Handling of Reactor Internals at Forsmark Nuclear Power Plant

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Background

• Uprating of the three BWRs at Forsmark required replacement of some reactor internals:
  – Core shroud head
  – Steam separators
  – Steam dryer
• These components are large, complex and highly radioactive after being exposed to radiation and contamination in the reactor for more than 25 years.
The problem

• The old reactor internals must be disposed of or stored away from the reactor as there is no space available in the storage pools to store more waste.
• Necessary to cut the components into smaller pieces to enable transportation and packaging.
• No final repository available for components with long-lived activity, such as the core shroud head.
• No transport container approved for shipment of these components in large pieces.
• No local storage facility available for material with high dose rates.
 Alternatives evaluated

• Packaging alternatives
  – 4-kokillslåda for steam separator and steam dryer - SFR
  – BFA-tank for Core Shroud Lid
  – Small containers suitable for storage in the pools at Clab (Central Storage for Spent Fuel)

• Storage location alternatives
  – Interim storage at BFA at Oskarshamn
  – Storage in the pools at Forsmark or Clab
  – Interim storage in an existing Forsmark building
  – New interim storage facility
Alternatives evaluated – rejected and selected

• Packaging alternatives
  – 4-kokillsåda for steam separators and steam dryer – not practical to have 2 systems
  – BFA-tank for Core Shroud Lid – to be used for all components
  – Small containers suitable for storage in the pools at Clab – impractical, too much cutting

• Storage location alternatives
  – Interim storage at BFA at Oskarshamn – no transport container
  – Storage in the pools at Forsmark – no space
  – or Clab – too much cutting
  – Interim storage in an existing Forsmark building – not possible, high dose rates, heavy containers
  – New interim storage facility – ultimately chosen
The solution

• Modify Oskarshamns Kraftgrupp’s (OKG) system using BFA-tanks (1 m x 2 m x 3 m)
  – Provide more shielding,
  – Enable remote handling to reduce dose
  – Allow for drying the waste
  – Redundant lifting

• Build an interim storage facility at Forsmark where the BFA-tanks can be stored until a permanent storage facility is available, or the waste can be treated
Investigations performed

• Waste characterization
  – Radionuclide inventory of the different internal components
  – Volumes of waste to be produced
  – Masses of waste

• Dose rates
  – Dose rates on the containers
  – Dose rates outside the interim storage facility
What made the process so interesting

The solution evolved over several years which meant that there was new information and requirements coming in.

- It was not permitted to have interim storage in SFR.
- The waste currently in the pools did not have to be removed right away, as originally intended.
- The transport container, ATB 1T, will take 5 years to design, test and manufacture.
What made the process so interesting (cont)

• Steam separators and steam dryer have too much void to be disposed of in SFR. Grouting would be necessary. Not a trivial operation.
  – We were running out of time
  – Decided to use a single system (BFA-tanks) for all components, despite the cost. BFA-tank is overdesigned for steam separators and steam dryer
  – OKG has successfully decontaminated ÅS using the CORD system.
The Development of the System - Sponsors and Major Stakeholders

- The Project was carried out within the Forsmark organization
- The design and manufacturing of the equipment was partly financed by Forsmarks Kraftgrupp AB and partly by the Swedish Nuclear Fuel and Waste Management Co (SKB)
- Vattenfall Power Consultant AB designed the equipment
- Oskarshamnsvarvet Sweden AB manufactured the equipment
The Hardware
The Development of the System - Major Requirements & Constraints

- Radiation => Shielding => Heavy lifting
- The system operates in the Reactor Hall => Redundant lifting
- Radiation => Remote-controlled lifting
- Water => Increases the complexity in the system and the number of components in use
- Storage Pools are deep in relation to the available lifting height in the Reactor Hall => Special lifting arrangements/manoeuvres
3 types/levels of containers - Cassettes, Tanks and Transport Box

- The System is dimensioned for a (BFA-tank-) surface dose rate of max. 200 mSv/h
- Cassettes - carriers of segmented Reactor Internals (max. 12 tonnes) from the Storage Pools to the Reactor Hall floor and into the BFA-tanks
- Optimization of material with respect to various radioactivity levels of the waste; BFA-tanks are manufactured with 4 different wall thicknesses; 50, 100, 150 and 200 mm
- Transport Box - carrier of BFA-tanks between the Reactor Hall and the Interim Storage Facility

Cassette (3-6 tonnes)  BFA-tank (10-33 tonnes, ext. dim. 1,3 x 2,3 x 3,3 m)  Transport Box (58 tonnes)
Handling of Cassettes

- Cassette Strongback - lifting of empty Cassettes
- Cassette Frames - guiding and positioning of the Cassettes, the Wet Hood and the Cassette Strongback under water
- Wet Hood - lifting of filled Cassettes from the Storage Pools and positioning them in the BFA-tanks/Transport Box
Handling of BFA-tanks and the Transport Box

- Redundant BFA-tank Strongback – lifting the BFA-tanks lids on and off, also used for lifting of the Vacuum Cover
- BFA-tank Strongback - lifting and positioning of BFA-tanks in the Interim Storage Facility

Redundant BFA-tank Strongback

BFA-tank Strongback

Transport Box Strongback (fixed in the Rotatable Crane Hook)
Vacuum Cover, Docking Protection and Rotatable Crane Hook

- Vacuum Cover – device for drying the contents of the BFA-tanks (is connected to existing equipment for drying of spent fuel)
- Docking Protection Plate - minimizes the risk for contamination when the Wet Hood is operated around and on the Transport Box
- Rotatable Crane Hook - enables remote-controlled rotation of load (temporary modification of existing Crane Hook)
Handling of empty Cassettes and the Cassette Frames
Handling of the Transport Box, the BFA-tank lid and the Docking Protection Plate
Wet Hood – handling of loaded Cassette in the Storage Pool
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Wet Hood – preparations for docking against the Transport Box and the BFA-tank
Wet Hood – docking against the Transport Box and the BFA-tank
Wet Hood – Loading of the BFA-tank and preparations for transportation of the Transport Box
Transport Box – transportation from the Reactor Building to the Interim Storage Facility
The Interim Storage Facility at Forsmark

- Fully remote-controlled handling
- Originally intended to store 56 BFA-tanks in 2 layers
- Now planned to have 3 layers (84 BFA-tanks)
- In order to minimize dose rate, the tanks are placed in a specific pattern (hottest in the middle)
The Interim Storage Facility - remote-controlled handling of the BFA-tank
Lessons Learned and Key Success Factors

- The combination of large components, tight design tolerances and close interfaces between components has been a challenge!
- The identification and involvement of Stakeholders at an early stage have contributed to a safe and workable system
- The importance of a thorough Factory Acceptance Test Programme (as close to the real environment as possible)
- A close and positive relationship with the manufacturer – part of the project, not counterpart