Decommissioning of the Danish 5 MW research reactor DR2

by

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Danish Decommissioning

Introduction

Reactor DR 2 at Risø National Laboratory was a 5 MW open tank type light water cooled and moderated reactor that was in operation from 1959 to 1975. After the final shutdown it was defuelled and brought to a state of safe enclosure, awaiting the decommissioning of other facilities at the site. Final dismantling and demolition of the reactor took place in 2006-08 as the second decommissioning project at the site. A sketch of the facility is shown in Figure 1 below.

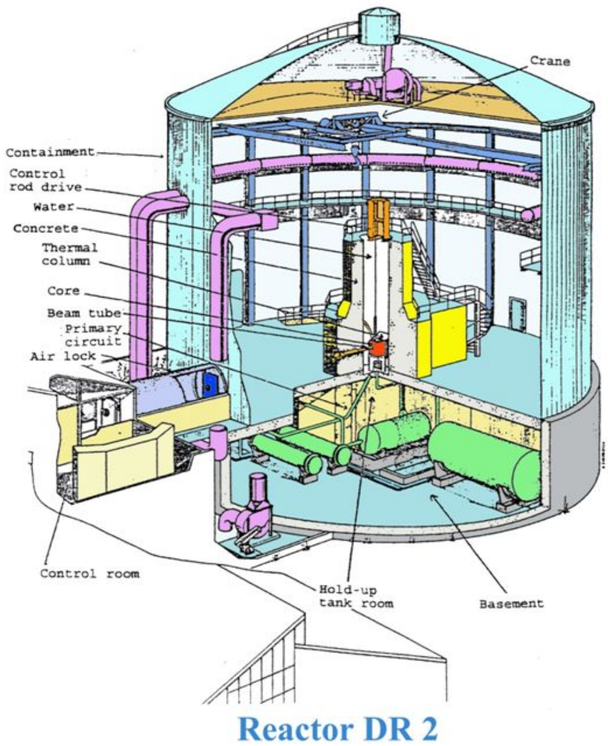

Figure 1 Cut-away drawing of the DR 2

Following the final shutdown of the reactor in 1975 the fuel was shipped to the USA, part of the cooling circuit was dismantled, the reactor block was stripped from experiments and all loose parts were removed from the reactor tank. At the outset of the decommissioning, described below, the reactor had experienced more than 30 years of decay time; but it still contained components and structures with a considerable activity.

Dismantling work began in the spring of 2006 and was finished in 2008. A thorough description of the whole dismantling process is given in [1], and a general overview of the facilities to be decommissioned at the site can be found in [2]. The present paper will give a summary of the dismantling and demolition process and highlight some of the experience gained during this project, for instance with a view to the selection of dismantling methods and methods for the separation of radioactive waste from material to be cleared.

Decommissioning approach

Selection of decommissioning methods started when the first overall plan [2] was drafted for decommissioning of all nuclear facilities at the site. A much more detailed planning was made in the project description put forward for approval by the nuclear regulatory authorities and when setting up the budget to be approved by the Parliament's Finance Committee. But the selection of precise approaches and tools to be used in the individual decommissioning operations to some extent was made during the detailed preparation of these operations. The general approach by Danish Decommissioning is to do as much of the dismantling of active components as possible with our own staff and only to call in external contractors for work that involves little or no radioactivity. This was also the case in the DR 2 project, although demolition of the biological shield did cause some minor radiation doses to contractor personnel.

Dismantling of remaining active components

The cross-section shown in Figure 2 illustrates the remaining active components and shows the exposure rates in selected points. There were eight curved irradiation tubes ("S" and "R" tubes) that went down into the core region from the balcony, and eight horizontal beam tubes. The inner parts of these tubes still contained activity above clearance levels. But the major radiation sources and those requiring some attention during dismantling were the fuel element grid plate and thermo elements placed in the nose of the thermal column. The dose rate measurements were made as part of a characterisation project [3] carried out some years before start of the decommissioning.

