Decommissioning of the Reactor Pressure Vessels by Remote Controlled Thermal Cutting Segmentation Facilities of the ZION Nuclear Power Plant at ZION, USA

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ABSTRACT

This paper presents the experiences for the segmentation of both reactor pressure vessels (RV) Units 1 and 2 at the ZION nuclear power plant. The Zion Station project was the first to use the large-scale application of thermal cutting (oxy-propane) technology in the USA.

INTRODUCTION

Zion was the third dual-reactor nuclear power plant in the ComEd network and served Chicago and the northern quarter of Illinois. The plant is located on the western shore of Lake Michigan shoreline, in the city of Zion, which is in Lake County, Illinois.
The ZION Nuclear Power Plant was a pressurized water reactor with two units and a combined electrical output of 2170 MW (gross). Its first criticality was in December 1973. After more than 20 years of successful operation, both reactors were permanently shut down in January 1998.

The dismantling of radiologically contaminated as well as partly activated large components is one of the most complex and challenging tasks within the decommissioning of nuclear facilities. This is partly due to the radiological conditions that prevent direct work on the components to be separated, on the other hand to their dimensions, structures and the installation situation.

In the segmentation of activated components shielding applications are necessary. All in this area used strategies and technical facilities must therefore be suitable for their specific application.
For the successful execution of those dismantling tasks, various technologies and strategies have been established and each method has their specific advantages and disadvantages.

In particular, with regard to the feasibility, the personal safety and process safety we can increasingly speak of a standardization in relation to segmentation tools and segmentation strategy.

DESCRIPTION

At the present time the Siempelkamp NIS, after completion of different projects in dismantling of nuclear facilities, has reputable experience for processes and technologies especially for RV segmentation. Siempelkamp NIS used the thermal cutting techniques for the first time in the USA for the segmentation of a reactor pressure vessel.

Another key differentiator in this project is the dismantling strategy. In addition, each RPV was raised with a lifting rod. The Lifting Rod was connected among the core support guides of the former internals. For hoisting the RPV the lifting rod was connected to a strand jack assembled at the pool floor. Consequently entire cylindrical part of the RV could be raised and segmented into installation position.

The main work activities for the segmentation of both RVs were:

- Planning and development of strategy for segmentation and packing for RV segmentation
- Development, procurement, manufacturing, testing, Mock-Up and installation of the necessary equipment for RV segmentation
- Mock-up of the equipment and training of personnel in a test facility in the greater area of Zion in which all systems were assembled and tested as a compound system. In this case, the operating personnel (SNS personnel) was trained on the systems and also prepared for the implementation of maintenance work
- Preparatory works (Prepworks) to bare the RVs:
    - Opening of sandboxes with plasma cutting and emptying sandboxes
    - Dismantling of concrete around RV flange by means of wire saw
    - Performing of precuts with wire saw for the subsequent thermal segmentation
    - Disconnection of the loop pipes and closing loop nozzles by means of wire saw
    - Dismantling of seal ledge by means of remote controlled flame cutting torch
    - Draining of ICI-conduits and cut ICI-conduits below the Hemispherical Bottom Head by means of a angle grinder
- Dismantling and packaging of the RV Unit 2 and Unit 1

Included is the Supervision of all activities related to Prepworks and Thermal Cutting of both Reactors.

The timeline for the decommissioning process for the RVs will be shown in the following time schedule:

Nov 2014 – May 2015	Preparation in Unit 2 incl. calotte of biological shield and installation of the dismantling facilities incl. startup for the segmentation of the RV
May 2015 – July 2015	RV-Segmentation and packing in Unit 2
July 2015 – YTD of the	Cleaning of segmentation and packing areas and move facilities from Unit 2 to Unit 1

Sep 2015 – Oct 2015	Preparation in Unit 1 incl. calotte of biological shield and installation of the dismantling facilities incl. startup for the segmentation of the RV
Oct 2015 – Dec 2015	RV-Segmentation and packing in Unit 1
Q1/2016	End of Project

After finishing the basic design and final design, all necessary segmentation facilities were manufactured and tested. After completion of the equipment a mock-up was performed in a test facility in Milwaukee closed to ZION NPP. After successful termination of the mock-up the equipment was installed in the control area in Unit 2 of ZION NPP.

For the installation of the equipment and the later ongoing segmentation, especially for the packaging the initial radiological status had to be determined beforehand.
The activation analyses based on the operation history of both RV. The activation product scaling factors were decay corrected and normalized to measured underwater surveys of the vessels. Due to the long decay time over app. 17 years the radiolocical conditions were manageable.

