THE DISMANTLING OF THE VESSEL FROM THE BELGIAN BR3 PWR TEST REACTOR

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ABSTRACT

Since 1989, the first European pressurised water reactor BR3 situated at the Belgian Nuclear Research Centre in Mol Belgium, is under decommissioning. Started as a European pilot project for the dismantling of the high-activated internals, the project achieved a major milestone at the end of June 2000 with the full dismantling of the reactor pressure vessel (RPV).

The paper will describe in a first part the different steps, which were carried out for the dismantling of the RPV. Specific attention will be given to a particular challenge.

The RPV being a part of the water tightness of the Refuelling Pool, the reinstalling of this water tightness after cutting the hot and cold legs had to be done very carefully, also because the actual cutting of the RPV would be done under water and in the same pool.

The cutting of the RPV was performed using underwater mechanical techniques (circular saw and bandsaw) and a rotating table. These techniques had already been used for the dismantling of the internal pieces and worked quite satisfactorily.

In a second part, the encountered main problems and how they were solved, will be given.

A first category of problems was encountered with the installation of the sealing devices and the removal of the insulation shroud, a protective metal sheet for the vessel's thermal insulation. These problems were caused by discrepancies between as built drawings and the reality, which is a regular problem in a lot of decommissioning projects.

A second category of problems was the decrease of the visibility of the pool water during the removal of the thermal insulation of the RPV. This insulation was situated between the RPV and the insulation shroud. The purification of the water to recover a good visibility as fast as possible was a great challenge.

Two pieces must still be cut into small pieces: the bottom of the RPV as well as the reactor head. These pieces cannot be cut simply with the available techniques and therefore a new technique, the high-pressure water jet cutting, was selected. This machine is already ordered and the cutting studies are going on.

The paper ends with the main conclusions and the lessons learned

INTRODUCTION: THE BR3 DECOMMISSIONING SUMMARY

BR3 is a small 10 MWe PWR shutdown in 1987 after 25 years of operation. It was selected as one of the four pilot projects of the EU for its R&D programme on Decommissioning of nuclear installations. The decommissioning project started in 1989. In 1991, a Full System Decontamination of the primary loop reduced the dose rate in the vicinity of the primary loop by a factor 10. The same year, a first high active internal, the 5.4 t thermal shield was dismantled underwater by 3 different dismantling techniques: the EDM cutting, the milling cutter and the plasma arc torch. Mechanical cutting, essentially milling cutter and bandsaw, were selected for the further dismantling of the two sets of internals; the original Westinghouse internals ("33 years decay") and the Vulcain internals ("7 years decay"). This allowed comparing deferred dismantling with immediate dismantling. No significant radiological, technical or economical profit was gained by dismantling the old internals because due to the still high dose rate of 2 to 3 Sv/h at mid plane, remote underwater cutting was still required.

The next important step was the cutting of the 28 t Reactor Pressure Vessel. The produced waste has been sent to the Belgian waste conditioner for conditioning and interim storage. Only three pieces of the vessel still remain: the bottom, the head and the insulation shroud. They will be cut in the next phase with a new technique, the high-pressure water jet cutting technique.

Besides the dismantling of high-activated pieces, the dismantling of some contaminated circuits was also performed using mostly hands on cutting techniques. Minimizing the amount of radioactive waste and free release of the dismantled materials have always been our main objectives. Recycling of slightly radioactive metallic materials could be performed thanks to an agreement with a nuclear foundry. For concrete, an R&D programme has been started to recycle radioactive concrete in the radioactive waste conditioning sector. Progress was also made on the establishment of free release procedures and on the development of decontamination techniques for metals and concrete [1] [2].

THE DISMANTLING OF THE VESSEL

This paragraph discusses first the selection of the strategy. Two main strategies, namely dry and wet cutting, were compared. The paragraph describes further the different steps of the vessel dismantling. The steps to be discussed start from the vessel's separation from the primary circuit through the cutting of the vessel and removal of the waste materials.

Strategy selection

A detailed study for the complete dismantling of the RPV in air or under water has been carried out. Based on the results of the preceding projects, the mechanical cutting processes were first promoted and analysed.

