

## **Reactor Internals Segmentation Experience in the Nordic Region - 14267**

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### **ABSTRACT**

The Nordic region has a long history of upgrading power and extending lifetime of nuclear power plants. The upgrade process includes replacement and segmentation of reactor internals where Westinghouse has a long experience. The segmentation projects performed by Westinghouse include cutting of almost all internal parts in a Boiling Water Reactor (BWR). Examples of projects are cutting of steam dryers and core shroud covers in Forsmark Nuclear Power Plant (NPP) and cutting of control rod shafts in Olkiluoto NPP. All cutting work has been done with underwater mechanical cutting technique which has proved to be very well suited for this application. Several various types of mechanical cutting tools have been developed throughout the years applicable for different dimensions and geometries. Lessons have been learned from every project and have given Westinghouse the chance to improve items such as cutting parameters, tool design, handling and packaging strategies.

### **INTRODUCTION**

There is an ongoing upgrade process in the Nordic BWR NPP's with the aim to extend the operation life time, to increase the power output and also to adapt to the new nuclear safety regulation. The upgrade process includes replacement of reactor internals.

Westinghouse has developed a system that allows the highly irradiated internals to be removed and disposed in storage buildings. Westinghouse concepts to dismantle and segment the reactor internals are based on clean, safe and reliable techniques. All segmentation projects have been performed with mechanical cutting tools based on thorough internal assessment and to comply with the NPP requirements.

Since 1999, Westinghouse has received almost all awards for reactor internals segmentation projects in the Nordic region. The latest two segmentation projects were performed at Forsmark and Oskarshamn in Sweden. Figure 1 shows all BWR internal parts that Westinghouse has segmented.

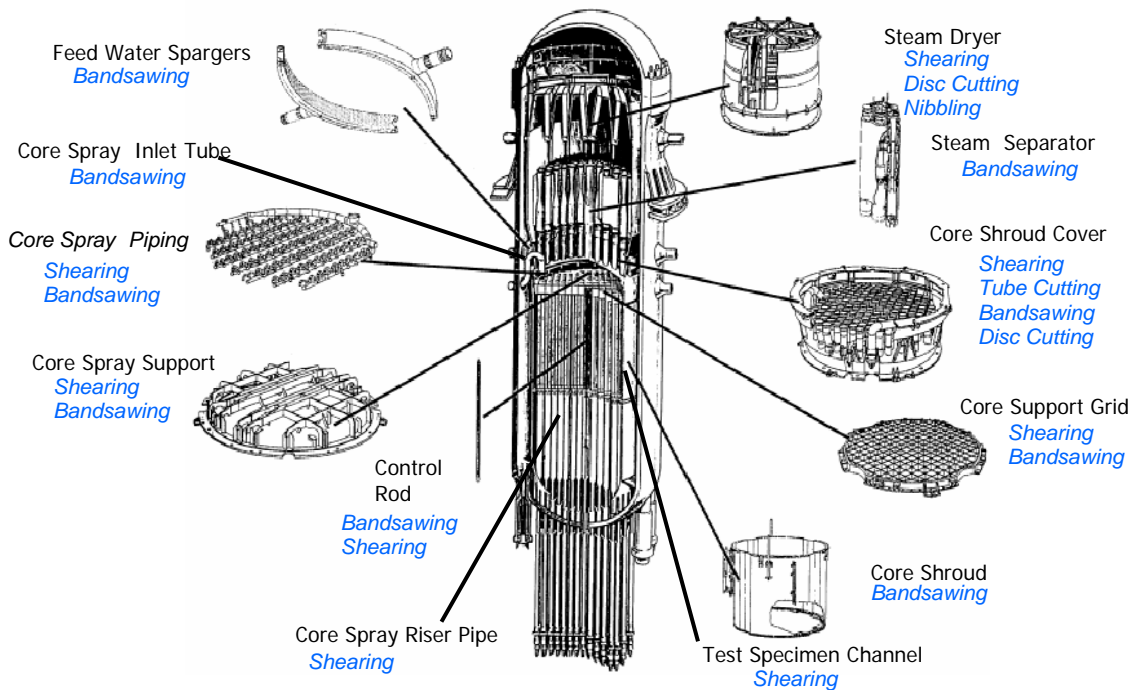


Fig. 1. Internal parts segmented by Westinghouse.

