Dry Storage of Encapsulated Defective Fuel Rods at Doel 1&2 in Belgium 17581

Inge Suls*, Anne Boogaerts**, Vanessa Vo Van***, Nathalie Allimann***, Kay Muenchow****

*Engie-Electrabel, Brussel, Belgium
**Synatom, Brussel, Belgium
***AREVA NC, Courbevoie Paris La Defense, France
****AREVA GmbH, Erlangen, Germany

ABSTRACT

The project of removing all fissile and non-fissile material out of the spent fuel ponds of Belgian Doel power plant is on-going and in that framework, a solution was needed for evacuating all used fuel elements from Doel 1&2 storage pool, including Defective Fuel Assemblies (DFA) and Defective Fuel Rods (DFR). Following the moving out of storage pool, all used fuel elements are intended to be loaded in dry storage casks, this used fuel management option being the one implemented today in Belgium while waiting for final management.

Synatom, in charge of all fuel cycle related activities for the nuclear power plants of Belgium and Engie-Electrabel, the operator of both Belgium power plants (Doel and Tihange), had then to find an industrial solution for emptying Doel 1&2 used fuel pool and loading DFR in dry storage casks.

After having thoroughly reviewed the possible options for implementing dry storage of DFR, Synatom selected AREVA technology. It consists in:

- encapsulating each DFR by loading the fuel rod in a capsule, drying the fuel rod using a process which allows to physically verify with high accuracy the residual water content inside the DFR, and welding the capsule,
- assembling the capsules in a capsule canister (a skeleton with external dimensions similar to fuel assembly's) and
- transferring this capsule canister along with intact fuel assemblies in an associated dry transport and storage (dual purpose) cask, as already used for interim storage of used fuel at Doel site.

The French as well as the Belgian competent authorities are parties to the licensing process project.

The purpose of the paper is to present the on-going industrial project related to dry storage of dried and encapsulated DFR - along with intact used fuel in dual purpose casks - at Doel 1&2 in Belgium, its challenges and progress.

The paper presents:

- why the drying method, welded capsule and associated cask is the best available technology for dry storage of DFR;
- a focus on fuel assembly repair operations (initial step before encapsulation) performed in 2015 which consisted in successful extraction of four DFR from their original fuel assembly, using proven and experienced methods and tools;
- in conclusion, an update of Doel 1&2 DFR dry storage project: reaching of major qualifications and licensing milestones and overview of the project perspectives.

INTRODUCTION

As all fissile and non-fissile material needed to be removed out of the spent (or used) fuel ponds of Doel power plant, a solution was required for evacuating and storing all used fuel elements from Doel 1&2 storage pool, including Defective Fuel Assemblies (DFA) and Defective Fuel Rods (DFR).

According to [1], a spent (or used) fuel assembly is categorized as either defective or not, based on its ability to perform its designated functions without requiring the fuel assembly to be handled in a non-standard manner.

Regarding confinement defects, DFA are usually classified in the USA in two main categories:

Damaged fuel assembly (see fig. 1): assembly containing leaking or suspect leaking fuel rods, with cladding that can be breached.

Damaged fuel assemblies (rods) can be handled by normal means.

Fig. 1. Damaged fuel rod

Failed fuel assembly (see fig. 2):
- assembly containing grossly damaged fuel rods; grossly damaged fuel rods have breached cladding or parts of cladding
- fuel debris, e.g., nuclear pellets, fragments of pellets, or fuel powder.

Failed fuel assemblies (rods) cannot be handled by normal means.

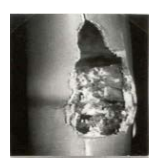

Fig. 2. Failed fuel rod

Synatom, in charge of all nuclear fuel cycle related activities for the commercial nuclear power plants of Belgium, and Engie-Electrabel, the operator of the Doel and Tihange power plants, reviewed the possible options for implementing dry interim storage of DFR in transport and storage casks (dual purpose casks or DPC), while waiting for implementing final management (reprocessing or direct disposal) of these DFR.

Among the various solutions, Synatom selected AREVA technology, based on a solution developed in Germany for shutdown plants. The approach consists in encapsulating each DFR previously extracted from fuel assembly by:

- inserting the DFR in the capsule
- drying the fuel rod with hot inert gas, using a process allowing to physically verify with high accuracy the residual water content inside the DFR,
- welding the capsule.

Then the capsules are assembled in a capsule canister (a skeleton with external dimensions similar to fuel assembly's) and transferred along with intact spent fuel assemblies in an associated DPC, as already used for interim storage of Doel 1&2 spent fuel, the AREVA TN "TN®24 SH" cask. All these operations are performed under water, thus minimizing radiation exposure.