For the comparison of dry and wet cutting, the study focused on the following areas:

- the technical feasibility;
- the radiation protection and safety of the operators, including the case of equipment failure;
- the shielding needs for coping with the radioprotection requirements.

The studies allowed to foresee globally the manpower, operation duration and costs of both operations. For the dismantling of the RPV, the underwater method was finally selected. The RPV being surrounded by an annular Neutron Shield Tank (NST), the vessel can be submerged and only the three penetrations for the primary loop pipings have to be closed to assure the leak tightness of the pool during the operation.

Further design for the RPV dismantling led to analyse two different approaches: the in-situ dismantling, where the RPV remains in place (under the bottom of the refuelling pool) while being cut into rings, and the "one-piece removal", where the vessel is removed in one piece into the refueling pool, and then segmented into pieces ready for packaging.

The advantage of the latter is the accessibility of the RPV and its insulation shroud from the outside, giving the possibility to reuse the dismantling tools and equipments designed for the internals dismantling. Moreover, this approach simplifies greatly the dismantling of the RPV insulation shroud situated at about 100 mm outside the vessel wall.

Preliminary operations

These operations (**see figure 1**) were executed with a dry refueling pool, the RPV still being in its cavity under the bottom of the refuelling pool. So the access to the pool floor was possible but had to be reduced as much as possible for radioprotection reasons.

Desolidarization of the RPV from the bottom of the reactor pool

The selected process for cutting the bottom of the reactor pool is the plasma arc torch handled by an operator. The cutting has to be done quickly for limiting the dose uptake of the operations (radioprotection optimization). In addition to this separation, different cuts at the bottom of the reactor pool were also needed to give access to the fastening bolts of the RPV support flange, to give access to the hot and cold legs thermal insulation and to allow the installation of the sealing equipment for the future watertightness of the pool.

Removal of the asbestos situated around the primary pipes near the RPV

This operation was carried out by SCK•CEN personnel, as the nuclear hazard was estimated to be far above the asbestos hazard. Nevertheless, to avoid the spread of asbestos fibers, a double confinement was installed in the RPV pool.

Desolidarization of the RPV from the hot and the cold legs

- *Cutting of the primary pipes at the outside of the bioshield*. The main operation is the cutting of the pipes at the RPV flange level. But regarding the very tight space available to perform this operation, access was needed through the primary pipes at the bioshield side. This operation was carried out with a quite common automatic pipe cutter, using two lathe tools diametrically opposed.
- *Cutting the primary pipes near the RPV*. This operation was delicate due to the fact that access was only available at the inside of the piping. We thus developed, with an industrial partner, an automatic milling cutter able to cut the necessary thickness. The challenge was to have a machine fitting into a diameter of 254 mm, able to cut up to 110 mm wall thickness. Finally, it was decided to make a second cut of the primary pipe connections just above the support flange of the RPV in order to get access to all the RPV fastening bolts. The cutting tool is an automatic milling cutter with a diameter of 30 mm for the first part of the cut, 25 mm for the second, deepest, part.

Separation of the RPV from the NST

The selected procedure to remove the 24 fastening bolts of the RPV on the Neutron Shield Tank is the pneumatic unbolting. Due to the high level of corrosion, this operation took about three times more than foreseen.