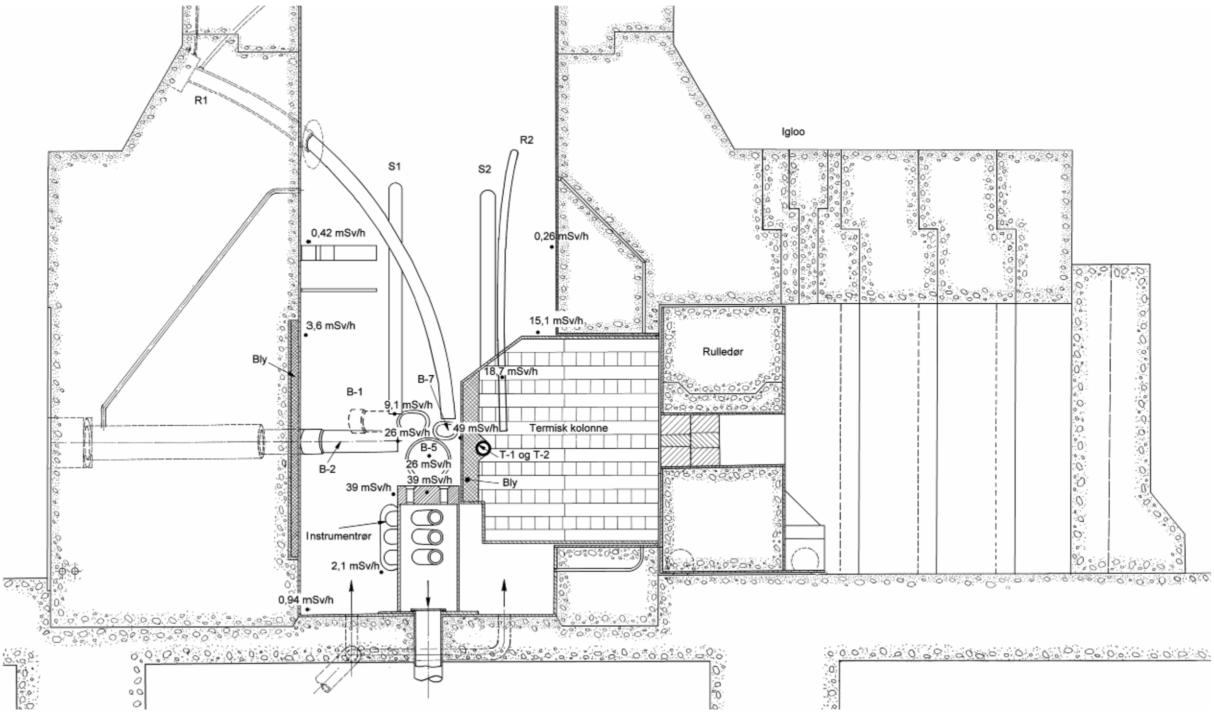

Figure 2 Cross-section of the reactor block and thermal column showing radiation levels measured with TL-dosimeters in the spring of 2001.

Removal of "S"- and "R" tubes

The photo in Figure 3 shows the internals seen from above just prior to the start of dismantling. The curved "S" and "R" irradiation tubes could be pulled out fairly easy by hand, as illustrated in Figure 4. Only the inner one metre or so had to be cut off and disposed of as radioactive waste. The horizontal beam tubes were somewhat more difficult to remove. For one thing they were much heavier and had to be pulled out by means of a small truck. But one of them also was stuck so firmly that pulling it out was abandoned. Instead it was left for being cut out together with 10 cm of the surrounding concrete by diamond wire cutting in conjunction with the demolition of the biological shield.