This solution is fully compatible with both possible used fuel final management options (see fig. 3): reprocessing (including transport to the treatment plant) and direct disposal (including transport to the disposal site), thus preserving flexibility for Synatom.

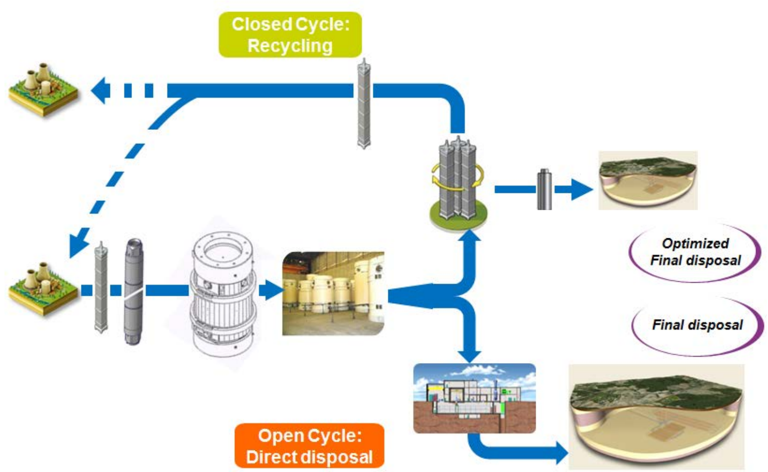

Fig. 3. Welded capsule and associated DPC: a solution for DFR management, compatible with both reprocessing and direct disposal (transport included)

The paper presents the progress of this on-going industrial project related to dry storage of encapsulated DFR - along with intact used fuel in TN®24 SH DPC - at Doel 1&2 in Belgium.

TRANSPORT AND DRY STORAGE OF DFR: WELDED CAPSULE AND ASSOCIATED CASK

In the objective of implementing long-term dry interim storage of spent nuclear fuel including various types of defective fuel assemblies, Synatom was looking for a solution that would ensure long-term stability of Doel DFR thus keeping open the doors for the possible final management options, without need for re-conditioning step before reprocessing or direct disposal.

After having thoroughly reviewed the possible DFR dry storage options, Synatom selected AREVA technology: dried and welded capsule with associated DPC (see fig. 4), applicable for all types of confinement defects as described in the Introduction.

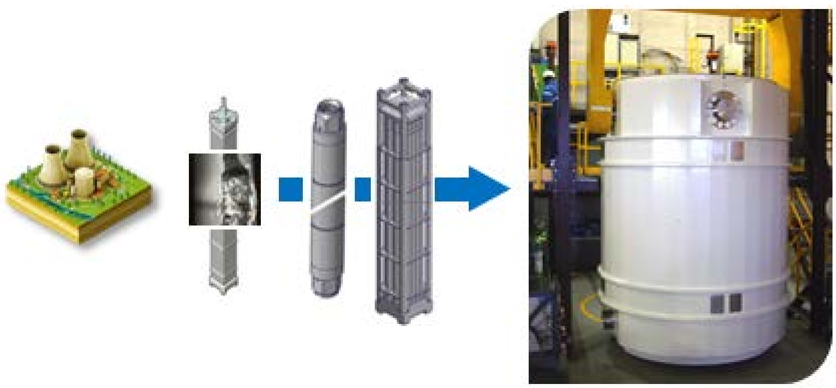

Fig. 4. Dried and welded capsule with associated DPC

Offering since years solutions for transport and reprocessing of DFR, AREVA proposes today this welded fuel rod capsule concept based on an existing and experienced screwed fuel rod capsule concept that has been already in use for wet storage and/or transport purposes.

The principles of the process are the following (see fig. 5):

- Preparation and pre-treatment of the defective fuel rod;
- Transfer of the DFR (or cartridge for debris) into the fuel rod capsule positioned in the encapsulation facility (as presented in fig. 5) on the bottom of the pool;
- Inside the encapsulation facility:
  - oDewatering and drying of the DFR (or cartridge) within the fuel rod capsule;
  - oGas-tight enclosure of the fuel rod capsule by welding;
  - oNon-destructive testing of the welds;
- Transfer of the fuel rod capsule into the capsule canister, mounting of the top end piece of the capsule canister;
- Handling and transfer of the loaded capsule canister to the DPC where it is then stored and transported along with intact spent fuel assemblies;
- Transfer of DPC to the interim storage facility.