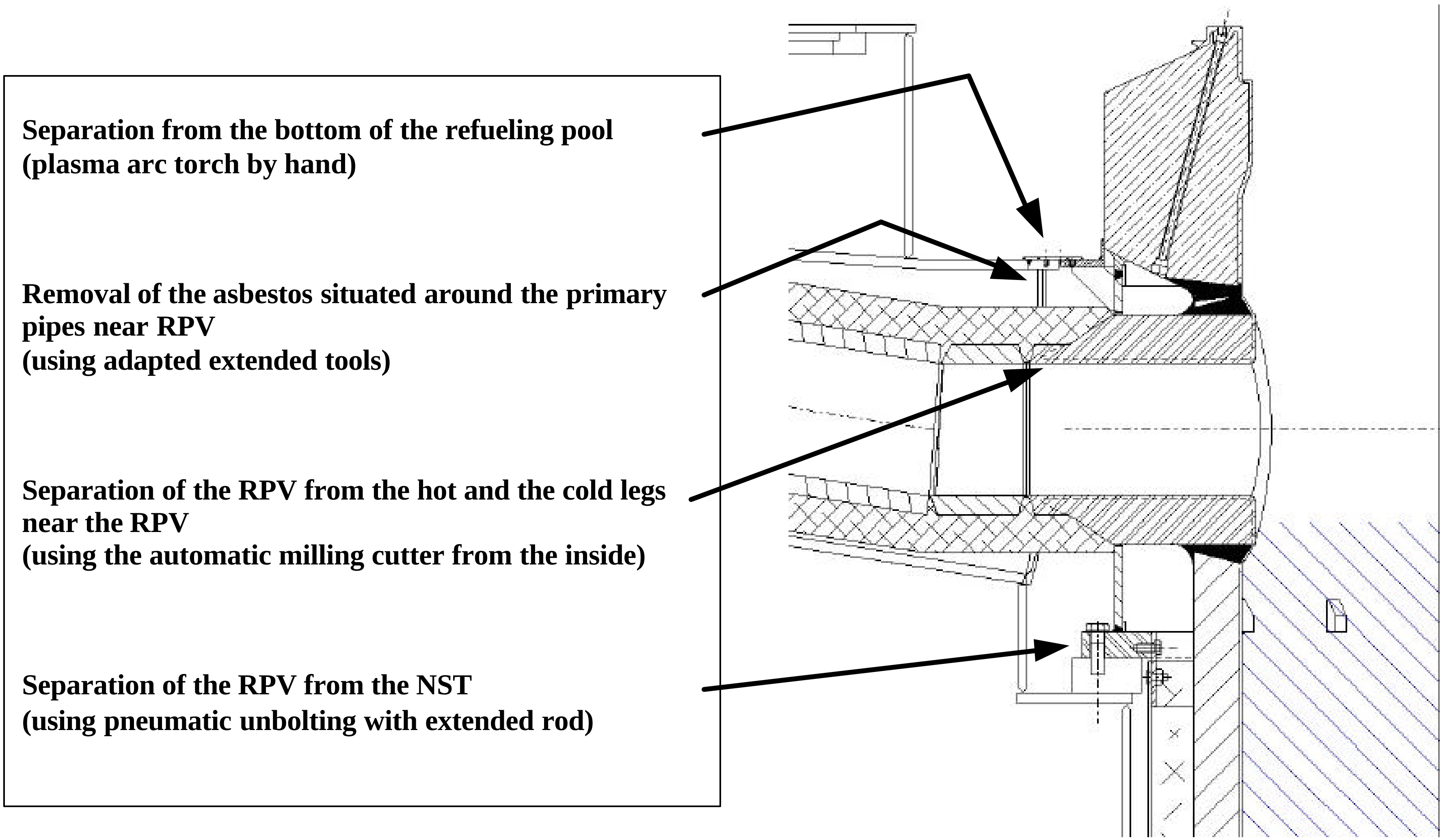

Fig. 1: The separation steps of the reactor pressure vessel

Reinstallation of the the water tightness of the NST and the reactor pool

As the RPV and its primary pipes were part of the pool leak tightness system, we had to seal the openings made by the primary pipe cutting, which is a very tight space. The operation was carried out with an industrial partner, who developed a system based on an epoxy-based polymer and form-shaped sealing system. Cold testing was carried out on real scale mock up and everything was ready for the installation (Figure 2). During the installation, a major positioning problem raised. More about this problem further on in the paper.

Fig. 2: Actual installation of the sealing device.

Finally the RPV was ready to be lifted. A guiding system was also installed as the mechanical clearance between the RPV and the sealing devices was less than 10 mm. On August 24, 1999 the pressure vessel (28 ton) was then lifted up in one day, using a new gantry crane installed above the RPV pool. The water level in the pool was raised at the same pace as the RPV lifting.

Removal of the insulation shell

The insulation shell is bolted to the RPV through two profiles and on the upper side it is bolted to the RPV supporting skirt. It was necessary to remove 60 bolts to free the insulation shell from the RPV. Because of the horizontal position of these bolts they would be drilled by a remote hydraulic hole cutter. For reaching easily the different levels at which the bolts were placed, the remote hydraulic hole cutter can move up and down along a beam. Here again, cold tests were organized.