The Table (1) shows the radiological conditions of both units.

Assembly Group	Unit 1				Unit 2			
	Avg. Specific Activity [Bq/g]	Co-60 [activity-%]	Dose Rate of Cut Pieces @ 1 ft in Air [rem/h] Estimated	Max. Measured	Avg. Specific Activity [Bq/g]	Co-60 [activity-%]	Dose Rate of Cut Pieces @ 1 ft in Air [rem/h] Estimated	Max. Measured
nozzle	1.39E+03	43.7%	0.230		5.20E+02	21.3%	0.124	0.85 - 1.10
belt line	1.60E+04	43.8%	2.222		1.43E+04	25.6%	2.718	2.50 - 3.75
hemisph. bottom head	2.47E+03	44.2%			1.71E+03	30.0%	0.127 (side, contact)	0.030 (side, contact)
	contamination (primary side, Co-60)		1.6E+03 Bq/cm^2		contamination (primary side, Co-60)		7.9E+03 Bq/cm^2	

Table (1) radiological conditions Unit 1 and 2

The Reactor Vessel (RV), in both units, were manufactured with high strength steel and a chromium nickel steel cladding inside each vessel.

The RPV had the following dimensions:

Term	metric	imperial
external diameter	5207 mm	205 in
height	10840 mm	427 in
max. wall thickness (flange)	481 mm	19 in
wall thickness (cylindrical part)	223 mm	8,8 in
thickness of the cladding	4 mm	0,16 in
total weight of RPV	312 Mg	344 tn.sh.

Table (2) RV dimensions

The segmentation of the vessel was executed in the reactor cavity using equipment installed in the reactor cavity and above. The RPV in Unit 2 was cut and packaged first.

Prior to mobilization and segmentation of the RV the following preliminaries needed to be ac-complished:

- Refueling pool is empty of water and cleared from any equipment
- Sandboxes around reactor flange are removed
- Nozzle area in Reactor cavity are cleared except the concrete bearing blocks

To get access to the outer face of the RV in the necessary elevation for cutting, the RV needed to be lifted. Prior to that the coolant pipes had to be separated from the vessel and the insulation had to be retained independent from the RV. After installing the Turnable Shielding Plate (TSP) over the reactor cavity the reactor could be lifted to the first segmentation elevation. To lift the RV a Lifting Rod (LR) was installed inside the reactor engaging geometrically and connected to a Strand Jack System (SJS) sitting above on the 617’ floor. While resting on the Strand Jack System (SJS) the RV was segmented by using the Flame Cutting System (FCS) which was mounted to the Turnable Shielding Plate (TSP). During the segmentation process a Venting System (VS) connected to the TSP ensured a guided airstream from the clean outside into the RV and sucked the resulting cutting off-gases for cleaning over filtration unit to provide clean air to the building purge air system.

The RV was be segmented in 2 rings with 8 pieces each and the Hemispherical Bottom Head in one piece. Figure (1) shows the cutting plan of the RPV in single segments.

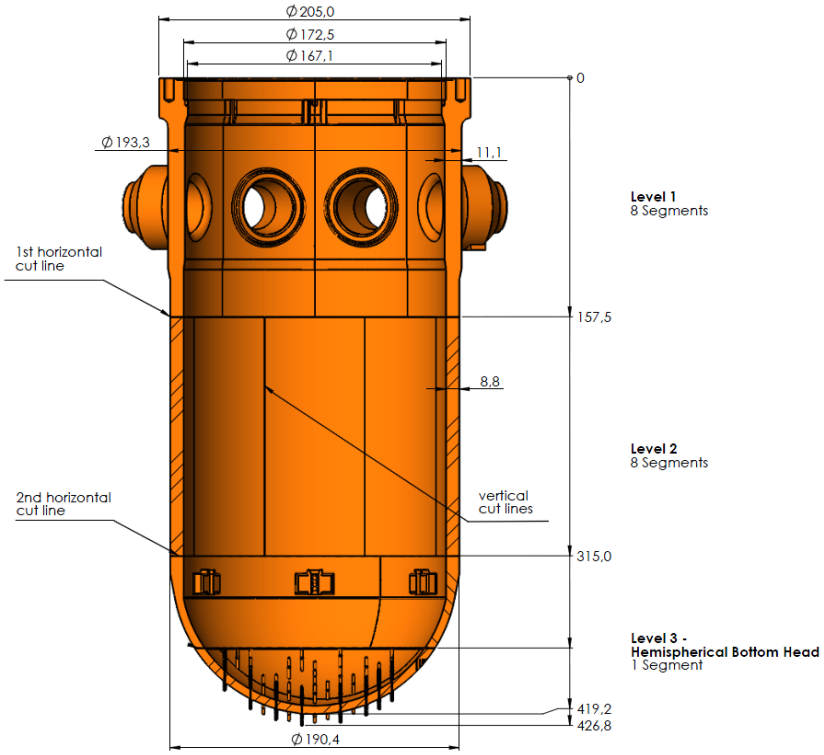

Fig. (1) RV cutting plan

The 17 segments had to be radiologically characterized and packed into 8 Container Class B for the flange and 4 Container Class B for the cylindrical part. The Hemispherical Bottom Head has been welded with a lid and packed into a lamination for transport.