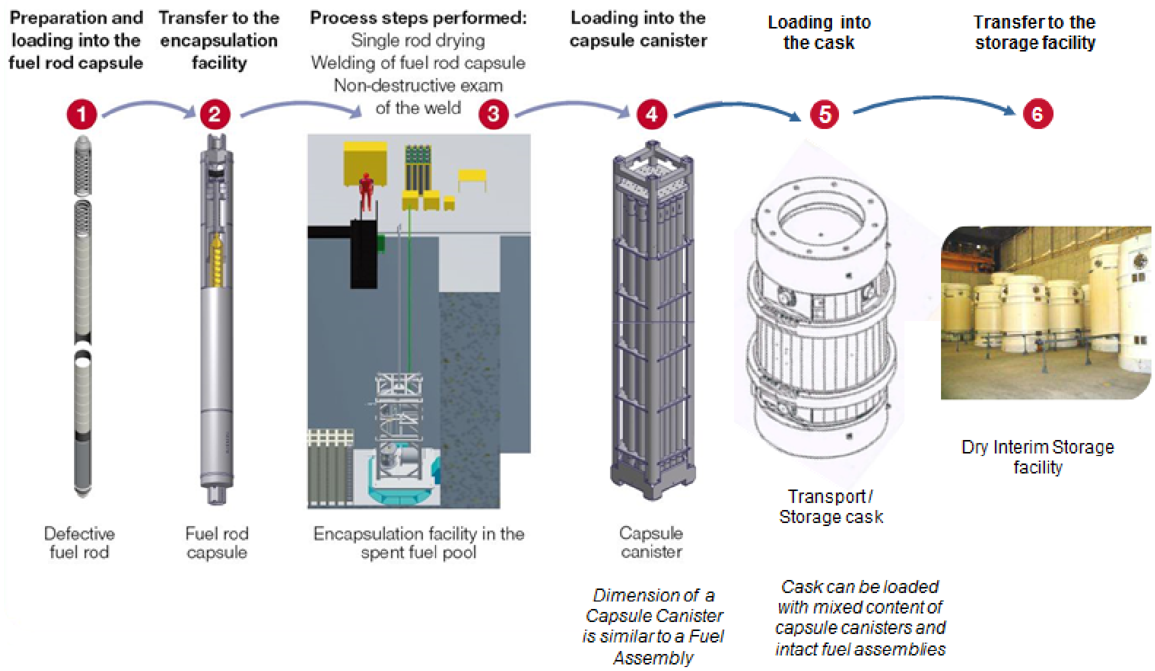

Fig. 5. Process for encapsulation of a DFR for transport and/or dry storage

The advantages of this technology are numerous:

- The capsule replaces the breached cladding of the DFR (recovery of cladding integrity to avoid radioactivity release: gaseous and/or particles);
- Drying of DFR inserted in the capsules with hot gas is an effective and efficient method;
- Dryness of encapsulated DFR is physically verifiable by temperature and pressure measurement;
- Treatment of DFR one by one (drying and welding of one capsule containing one DFR) is limiting the impact of potential failure;
- Licensing work is facilitated by the approach which consists in replacing one fuel assembly by one capsule canister in the DPC;
- Encapsulation execution is performed under water permanently meeting the ALARA principle in minimization of radiation exposure;
- This encapsulation is compatible with both used fuel final management options, reprocessing and direct disposal, including transport.

To conclude, the technology developed by AREVA is highly efficient in terms of residual water (moisture) in the DFR which allows to demonstrate robust safety margins for the transport and storage licenses of the DPC: it is the best available technology regarding safety requirements for dry storage.

FUEL ASSEMBLY REPAIR OPERATIONS AT DOEL SITE

As a preliminary step before encapsulation operations, fuel assembly repair operations have been and will be organized by Engie-Electrabel at Doel power plant (see fig. 6), using proven fuel services methods and equipment.

Fig. 6. Doel nuclear power plant

In 2015, four DFR were successfully extracted from their original fuel assembly and inserted in fuel rod basket, pending encapsulation which will be performed in 2017. The repair was verified trough sipping of the fuel assemblies and these were evacuated from the spent fuel ponds via a TN®24 SH cask.

In 2017, prior to the start of encapsulation campaign, one DFA will be repaired by AREVA, using the RSA equipment (see fig. 7).