During the execution of this dismantling task, we encountered two problems. First of all, there was a positioning problem for the cutting tool and second, there was a visibility problem with the pool water. A detailed explanation of these problems follows in a next chapter.

Removal of the insulation and the fastening profiles of the insulation shell

The insulation shell was bolted on the RPV by T-shaped fastening profiles and connection pieces on two levels. Between and on top of these fastening profiles there is a thermal glass fiber insulation, fastened with a metal mesh. The insulation was also held together with metal strips. On the bottom side of the RPV the insulation is tightened to the RPV with eight strips. The strips are attached on the RPV by bolts throughout the insulation material.

As the mesh was totally rusty, the removal of the insulation was done using a long handling tool. The liberated insulation fell into a fishing net previously installed on the floor of pool. By remotely closing the fishing net, the insulation was taken out of the water and removed as standard low level waste.

The T-shaped fastening profiles of the insulation shell were the last items that had to be removed before the actual cutting up of the vessel could take a start. First, it was foreseen to unscrew the bolts of these fastening profiles. But due to the strong corrosion of the bolts, these profiles could easily be ripped of the vessel with a hook. As the fastening profiles are low activated, their further dismantling was done by hand.

Dismantling operations of the RPV

Cutting of the RPV in rings

After the completion of the study, the adaptation pieces, the positioning and the clamping devices were ordered and fabricated. **Figure 3** shows the different levels of the horizontal cut. These cuts will be executed by a circular saw available at BR3. The tests in the pool on a mock-up of the RPV scale (scale 1/1) were programmed for validation of the cutting parameters. Cut 1, of the bottom of the RPV, was the most difficult one and the first clamping system was not perfect (lot of vibrations during cutting). This problem led us to a design review. Some additional clamping devices were added and the cutting procedure was adapted. For the RPV flange cutting, a band saw system was used.

Cutting the rings in segments

These cuts were done by a band saw used before for the dismantling of the reactor internals. The tests in the pool on a mock-up of the RPV (scale 1/1) were also programmed for validation of the cutting parameters. The most difficult cut was the one through the RPV flange. Nevertheless, on the mock-up, we succeeded to cut at the first time.

ENCOUNTERED PROBLEMS AND SOLUTIONS

During the whole dismantling phase of the RPV, the team encountered two major problems. These problems concerned on one hand some "non conformities" or discrepancies with the "as built" drawings and, on the other hand, severe turbidity problems of the cutting pool.