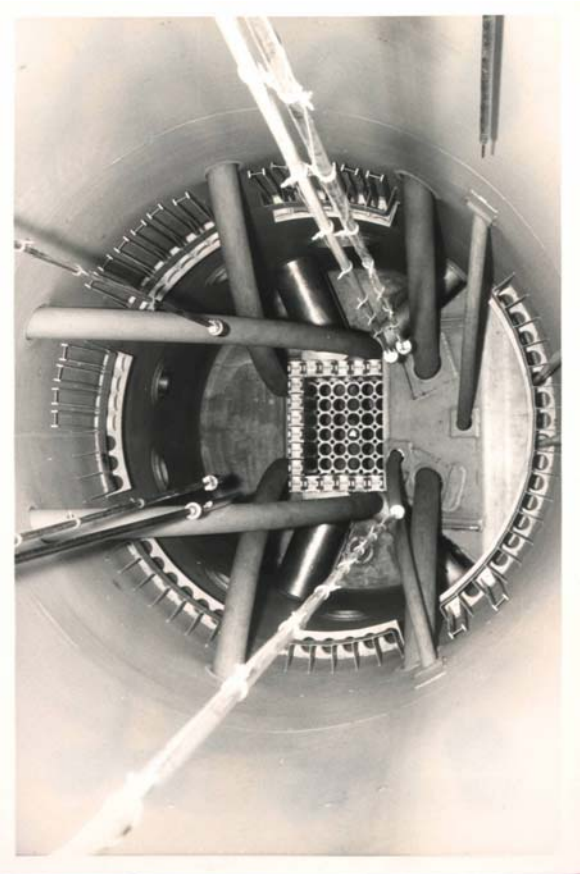

Figure 3 Remaining internals of the reactor tank

Figure 4 Removal of an "S" tube

Figure 5 Removal of a beam tube (plug)

Removal of graphite from the thermal column

The thermal column contained approximately 200 graphite stringers of mainly 1 metre length with a total weight of around 2 tons. The graphite was removed before proceeding with the internal parts of the reactor tank, in order to allow access to the lead nose of the column from the back side (Figure 6). The graphite could be approached on the outer side for measuring of radiation levels, but there were concerns that the inner part of the stringers would present serious levels of radiation. It was, therefore, decided that close handling by the staff should be minimised.

In relation to other works DD-staff had developed purpose specific pneumatic tools with vacuum suction pads and methods for lifting and removal of graphite and other materials with even surfaces. The device was therefore already available in DD and required only minor maintenance and changes before it could be applied (Figure 7).

The work included removal of all the graphite stringers to dedicated containers including measurement and registration of each individual stringer. This registration together with experiments carried out on selected stringers would serve to identify stringers that had to be annealed for Wigner energy before final disposal.

The pneumatic tools were mounted on an aluminium bearing beam for lifting the graphite stringers. An extension arm was also mounted with a pneumatic device for pulling the stringers out of the thermal column. The removal of the stringers by use of the pneumatic devices proved efficient and the work was carried out safely and according to the work plan drawn up (Figure 8).

Figure 6 External surface of the thermal column

Figure 7 Graphite stringers removed and placed in waste container by use of vacuum lifting device

Figure 8 Arrangement for remote handling of graphite and packaging of container

Subsequent tests showed that Wigner energy was indeed present in about half of the graphite stringers, i.e. the ones that had been closest to the reactor core. The amounts of Wigner energy are not very high, but it is the plan to anneal these stringers anyway.

Removal of the lead nose of the thermal column and the grid plate

As mentioned earlier, the nose of the thermal column and the grid plate were found to be the most active components in the reactor tank. The radiation level measured on the outer side of the lead nose after removal of the graphite stringers (Figure 9) was around 2 mSv/h. From previous measurements it was known that the highest radiation level inside the reactor tank was right in front of the lead nose with a level of 60 mSv/h. The majority of the radiation was considered to be coming from the grid plate but a fair amount originated from the lead nose with its position directly up to the core of the reactor. After removal of the graphite it was found that the majority of the radiation in the thermal column could be located to the central part of the lead nose containing built-in thermo elements.

The lead nose was cut loose from the thermal column casing by means of plasma cutting. The plasma cutter was mounted on an extension arm of 2 metres in order for the operator to have some distance to the source. In addition, the nose was shielded by means of 300 mm thick concrete blocks, cf. Figure 10. The cutting was performed by 2 operators, with one doing the cutting with the extension arm and the second one managing the power switch from a distance of approximately 4 metres to the column. This was found to ensure sufficient safety in relation to the radiation but also to the fact that the plasma cutter requires high voltage supply and works by electrical contact between the cutter and the medium to be cut.

The plasma cutter subsequently was used in the same manner to cut out the grid plate and other remaining structures in the reactor tank, cf. Figure 11 and Figure 12. Furthermore, plasma cutting proved very useful for cutting up the thermal column casing, which was made of 19 mm aluminium plates lined with 6 mm Boral plates on the side facing the graphite. A number of tests were made with various cutting tools, such as circular saws of different types and plasma cutter. The problem was to cut through a construction consisting of both the ‘soft’ material aluminium and the particularly ‘hard’ Boral plates, with a thickness totalling 25 mm. The plasma cutter did it quickly and without problems.