## REACTOR VESSEL INTERNALS SEGMENTATION

All large scale reactor internals in the Nordic area are designed to be easily removed. The plant internals are replaced and put in storage in a nearby water filled pool, during the upgrade process. Westinghouse and the NPP together with the Swedish Radwaste Agency have developed a system that allows the highly irradiated components to be segmented, transported out of the plant and put in a nearby storage building. A project in accordance with this system must be thoroughly planned together with the customer. The radiation level of the internals and complexity of the site work has to be foreseen in all aspects. All procedures and design of advanced tools have to be tested and qualified before the site work starts. The three most vital factors for Westinghouse and our customers during execution in the NPP are personal and plant safety, cleanliness of the environment and minimization of the total disposal and storage cost.

The Westinghouse site work includes preparations, handling and segmentation of the internals in accordance with procedures and cutting plans, packaging of the cut pieces in containers according to a packaging plan and a waste disposal plan, handling of the containers and finally restoration of the pool environment to the initial condition. All segmentation projects performed by Westinghouse in the Nordic area have been performed on operating NPP's. Westinghouse has the knowledge to maintain the cleanliness during the whole site work and to perform the final clean-up of the pool and the surrounding areas.

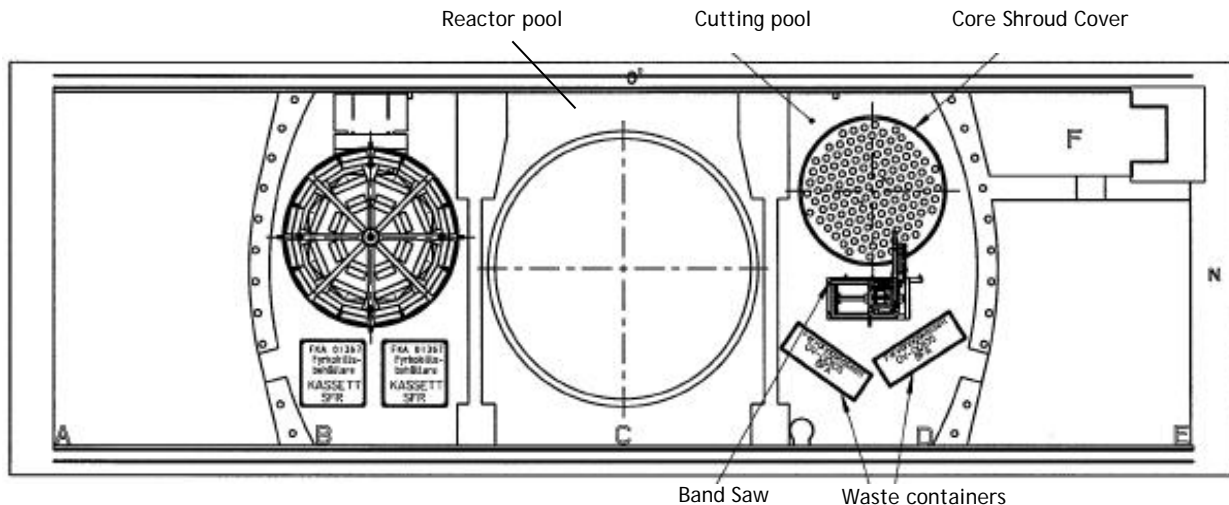


Fig. 2. Disposition plan for a typical project.

