, however, it had become clear that the process could also be applied to a number of other waste streams, such as Miscellaneous Contaminated Items (MCI) and the output of a dissolution plant for Fuel Element Debris (FED), where FAVORIT® will probably assist with maximising waste processing capacity until the safe enclosure state of Bradwell NPP is reached.

Lessons Learnt in the UK

In Germany, the GNS plant have been inspected and optimised for their tasks in a process that included the operators of the power stations, independent third party assessors, and also the regulators over a period of more than 20 years. The systems are now certified for use on Nuclear Licensed Sites, according to §7 StrSchV, the German Radiation Protection Ordinance. This ensures access to German sites with relatively little paperwork, but is of no use whatsoever abroad. GNS had to go through a learning process on the way to establishing safety cases for the use of its plant in British nuclear licensed sites. In the multi-stage process of a Hazard and Operability study (HAZOP) a system will be scrutinised as if it has been purpose built for the specific task at hand. Operational experience (OPEX) over many years can sometimes be of little use. If the same plant were then moved for performing a similar task in another power station, that process can sometimes start almost from the beginning, depending, it has to be said, somewhat on the attitude of the individual stakeholders. The advantage of this approach is maximum scrutiny to detect and mitigate potential safety issues before a system is deployed. The disadvantage is the rather long time this takes and, last but not least the fact that a developer has to explain details about equipment that would normally be regarded as commercially protected know-how. In some cases Site License Companies (SLC) have indeed used information obtained in this way to subsequently make the supplier redundant. There is no recipe to make this process safe and easy, but a few general observations may be useful:

- Robust non-disclosure agreements should be put in place early.

- Instead of bringing manufacturing drawings and parts lists to the table, information such as simplified drawings and plant descriptions should be prepared for the HAZOP process. This not only protects valuable Intellectual Property (IP) but also helps to avoid confusion and side tracking. Some experience in the process is necessary to judge the required level of detail.
- Explain issues with IP to the customer when the discussion moves into sensitive areas. Agree on what information is needed to make a specific claim and how to provide it with minimum risk of uncontrolled IP proliferation.

New Technology Optimised for UK waste

Waste types encountered in operation and decommissioning of NPP in the UK are in some ways different from those usually treated in Germany by GNS. There are several reasons for this:

- Different technology: Germany used almost exclusively BWR and PWR, which use different consumable materials (e.g. IEX media) and produce different isotope fingerprints than graphite moderated gas cooled reactors.
- Different history: In the UK, the worlds first nuclear installations are now being decommissioned, some dating back to the 1950s. Back then, attitudes towards safe disposal, planning of future treatment, and documentation of waste were completely different.
- Different philosophy: German NPP tend to package and condition operational waste during operation, at least to some extent. In the UK, a large fraction of operational waste is accumulated for bulk treatment at the time of decommissioning. Such an approach has advantages (+) and disadvantages (-):
    - (+) Waste is handled for the first time, after the maximum possible decay time has elapsed.
    - (+) Bulk treatment can be cheaper if bespoke equipment has to be installed.
    - (+) Advance in technology will generally make waste treatment more efficient in the future.
    - (-) No OPEX can be developed (or processes optimised) for specific waste streams over time.
    - (-) Non-treatment can produce expensive surprises at the time of decommissioning, such as corroded and leaking tanks or decomposition of the waste itself, making more expensive treatment necessary, or retrieval very difficult.

In addition, the UK's strategy for final disposal leads to some major requirements for waste packages:

- Suitability for long interim storage periods, possibly more than 100 years.
- Suitability for final storage in a variety of host geologies.
- Longevity of the container to ensure possible retrieval after as long as 500 years.

The resulting different challenges can be addressed in a number of ways. One way is the extensive use of robust self-shielding packages, such as the 3m^3 *type VI* container, with one example being the GNS Yellow Box®. The form factor appears to optimise payload (therefore price) and relative ease of use (gross mass less than 25t). With that in mind, GNS and Eisenwerk Bassum (EWB) have developed a package fabricated from construction grade steel, the SBox®. This new container addresses some major issues:

- Price: Although the manufacturing process of the ductile cast iron container (DCIC) has been optimised over the years, a welded steel container of the same size can be made at roughly 60% of the cost.
- Structural integrity: FE calculations and a drop test performed with a full sized SBox® indicate that the fabricated container survives difficult drop scenarios better by a wide margin.
- Material properties: While properties such as tensile strength and elongation yield at low temperatures need to be evaluated with great effort for ductile cast iron, they can simply be looked up in the standard description (EN/ISO etc.) for common types of mild steel.
- Rectangular Lid: Allows easier access and placing of large items such as Magnox zeolite- and fuel-skips.
- Drying of difficult content: An optionally available internal heating system turns the SBox® into a container that partly comes with its own conditioning capabilities. The much higher temperatures possible with that system allow for drying of contents that leave an air-gap between the inner wall of the container and the waste. The internal heating system avoids having to heat up the entire steel body, thus saving energy and avoiding the long cool-down period during which a container that was heated externally cannot be handled.

SBox® - Fabricated Package with built-in Conditioning Technology