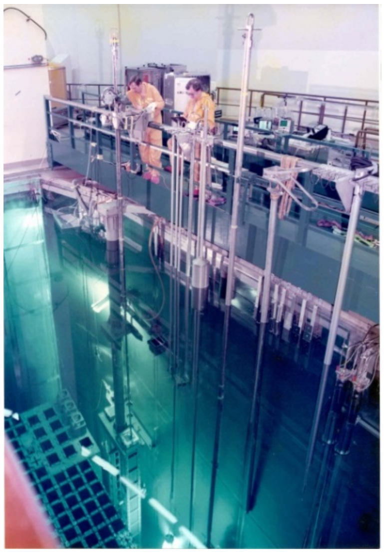

Fig. 7. RSA equipment

The RSA equipment is a lightweight system that can be easily moved from plant to plant, and enables fuel rod extraction and insertion in a fuel skeleton, using the elevator of the spent fuel pool to move the fuel assembly vertically. It is used to extract damaged or failed fuel rods out of the affected fuel assembly and to replace them by undamaged or dummy fuel rods for continued irradiation in the reactor of the repaired fuel assembly.

DOEL 1&2 DFR DRY STORAGE PROJECT: DRY AND WELDED CAPSULES ASSOCIATED WITH TN®24 SH CASK

DFR dry storage project progress

The Doel 1&2 DFR dry storage project has started in 2014 and progresses well. The project performance is as follows:

- Main technologies, drying, welding (see fig. 8) and weld testing, have been
  - qualified under laboratory conditions,
  - confirmed as robust by German TÜV independent experts and
  - acknowledged by Synatom
- All project milestones have been met so far e.g.
  - qualification acknowledgement,
  - submission of Safety Analysis Report (SAR) and application documents to French Competent Authority ASN,
  - TN®24 SH transport license with new content granted by ASN in June 2016,
  - submission of SAR and application documents for validation of this transport license to Belgian Competent Authority FANC,
  - TN®24 SH transport license with new content validated by FANC in August 2016,
  - submission of Topical Safety Analysis Report (TSAR) for storage to Synatom and Doel power plant team,
  - TSAR already reviewed by Synatom and Doel power plant team,
  - on-going review of TSAR by Bel V, FANC's subsidiary providing technical expertise.

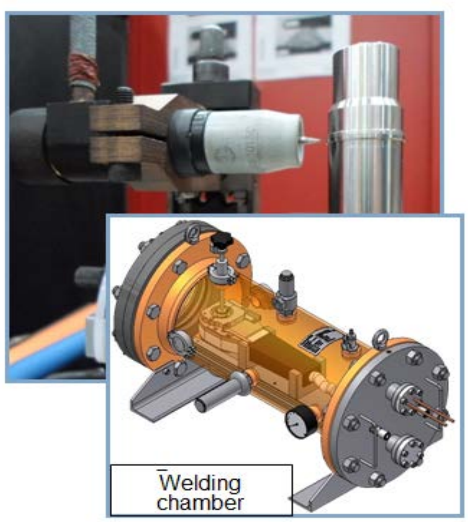

Fig. 8. Qualified welding method and equipment
for dry and welded capsule for DFR

The first encapsulation campaign will be implemented in Doel 1&2 pool in Q4 2017. Through this project, an industrial solution for transport and long-term dry storage of

DFR is being implemented, coming in addition to existing solutions for transport and reprocessing of DFR.

TN®24 SH DPC at Doel

For transport and dry storage of used fuel assemblies from Doel 1&2 units, Synatom has since long made the choice of the TN®24 SH DPC (see fig. 9).

Fig. 9. TN®24 SH DPC

This cask design can be loaded with 37 PWR used fuel assemblies and is licensed

- for transport in France and in Belgium
- for dry storage in Belgium.

The first unit was loaded in 2001. Today, over 30 units are loaded and stored at Doel site and 10 units are being manufactured, one of them being intended to be loaded with the encapsulated DFR.

CONCLUSIONS

Synatom, Engie-Electrabel and AREVA jointly work on safely managing Doel 1&2 DFR for long-term operations. The team is implementing long-term dry storage of DFR based on a comprehensive and robust technology: the dried and welded capsule and associated TN®24 SH DPC, compatible with both used fuel management options, reprocessing and direct disposal.

Having started in 2014, the project is well on track and has achieved main qualification and licensing milestones in 2015 and 2016, leading to performance of encapsulation campaign in 2017 as requested by Synatom.

ACRONYMS

ALARA	As Low As Reasonably Achievable
DFA	Defective Fuel Assembly/ies
DFR	Defective Fuel Rod(s)
DPC	Dual Purpose Cask (cask for transport and storage of used fuel)
PWR	Pressurized light Water Reactor
SAR	Safety Analysis Report (transport licensing safety report)
TSAR	Topical Safety Analysis Report (storage licensing safety report)

REFERENCES

1. IAEA Nuclear Energy Series No. NF-T-3.6: Management of Damaged Spent Nuclear Fuel, issue IAEA 2009