## EXPERIENCE FROM PERFORMED PROJECTS

From the year of 1999 until today, Westinghouse has segmented all types of reactor internals in a BWR reactor. The projects has been performed on the Nordic market, in nuclear power plants such as Forsmark 1, 2 and 3, Oskarshamn 1, 2 and 3 in Sweden and Olkiluoto 1 and 2 in Finland. During these projects, Westinghouse has gathered a wide range of experiences from managing segmentation projects to the actual cutting of the internals. The internals segmentation is always performed under water due to the high radiation and all tools must therefore be remote controlled. ALARA and personal safety are the number one priorities during the site work. The complexity of the work requires well designed and reliable tools. Westinghouse has optimized the mechanical cutting technologies based on its experience collected from numerous number of segmentation projects. Examples on areas where improvements have been made are handling and cutting speed, cleanliness, fail-safe and safety. Neutron-irradiated internals material and storage container design are knowledge that Westinghouse possess. Typically, for most reactor internals cutting projects, the majority of time is used on non-cutting activities like tool handling, arrangement of equipment, movement of cut pieces, etc.

Optimization to the whole segmentation process includes the cutting speed, a well planned tool handling strategy and the overall logistics. Westinghouse personnel are experienced on site and well trained and are also very familiar with all the procedures and situations concerning segmentation of internals.

## RADIATION EXPERIENCES

Assessments of the level of radiation dose that the personnel will be exposed to are always performed before any site activities start (dose budget for the segmentation project). If these assessments show that the dose rate will be too high, measures are taken to reduce it. The actual dose rate taken by the personnel is continuously followed throughout the work. The outcome of man dose for almost all performed segmentations has been according to the assessments in the dose budget. Careful planning results in man dose levels no more than the normal levels achieved when working inside the reactor hall.

All site activities are planned in detail and in close cooperation with the plant owners. Special areas for tool maintenance are set up in the reactor hall containment. All tools are designed to be used and controlled remotely. Training on mock-ups in a non hostile environment before going to site is a very important step in order to optimize all procedures and thereby minimize the dose rate exposure on site for the personnel. The waste containers that are filled with cut pieces have restrictions regarding the allowed dose rate. Westinghouse has the experience from the radiation level of the cut pieces from the Nordic NPP. In addition we also have the competence to perform advanced dose rate calculations in order to find out the specific activity for each component. The dose rate calculations in combination with our experience are used to optimize the waste container packaging and types. Figure 3 shows the dose rate around a filled waste container.

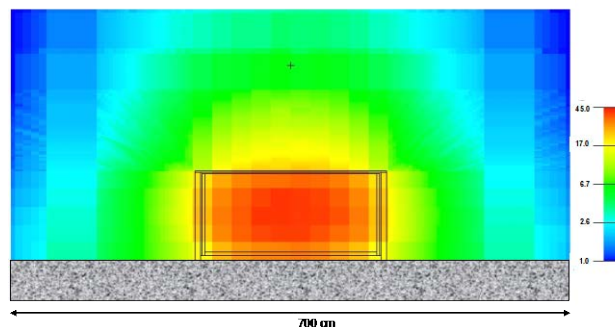


Fig. 3. Dose rate around waste container.

## PACKAGING EXPERIENCE

When performing a segmentation project, it is very important to plan the cutting and packaging activities thoroughly. An important part of every project is therefore to create a cutting and packaging plan. In the cutting plan all cuts of the internal parts are studied thoroughly to obtain cut objects with dimensions to receive the highest filling ratios inside the storage containers. The packaging plan is a detailed report with good accuracy of how many containers will be needed and also works as an instruction to the site personnel on how to position the cut pieces in the best way inside the inserts. The packaging plan specifies which type of waste containers and how many that must be ordered for the whole project execution.

As the storage cost is significant for our customers it is very important that the actual packaging corresponds to the forecast. Westinghouse has never exceeded the number of containers that we have stated in the packaging plans. We have even managed to obtain fewer containers than we anticipated in some projects. Figure 4 shows a container filled with cut pieces from a packaging plan. Figure 5 shows packaging activities from a segmentation project in Forsmark, Sweden.