To minimize the off gas suction leakage the strategy of segmentation sets the performance of L-cuts for one ring keeping a small connection for each piece. So the material to be cut is minimized for performing the final cut due to having large openings after having removed one or more segments.
For rigging of the segments a remote controlled and turnable gripper was attached to the polar crane of the building. The separated segments were carried in the refueling pool for subsequent packaging.
After the segmentation of the second ring was accomplished the Hemispherical Bottom Head (HBH) of the RV needed to be transferred to the deep end of the refueling pool for further preparation using the polar crane. For this purpose the LR with the attached HBH was connected to the Handover Traverse to allow detaching and removing the SJS from the re-fueling pool to provide crane access to the LR.

Subsequently the HBH was transferred to the “beach” onto a stand where the preparational work for the transport outside the reactor building was performed.

The execution strategy is divided into the following steps:

Step 1: Prepworks:
Open RV Flange area, remove its content, uncouple concrete around flange from bioshield incl. removal, remove insulation around flange, generation of precuts in RV flange and cut coolant pipes

Fig. 2 Tent with lock above the cavity

Step 2: Installation of all equipment for RPV segmentation. e.g. Lifting Rod (LR), Turnable Shielding Plate (TSP), Flame Cutting System (FCS), Control Station (CS)

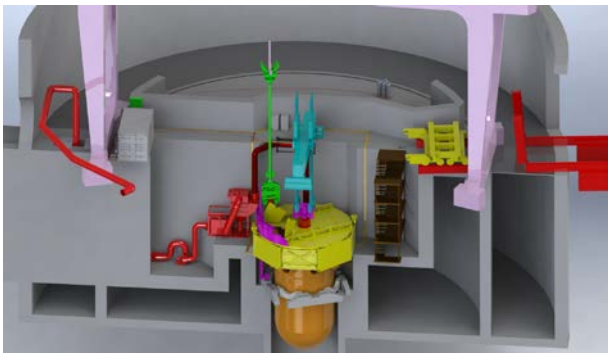

Fig. 3: 3D-view of the installation plan for the RPV Segmentation equipment

Step 3: Raise RV and function test of whole equipment

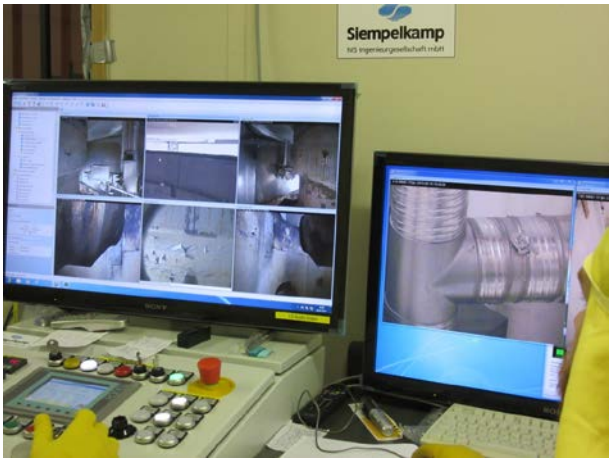

Fig. 4: Control Station for the remote controlled dismantling

Step 4: RV Segmentation and packaging

Fig. 5: Remote controlled thermal cutting segmentation of RV

RESULTS and CONCLUSIONS

The elaborate planning and engineering was the basis for a quick, safe and flawless project execution without any aerosol migration or release of contamination. The used segmentation technology based on industry-tested methods with its big advantage of availability and spare parts inventory. For safeguarding Simulation (interfering edge analysis), animations and Trials with mock-ups dummies were executed prior.

Also risk assessments and rescue concepts are part of the planning.

Lean project organization for decommissioning and the flexibility, creativity, willingness to cooperate and willing for uninterrupted decisions of client and contractor are the essential basis for a successful project execution and a short project duration. The remote controlled segmentation of the RV of Unit 2 was performed in 3 month an in Unit 1 in less than 2 month.