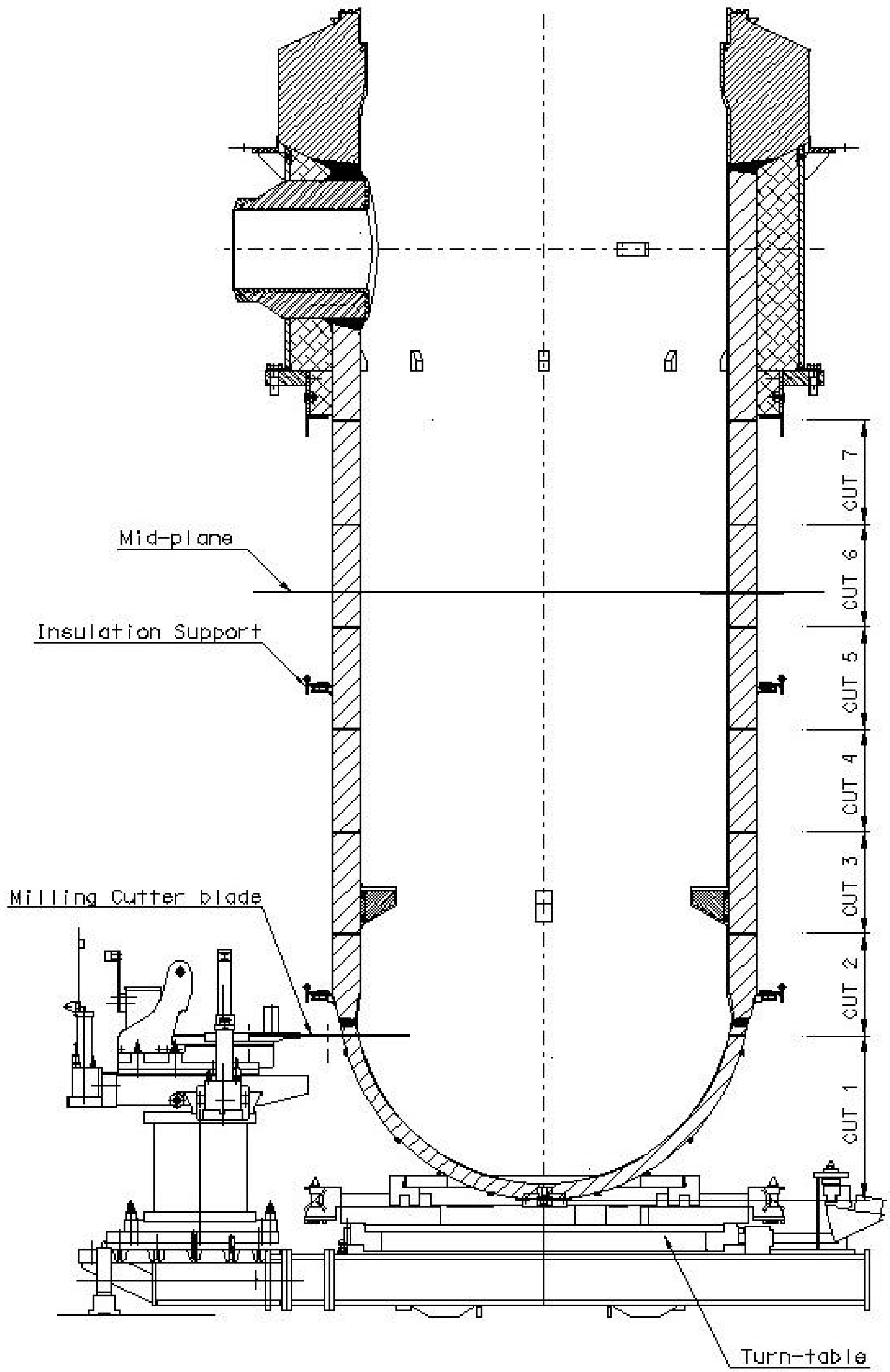

Fig. 3: The BR3 circular saw will carry out the horizontal cuts

- *Problems with the "non conformities" of as built drawings.*

As already explained earlier in the text, one had to reinstall the watertightness of the reactor pool. This would be done with three special designed sealing devices. Already in the very beginning, one had to stop the operation because it was impossible to position the sealing devices due some discrepancies between the "as built" drawings and the reality. This problem is a common problem in the dismantling of old nuclear facilities. Therefore, the design of the sealing devices had to be revised, and the sealing devices themselves had to be adapted. The positioning of these devices was finally carried out in June 1999 instead of March 1999.

Another problem of the same category is the one encountered with the insulation shell removal. Starting the work, it became almost impossible to locate the screw heads due to a high level of corrosion on the shroud surface. Therefore it was impossible to locate these bolts for cutting them with a hole cutter machine. It was then decided to cut the entire circumference of the core shroud at the corresponding level of the bolts. This work method required 10 times more holes to be cut than foreseen.

- *The turbidity problem of the pool*

When we removed the insulation shell (a protective metal sheet for the thermal insulation situated around the RPV) a major problem occurred: significant water turbidity appeared. This was due to the thermal insulation, which became breakable into something looking like dust but also to rust. Sometimes, the visibility was so bad that the operation had to be stopped. Additional filtration and purification facilities were installed to solve this problem. Resolving this visibility problem led to an extra burnable waste volume of 0.4 m³ of filters.

The same problem appeared again when we carried out the horizontal cut with the bandsaw for the removal of the vessel flange. Remaining insulation, situated under the vessel flange came again in the pool water and caused a new turbidity problem. Nevertheless, due to the presence of the additional filtering equipment, the water visibility could be recovered in a rather fast way.