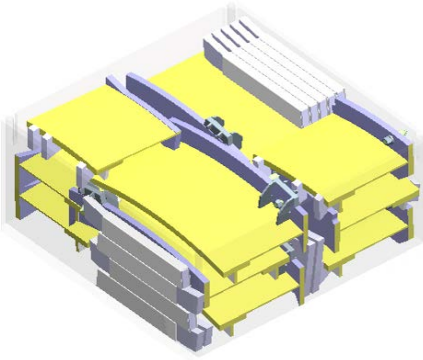


Fig. 4. Container from a packaging plan.

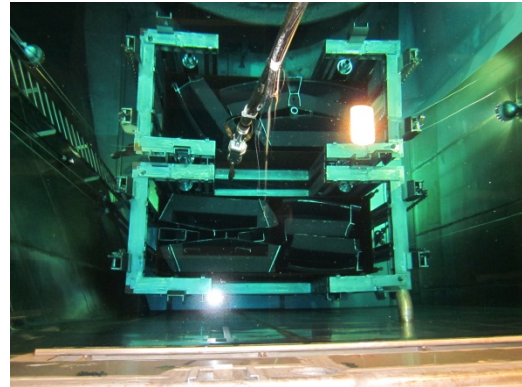


Fig. 5. Packaging activities on site.

### **SEGMENTATION IN FORSMARK 2000-2001**

Westinghouse first segmentation project in the Nordic region was performed in Forsmark in connection with the replacement of the Core Shroud and Core Support Grid at Forsmark 1 and 2. The cutting of the two Core Shrouds was performed with a band saw and the two Core support grids were cut with a heavy plate shearing tool (see fig. 6) and a band saw.

All lessons learned received from one segmentation work of a special reactor internal normally improves all work significantly when performing a similar segmentation. In this Forsmark segmentation, the repeated work in the second reactor was executed with 30% less time on site.

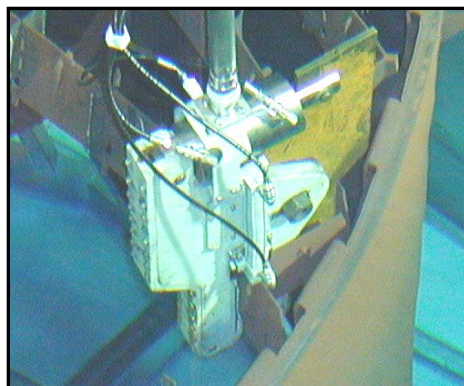


Fig. 6. Cutting of Core support grid in Forsmark.

## SEGMENTATION IN FORSMARK 2003-2005

Westinghouse has segmented the Core spray system (CSS) in all three reactors in Forsmark (F1, F2 and F3). The first two CSS (in F1 and F2) were removed from the Core Shroud Cover (CSC) with Electrical Discharge Machining technique (EDM) before the CSS was cut with different shearing tools (see fig. 7). As the Core shroud cover was to be reused in the reactor operation this cutting procedure and handling had to be performed with the highest accuracy, quality and cleanliness.

The cutting of CSS in F3 was performed during two months in 2005. Westinghouse used different shearing tools and a specially developed type of band saw (see fig. 8). The project execution on site was done according to the timetable and with the full satisfaction for the customer.

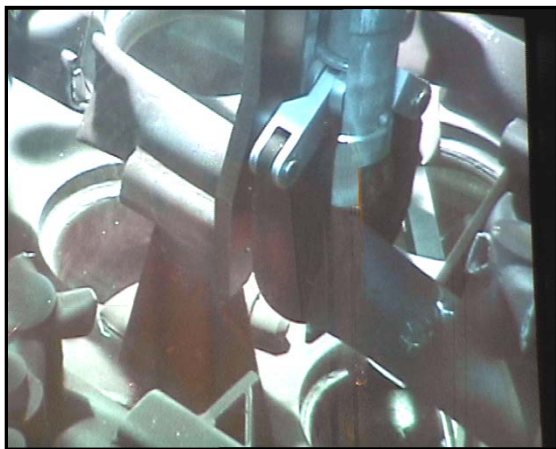


Fig. 7. Cutting with a shearing tool.