Figure 9 Thermal column with lead nose exposed

Figure 10 Plasma cutting of the lead nose

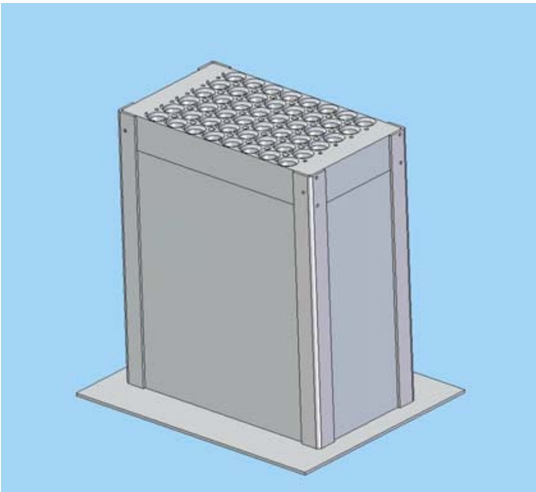

Figure 11 Sketch of the aluminium grid plate

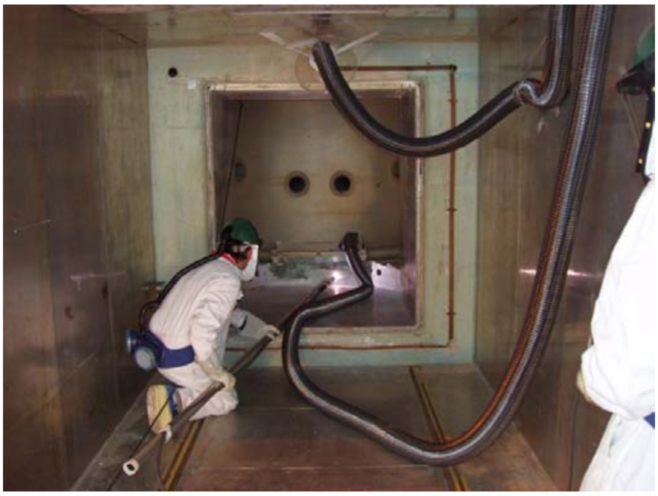

Figure 12 Grid plate being cut loose

Demolition of the biological shield

The concrete demolition was carried out by an external contractor following a tendering process where the tenderers were given some freedom in the choice of methods, but for instance with the explicit requirement that water was not to be used, for instance with wire cutting. DD had some bad experience with wet wire cutting in the DR 1 demolition and, therefore, selected to prescribe the somewhat more expensive dry methods.

Characterisation of the activity content in the concrete

Prior to issuing the call for tenders DD had established which parts of the concrete could be cleared as non-radioactive and which parts had to be disposed of as radioactive waste.

A total of 20 drill cores were taken in the reactor block in order to determine the amount and distribution of neutron-activated concrete in the concrete structure. All drilling samples were taken horizontally. In most of them drilling was done towards the vertical centreline of the reactor tank. This generated a direct activity profile through the concrete layer. However, drill cores were also taken to determine the activity profile around the beam tubes and near the thermal column. Initially, taking a drilling sample from the floor/floor deck underneath the reactor block was contemplated. However, it was subsequently decided to let the active profile in the concrete continue down into the floor.

Based on the drill core examinations and analyses in DD's Clearance Laboratory, it was determined that the non-clearable concrete (the "active profile") extended cylindrically from the core in a thickness of one metre in the concrete structure, cf. Figure 13. Actually, it was a bit less, but to be on the safe side the profile was determined as stated. The height of the active cylinder was 2.5 metres from the floor with the same radius as mentioned above and 25 cm into the floor deck towards the basement. For practical reasons it was determined that the floor (deck thickness = 60 cm) underneath the reactor block was to be removed in its entirety.

Around the horizontal beam tubes and instrument thimbles a higher degree of activation of the concrete was found close to and around the tubes. It was, therefore, decided that a profile corresponding to the outer radius of the active tube + 10 cm was to be removed as radioactive waste.