WASTE

It is the Belgian National RadWaste Authority (ONDRAF/NIRAS) who sets up the different acceptance criteria on waste types and waste packages. Concerning the solid waste (big pieces), there are three important groups of waste and the distinction between these groups is based on the contact dose rate. These are Low Level solid waste (LLW) with a contact dose rate < 2 mSv/h, Medium Level solid waste (MLW) with a contact dose rate between 2 mSv/h and 0.2 Sv/h and High Level solid waste (HLW) with a contact dose rate > 0.2 Sv/h.

Concerning the waste packages, there are only two different types, namely the standard 400l drum land the standard 200l drum. The 400l drum is used for the big pieces. At the waste facility these drums will be filled with mortar. The 200l drum is used for small pieces and is foreseen for the supercompaction.

The vessel itself led to the production of a high volume of waste and more particularly high and medium activated waste.

For radiation protection reasons, this waste had to be manipulated under water. Therefore we used a system similar to the one used during the dismantling of the reactor internals; but, based on the gained experience, some modifications were carried out. The waste removal system existed out of two racks, an upper and lower rack. Both racks could be bolted together to fit in a 400l drum. The replacement of the carrier structure by 4 bolts was the main modification that was carried out, leading to the following advantages:

- weight saving of the 'death' mass,
- only one lifting device instead of two with the previous system, and
- an easier underwater manipulation of the racks (saves time and dose).

In total, nine transports were carried out to the Belgian waste conditioner and intermediate storage facility representing a volume of 3.6 m³ on high-activated waste (including high-activated swarfs). These transports were done in the second half of 2000 at a transportation rate of one transport every two days.

The medium activated waste was manipulated with the same rack system and represents a volume of 4.8 m³.

Low activated waste, mainly the vessel flange and the bottom ring led to a volume of 6.8 m³. The low activated secondary waste like swarfs, cutting blades and filters were spread out over several waste drums.

CONCLUSIONS

Being a pilot project, BR3 had demonstrated the feasibility of the dismantling of high-activated pieces using its two sets of internals. BR3 learned a lot about remote cutting techniques, remote operations and waste handling.

Using this experience, the BR3 team extrapolated his knowledge in order to demonstrate the feasibility of the same operation on the RPV of a PWR plant. As the used cutting techniques are now well known, the biggest part of the challenge was concentrated on the preparation works: to separate the RPV from the rest of the facility and to bring it under water into the refuelling pool which was used as underwater cutting workshop.

As these works are finished, we can conclude that the cutting of the primary loop from the inside and the reinstallation of the watertightness of the pool were important challenges.

BR3 completed the cutting phase of its Reactor Pressure Vessel. This operation was terminated just before the summer holidays of 2000, respecting the overall project planning. From a technical point of view, no significant problems were encountered which means that the BR3-team mastered the mechanical cutting techniques for the dismantling of high radioactive structures.

With the final dismantling study of the NST, a new challenge starts as a quite new cutting technique, the high pressure water jet cutting, will be used combined with a telemanipulated arm.

Even if BR3 is a PWR type plant, the SCK•CEN experts still think that the results and the lessons learned can be used to derive data for all kinds of power plants dismantling activities.

REFERENCES

[1] Progress report to the Technical Advisory Group (OECD/NEA), TAG 26, Ref. 231/99-03, V. Massaut
[2] Progress report to the Technical Advisory Group (OECD/NEA), TAG 27, Ref. 231/99-05, V. Massaut
[3] RPV and Internals Dismantling Project (BR3, EWN, KRB-A), Research Contract FI4D-CT95-0001, Progress Report January-June 96, Ref. 59/96-55
[4] RPV and Internals Dismantling Project (BR3, EWN, KRB-A), Research Contract FI4D-CT95-0001, Progess Report January-June 97, Ref. 59/97-30
[5] RPV and Internals Dismantling Project (BR3, EWN, KRB-A), Research Contract FI4D-CT95-0001, Progress Report January-June 98, Ref. 212/98-15
[6] RPV and Internals Dismantling Project (BR3, EWN, KRB-A), Research Contract FI4D-CT95-0001, Progress Report July-December 1998, Ref. 212/99-06
[7] "1999 Summer School on Radwaste and Decommissioning", Cambridge, June 1999, V. Massaut