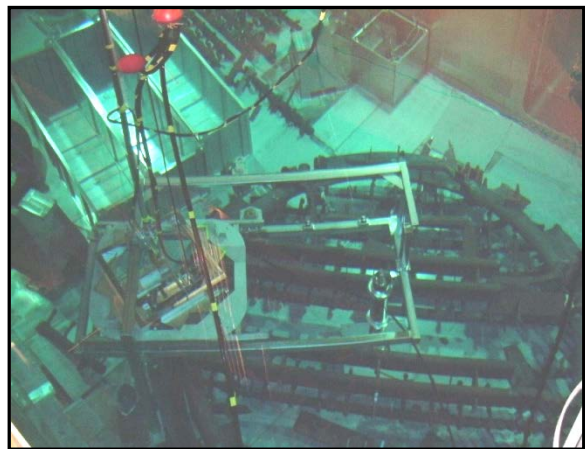


Fig. 8. Cutting with a band saw.

## SEGMENTATION IN OSKARSHAMN 2003-2004

Westinghouse performed segmentation of a number of internals in Oskarshamn 1 and 2 during an upgrade project 2003-2004, see table I. The Core Shroud Covers (CSC) complex design required a number of special developed cutting tools. A tube cutting tool was designed in order to cut the steam pipes on the CSC. When the pipes were cut, the CSC was turned upside down in order to reach the Core Spray System. The turning of the 15 ton CSC (see fig. 9) was a very critical operation that required extensive mock-up testing and structural verifications before the start of the actual site work. After turning the CSC the CSS was then segmented with different shearing tools before we could start to cut the remaining CSC with band sawing technique (see fig. 10). The segmentation time on site was around 2 months for O1 and 7 months for O2. Westinghouse made a lot of testing on full scale mock-ups before going on site. Improvement work on procedures and tools was also done on site in order to gain the best results. The adjustments and the experience we gained from the first CSC

improved the site work for the second CSC. The second execution was done in about 30% shorter time.

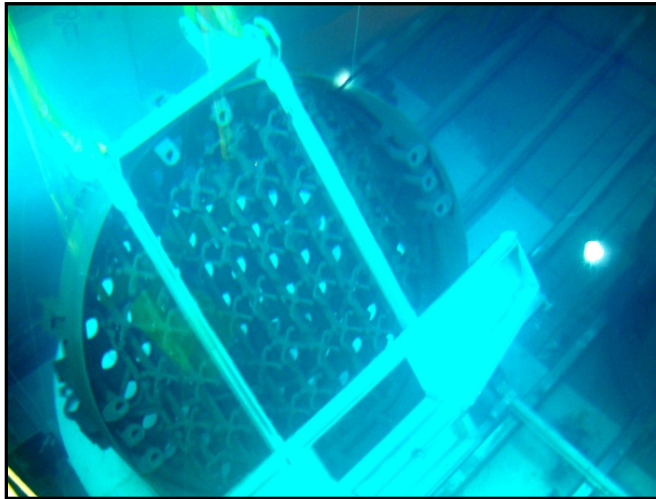


Fig. 9. Turning of CSC in Oskarshamn.

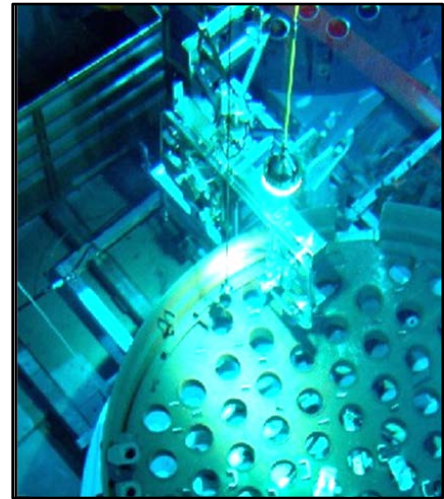


Fig. 10. Cutting of CSC.

TABLE I. Internal parts cut in Oskarshamn 2003-2004.