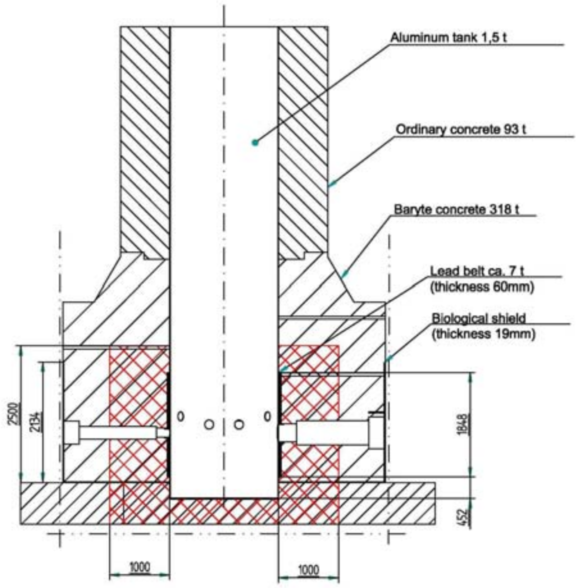

Figure 13 Cross section of the biological shield. Only the crosshatched part was disposed of as radioactive waste

The demolition process

After selection and contracting with the best tenderer the following method of demolition and tool was agreed:

- Demolition of concrete by use of a hydraulic hammer mounted on a remote operated 'Brokk' demolition robot
- Demolition of other materials by use of
  - Plasma cutter (steel, aluminium)
  - Dry wire cutting for cutting free the horizontal beam tubes (layers of concrete, steel, aluminium, lead)
  - Saw, handheld (aluminium tank)
  - Flame cutter (steel, pipes)

In order to prevent spreading of contamination to the building and the environment a tent was built around the reactor block. The tent was supplied with a filtered ventilation system, establishing a lower pressure than in the reactor building, and worked very well; no contamination was detected outside the tent at any time.

The main part of the concrete demolition was done by hydraulic hammering. Only the cutting away of activated areas around the horizontal beam tubes was done by wire cutting.

The biological shield was demolished from the outside and in, i.e. removing the non-active parts first. This approach was considered acceptable, even though it left the most active part exposed in the end. Due to the long time that had passed since shut down of the reactor the activity levels in the concrete and other materials were moderate and did not present any health physical problems.

As breaking down concrete by means of hydraulic hammering is not a very precise method, a way had to be found to show the operator of the demolition robot that he had come to the borderline between material to be cleared and material to be considered radioactive waste. This was achieved by drilling a number of horizontal and vertical holes along the dividing lines established by the characterization analyses, mentioned above. In addition to checking that no material had been hammered away beyond the dividing line, spot checks of the demolished "non active" material were performed.

The following pictures, Figure 14 –Figure 17, show the progress of the demolition of the concrete shield. The work carried out by the external contractor was conducted without any significant problems and on time.

Figure 14 Start of demolition from a platform

Figure 15 Chimney down, reactor tank exposed

Change of end state for the decommissioning

Originally it was the intention to decommission the DR 2 to green field, including removal of the reactor building. However, during the dismantling process DD realised that it would be useful to keep the building and its facilities, including for instance the 15 t crane, for handling of large components dismantled from the other facilities at the site. Therefore – and in agreement with the nuclear regulatory authorities – the project ended with control measurements documenting that no activity from the operation from DR 2 was left, except some contamination in a pipe that is cast into the bearing construction. The removal of this pipe and demolition of the building will wait until the final stages of the overall decommissioning project at Risø.

Figure 16 Radioactive parts exposed

Figure 17 The floor in the reactor building after removal of the reactor. The hole in the floor has been closed by a removable lid, giving access to the basement.

Conclusion

The decommissioning of DR 2 was a relatively easy project in the sense that the activity contents and radiation levels were moderate. The project was carried through within budget and time schedule. A number of experiences were gained that will be useful for other decommissioning projects; among them the following two are worth mentioning in particular. Plasma cutting proved to be a very useful method for carrying out fast cutting of a number of metallic materials; the cutter is not heavy and can be placed on an extension rod (or a robot) to reduce the dose to the operator. Dry methods for demolition of concrete were used successfully, thus eliminating the risk of water bringing contamination to unexpected places.

References

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