Internal Part	Power Plant
Core Shroud Cover (2 pcs)	O2
Core support grid	O1
Core support grid	O2
Feed Water spargers (6 pcs)	O2
Core spray riser pipes (8 pcs)	O1
Core spray riser pipes (8 pcs)	O2
Test channels (9 pcs)	O1
Test channels (3 pcs)	O2

## SEGMENTATION IN OLKILUOTO 2004-2006

A segmentation project was performed in the two operating NPPs in Olkiluoto (OL1 and OL2). The cutting in OL2 was made in the time period between the outages 2004-2005 and for OL1 between outages 2005-2006. The internal parts that were cut in this project are described in table II below. We had experience from cutting CSC and Core support grid so these activities were performed excellently. The new activity for this project was cutting of steam separators which were segmented with a band saw (see fig. 12). Overall all project procedures were performed with the full quality. New experience was the sawing in inconel material which is very hard. During this project, we also introduced a new cutting technique for some support beams on the CSC. We used a disc cutting tool that proved to be very well suited for this kind of cut. Figure 11 shows cutting of steam tubes in Olkiluoto.

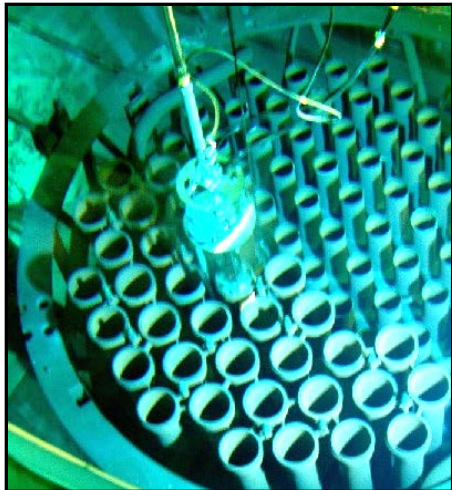


Fig.11. Cutting of steam tubes.

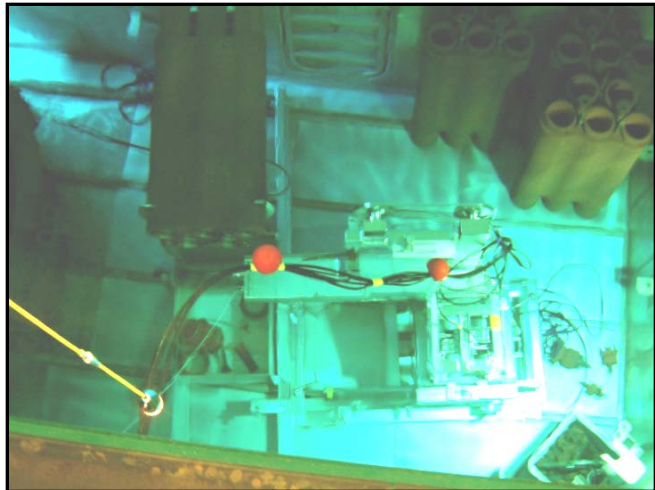


Fig.12. Cutting of Steam separators.

TABLE II - Internal parts cut in Olkiluoto 2004-2006.

Internal Part	Power Plant
Core Shroud Cover	OL2
Core Shroud Cover	OL1
Core support grid	OL2
Core support grid	OL1
Steam Separators (19 pcs)	OL2
Steam Separators (19 pcs)	OL1

### SEGMENTATION IN OLKILUOTO 2009-2013

Westinghouse has segmented two Steam Dryers and 201 control rod shafts in OL1 and OL2 NPP's. This project ran in parallel with another segmentation project in Forsmark 1, 2 and 3 (See next chapter) which also included segmentation of steam dryers. The cutting of steam dryers were new to Westinghouse and a lot of effort in form of design and testing were made on finding the best way to cut the complex design into suitable sized pieces. We decided to use disc cutting technology for the cutting of the steam dryer which proved to be very successful. Another tool that was introduced in this project was a nibbler tool that was used to cut 6mm sheet plates. The first Steam dryer was cut in 2009, followed by a long waiting period until the second was finalized in 2013.

The control rod shafts were cut with a special designed shearing tool which proved to work very well. The cutting of the 201 shafts was made within one month in 2009 and cutting edges were only replaced one time.





Fig.13. Cutting of control rod shafts.

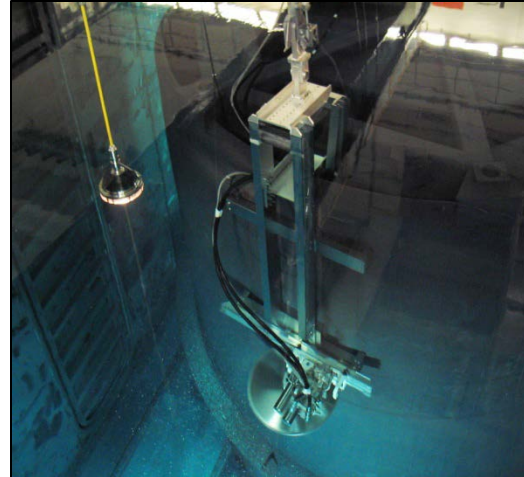


Fig.14. Cutting of a Steam dryer.

### SEGMENTATION IN FORSMARK 2010-2012

Westinghouse recently performed a large segmentation project for Forsmark Kraftgrupp AB in Sweden. The project, which was awarded in June 2006, was a part of a large upgrade process to increase the power output which included the replacement of a number of reactor internals at the three nuclear power plants Forsmark 1, 2 and 3. The scope of the project included segmentation of three core shroud covers, 83 steam separators, two steam dryers, one core spray flange and repackaging of an already segmented core spray system.

The site work started at the Forsmark 2 NPP in February 2010 with the segmentation of a steam dryer. The cutting of the steam dryer was finalized on schedule in 2,5 months resulting in 150 pieces packaged in twelve 7m<sup>3</sup> containers. The first cutting campaign was followed by four additional campaigns where the rest of the replaced internals were cut and packaged in a similar way as the steam dryer. Finalization of the site work occurred in June 2012.

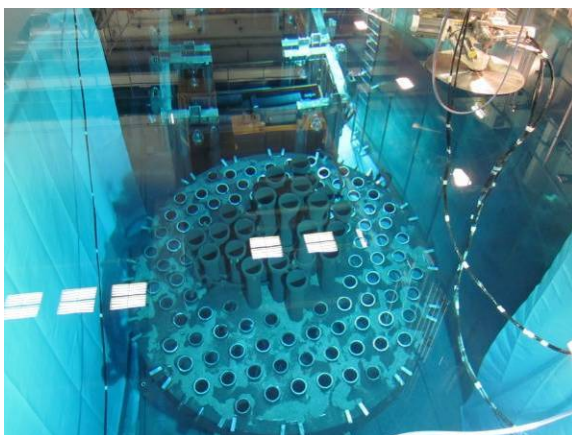


Fig. 15. Cutting of a core shroud cover.

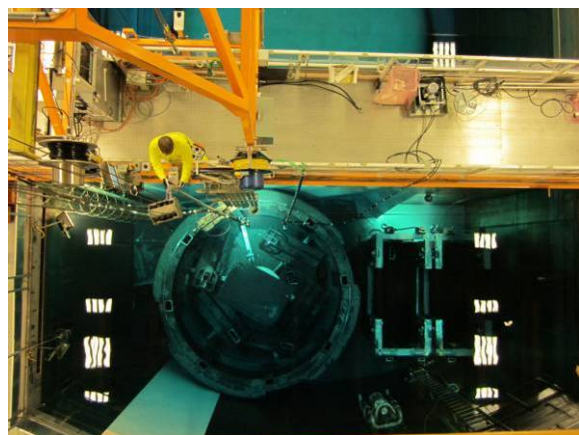


Fig.16. Cutting of a Steam dryer.

## ONGOING PROJECTS IN NORDIC REGION

Westinghouse has one ongoing segmentation project in Oskarshamn 3 where we are cutting one Core shroud cover and one steam dryer. The cutting of the core shroud cover was performed between July and November 2013, see fig 17 and 18, and the Steam dryer will be cut in 2014. The tools and methods used in Oskarshamn are the same or similar to the ones used in previous projects which is a big advantage. By using already qualified tools, we minimize problems on site.

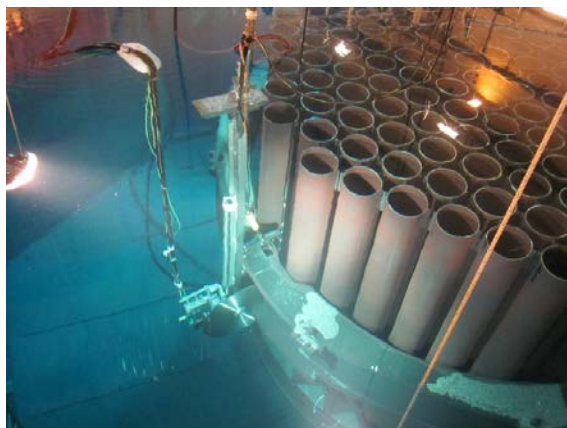


Fig. 17. Cutting of CSC with a disc saw

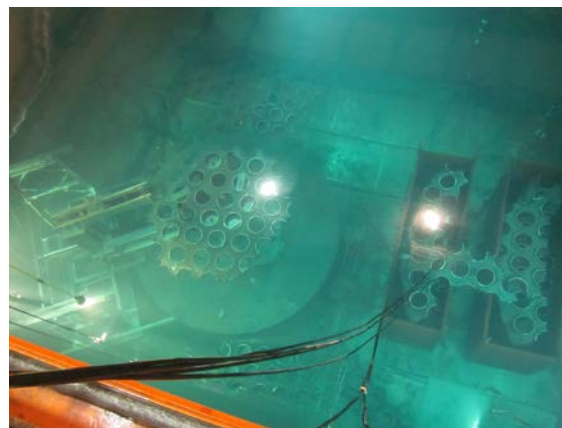


Fig. 18. Cutting of CSC with a band saw

## MECHANICAL CUTTING TECHNIQUE

Westinghouse has developed the segmentation technique based on mechanical cutting. Different band saws, disc saws, tube cutters and shearing tools have been used over the years to segment the reactor internals. Westinghouse has a good knowledge around these techniques and is constantly improving the tools based on feedback from experience. The power and drive for almost all tools are hydraulic which is very suitable for submerged applications. Different kind of hydraulic power units, provided with approved water/hydraulic oil, supplies the power to the tools.

The capacity of the different mechanical cutting techniques is varying. Westinghouse different band sawing tools can cut in almost all thicknesses and different materials. The disc cutting tools are very effective but long cuts in very thick materials are not recommendable. The shearing tools are designed with various design and hydraulic forces. The tube cutter is used to cut thick tubes and the design facilitates rebuilding to fit many different dimensions.

We have learned that normal parameters used in the industry for metal cutting can only be applied to a small extent to the underwater internals segmentation tools.

Westinghouse best performing tools are those where a standard cutting machine has been re-built to fit the plant environment, mobile and under water in the pools.

Mechanical cutting has according to Westinghouse a number of advantages compared to other cutting techniques that are listed below.

- No contaminated debris on the water surface and no airborne gases are produced.
- Full sight is kept through the water during the whole segmentation.
- Cutting debris sinks to the pool bottom and stays there.
- The debris is easy to collect with different cleaning devices after the segmentation is finished.
- Only a small amount of secondary waste for the customer to handle.
- Almost all thicknesses and materials can be cut.
- Safe, optimized and tested cutting equipment requiring minimal service.
- Cutting technology is well suited for BWR as well as for PWR RVI.

## **CONCLUSION**

Decommissioning of nuclear power plants is a growing market. The life time of many NPPs around the world has indeed expired and segmentation of the internals is an important activity during a decommissioning project. Westinghouse has the experience, knowledge and organization to perform large scale decommissioning projects, including reactor internals segmentation.

The Westinghouse mechanical cutting technique is well suited for segmentation of BWR components but can also be used without extra adaptation for PWR reactors.